Currency competition, Monetary policy and Transaction costs: theory and experiments *

Preliminary draft, please do not quote, do not circulate

Latest draft available **here**

Jasmina Arifovic† Isabelle Salle‡ Linda Schilling§

March 18, 2025

Abstract

We examine competition between a central bank-guided currency (Dollar) and a fixed-supply currency (Bitcoin), considering currency-specific transaction costs. Without transaction costs, an increase in Dollar supply raises Dollar prices, crowds out Bitcoin, and boosts both the Dollar trade share and Bitcoin prices. Transaction costs, however, can counteract the impact of monetary policy on the trade share by shifting trade to Bitcoin, while amplifying the effect of Dollar monetary policy on its price. Our theoretical findings are supported by a laboratory experiment with student participants, offering insights into the dynamics of monetary policy and transaction costs in currency competition.

key words: currency competition, Bitcoin, dominant currency, exchange rates, transaction costs, currency crowding out, inflation, monetary policy
JEL: E5, E4, C92

*We dedicate this paper to our coauthor Jasmina Arifovic who sadly passed away before its completion. While she made substantial contributions to the earlier stages of the project, the views ultimately expressed in the paper may only be attributed to the remaining two authors. We thank our excellent research assistants Ibrahim Abuallail, Liang Diao, and Will Ho. Our experiment has been pre-registered on the AEA RCT registry under project number AEARCTR-0009274 and has been granted ethical approval by the Research Ethics Committee at Simon Fraser University under project number 2013s0789. Financial support from the Canadian Research Chair program and the Faculty of Economics & Business of the University of Amsterdam through the Research Priorities Area (RPA) 'Complex Human Systems Lab.' is gratefully acknowledged.

†Department of Economics, Simon Fraser University, BC, CA.

‡Department of Economics, University of Ottawa, Canada, Amsterdam School of Economics, University of Amsterdam and Tinbergen Institute (NL).

§Olin Business School, Washington University in St Louis, CEPR, FTG, USA.

1 Introduction

With Bitcoin's market capitalization reaching 1.66 trillion USD as of March 2025, alternative currencies—such as central bank digital currencies (CBDCs) and cryptocurrencies—challenge traditional fiat money. Understanding the competition between currencies is crucial, as it shapes both currency usage in trade and the effectiveness of conventional monetary policy tools. When economic agents can bypass the Dollar by transacting in Bitcoin, the impact of Dollar monetary interventions becomes uncertain. Simultaneously, monetary policy itself and currency-specific transaction costs influence how different currencies compete for usage in goods transactions.

This paper studies currency competition between a central bank-controlled currency (the Dollar) and a central bank-independent currency (Bitcoin), both theoretically and experimentally. We analyze how monetary policy and transaction costs influence trade volumes, prices, inflation, the Bitcoin exchange rate, and currency savings. Our findings highlight the crucial role of monetary policy and transaction costs in shaping market dynamics, offering insights into the effectiveness and limitations of central bank interventions in a dual-currency environment.

Our primary contribution is to first show, both in theory and the experiment, that the Dollar central bank can effectively defend the Dollar as a prime medium of exchange against Bitcoin and increase Dollar usage relative to Bitcoin by issuing proportional, asymmetric Dollar transfers that incentivize large Dollar savings. This result contrasts with the theory developed in Schilling and Uhlig (2019a), where symmetric Dollar transfers do not directly affect buyers' consumption-savings decisions or sellers' currency choices for sales.

Our second key contribution is to show that while monetary policy remains effective in influencing Dollar inflation, its impact is weaker in a currency competition setting than in a single-currency economy. This challenges the quantity theory of money (Friedman, 1956; Allais, 1966; Friedman, 1989; Lucas, 1980; Sargent and Surico, 2011; Teles et al., 2016), which predicts a direct, one-for-one pass-through of money supply changes into prices. In contrast, the experiment by Cardozo, Rosokha, and Zhang (2024) find that with symmetric monetary transfers, the quantity theory holds even in the presence of a competing currency. Our results differ because asymmetric transfers, which favor large Dollar balances, cause spillover effects from Dollar monetary expansion to Bitcoin in equilibrium. Both in theory and in the lab, we find that an increase in the Dollar supply raises Dollar trade volume while reducing Bitcoin trade, creating scarcity in Bitcoin-denominated transactions. The underlying economic mechanism hinges on sellers' inflation expectations. Without monetary policy, sellers who anticipate becoming buyers in the next period prefer transacting in the less inflationary currency—i.e., the one with a higher expected real return. However, with monetary

policy, sellers trade off inflation expectations against central bank transfers, which increase with larger Dollar holdings. As a result, sellers are to some degree willing to trade for a currency with higher expected inflation—the Dollar— as they seek to maximize their Dollar balances and benefit from central bank transfers. This incentive causes sellers to shift trade toward the Dollar, reducing Bitcoin-denominated transactions. This behavior resembles the carry trade strategy (Brunnermeier et al., 2008), but instead of bearing exchange rate risk when investing in foreign bonds, sellers here face inflation risk on the Dollar while earning a nominal interest rate - the central bank transfers - on their Dollar balances.

The resulting goods scarcity in the Bitcoin market drives up Bitcoin goods prices, leading to Bitcoin inflation. This effect is particularly striking given Bitcoin's fixed supply and the absence of a Bitcoin central bank to counteract inflationary pressures. Furthermore, Dollar expansion systematically raises the Bitcoin exchange rate, causing Bitcoin to appreciate relative to the Dollar. Our findings suggest a form of money illusion (Shafir, Diamond, and Tversky, 1997; Fehr and Tyran, 2001; Brunnermeier and Julliard, 2008) or can be interpreted as a variant of Gresham's Law ("bad money drives out good," see Fetter (1932); Rolnick and Weber (1986); Greenfield and Rockoff (1995)), where sellers increasingly prefer trading in Dollars despite its relative depreciation. In contrast, Cardozo, Rosokha, and Zhang (2024) find that the more inflationary currency loses acceptance in trade. Our findings demonstrate a weakening of the quantity theory of money because the increase in goods offered for trade against Dollar mitigates inflationary pressure on the Dollar. In a single-currency economy, monetary expansion would have had a stronger pass-through into prices since trade volume could not shift between competing currencies.

As a third key result, we show that transaction costs can weaken the central bank's ability to steer trade toward the Dollar. As transaction costs rise with Dollar-based purchases, sellers—who anticipate becoming buyers in the future—may shift trade to Bitcoin to equalize relative costs across currencies. This reallocates trade and effectively neutralizes the impact of monetary policy on Dollar usage. Additionally, transaction costs exacerbate both Dollar and Bitcoin inflation by reducing aggregate output, amplifying monetary expansion effects.

In this paper, the Dollar represents a central bank-controlled currency with a flexible supply that can be adjusted as needed, whereas Bitcoin serves as a proxy for a currency with a rigid supply, either fixed or predetermined by its underlying protocol. To illustrate quantity-dependent transaction costs, the Dollar exemplifies a currency where costs increase with usage intensity. For example, as Dollar transactions accumulate, concerns such as loss of privacy and the risk of identity theft become more pronounced. More transactions enable financial institutions or online platforms to collect extensive consumer data, potentially lead-

ing to account restrictions or closures in response to political or regulatory pressures (e.g., the 2022 Canadian trucker protests). In contrast, Bitcoin represents a (semi)anonymous currency where transaction costs are proportional to total transaction volume, primarily in the form of mining fees, similar to a value-added tax. In the experiment, we refer to the competing currencies as Currency A and Currency B to eliminate any potential bias among subjects toward specific real-world currencies such as Bitcoin or the Dollar.

Our work lies at the cross-road between theoretical models of currency competition and the experimental finance literature exploring the use of money in the laboratory. Our work contributes to the literature on currency competition by providing empirical and theoretical evidence on how monetary policy and transaction costs shape the dominance of competing currencies. We build on the theoretical models of Kareken and Wallace (1981); Manuelli and Peck (1990); Schilling and Uhlig (2019a,b) but differ in key ways: Unlike Kareken and Wallace (1981) and Manuelli and Peck (1990); Arifovic (2001); Garratt and Wallace (2018), who analyze currency competition without strategic monetary interventions, our model incorporates both monetary policy and transaction costs. Unlike Schilling and Uhlig (2019a), who assume that monetary policy affects all agents symmetrically, we introduce an asymmetric mechanism where its impact depends on agents' Dollar balances, directly influencing consumption-savings decisions and sellers' allocation of goods across markets, and we additionally study transaction costs.

Our findings challenge the classical Quantity Theory of Money (Friedman), which predicts a one-for-one pass-through of money supply increases into the price level. We show that when currency competition exists, the rise in Dollar trade volume counteracts inflationary pressure—meaning that in a single-currency economy, the inflationary effect of a Dollar expansion would have been stronger.

Our study differs from Benigno, Schilling, and Uhlig (2022), who study international currency competition with a global currency and focus on monetary policy independence under uncovered interest parity, whereas our work directly examines the interplay of monetary policy, transaction costs, and currency substitution in trade. Similarly, Biais, Bisiere, Bouvard, Casamatta, and Menkveld (2023) analyze Bitcoin pricing and volatility under crypto transaction costs but do not consider monetary policy. Our model shares similarities with Schilling and Uhlig (2019b) in studying currency-specific transaction costs, but we differ by simplifying the setting to a single consumption good and modeling quantity-dependent costs jointly with monetary policy, which alter equilibrium outcomes. Camera, Craig, and Waller (2004) examine spending patterns and transaction velocities when a 'bad' money with purchasing power risk competes with a 'good' money without such risk in a Kiyotaki and Wright (1989) framework. While they do not analyze monetary policy, their interpretation of bad money taxation as transaction

costs aligns with our study.

While the focus of our study is on quantity theory and trade shares of competing fiat moneys, Fernández-Villaverde and Sanches (2019) explore competition among privately issued monies in a Lagos and Wright (2005) model, where profit-maximizing entrepreneurs determine the money supply. Building on this, Rahman (2018) and Zhu and Hendry (2018) examine optimal monetary policy under currency competition to private moneys.

Empirically, studying currency competition using field data is challenging due to regulatory influences and limited transaction-level data. Laboratory experiments offer a controlled setting to explore these dynamics systematically. Our in-person experiment at the CREED lab, University of Amsterdam (2022–2023) used a 2x2 design to study monetary policy and transaction costs across 24 sessions with 288 participants.

The experimental design is grounded in the theoretical model by Schilling and Uhlig (2019a), allowing for a continuum of equilibria, where prices, quantities, or both can adjust in response to transaction costs, monetary expansions, and inflation expectations. This flexibility makes the lab an ideal setting for exploring equilibrium selection and price dynamics in currency competition.

Our study contributes to the experimental finance literature on money and currency competition. Previous experimental studies, such as Camera, Noussair, and Tucker (2003b); Rietz (2019); Jiang and Zhang (2018), focus on competition between fiat money and a superior currency or indivisible goods and moneys in search-based settings. Unlike these, we examine two intrinsically worthless fiat currencies in a centralized market with flexible exchange rates, where dynamic price formation plays a critical role. Relative to Ding and Puzzello (2020) and Vidal, Hoyle, Vargas, and Vásquez (2022), who study government interventions in currency competition through legal restrictions and taxation, our setup focuses on how monetary policy - with and without transaction costs- shapes currency dominance in the absence of capital controls.

The study most related to ours is Cardozo, Rosokha, and Zhang (2024), who also examine the quantity theory of money under currency competition in the lab. However, we differ in three key respects: (i) They employ a search model with both centralized and decentralized markets, while we use fully centralized markets with flexible exchange rates. (ii) They include a currency exchange market, which we do not. (iii) Their monetary transfers are symmetric, whereas ours favor agents with higher Dollar balances. These differences yield contrasting findings. Cardozo et al. (2024) confirm the classical quantity theory—whereby a currency's supply increase leads to proportional inflation, and they show that monetary expansion reduces acceptance of that money in trade. We find a more complex dynamic. Although inflation occurs in the expanded currency, sellers may shift trade

toward it to benefit from proportional monetary transfers, creating a money illusion absent in Cardozo et al. (2024). This shift mitigates inflation's impact, as increased trade volume absorbs some of the supply expansion, and challenges the standard one-to-one money supply-inflation pass-through. Additionally, we identify a scarcity-driven inflation effect, where increasing one currency's supply can also inflate the competing currency—an effect they do not observe. Another distinction is transaction costs: we incorporate both flat and quantity-dependent costs, while they impose only a flat fee on sellers accepting foreign currency in decentralized markets. Unlike them, we do not study welfare, as money neutrality in our centralized setup without transaction costs prevents aggregate consumption effects.

Finally, unlike Jiang, Puzzello, and Zhang (2023), who study the quantity theory of money in a single-currency economy, we examine how monetary policy operates in a dual-currency setting, identifying the spillover effects of inflation across competing currencies.

Our theoretical and experimental framework assumes the use of money in trade, rather than deriving it from first principles. Search-based models provide microfoundations for money's acceptance in trade by explaining how intrinsically worthless objects can become media of exchange under fixed prices, trade frictions, and decentralization (Kiyotaki and Wright, 1989; Camera and Corbae, 1999). Experimental work on these models has focused on the emergence of money (Brown, 1996; Duffy and Ochs, 1999, 2002; Camera et al., 2003a; Camera and Casari, 2014) and price formation in monetary search environments (Duffy and Puzzello, 2014a,b).

Instead, we build on Schilling and Uhlig (2019a) and Kareken and Wallace (1981), employing centralized goods markets to abstract from the double coincidence of wants problem. This approach reduces structural assumptions, allowing us to focus on monetary policy and transaction costs under currency competition in a controlled lab setting where subjects have limited cognitive capacity.

No prior experiments have tested the dynamics of Schilling and Uhlig (2019a,b) in the lab, particularly in relation to monetary policy and equilibrium selection under trade frictions. When theory predicts multiple equilibria, laboratory experiments help identify which outcomes are more likely to emerge in practice (Lucas Jr, 1986; Camerer, 2003; Marimon and Sunder, 1993, 1994; Van Huyck et al., 1990).

2 The model

We consider an infinite-horizon endowment economy with discrete time $t = 1, 2, \ldots$. The model builds on a perfect foresight version of the currency competition model

of Schilling and Uhlig (2019a), which examines monetary policy, and Schilling and Uhlig (2019b), which introduces transaction costs. We discuss the differences as they occur along our model description.

2.1 Core ingredients

Media of exchange There is a single, perishable consumption good, which we call packages of "chips," that can be exchanged using either of two competing currencies, which we refer to them as Dollars and Bitcoins to simplify the exposition of the theory. The name "Dollar" represents a currency whose supply is at the discretion of a monetary institution, i.e. a central bank or a smart contract that can react spontaneously to specific market situations.[1] The name "Bitcoin" should be thought of as a placeholder for currencies for which no such institution exists.[2] Both currencies are equally accepted for transactions.

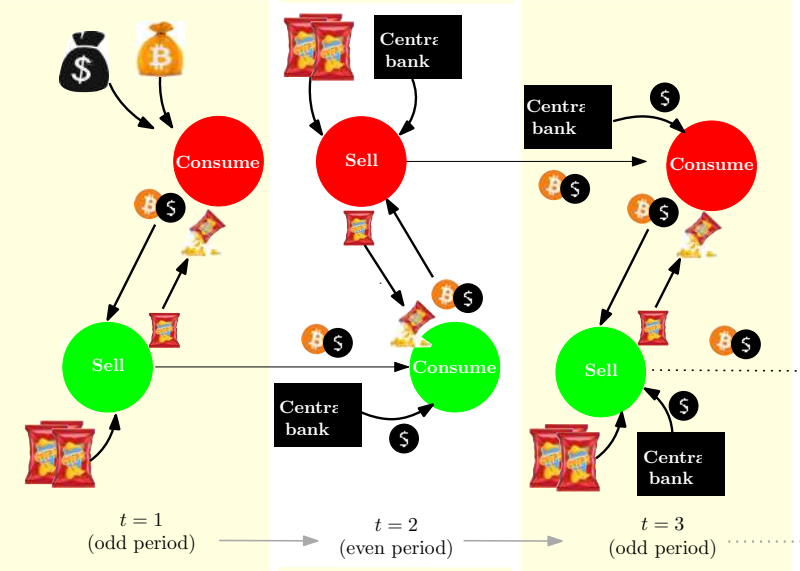
Buyers and sellers To match the experiment, unlike in Schilling and Uhlig (2019a,b), we consider a discrete and finite number of agents in the economy. There are two equally sized, infinitely-lived groups of N "green" and N "red" agents. Both agent-types enjoy utility $u(c_{t,j})$ from chips package consumption $c_{t,j} \geq 0$. The utility function $u(\cdot)$ is positive, strictly increasing, concave and twice differentiable with $u(0) = 0$. Agents derive no utility from money balances. Following Schilling and Uhlig (2019a,b), to create a motive for trade and a role for money as a medium of exchange, we assume that the agent groups alternate in consuming and selling the consumption good across time periods, see Figure 1. In even periods, every red agent is exogenously endowed with some packages to sell against either Bitcoin or Dollar to the green agents who are then buyers, and thus can consume, and vice-versa in the odd periods. Agents do not enjoy consuming in periods in which they are sellers. All red and green agents maximize their expected discounted lifetime utility subject to the constraint that they consume only every other period, that is:

$$\underbrace{U_g = \sum_{t=0}^{\infty} \beta^{2t}\, u(c_{2t})}_{\substack{\text{utility of green agents who} \\ \text{only consume in even periods}}} \quad , \quad \underbrace{U_r = \sum_{t=0}^{\infty} \beta^{2t+1}\, u(c_{2t+1})}_{\substack{\text{utility of red agents who} \\ \text{only consume in odd periods}}} \qquad \beta \in (0,1). \quad (1)$$

Since the good is perishable, the sellers have an incentive to sell all their endowment to the buyers against currency an, by doing so, raise funds for financing their consumption in the next period, when they turn into buyers.

[1] One may think, for instance, of the Terra-Luna swap contract that allowed swapping Terra for Luna and vice versa by mining or burning Luna at a rate that did depend on the current Luna price.

[2] Note that the Bitcoin protocol can be thought of as a constrained central bank since it prescribes the supply increase over time, until 21 million Bitcoin are mined. However, unlike the Dollar, its total quantity cannot be altered 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 1: Schematic representation of the structure of the economy

Endowments We assume that each seller is endowed with the same quantity of packages that is constant over time and denoted by $y_{i,t} \equiv \bar{y}$. Given N sellers in the economy, the total good supply in any period is $Y_t \equiv \bar{Y} = N y_{i,t}$. As for the currency endowments, in $t = 1$, the buyers are each endowed with d_1 Dollar and b_1 Bitcoin, implying an initial money supply of $D_1 \equiv N d_1$ and $B_1 \equiv N b_1$. In any subsequent period, agents' money balances evolve according to their trade history and, possibly, monetary policy, see hereafter.

Trade and market-segmentation Unlike Schilling and Uhlig (2019a,b) where all goods are simultaneously for sale against both currencies, our goods markets are semi-segmented. In each period, the sellers preallocate their packages to the Dollar- and the Bitcoin-denominated markets. Let $x_{i,t} \geq 0$ be seller i's packages offered for sales against Bitcoin and $z_{i,t} \geq 0$ those against Dollar. Sellers face the following allocation feasibility constraint:

$$y_{i,t} \equiv \bar{y} \geq x^s_{i,t} + z^s_{i,t}. \tag{2}$$

Any allocation is possible, meaning a seller can sell all, some or no packages against Dollars and Bitcoin, and there is no segmentation from the sellers' perspective. Only after the sellers' allocation choice, markets open for trade to the buyers. The sellers cannot reallocate packages during trade, and there is no direct currency exchange. The Bitcoin and the Dollar-denominated markets are, therefore, segmented from the buyers' perspective. Sellers, however, know that they will be buyers in the next period, and allocate their packages to the markets in a way that

makes them indifferent with regard to receiving either currency in trade. In that regard, despite the semi-segmentation, the Dollar- and the Bitcoin-denominated package markets are interconnected through the sellers' strategies (i.e. next period's buyers' strategies).

Denote by P_t the market clearing price of a package in the Dollar-denominated market, and let $\hat{P}_t$ be the market clearing price of a package sold against Bitcoin. Let Q_t denote the implicit price of one Bitcoin in terms of Dollar, that is $\hat{P}_t = P_t/Q_t$ or, in other words, the Bitcoin exchange rate in Dollar:

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

A buyers' consumption can be decomposed as Dollar- and Bitcoin-financed consumption:

$$c_{i,t} = q^D_{i,t} + q^B_{i,t}, \tag{4}$$

where $q^D_{t,i}$ and $q^B_{t,i}$ are buyer i's number of packages purchased, respectively in Dollar and in Bitcoin. A buyer faces a Dollar and a Bitcoin budget constraint:

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

where $d_{i,t}$ and $b_{i,t}$ denote individual money balances at the beginning of t, *before* trade occurs.

Monetary policy and money balances In the absence of a Bitcoin central bank, mining and "lost" Bitcoin, the Bitcoin supply is constant, namely $B_t \equiv \bar{B}$. As in Schilling and Uhlig (2019a), there exists a Dollar central bank that implements an inflation target by adjusting the Dollar supply via a money multiplier $m \geq 1$, printing Dollars at zero costs. The central bank multiplies the Dollar balances of all agents by m at the end of each period t, after trade has occurred, and the aggregate Dollar supply evolves as: $D_t = mD_{t-1} > D_{t-1}$. Hence, monetary policy affects all agents' Dollar balances. Unlike in Schilling and Uhlig (2019a) where the Dollar transfers are symmetric across all agents, transfers are proportional to agents' Dollar balances and can thus differ across agents, favoring high Dollar balances. Dollar monetary policy is mute. Define the Dollar inflation as $\Pi_t = \frac{P_t}{P_{t-1}}$.

After consumption spending in a given period t, which reduces their Dollar and Bitcoin money balances, a buyer becomes a seller in the next period $t+1$, and their Dollar and Bitcoin balances equal, respectively:

$$d_{i,t+1} = m\left(d_{i,t} - q^D_{i,t}P_t\right), \tag{6}$$

$$b_{i,t+1} = b_{i,t} - q^B_{i,t}\hat{P}_t, \tag{7}$$

Equivalently, $d_{i,t+1}, b_{i,t+1} \geq 0$ denote buyer i's Dollar and Bitcoin savings, respec-

tively. Conversely, money balances of a seller in time t are augmented by their sales revenues, and they enter the next period $t+1$ as a buyer with the following Dollar and Bitcoin balances:

$$d_{i,t+1} = m\left(d_{i,t} + z^s_{i,t}P_t\right), \tag{8}$$

$$b_{i,t+1} = b_{i,t} + x^s_{i,t}\hat{P}_t. \tag{9}$$

Individual money balances need to sum up to the total supply, i.e. no currency is lost, $B = \sum_{i\in I_g\cup I_r} b^i_t$, and $D_t = \sum_{i\in I_g\cup I_r} d^i_t$, where I_g denotes the group of green, and I_r the group of red agents.

Transaction costs We may introduce asymmetric, currency-specific transaction costs on Bitcoin and Dollar-financed purchases but, unlike Schilling and Uhlig (2019b), the transaction cost for Dollar purchases is quantity-dependent. Quantity-dependent transaction costs, which reduce utility from consumption, can be illustrated by real-world examples such as the freezing of bank accounts for politically motivated actions (e.g. the Canadian trucker protests in 2022) or credit card companies flagging customers due to gambling-related purchases (such as casino visits). These increasing costs in Dollar transactions can be understood as a loss of privacy: the more a buyer transacts in Dollars, the more information is revealed through purchase histories, reducing effective consumption utility. This is modeled in our framework as a reduction in the chips content of a package available for consumption to the buyers, while leaving the total package supply and individual package endowments of the sellers unaffected.

To model these costs, it is convenient to introduce $R(q^D_{i,t})$, the buyer i's marginal increase in chips consumption in period t when buying an additional package with Dollar, while they already bought $q^D_{i,t}$ packages in this period with that currency; and $r(q^D_{i,t})$, their average chip consumption in t per Dollar-financed package after costs. Define $R(q^B_{i,t})$ and $r(q^B_{i,t})$ similarly for chip consumption purchased in Bitcoin. In the benchmark case, there are no transaction costs: a buyer receives and consumes the full content of chips in each purchased package, regardless of the currency used and the amount of packages they overall purchase in that period. We therefore have:

$$r(q^D_{i,t}) = 1,\, r(q^B_{i,t}) = 1, R(q^D_{i,t}) = 1,\, R(q^B_{i,t}) = 1. \tag{10}$$

In the Dollar-denominated market, the transaction costs are increasing in the number of packages a buyer purchases using Dollar in a given period.[3] Let $\gamma(q^D_{i,t}) \in [0,1]$ be a positive, strictly decreasing, continuous function, describing the marginal after-cost consumption of the $q^D_{i,t}$'th package bought by buyer i in period t. When

[3] This implies that in each period t and for each buyer i, the Dollar costs are reset.

purchasing a total of $q^D_{i,t} \in \mathbb{R}_+$ packages in Dollars, buyer i's average consumption per Dollar-financed package (after costs) then equals:

$$r(q^D_{i,t}) = \frac{\int_0^{q^D_{i,t}} \gamma(k)\, dk}{q^D_{i,t}} \tag{11}$$

where the numerator represents the total Dollar-financed consumption of buyer i in t. After costs, a buyer consumes on average only a share $r(q^D_{i,t})$ of the total $q^D_{i,t}$ packages purchased with Dollar, each at a price P_t, while the rest is lost due to frictions, reducing consumption in the economy. In particular, this consumed share is decreasing in the number of packages bought using Dollars, i.e. $r'(q^D_{i,t}) < 0$. Since $\gamma(\cdot)$ declines, the marginal increase in Dollar-financed consumption when buying an additional package in Dollar is given by:

$$R(q^D_{i,t}) \equiv \frac{\partial}{\partial q^D_{i,t}} \left(\int_0^{q^D_{i,t}} \gamma(k)\, dk \right) = \gamma(q^D_{i,t}) < r(q^D_{i,t}) \tag{12}$$

One can interpret $P_t / R(q^D_{i,t})$ as the price of an additional full package purchased with Dollars for buyer i, if they purchase overall $q^D_{i,t}$ packages using Dollars in a given period t. Note that the market-clearing Dollar price P_t cannot explicitly depend on the transaction cost since the Dollar transaction cost $r(q^D_{i,t})$ is buyer-specific and is inherently tied to their purchase history. However, transaction costs indirectly influence prices through equilibrium conditions: As buyers may anticipate a reduction in package content with increased Dollar purchases, their willingness to use Dollars versus Bitcoin may shift, affecting market allocation and, consequently, price formation.

In contrast, Bitcoin transactions incur a flat fee, representing mining costs proportional to purchase volume or the environmental impact of maintaining the proof-of-work network.[4] We impose a cost (akin to a consumption tax) of $1 - r(q^B_{i,t})$ of the package content to all buyers and independently of the quantity purchased so far in that period with Bitcoin. The average consumption per Bitcoin-financed package after costs then equals $r(q^B_{i,t}) \equiv r^B < 1$. Since the cost is flat, we have $R(q^B_{i,t}) = r(q^B_{i,t}) \equiv r^B$, and every additional package bought with Bitcoin brings an extra $R(q^B_t) = r^B$ chip consumption. One can interpret $\hat{P}_t / r^B$ as the price of an additional full package purchased with Bitcoin.

[4]While one might question the assumption of increasing Dollar costs, it is important to note that, absent monetary policy, the currency names could be reversed, interpreting Bitcoin as the currency with increasing costs and Dollar transactions as subject to flat fees. However, when introducing monetary policy, only the currency governed by a central bank with discretionary transfers can represent the Dollar, as Bitcoin's supply remains fixed by protocol. Assigning the increasing fee to the Dollar is more reasonable, given that Bitcoin transactions are semi-anonymous. In detail, Bitcoin transactions are publicly visible for addresses, but the identity behind an address is generally unknown to the network, whereas banks and payment providers like VISA and PayPal have direct access to customer identities linked to account numbers. Additionally, implementing flat costs for both currencies is straightforward, as shown in our robustness check.

2.2 Market clearing and equilibrium

Unlike in Schilling and Uhlig (2019a), the sellers predetermine the package allocation across markets, which prescribes two market-clearing constraints. Accounting for unsold packages and transaction costs if they are imposed, in each period, the following must hold on the Dollar- and the Bitcoin-denominated markets:

$$\begin{cases} Y_t^D = \sum_{i=1}^N z_{i,t} & = \sum_{i=1}^N r(q_{i,t}^D) q_{i,t}^D & + \sum_{i=1}^N \left(1 - r(q_{i,t}^D)\right) q_{i,t}^D + & \sum_{i=1}^N \ell_{i,t}^D, \\ \underbrace{Y_t^B = \sum_{i=1}^N x_{i,t}}_{\text{aggregate supply}} & = \underbrace{\sum_{i=1}^N r^B q_{i,t}^B}_{\text{consumption}} & + \underbrace{\sum_{i=1}^N (1 - r^B) q_{i,t}^B}_{\text{transaction costs}} & + \underbrace{\sum_{i=1}^N \ell_{i,t}^B}_{\text{unsold packages}}, \end{cases} \tag{13}$$

where $\ell_{i,t}^D, \ell_{i,t}^B \geq 0$ are seller i's unsold packages in t on each respective market, and the transaction costs incurred by the buyers in either currency reflect a loss of consumption.

Furthermore, we have $Y_t \equiv \bar{Y} = Y_t^B + Y_t^D$ and it is convenient to define the *Dollar sales share*

$$k_t^C \equiv \frac{Y_t^D}{Y} \in [0,1] \tag{14}$$

as the share of output (packages) offered for sale in the Dollar market, and the *Dollar trade share*

$$\hat{k}_t^C \equiv \frac{\Sigma_i^N q_{ti}^D}{Y} = k_t^C - \frac{\ell_t^D}{Y} = \in [0,1] \tag{15}$$

as the share of output traded against Dollars, which is equivalent to the consumption share financed using Dollars. If there are no unsold packages in the Dollar market, the two shares coincide. The Dollar sales share is a key variable in our analysis since it reflects the sellers' output allocation decision across the Dollar- versus the Bitcoin-denominated markets.

We also compute the velocity of money, that is the average number of times a unit of currency changes hands per period. By design, our model imposes an upper bound of one on the velocity of either currency, which thus corresponds to the fraction of the total supply spent per period:

$$V_t^B = \frac{\hat{P}_t \Sigma_i^N q_{i,t}^B}{B} \in [0,1], \qquad \text{and} \qquad V_t^D = \frac{P_t \Sigma_i^N q_{i,t}^D}{D_t} \in [0,1], \tag{16}$$

where the numerators represent the total amount of respective currency spent in each market in time t.

Following Friedman's quantity theory of money and considering the market segmentation described above, the total output sold in each market must equal the real value of the corresponding currency spent in that market:

$$Y_t^D - \ell_t^D = \frac{D_t V_t^D}{P_t}, \qquad \text{and} \qquad Y_t^B - \ell_t^B = \frac{B V_t^B}{\hat{P}_t} = \frac{B V_t^B}{P_t} Q_t. \tag{17}$$

Currency savings reduce spending and, consequently, the velocity of money, as given by:

$$V_t^B = \frac{\sum_i^N (b_{i,t} - b_{i,t+1})}{B}, \qquad \text{and} \qquad V_t^D = \frac{\sum_i^N (d_{i,t} - d_{i,t+1}/m)}{D_t}. \tag{18}$$

Note that for accurately measuring the Dollar velocity, we must account for the monetary policy multiplier m, which increases Dollar balances $d_{i,t+1}$ without reflecting savings between t and $t+1$.

Finally, given monetary policy $m \geq 1$ and transaction costs $(1 - r(q_{i,t}^D)), 1 - r^B) \in [0,1]^{2N+1}$, the following equilibrium definition applies:

Definition 2.1 (Equilibrium)**.** *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* $\left\{\hat{P}_t\right\}_{t\geq 0}$*, implying an exchange rate* $\left\{Q_t\right\}_{t\geq 0}$*,* $Q_t = \frac{P_t}{\hat{P}_t}$*;*
(ii) package allocation decisions by sellers to the Dollar market $\left\{z_{i,t}\right\}_{t\geq 0}$ *and the Bitcoin market* $\left\{x_{i,t}\right\}_{t\geq 0}$*, which imply the quantity of output* Y_t^D *and* Y_t^B *offered for sale in the respective markets;*
(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* $\left\{q_{i,t}^B, b_{t+1,i}\right\}_{t\geq 0}$
such that:

1. *the seller's allocation decisions of packages to the Dollar and the Bitcoin market are optimal given prices subject to feasibility, possible transaction costs, and the Dollar central bank's monetary policy;*
2. *the buyers' consumption-savings decisions are optimal given prices subject to both budget constraints, transaction costs and monetary policy;*
3. *prices clear their respective markets.*

3 Theoretical results

We now state the equilibrium conditions that form our theoretical predictions underlying our testable hypotheses in the experiment. The corresponding derivations can be found in Appendix A.1.

Lemma 3.1 (Efficiency)**.** *For any configuration of monetary policy and transaction costs considered above, the sellers offer all packages in the markets, and the buyers buy them all, i.e.* $\ell_t = \ell_t^B + \ell_t^D = 0,\ t \geq 1.$

This implies that the Dollar sales share should equal the Dollar trade share equalize, i.e. $k_t^C = \hat{k}_t^C,\ \forall t$.

As a direct corollary of Lemma 3.1, we obtain:

Corollary 3.1. *Absent transaction costs, in every equilibrium, aggregate consumption is constant across periods.*

This Corollary is evident since individual and aggregate endowments are constant and all packages for sale always find buyers. In the treatments with transaction costs, aggregate consumption can vary across periods, because the Dollar transaction cost is quantity- dependent. Therefore, aggregate consumption varies with the aggregate number of packages purchased in Dollars.

Hypothesis 3.1 (Market efficiency)**.** *All sellers should sell all their packages in each period $t \geq 1$.*

3.1 Benchmark case (no transaction costs)

In the benchmark economy, there are no transaction costs and the following proposition summarizes the equilibrium conditions for any mute or active monetary policy, i.e. for any multiplier $m \geq 1$:

Proposition 3.1 (Benchmark equilibrium (no transaction costs))**.**

1. *Inflation/exchange rates (sellers' indifference): Sellers prefer selling for Dollars if $\frac{P_{t+1}}{P_t} < m \frac{\hat{P}_{t+1}}{\hat{P}_t}$. Sellers are indifferent w.r.t. allocating packages to the Dollar- versus the Bitcoin-denominated market if the Dollar inflation equals m-times the Bitcoin inflation at any point in time,*

$$\frac{P_{t+1}}{P_t} = m \frac{\hat{P}_{t+1}}{\hat{P}_t}, \tag{19}$$

which is equivalent to requiring that the Bitcoin price in Dollars (i.e. the Bitcoin exchange rate) grows at rate m over time:

$$Q_{t+1} = m\, Q_t = m^t\, Q_1. \tag{20}$$

2. *Pricing (buyers' consumption-savings): The buyers spend all Dollars on goods if $\beta^2 m^2 \frac{1}{P_{t+2}} u'(c_{t+2}) \leq \frac{1}{P_t} u'(c_t)$, and spend all Bitcoins if $\beta^2 \frac{1}{\hat{P}_{t+2}} u'(c_{t+2}) \leq \frac{1}{\hat{P}_t} u'(c_t)$. In case of equality, the buyers are indifferent with regard to saving and consuming, resulting in prices*

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2 \frac{u'(c_{t+2})}{u'(c_t)}, \tag{21}$$

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \frac{u'(c_{t+2})}{u'(c_t)}. \tag{22}$$

3. *Clearing of both good markets requires:*

$$\begin{cases} Y_t^D = Y - & Y_t^B = \sum_{i=1}^N z_{i,t} = \sum_{i=1}^N q_{i,t}^D = \frac{D_t V_t^D}{P_t} = \frac{m D_{t-1} V_t^D}{P_t}, \\ & Y_t^B = \sum_{i=1}^N x_{i,t} = \sum_{i=1}^N q_{i,t}^B = \frac{B V_t^B}{\hat{P}_t}. \end{cases} \tag{23}$$

In the case of mute monetary policy ($m = 1$), both currencies are perfect substitutes, and our setting is akin to the perfect foresight model analyzed in Kareken and Wallace (1981) and we recover their key result:[5] to make sellers indifferent between Dollar and Bitcoin (Item 1. of Proposition 3.1), Dollar inflation must equal Bitcoin inflation and the exchange rate must be constant, the initial prices – and thus the initial exchange rate Q_1 – are undetermined, but for all following periods, the exchange rate is pinned down by Q_1. Independently of m, any allocation of packages across markets (z_{ti}, x_{ti}) is rationalizable since sellers are indifferent. Item 2 of Proposition 3.1 states that buyers must be indifferent between spending and saving their Dollar and Bitcoin today. In a symmetric equilibrium, $u'(c_{t+2}) = u'(y_{t+2}) = u'(y_t) = u'(c_t)$ and buyers' indifference requires Dollar and Bitcoin prices to change at a rate β. Therefore, theory suggests the following testable hypothesis:

Hypothesis 3.2 (Benchmark with muted monetary policy ($m = 1$))**.**

1. *The Dollar inflation equals the Bitcoin inflation.*
2. *The exchange rate is constant across time.*
3. *In every symmetric equilibrium with $\beta < 1$, Dollar and Bitcoin prices are weakly decreasing across time.*
4. *In every symmetric equilibrium with $\beta < 1$, if prices are constant, the buyers should spend all of their Dollar and Bitcoin endowments in every period.*

Active monetary policy ($m > 1$) incentivizes sellers to trade in Dollars by providing proportional transfers, potentially outweighing the inflation differential between the two currencies. In this case, sellers will prefer Dollars if the benefit of these transfers is sufficiently large, even if Dollar inflation exceeds Bitcoin inflation. To make sellers indifferent between Dollar and Bitcoin, Item 1. of Proposition 3.1 states that Dollar inflation must exceed Bitcoin inflation by a factor of m, in which case the Dollar trade share does not change. If Dollar inflation does not grow fast enough, the Dollar sales share must increase, i.e. $Y^D_{t+1} > Y^D_t$ and $Y^B_{t+1} < Y^B_t$. We refer to such an outcome as an equilibrium with *partial Dollar price pass-through* (i.e., slow Dollar price adjustment), since the Dollar price does not rise quickly enough to keep sellers indifferent. If the sellers could only trade in one currency, package reallocation would not be possible, and the price impact of Dollar monetary policy would have been stronger than in our model, as shown in Appendix A.1.3.

Per Item 2. of Proposition 3.1, monetary policy also influences buyers' decisions by rewarding Dollar savings. The future Dollar price level P_{t+2} must adjust to maintain buyers' indifference between consumption and savings in the Dollar

[5]The only difference is that our markets are semi-segmented because sellers predetermine the allocation of goods across the two markets.

market. In a symmetric equilibrium, $u'(c_{t+2}) = u'(y_{t+2}) = u'(y_t) = u'(c_t)$, the Dollar price must change at a rate of βm it must increase if $\beta m > 1$, and weakly decrease otherwise to prevent an increase in the Dollar savings. If the Dollar price level does not increase sufficiently, buyers do not face enough inflationary pressure to incentivize immediate consumption and instead prefer to save Dollars to benefit from proportional transfers.

Per Item 3 of Proposition 3.1, if Dollar inflation does not adjust enough and sellers shift packages into the Dollar market, the market-clearing conditions for both currencies adjust. In the Dollar market, the quantity theory of money gives:

$$Y_{t+1}^D = \frac{mD_t V_{t+1}^D}{P_{t+1}} > \frac{D_t V_t^D}{P_t} = Y_t^D. \tag{24}$$

Since markets are segmented, buyers observe Y_{t+1}^D, and Dollar prices must adjust until buyers are indifferent between consumption and savings, which affects Dollar velocity V_{t+1}^D. Two effects influence buyers' behavior: (i) Increased Dollar holdings relax budget constraints, which pushes prices up; and (ii) a higher supply raises Dollar-financed consumption, which lowers marginal utility (i.e. the willingness to pay) and pushes prices down. Over time, the first effect dominates, because aggregate supply is bounded, while Dollar growth is not.

By contrast, in the Bitcoin market, the first effect is absent since the Bitcoin supply is fixed and the buyers' consumption-savings condition (22) is unaffected by m. However, the second effect remains and a fixed Bitcoin supply meets a reduced output supply, leading to lower Bitcoin-financed consumption, a higher marginal utility, and an increase in Bitcoin-denominated good prices. Thus, if Dollar inflation does not increase sufficiently, causing supply shifts across markets, Dollar monetary policy indirectly affects the Bitcoin price i.e., there is a spill-over effect.[6]

Overall, Dollar monetary policy enforces either high Dollar inflation where its pass-through to Dollar prices is complete, or an increase in the Dollar trade share, in which case its pass-through is partial only and currency competition weakens the effectiveness of Dollar monetary policy. Theory therefore suggests either of the following sets of equilibrium dynamics, which forms our set of alternative testable hypotheses:

Similar inflation-deterring behavior is documented in Schilling and Uhlig (2019a), where symmetric Dollar transfers can induce Bitcoin deflation instead of Dollar inflation. Further, Schilling and Uhlig (2019b) show that an increased Dollar supply may shift the "critical good" at which buyers switch from using Dollars to Bitcoin

[6]The spill-over effect is apparent if one notices that the Dollar and the Bitcoin prices for goods are interconnected by the seller's indifference condition i.e., given initial price levels P_1 and $\hat{P}_1$, we have: $\hat{P}_{t+1} = \frac{1}{m^t Q_1} P_{t+1} = \frac{1}{mQ_t} P_{t+1}$, which states that if P_{t+1} increases, $\hat{P}_{t+1}$ adjusts slower, or may even decrease. For instance, assume P grows at a rate $\beta m < m$, $P_{t+1} = \beta m P_t$, then $\hat{P}_{t+1} = \frac{1}{m} P_{t+1} \frac{\hat{P}_t}{P_t} = \beta \hat{P}_t < \hat{P}_t$.

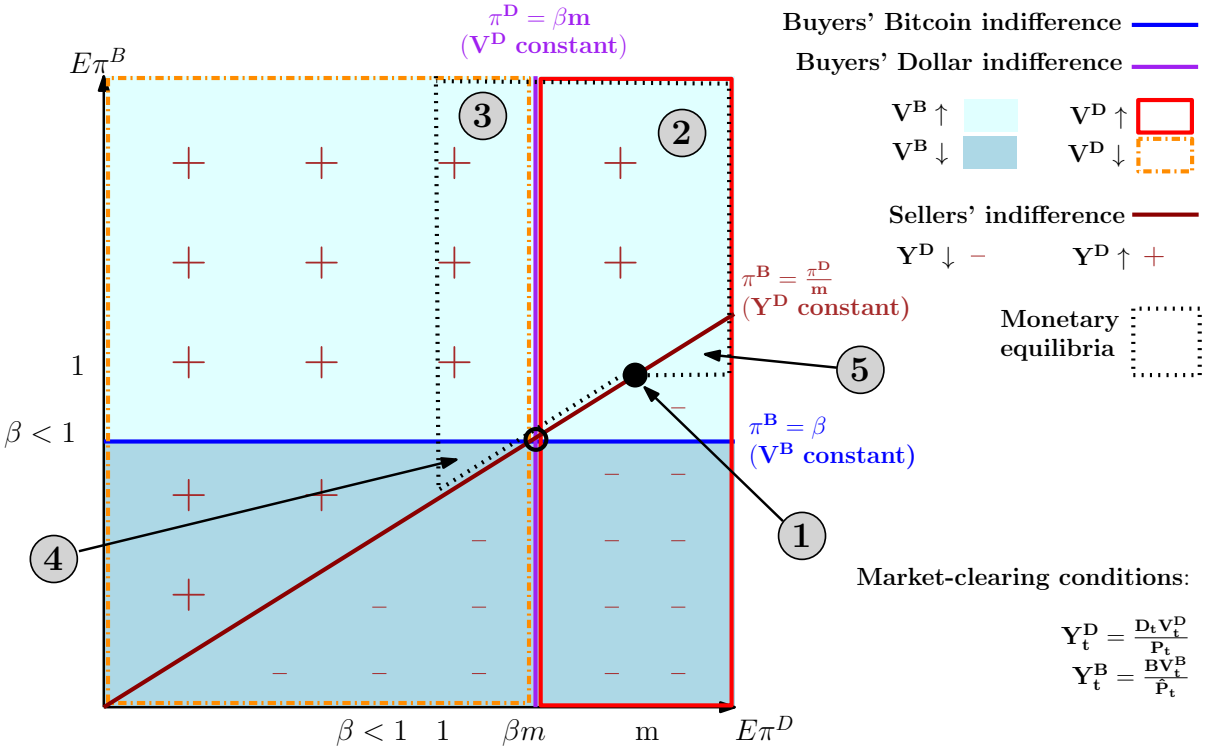


Figure 2: Inflation dynamics with monetary policy $m \geq 1$ in the absence of transaction costs

for purchases.

Hypothesis 3.3 (Benchmark with active monetary policy ($m > 1$))**.**

H0 ***Equilibrium with complete monetary policy pass-through into prices (Full Dollar price adjustment)***

(a) ***Sellers' Indifference***

i. Dollar good prices raise m times faster than Bitcoin prices.

ii. The Bitcoin exchange rate grows at the rate m in every period, by (20).

iii. Sellers keep their allocation of packages $(z_{i,t}, x_{i,t})$, constant across time, implying $Y^D_{t+1} = Y^D_t$, $Y^B_{t+1} = Y^B_t$.

iv. The Dollar sales share k^C_t is constant over time.

(b) ***Buyers' Indifference***

- *The Dollar inflation raises fast enough across rounds to keep buyers indifferent between consumption and savings at the same level. There should be no increase in the buyers' Dollar savings rate, i.e. the Dollar velocity does not go down.*

(c) Sequential market clearing at a constant Dollar sales share, $Y^D_t = Y^D_{t-1}$, requires

$$Y^D_t = \frac{D_t V^D_t}{P_t} = \frac{m D_{t-1} V^D_t}{P_t} = \frac{D_{t-1} V^D_{t-1}}{P_{t-1}} = Y^D_{t-1}$$

and thus requires Dollar velocity to change across time by

$$V_t^D = \frac{1}{m}\frac{P_t}{P_{t-1}}\, V_{t-1}^D \tag{25}$$

At a constant Bitcoin supply, sequential market clearing at a constant Bitcoin sales share $Y_t^B = Y_{t-1}^B$ requires

$$Y_t^B = Y - Y_t^D = \frac{B\, V_t^B}{\hat{P}_t} = \frac{B\, V_{t-1}^B}{\hat{P}_{t-1}} \tag{26}$$

and thus a change of the Bitcoin velocity according to

$$V_t^B = \frac{\hat{P}_t}{\hat{P}_{t-1}}\, V_{t-1}^B \tag{27}$$

H1 ***Equilibrium with partial Dollar price pass-through (Slow Dollar price adjustment)***

(a) ***Buyers' partially indifference***

- *The buyers increase their Dollar savings, bidding lower prices in the Dollar market, which reduces Dollar inflation $\beta^2 m^2 > P_{t+2}/P_t$ across two consecutive periods.*
- *Buyers remain indifferent between consumption and savings in the Bitcoin market requiring that $\beta^2 = \hat{P}_{t+2}/\hat{P}_t < 1$, i.e. Bitcoin prices must weakly decrease across time.*

(b) ***Sellers' not indifferent***

i. *Since buyers hold back Dollars, the Dollar inflation undercuts m-times the Bitcoin inflation, $P_{t+1}/P_t < m\, \hat{P}_{t+1}/\hat{P}_t$.*

ii. *The Bitcoin exchange rate, i.e. the price of a Bitcoin denominated in Dollars grows at a rate below m, $Q_{t+1} < mQ_t$ for all $t \geq 1$.*

iii. *Sellers prefer selling for Dollars, and reallocate packages to the Dollar market, $Y_{t+1}^D > Y_t^D$, $Y_{t+1}^B < Y_t^B$.*

(c) Sequential market clearing at an increasing Dollar sales share $Y_t^D > Y_{t-1}^D$, requires

$$Y_t^D = \frac{m\, D_{t-1}\, V_t^D}{P_t} > \frac{D_{t-1}\, V_{t-1}^D}{P_{t-1}} = Y_{t-1}^D$$

and thus requires Dollar velocity to change across time by

$$V_t^D > \frac{1}{m}\frac{P_t}{P_{t-1}}\, V_{t-1}^D \tag{28}$$

Due to $\beta^2 m^2 > P_{t+2}/P_t$, we can have $\frac{1}{m}\frac{P_t}{P_{t-1}} < 1$ so that the Dollar velocity may decline across time (increase in Dollar savings).
An increasing Dollar sales share requires a decreasing Bitcoin sales share, $Y_t^B < Y_{t-1}^B$, and thus

$$Y_t^B = Y - Y_t^D = \frac{B\,V_t^B}{\hat{P}_t} < \frac{B\,V_{t-1}^B}{\hat{P}_{t-1}} \tag{29}$$

and thus a change of the Bitcoin velocity according to

$$V_t^B < \frac{\hat{P}_t}{\hat{P}_{t-1}}\, V_{t-1}^B \tag{30}$$

If the sellers reallocate packages to the Dollar market, there are fewer packages in the Bitcoin market, and sequentially increased package scarcity in the Bitcoin market jointly with market clearing and requires the Bitcoin velocity to go down over time (reduced Bitcoin savings).

3.2 Economy with currency-specific transaction costs

The following equilibrium conditions must hold for any multiplier $m \geq 1$,

Proposition 3.2 (Transaction cost equilibrium)**.**

1. *Inflation/exchange rates (sellers' indifference): Sellers prefer selling for Dollars if* $\frac{P_{t+1}}{P_t} < m\,\frac{R(q_t^D)}{R^B}\,\frac{\hat{P}_{t+1}}{\hat{P}_t}$. *Sellers are indifferent w.r.t. allocating packages to the Dollar versus Bitcoin market if*

$$\frac{P_{t+1}}{P_t} = m\,\frac{R(q_t^D)}{R^B}\,\frac{\hat{P}_{t+1}}{\hat{P}_t}. \tag{31}$$

or

$$\hat{P}_{t+1} = \frac{1}{m}\frac{R^B}{R(q_t^D)}\,P_{t+1}\frac{\hat{P}_t}{P_t} = \left(\frac{1}{m^t}\,\frac{(R^B)^t}{\prod_{k=1}^t R(q_k^D)}\right) P_{t+1}\,\frac{\hat{P}_1}{P_1}. \tag{32}$$

Equivalently, the exchange rate (Bitcoin price in Dollars evolves according to)

$$Q_{t+1} = m\,\frac{R(q_t^D)}{R^B}\,Q_t = m^t\left(\frac{\prod_{k=1}^t R(q_k^D)}{(R^B)^t}\right) Q_1 \tag{33}$$

2. *Consumption-savings (Buyers' indifference): As long as some Dollars and Bitcoins are spent in each period, the buyers spend all Dollars on goods if* $\beta^2\,m^2\,R(q_{t+2}^D)\,\frac{1}{P_{t+2}}u'(c_{t+2}) \leq R(q_t^D)\,\frac{1}{P_t}u'(c_t)$ *and spend all Bitcoins if* $\beta^2\frac{1}{\hat{P}_{t+2}}u'(c_{t+2}) \leq \frac{1}{\hat{P}_t}u'(c_t)$. *In case of equality, the buyers are indifferent with regard to saving and consuming, resulting in the Euler-pricing equations for Dollars,*

$$\frac{P_{t+2}}{P_t} = \beta^2\,m^2\,\frac{R(q_{t+2}^D)}{R(q_t^D)}\,\frac{u'(c_{t+2})}{u'(c_t)} \tag{34}$$

and for Bitcoin

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2\,\frac{u'(c_{t+2})}{u'(c_t)} \tag{35}$$

3. *Clearing of both goods markets requires*

$$\begin{cases} Y & = Y_t^B + Y_t^D \\ Y_t^B & = \sum_{i=1}^{6} q_{ti}^B = \underbrace{r^B \frac{B V_t^B}{\hat{P}_t}}_{\text{consumption}} + \underbrace{(1-r^B) \frac{B V_t^B}{\hat{P}_t}}_{\text{transaction costs (friction)}} \\ Y_t^D & = \sum_{i=1}^{6} \underbrace{r_t(q_{ti}^D) \frac{m D_{t-1} V_t^D}{P_t}}_{\text{consumption}} + \underbrace{(1-r_t(q_{ti}^D)) \frac{m D_{t-1} V_t^D}{P_t}}_{\text{transaction costs}} \end{cases} \tag{36}$$

Since the marginal Bitcoin transaction cost is constant in the number of packages purchased with Bitcoin, it cancels out in equation (35) and does not affect the buyers' optimal Bitcoin savings and consumptions decisions. In contrast, equation (34) shows that the quantity dependent Dollar transaction cost does affect the buyers' Dollar consumption-savings decisions, which vice versa affects the Dollar price level. This holds unless the sellers coordinate on a steady Dollar trade share, i.e. a constant allocation of packages to the Dollar market across time, yielding a constant Dollar financed consumption $q_t^D = const$ across t. In this case, and this is indeed the equilibrium that we observe in the experiment with mute monetary policy $m = 1$, it holds $R(q_{t+2}^D)/R(q_t^D) = 1$ is constant in equation (34), and the transaction costs neither affect consumption-savings decisions in the Dollar nor the Bitcoin market.

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2 \frac{R(q_{t+2}^D)}{R(q_t^D)} \frac{u'(c_{t+2})}{u'(c_t)} = \beta^2 m^2 \frac{u'(c_{t+2})}{u'(c_t)}. \tag{37}$$

Transaction costs also influence the seller's decision regarding package allocation across markets, see equation (31). This is because the seller today anticipates being a buyer tomorrow and compares future package prices per content in either currency, i.e., $P_{t+1}/R(q_t^D)$ versus $\hat{P}_{t+1}/0.75$, when making allocation decisions.

If monetary policy is neutral ($m = 1$), given today's prices P_t and $\hat{P}_t$, the seller prefers selling in the currency with lower expected package inflation per content, favoring Dollars if

$$\frac{P_{t+1}}{R(q_t^D)} \frac{1}{P_t} < \frac{\hat{P}_{t+1}}{R^B} \frac{1}{\hat{P}_t}. \tag{38}$$

However, the sellers' package allocation itself influences condition (38). Selling more packages for Dollars increases q_t^D, reducing the marginal package content per Dollar-purchased package, $R(q_t^D)$. Consequently, Dollar package inflation per content, $\frac{P_{t+1}}{R(q_t^D)} \frac{1}{P_t}$, rises, making Dollar transactions less attractive due to increasing transaction costs. Thus, when allocating packages, sellers must balance package inflation and transaction costs across currencies, leading to Hypothesis 3.4.

In Hypothesis 3.4, one possible and experimentally observed equilibrium occurs where sellers allocate packages such that the marginal package content is

equalized across currencies, i.e., $R(q_t^D) = R^B$. This holds for $q_t^D = 3$, meaning sellers allocate, on average, 3 out of 5 packages to the Dollar market.

To achieve this interior package allocation, sellers must be indifferent between markets, requiring:

$$\frac{1}{R^B}\frac{\hat{P}_{t+1}}{\hat{P}_t} = \frac{1}{R(q_t^D)}\frac{P_{t+1}}{P_t}. \tag{39}$$

For $q_t^D = 3$, this simplifies to:

$$\frac{\hat{P}_{t+1}}{\hat{P}_t} = \frac{P_{t+1}}{P_t}, \tag{40}$$

implying that Bitcoin and Dollar inflation rates must be equal.

In other words, by selecting $q_t^D = 3$, sellers in an economy with neutral monetary policy create the appearance that transaction costs do not affect their indifference condition. The resulting condition (40) resembles the indifference condition in an economy without transaction costs (19) and neutral monetary policy.

However, alternative equilibria exist where sellers do not offset transaction costs via package allocation. Instead, they attain indifference by allowing inflation rates of Bitcoin and Dollars to adjust. Thus, our hypothesis with mute monetary policy ($m = 1$) suggests two equilibrium types:
As the first equilibrium type, the package allocation neutralizes transaction costs, leading to equal inflation rates and a stable Bitcoin exchange rate. For the second equilibrium type, the package allocation results in asymmetric transaction costs across currencies, causing differing inflation rates and an increasing or decreasing Bitcoin exchange rate.

Active monetary policy, $m > 1$, alters the seller's allocation problem. On the one hand, the seller seeks to take advantage of proportional Dollar transfers by selling for Dollars. Given today's prices, P_t and $\hat{P}_t$, active Dollar monetary policy ($m > 1$) may lead a seller to prefer selling for Dollars even when the Dollar package inflation per content—adjusted for transaction costs—exceeds the Bitcoin package inflation per content. This occurs if:

$$\frac{1}{R(q_t^D)}\frac{P_{t+1}}{P_t} > \frac{1}{R^B}\frac{\hat{P}_{t+1}}{\hat{P}_t} \geq \frac{1}{R(q_t^D)}\frac{P_{t+1}/m}{P_t}. \tag{41}$$

On the other hand, anticipating their role as buyers in the next period, sellers recognize that Dollar-financed packages yield diminishing real returns per package as $R(q_t^D)$ declines. This limits the benefit of large Dollar transfers and influences sellers' decisions regarding the reallocation of packages to the Dollar market. Specifically, an increase in the trade share of the Dollar market raises the average quantity of packages purchased with Dollars, q_t^D, thereby reducing the marginal consumption increase per Dollar-financed package, $R(q_t^D)$. This feedback mechanism affects the seller's indifference condition (41) by increasing the right-hand side, thus reducing the attractiveness of selling for Dollars—unless Dollar infla-

tion, P_{t+1}/P_t, declines.

Overall, as the Dollar multiplier m increases, sellers become more inclined to sell for Dollars, increasing the package allocation to the Dollar market, q_t^D. However, this reallocation causes a decline in consumption per Dollar-financed package, $R(q_t^D)$, which—through a feedback effect—helps maintain seller indifference between selling for Dollars or Bitcoins, as reflected in the right-hand side of (41), given stable Dollar and Bitcoin prices. If sellers do shift packages to the Dollar market, the resulting reduction in $R(q_t^D)$ may outweigh the benefit of a higher multiplier m in (41), potentially leaving the seller ex post better off remaining in the Bitcoin market.

This trade-off implies that an expansion in the Dollar supply in a transaction cost economy does not necessarily lead to an increase in the Dollar trade share due to diminishing real returns to scale in the Dollar package market.

Considering the market clearing equations (36), transaction costs act as a friction that reduces individual and aggregate consumption in the economy. While the Bitcoin and Dollar supplies remain constant or increase, transaction costs reduce output, which directly impacts market clearing prices in both the Bitcoin and Dollar package markets. Transaction costs, therefore, increase both the Bitcoin and Dollar prices of packages in the economy. In particular, transaction costs amplify the effects of Dollar monetary policy.

Aggregate transaction costs depend on the Dollar trade share, i.e., the proportion of trade conducted in Dollars. As a result, aggregate consumption can fluctuate over time with changes in currency usage, even though output remains constant. Aggregate consumption is maximized at a Dollar trade share of $3/5 = 60\%$, since marginal consumption per Dollar-financed package decreases for $q_t^D > 3$.

In our experiment, with mute monetary policy ($m = 1$), we observe that sellers maintain a steady Dollar trade share around 50-60% over time, which maximizes aggregate consumption since agents can only trade full packages. This steady Dollar trade share leads to constant aggregate consumption, despite the presence of quantity-dependent transaction costs, as shown in our Experimental Results (5.4).

With active monetary policy ($m > 1$), the Dollar trade share declines over time. Initially, it starts around 60-65%, but it eventually decreases to the 45-50% range. This shift occurs as agents realize that the large increase in Dollar supply does not translate into proportional increases in consumption, also due to rising Dollar package prices.

Intersting: can we plot aggregate consumption across time (after accounting for transaction costs), this should comove (inversely) with the Dollar trade share!

From this reasoning, we derive the following Hypothesis for a Transaction cost Economy with mute and active monetary policy.

Hypothesis 3.4 (Hypotheses: Transaction costs (no MP))**.**

1. ***Scenario 1: Equilibrium that equalizes transaction costs***
   (a) *The sellers set $z_{ti} = 3$, allocate packages to markets to equalize transaction costs, $R(q_t^D)) = R^B$, $k_t^c = Y_t^D / Y = 0.6$. Such an interior allocation of packages requires sellers' indifference, i.e. requires*

$$\frac{P_{t+1}}{P_t} = \frac{R(q_t^D))}{R^B} \frac{\hat{P}_{t+1}}{\hat{P}_t} = \frac{\hat{P}_{t+1}}{\hat{P}_t} \tag{42}$$

   (b) *Given $R(q_t^D)) = R^B$, the exchange rate is constant, $Q_{t+1} = \frac{R(q_t^D)}{R^B} Q_t = Q_t$*
   (c) *The Bitcoin price is weakly decreasing across time*
   (d) *In a symmetric equilibrium, the Dollar and the Bitcon prices are weakly decreasing.*
   (e) *With $\beta < 1$ and $u(0) = 0$, at constant prices, agents should spend all Dollars and Bitcoins per period*

2. ***Scenario 2: Equilibrium with asymmetric transaction costs***
   (a) *The sellers choose $z_{ti} \neq 3$, yielding asymmetric transaction costs, $R(q_t^D)) \neq R^B$, and asymmetric inflation rates across currencies.*

$$\frac{P_{t+1}}{P_t} = \frac{R(q_t^D))}{R^B} \frac{\hat{P}_{t+1}}{\hat{P}_t} \neq \frac{\hat{P}_{t+1}}{\hat{P}_t} \tag{43}$$

   (b) *The Bitcoin exchange rate increases if $\frac{R(q_t^D))}{R^B} > 1$ or decreases for $\frac{R(q_t^D))}{R^B} < 1$.*
   (c) *q_t^D is constant across time, thus, $R(q_{t+2}^D))/R(q_t^D)) = 1$ so that neither the Dollar nor the Bitcoin consumption-savings decisions of buyers are altered by the transaction costs. In a symmetric equilibrium, the Bitcoin and the Dollar price are weakly decreasing. Savings rates should be similar to the benchmark.*

Even though transaction cost reduce individual and thus aggregate consumption, if sellers choose a constant package allocation to markets, the Dollar trade share is constant, implying $u'(c_{t+2}) = u'(c_t)$ in a symmetric equilibrium. With mute monetary policy, $m = 1$, both the Dollar price and the Bitcoin price should, therefore, be weakly decreasing. Furthermore, the agents should spend all of their currency on goods since there is no motive for precautionary savings, since the endowents of the sellers are fixed, and aggregate output is constant across time. In addition, the assumption $u(0) = 0$ should prevent precautionary savings. Also the experiment ends every round with probability $1/6$, which should cause impatience $\beta < 1$. The fact that that we observe steady prices and savings in either currency in the experiment indicates precautionary savings, and asymmetry in equilibria, possibly due to rationing or bidding wars in the experiment.

Hypothesis 3.5 (Hypotheses: Transaction costs with MP)**.**

1. *Sellers allocate packages to markets to equalize transaction costs, $R(q_t^D)) = R^B$, and prices rise such that the Dollar inflation is m-times larger than the Bitcoin inflation*
    - *If the sellers' allocation to the Dollar market, $z_{ti} = q_{ti}^D$, declines over time, then $R(q_{t+2}^D)/R(q_t^D) > 1$, and transactions costs amplify the monetary policy effect on Dollar prices, i.e. Dollar prices increase faster than with monetary policy only.*
    - *If the sellers' allocation to the Dollar market, $z_{ti} = q_{ti}^D$, increases over time, then $R(q_{t+2}^D)/R(q_t^D) < 1$, and transactions costs dampen the monetary policy effect on Dollar prices, i.e. Dollar prices increase slower than with monetary policy only.*
2. *Given that sellers allocate packages to equalize transaction costs, $R(q_t^D)) = R^B$, the exchange rate grows at rate m*
3. *The Bitcoin price is weakly decreasing across time*

Both kinds of equilibria may be constructed and the theory is agnostic as to which one may prevail. Our experiment may help discriminate between these equilibria by pointing at the ones that emerges in the lab as the ones that may be empirically relevant. Can the Dollar inflation stay constant if the critical good adjusts to changes in the money supply? What are the circumstances that cause a crowding-out of the Dollar (i.e., a decline in the critical good k^c) or a crowding-out of the Bitcoin (i.e., an increase in the critical good k^c)?

Our experiment aims to test these predictions with a focus on equilibrium selection. We address two sets of questions. First, do the experimental market forces achieve an efficient coordination between buyers and sellers on a constant critical quantity? If so, which share of the goods is traded in Bitcoin versus Dollar? Second, how does monetary policy affect currency substitution, i.e. how does the critical good adjust to changes in the money supply? Do CB transfers result in a crowding out of the Bitcoin in the absence of transaction costs and a crowding out of the Dollar in the presence of transaction costs, as the model suggests? In both cases, what is the realized rate of Dollar price inflation? Before discussing the experimental results along this set of questions, we briefly describe the lab implementation.

4 The laboratory experiment

4.1 The experimental environment

We design a group experiment with a between-subject design. In each experimental session, we run an experimental economy encompassing 12 subjects, six 'red

agents' and six 'green agents' who alternate in the role of buyers and sellers in every period.[7]

Sequences of play To emulate an infinite-horizon economy and discounting in the lab, we employ 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, i.e. 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. 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. 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.

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;[8] see the trading interface in Appendix B.2 for illustration. We use the labels "Currency A" for Dollars and "Currency B" for Bitcoin to avoid framing. 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.

[7] 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 multiple independent observations, namely 24 in total, see below.

[8] CDA experiments are well-known in the experimental literature to quickly and accurately converge to the predictions of the competitive market model even with few traders and limited information; see, e.g., Smith (1982).

Additionally, each market has a shortcut for participants to instantly accept the best standing trade, preventing automatic matching.

Trade occurs when a seller's ask price is less than or equal to a buyer's bid price. If multiple matches are possible, the first-come-first-match rule applies, and buyers are matched to the lowest ask price. The transaction price is set at the buyer's bid price, and the number of packages exchanged is the minimum of the buyer's demand and the seller's supply. If the seller has remaining packages, they may be rematched with another buyer.

Sequence of events In each round of a given sequence, events unfold as follows:

1. In the first round of each sequence ($t = 1$), half of the subjects are randomly assigned to be first buyer or seller. 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, each containing 100 chips. 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, adjusted by central bank policy and possibly altered by transaction costs (see Section 4.2). Hence, $B = 600$, $D_1 = 600$ and $Y = 30$.
2. Monetary policy multiplies each Dollar (currency A) by $m \geq 1$ per round for both buyers and sellers.
3. 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.
4. Subjects trade for a maximum of 90 seconds (the auction houses may close earlier if one side of the market becomes exhausted): buyers accumulate chips towards their real-world earnings, and sellers accrue Dollar and Bitcoin balances from sales proceeds.
5. After each round, participants are informed whether the sequence continues, in which case their roles flip, currency balances carry over, and unsold packages perish. If the sequence ends, a new sequence starts, with balances reinitialized as in Step 1.

Payoff Subjects are compensated only based on purchased chips, converted into euros using $\frac{\sqrt{\#\text{chips}}}{10}$.[9] Experimental currency balances (Dollars and Bitcoin) are not paid out to prevent hoarding and implement the fiat currency property (intrinsically worthless). Since subjects alternate roles, they earn payoffs every other

[9] This CRRA function simulates consumption smoothing.

period when they are buyers. Sellers increase their currency holdings to buy packages and earn payoff in subsequent rounds as buyers. In the end, cumulative earnings from two randomly selected sequences are paid out, ensuring reasonable payoffs without wealth effects. Payments were made anonymously via bank transfers, with subjects earning an average of 13 euros (SD=2 euros) excluding a 9-euro show-up fee.

4.2 Treatments

To test the equilibrium implications derived in Section 3, we use a two-by-two design where we switch on and off monetary policy and transaction costs. We run six experimental economies per treatment, see Table 1. Under muted monetary policy ($m = 1$), the Dollar supply always remains fixed like the Bitcoin supply. Under active monetary, we set $m = 1.3$ so that every subject's Dollar balance (both buyers and sellers) increases by 30% in each round resulting in proportional transfers. These transfers are asymmetric across subjects, as discussed in Jiang et al. (2021).

In treatments without transaction costs, each purchased package always gives raise to #chips = 100 units of consumption, i.e. $r(q^D_{i,t}) = r^B = 1, \forall i, t$. With transaction costs, the metaphor of the goods being packages of chips turns particularly handy for conveying quantity-contingent transaction costs to the subjects.[10] Each Dollar-financed additional package contains fewer and fewer chips: a buyer in a given round consumes 100 chips out of their first Dollar-financed package, only 90 out of the second one, down 80 out of third one, 70 out of the fourth one, and so on until 10 chips from the 10th package, then nine out of the 11th package, eight out of the 12, ... and one single chip per package beyond 19 Dollar-financed packages.[11] By contrast, each Bitcoin-financed package is subject to a flat cost and always contains 75 chips, i.e. $r(q_{i,}t^B) = 0.75$, $\forall i, t$. This cost structure implies that each additional Dollar-financed package reduces the advantage of using Dollar over Bitcoin. For $q^D_{i,t} \leq 3$, Dollar-financed packages provide higher consumption than Bitcoin-financed packages, and the opposite holds from the fourth package on.

4.3 Implementation

We program the experiment in oTree (Chen et al., 2016). The experiment was run in-person at the CREED lab of the University of Amsterdam, 12 sessions were run in spring 2022 and the remaining 12 in spring 2023. A total of $12 \times 4 \times 6 = 288$ subjects participated in the experiment, and no subject participated more than once.

[10] Appendix A.2 provides the implied explicit forms of $r(q^D_{i,t}) \leq 1$ and $R(q^D_{i,t}) < 1$.

[11] With an average of five packages in the markets per buyer, such large numbers of purchases were never observed, with no participant buying more than 16 Dollar packages in a round, out of 4,608 individual trade outcomes. Transaction costs are then reset to zero for the first Dollar-financed package in each round for each buyer.

	Monetary policy	
Transaction costs	Muted: $m = 1$	Active: $m = 1.3$
No: $r(q^D_{i,t}) = r^B = 1, \forall i, t$	6 `noInfl-noCost`	6 `noInfl-cost`
Yes: $r(q^D_{i,t}), r^B \leq 1$	6 `infl-noCost`	6 `infl-cost`

Table 1: Number of independent observations per treatment

All participants were students, on average 22 year old: about 60% of them in Economics and Business, and most of the others in Social Sciences and Humanities, including Law. 52% identified as female,[12] about 60% came from Europe and 30% from Asia. 90% of them declared being proficient in English, the language used in the experiment. Less than half of them declared a previous experience as a subject in a lab experiment. Assignment of students to treatments was randomized across all these characteristics.[13]

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 B. They then completed a four-question quiz on transaction costs, payoffs, and currency supply for their assigned treatment before starting the game. At the end of the last sequence, participants completed a questionnaire on demographics, strategies, and comments.

5 Experimental results

We observe both, increases and decreases in the Bitcoin price in our experiment when Dollar monetary policy is active.

5.1 Market efficiency

A reasonable measure of market (in)efficiency in our experiment is the number of unsold packages in the economy. Unsold packages perish after every round in the experiment, and are thus neither consumed in the experimental economy nor paid in the real world out after the experiment. At a positive goods price, selling an additional unsold package always yields a Pareto improvement. In the experiment, we observe:

Experimental results 5.1 (Market efficiency)**.** *Across all treatments, the number of* ***unsold packages*** *declines across rounds and experimental sequences, yielding a gradual*

[12] Among the options were male, female and other.

[13] The F-statistic of joint significance of the demographics on treatment assignments are, respectively, 2.00^*, 0.69, 1.22 and 1.35 for Trs. `noInfl-noCost`, `noInfl-cost`, `infl-noCost` and `infl-cost`.

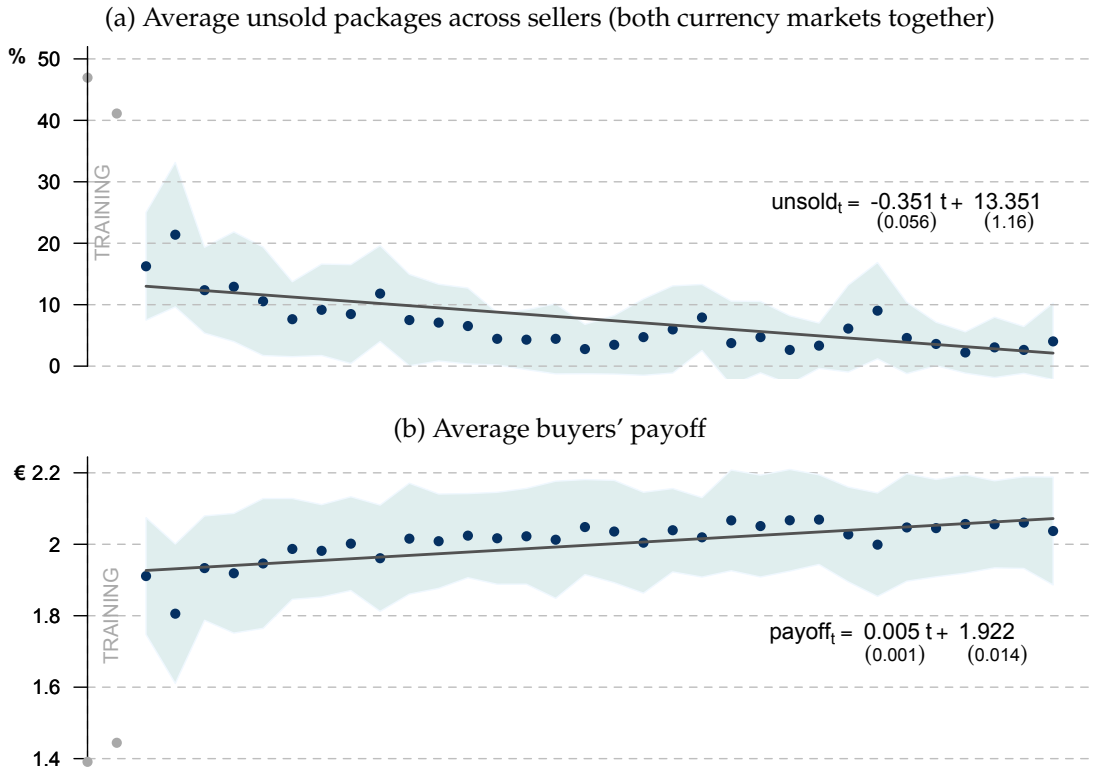


Figure 3: Efficiency over time averaged across all treatments and currency markets over time. The dots indicate the average per paid period. The shaded blue area indicate ± one standard deviation. The black line is the trend, represented by the linear regression line of the variable over the time period. The robust standard errors are reported between brackets underneath the estimated coefficients.

increase in allocative efficiency.

Figures 3a and 3b illustrate the dynamics of unsold packages, buyers' real-world payoffs, and currency savings over time, combining data from both currency-specific markets and all experimental sessions.

Figure 3a (top) reveals a substantial decrease in unsold chip packages over time, eventually stabilizing at approximately 5% of the total supply across sessions. This trend suggests that participants progressively adapted their strategies to maximize real-world payoffs, leading to increased allocative efficiency and convergence toward the theoretical prediction. Specifically, sellers recognized that retaining unsold packages diminished their monetary balances in subsequent periods, thereby weakening their competitive position as buyers in future bidding rounds.

Concurrently, Figure 3b demonstrates a steady rise in buyers' payoffs across trading rounds and sequences, averaging over 2 euros per period by the later stages of the experiment.

These findings align with our efficiency hypothesis (3.1), which posits that the

number of unsold packages should equal zero from the first period onward. Furthermore, since package endowments and aggregate supply were held constant across trading rounds, theory predicts that average real-world payoffs for buyers should remain constant over time, even with the introduction of monetary policy (but absent transaction costs).

5.2 Benchmark economies (i.e. without transaction costs)

the fact that we observe savings despite hte absence of Dollar monetary policy points to asymmetry in equlibrium allocations, which we indeed verify in the experiment. The agents produce precaustionary savings.

Experimental results 5.2 (Benchmark: no monetary policy, no transaction costs)**.** *In the benchmark treatment (no MP and no Tra CO), we observe that*

1. *Both currencies are used for goods purchases to a similar extent.*
   (a) *The Dollar sales share, k_t^*, remains relatively stable at 50–60%.*
   (b) *Buyers' consumption shares in Dollars also stabilize at 50–60%, with minimal unsold packages.*
2. *Package market prices in Dollar and Bitcoin are stable and similar, ranging from 25–30 in their respective units.*
3. *Savings rates for Dollars and Bitcoins show oscillations between rounds due to the alternation of roles between sellers and buyers, but are stable when comparing every other round.*
4. *The implicit exchange rate Q_t (Bitcoin price in Dollars) is stable across rounds, consistent with Kareken and Wallace (1981), and approximately* 1.

Figure 6 presents the key experimental results, highlighting the effects of central bank Dollar monetary policy on currency competition absent transaction costs. The figure displays average changes across trading rounds and experimental sequences for each of the two treatmentsEach of the two treatments involves six independent groups (economies), each group comprising 12 subjects (6 buyers and 6 sellers). The following paragraphs discuss the experimental findings, comparing behaviors both within and across treatments, and interpreting it with regard to our theoretical hypothesis.

Starting with a discussion of the benchmark treatment (no transaction costs) with muted monetary policy, $m = 1$, Figure 6 shows that both currencies are used almost equally for goods purchases. The Dollar sales share, (k_t^*), defined as the proportion of packages offered for sales in the Dollar-denominated market, remains

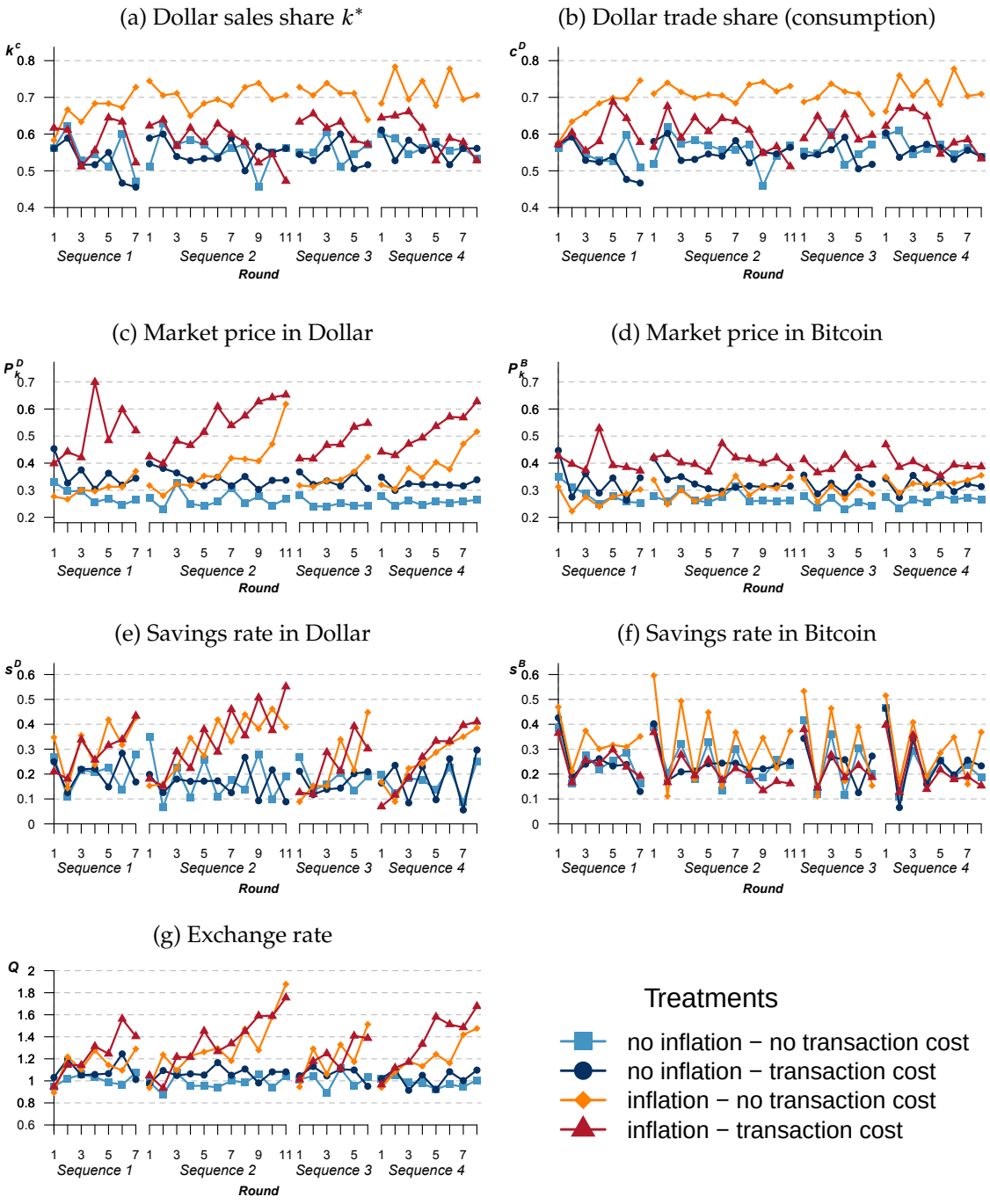


Figure 4: Average trade, price, and savings dynamics of each treatment

consistently within the range of 50–60%, reflecting the impact of sellers' currency allocation decisions. Despite Dollars and Bitcoins being perfect substitutes in this benchmark treatment, sellers display a slight, unexplained preference for Dollars. Notably, the currencies were labeled "currency A" and "currency B" during the experiment, removing any inherent bias in naming. Note, since in the benchmark the currencies are perfect substitutes, any Dollar trade share can arise as part of an equilibrium.



Figure 5: Benchmark dynamics (no transaction costs): with and without monetary policy

As nearly all packages are sold, also the buyers' consumption in Dollars stabilizes at 50–60%. Fewer than 10% of packages remain unsold after the first trading sequence. If all packages were sold, the Dollar sales share and the Dollar trade share (consumption purchased in Dollars) are equivalent.

Our experimental findings on a stable exchange rate are consistent with our hypothesis 3.2, and are consistent with Kareken and Wallace (1981), who demon-

strate that under perfect foresight and in the absence of monetary policy or transaction costs, exchange rates should remain constant over time. It is important to note that an exchange rate different from one would also align with Kareken and Wallace (1981) and our theoretical predictions, as their theory - and ours - indicate that the initial exchange rate Q_0 is undetermined. However, after the first period, the exchange rate must remain constant for $t > 1$. Thus, even highly asymmetric initial prices, and accordingly exchange rates away from one would be compatible with equilibrium, as long as the subequent exchange rate is constant.

Looking at the velocities, both the Bitcoin and the Dollar savings rates are fairly constant across time. To see this note, that one must only compare the savings rates of every other period since the buyer and seller groups alternate. Comparing the savings rates at t to the savings rates at $t+1$ would mean to compare the savings of different agent groups. The fact that savings rates are steady is unsurprising, given that inflation in either currency is close to zero, and given that the money supplies are constant across rounds. Because the money supply, savings, and prices are steady, also the velocities of both currencies are constant across time.

What is surprising is that, in opposition to our hypothesis 3.2, the agents do not spend all of their currency in every round, even though a symmetric equilibrium, price constancy and discounting (implied by the random termination probability of 1/6) would demand that.

Experimental results 5.3 (Benchmark with Monetary policy (no transaction costs))**.** *Comparing the benchmark treatment BT (no monetary policy and no transaction costs) with the monetary policy treatment MPT (without transaction costs) we observe*

1. ***Dollar sales and trade share increase in the MPT.***
   The Dollar sales and trade shares increase from 50–60% in the BT to 60–70% in the MPT. Despite the perpetual rise in Dollar supply across rounds, the Dollar sales and trade shares remain stable at 60–70% across rounds in the MPT.

2. ***Dollar package price increases in MPT, leading to Dollar inflation despite the increase in Dollar trade volume.***
   Dollar package prices rise steadily in the MPT treatment, resulting in significant Dollar inflation compared to the benchmark treatment, where Dollar prices remain constant. This inflation occurs even though sellers shift packages into the Dollar market, which should mitigate inflationary pressures.

3. ***Bitcoin package prices rise due to scarcity in the MPT treatment.***
   In the MPT, Bitcoin package prices increase slightly due to package scarcity in the Bitcoin market, as sellers shift packages to the Dollar market to take advantage of the monetary policy transfer. Bitcoin inflation remains low relative to the benchmark.

4. ***Dollar savings rate rises in MPT treatment.***
   The Dollar savings rate increases (velocity declines) consistently across rounds in the MPT, while in the benchmark, the Dollar savings rate is lower and stable.

5. ***Bitcoin savings rate declines in the MPT treatment.***
   The Dollar monetary policy results in a decline or stabilization of the Bitcoin savings rate (velocity increases).

6. ***Bitcoin exchange rate increases in MPT.***
   The Bitcoin exchange rate increases across rounds in the MPT, with Bitcoins becoming more valuable across rounds, relative to the Dollar.

The observed shift in trade share toward the Dollar-denominated market suggests that the indifference condition (19) was violated for some sellers. Specifically, the Dollar prices P_{t+1} they faced—and thus Dollar inflation—were too low relative to the multiplier m, making Dollar-denominated sales more attractive. Consequently, sellers reallocated their packages toward the Dollar market to benefit from larger proportional transfers tied to higher Dollar balances.

Since sellers were not indifferent and actively reallocated their packages, this supports Scenario 2 of Hypothesis 3.3 (equilibrium with partial price pass-through) and rejects Scenario 1 (equilibrium with full price pass-through).

Nevertheless, in the MPT, we do observe that the Dollar package prices rise over time, leading to significant Dollar inflation. The experimental results, however, also show an increase in the Dollar savings rate, suggesting that the Dollar price did not grow fast enough to keep the buyer subjects indifferent between spending and saving, suggesting that the indifference condition (**??**) was violated for some buyer subjects.

Akin to Schilling and Uhlig (2019a), our theoretical and exprimental results further demonstrate that if the central bank wants to implement an inflation target in a world where the Dollar competes with another currency, here Bitcoin, it may face challenges. Schilling and Uhlig (2019a) find that constant, symmetric Dollar transfers do not alter the seller's indifference between selling in Bitcoin or Dollars, or the buyers' indifference between consumption and Dollar savings because the transfers are made regardless of the Dollar balances held by the agents.[14]

In our case, despite proportional transfers, the increase in the Dollar supply does not fully pass through into the Dollar price of goods because agents trade in a competing currency and partially offset strong Dollar price pass-through by increasing the Dollar trade share. The sellers' shift of packages to the Dollar market and the buyers' increase in Dollar savings both mitigate inflationary pressures on the Dollar.

Thus, the rise in the Dollar supply does not fully translate into higher Dollar prices for goods.

The observed behavior of sellers and buyers can be interpreted as an instance of money illusion, where they prefer transacting and saving in Dollars despite its inflationary nature. While currency competition limits the central bank's ability

[14]See that in Proposition 1, the fundamental pricing equation is independent of τ_t in comparison to our equation (19) which depends on the multiplier m.

to control Dollar inflation, we conclude that a policy of proportional Dollar transfers, rather than constant transfers, is an effective strategy to support the Dollar against competing currencies. In particular, this suggests that Dollar monetary policy remains effective in guiding inflation even in the presence of currency competition. However, if the Dollar were the sole medium of exchange, its monetary policy would likely exert a stronger impact on inflation compared to the benchmark treatment (BT).

As predicted by theory, Dollar monetary policy causes a scarcity-induced rise in Bitcoin package prices (experimental sequences 2, 3, 4). As sellers reallocate packages to the Dollar market, fewer remain for sale in the Bitcoin market. Given the fixed Bitcoin supply, this creates upward pressure on Bitcoin prices, demonstrating an indirect effect of Dollar monetary policy.

Interestingly, in sequence 1, sellers maintain a stable package allocation in the Dollar market across rounds, except for the final round. Consequently, in that sequence, no spillover into Bitcoin prices is observed compared to the no-policy treatment ($m = 1$).

This observed spillover resembles the "unconventional monetary policy effect" in Corollary 4 of Schilling and Uhlig (2019a), which links Dollar policy to Bitcoin prices. However, unlike their model—where all goods are offered in both currencies at all times—our setup features semi-segmented markets, as sellers preselect their trade currency. As a result, proportional Dollar transfers shift trade volume toward the Dollar market, inducing scarcity-driven Bitcoin price increases absent in Schilling and Uhlig (2019a).

5.3 Experimental Results: Transaction cost Economy

Experimental results 5.4 (Transaction costs (without monetary policy))**.** *Comparing the benchmark treatment BT with the transaction cost treatment (TCT), both without monetary policy we observe that*

1. *the Dollar sales share k^*, and the Dollar trade share are steady around 50-60% across experimental rounds, as long as monetary policy is mute, $m = 1$ (in both treatments TCT and BT where no transaction costs are imposed). This implies that the representative buyer purchases $q_t^D \in \{2,3\}$ packages using Dollars, where the choice $q_t^D = 3$ equalizes the maginal consumption per package across currencies $R(3) = 0.75 = R(q_t^B)$.*
2. *The Bitcoin exchange rate is almost constant across rounds, in both the BT and the TCT*
3. *The Dollar and Bitcoin savings are fairly steady across both treatments*
4. *the Bitcoin and Dollar price levels are steady across rounds (close to zero Dollar and Bitcoin inflation), and are similar across treatments TCT, and the BT. This means,*

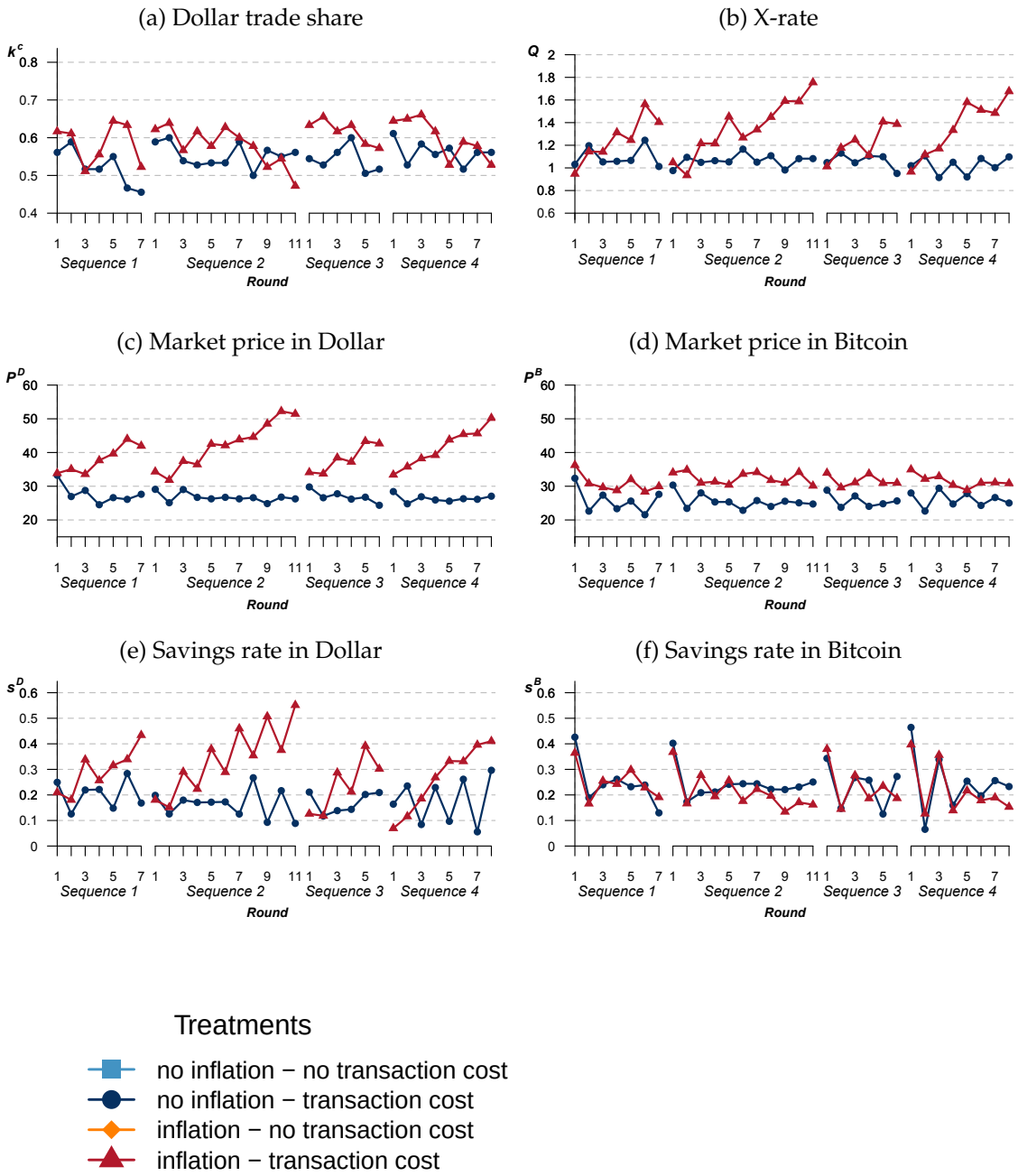


Figure 6: Transaction cost Economy: with and without monetary policy

that normalized per chips content, the subjects paid more for packages (in either currency) in the transaction cost treatment relative to the benchmark case.

The experimental results show that, indeed, the sellers try to mitigate the asymmetry of the transaction costs by choosing a package allocation that leads to an equalization of average costs across currencies. The seller choose the allocation

that yields an average quantity of packages of $q_t^D \in \{2,3\}$ bought using Dollars. The marginal Dollar consumption after costs equals $R(2) = 0.85$ for $q_t^D = 2$, and $R(3) = 0.75$ for $q_t^D = 3$, where the latter equals the marginal Bitcoin consumption after costs, $R(q_t^B) = 0.75$. Or, put differently, because the sellers allocate approximately 3 out of 5 packages to the Dollar market and 2 package to the Bitcoin market, the seller's undo the asymmetry of the transaction costs in their own optimization problem.

Experimental results 5.5 (Transaction costs: mute versus active monetary policy)**.** *Comparing the transaction cost treatment (TCT) without monetary policy to the treatment with monetary policy (MPTCT), we observe:*

1. *Adding monetary policy to transaction costs causes the Dollar trade share initially to increase, but across rounds, the Dollar trade share comes down. In the TCT without monetary policy, the Dollar trade share remained roughly constant across rounds.*
2. *The inclusion of Dollar monetary policy significantly raises both the Dollar and Bitcoin price levels, increases Dollar inflation, but leaves Bitcoin inflation unchanged.*
3. *Monetary policy also increases the Bitcoin exchange rate over time, with the price of one Bitcoin rising each round.*
4. *With monetary policy, the Dollar savings increase over time, the Bitcoin savings rate remains relatively unchanged.*

Comparing the monetary policy treatment MPT (without transaction costs) to the monetary policy treatment with transaction costs MPTCT we observe:

Experimental results 5.6 (Monetary Policy with versus without Transaction costs)**.** *The experimental results comparing the monetary policy treatment without transaction costs (MPT) to the monetary policy treatment with transaction costs (MPTCT) reveal the following key observations:*

1. ***Dollar trade share***
   - *The introduction of transaction costs within the monetary policy treatment significantly reduces the Dollar sales share (k^*) as well as the overall Dollar trade share (i.e., the proportion of packages sold for Dollars).*
   - *Specifically, when both monetary policy and transaction costs are present, the Dollar trade share declines over successive rounds, starting from approximately 60–65% and dropping to 45–55%. In contrast, under the monetary policy treatment without transaction costs, the Dollar trade share remains stable across rounds at around 70%.*
2. ***Price Levels and Inflation***
   - *Adding transaction costs to the monetary policy treatment results in an increase in the Dollar price level, while the Bitcoin price level exhibits a slight increase in 3 out of 4 experimental sequences.*

- *The rates of Dollar and Bitcoin inflation remain comparable across both treatments.*

3. ***Bitcoin exchange rate*** *The Bitcoin exchange rate (expressed as the price of one Bitcoin in Dollars) remains unchanged with the addition of transaction costs to the monetary policy treatment.*
4. ***Savings and Velocity*** *The inclusion of transaction costs does not impact the Dollar savings rate but leads to a reduction in the Bitcoin savings rate. This reduction, in turn, increases Bitcoin velocity.*

The decline in the Dollar trade share shows that, despite proportional Dollar transfers increasing with holdings, sellers increasingly favor Bitcoin. This shift occurs because high transaction costs make Dollars less appealing as a medium of exchange. Comparing monetary policy treatments with and without transaction costs reveals that Dollar dominance erodes with transaction costs. Even though the central bank continues to raise the Dollar supply by a factor of m=1.3 each round, fewer goods are traded for Dollars over time. In some rounds, the Dollar trade share falls below 50%, even lower than the benchmark case without monetary policy or transaction costs.

To understand the effects of transaction costs, consider the buyers' perspective first. Dollar transaction costs reduce the purchasing power of Dollars as more packages are purchased using them. This diminishes the incentive to spend Dollars, whether for immediate consumption or for future consumption through savings.

From the sellers' perspective—who anticipate becoming buyers in subsequent round—this leads to a preference for selling goods in exchange for Bitcoin to secure future purchasing power. Consequently, sellers reallocate their goods toward the Bitcoin market. Furthermore, with a steady increase in the Dollar supply across rounds, sellers cannot mitigate transaction costs across currencies by maintaining a constant allocation of goods across markets and rounds. This contrasts with the scenario of a steady Dollar supply (as in the transaction cost treatment without monetary policy), where such equalization of costs is possible, and observed in the experiment. Instead, the increasing Dollar supply forces sellers to continually adjust their allocations, favoring the Bitcoin market.

Overall, this comparison highlights how quantity-dependent transaction costs on the Dollar undermine the effects of monetary policy on the Dollar trade share. While it is difficult to directly compare the Dollar trade share in the benchmark case (where both currencies are perfect substitutes) to the monetary policy treatment with transaction costs (MPTCT), a comparison with the transaction cost treatment without monetary policy reveals a key insight: adding monetary policy does not influence the Dollar trade share when transaction costs are already present.

In summary, while expansionary monetary policy can increase the Dollar's acceptance as a medium of exchange by boosting its purchasing power, the intro-

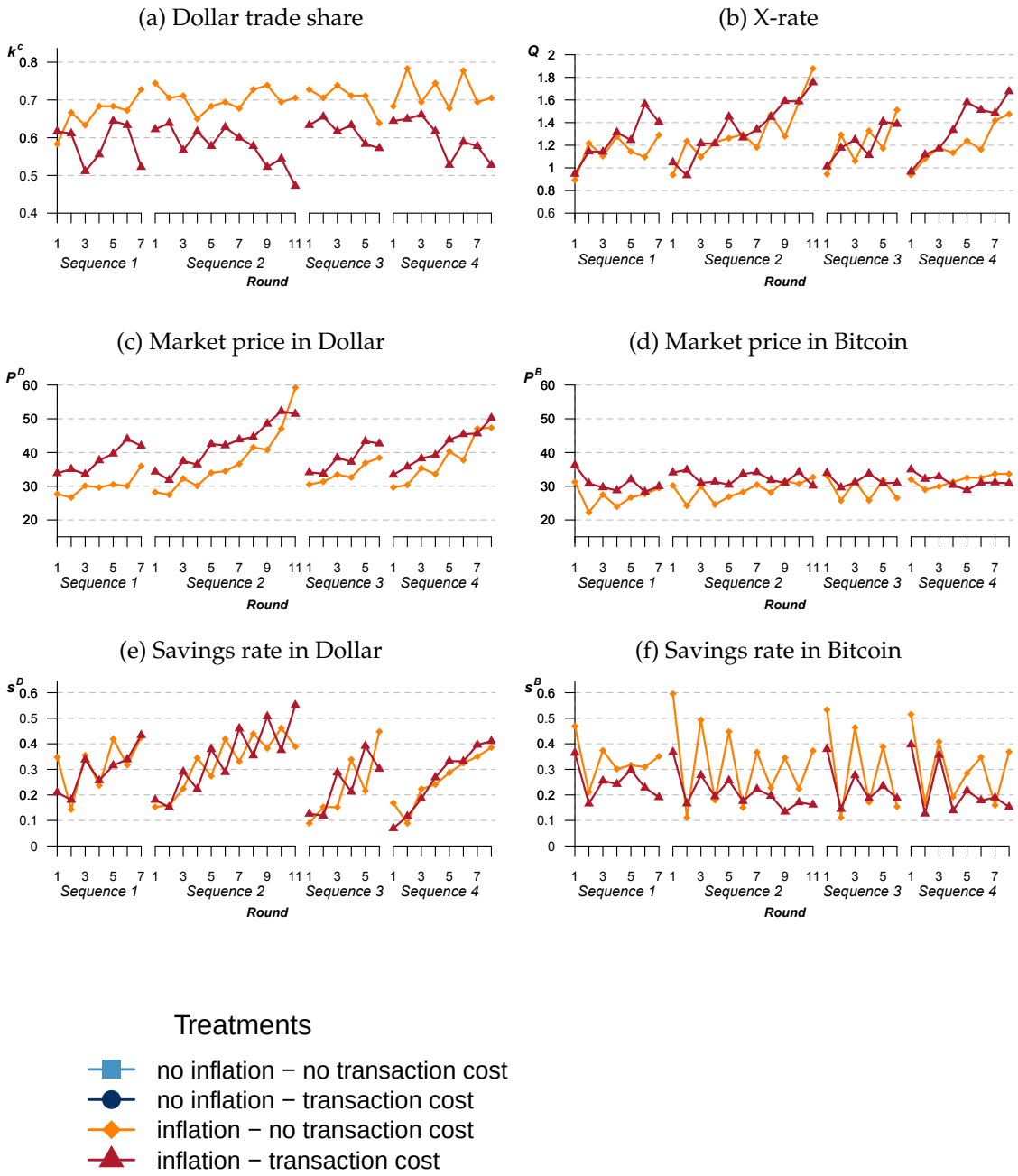


Figure 7: Transaction cost Economy: with and without monetary policy

duction of Dollar transaction costs counteracts this effect.

Additionally, the presence of transaction costs alongside monetary policy intensifies the effect of monetary policy on both Dollar and Bitcoin price levels. Firstly, transaction costs act as a friction that reduces the content of packages, effectively shrinking the aggregate output available for consumption. Following the

quantity theory of money, this reduction in output raises the price levels for both Dollars and Bitcoin, as fewer packages are available to meet demand. Secondly, as sellers increasingly avoid trading in Dollars due to the transaction costs, fewer packages are sold in the Dollar market, creating scarcity. This scarcity drives up the Dollar price level, even though the central bank maintains a constant increase in Dollar supply across treatments.

Conversely, the dynamics in the Bitcoin market are different. Over successive rounds, more packages are allocated to the Bitcoin market, creating an abundance of packages in that market. This abundance, combined with a reduced Bitcoin savings rate, mitigates the inflationary effect of transaction costs on Bitcoin prices. As a result, the impact of transaction costs on Bitcoin price levels is weaker compared to their effect on Dollar prices.

Interestingly, despite these dynamics, the inflation rates for both currencies remain similar between the monetary policy treatment without transaction costs (MPT) and the treatment with transaction costs (MPTCT). This similarity is notable because, although the Dollar supply increases by the same factor across rounds and Dollar savings remain consistent in both treatments, the Dollar trade share behaves differently: it remains stable in the MPT but declines steadily in the MPTCT.

5.4 Currency Hoarding

One might consider the share of unspent currency as an alternative measure of inefficiency. The experiment enforces the fiat money property by not paying out accrued balances and assumes no income shocks, with $u(0) = 0$ ensuring agents do not experience infinite disutility from missing chip consumption. Combined with a discount factor $\beta < 1$, these conditions render savings unnecessary in treatments without monetary policy.

However, in treatments with monetary policy, central bank transfers depend on subjects' Dollar balances and are asymmetric, favoring agents with higher balances. This asymmetry creates an incentive to save Dollars if the central bank multiplier m is sufficiently large relative to β, as higher balances enhance buyers' competitiveness in Dollar auctions.

Figure **??** depicts the share of unspent currency at the end of each period across trading sequences, combining all treatments and markets. Despite money balances being unpaid post-experiment, approximately 28% of balances remain unspent, indicating significant currency hoarding. This behavior may result from either strategic actions or market rationing.

Strategic hoarding reflects precautionary savings, where agents retain currency to mitigate future uncertainty (intertemporal substitution). Rationing, on the other



Figure 8: Word cloud of participants' self-reported strategies (post-experiment questionnaire)

hand, arises from experimental market frictions, including miscoordination between buyers and sellers during the time-constrained 90-second trading periods. For instance, buyers who are slow to make or adjust offers may lose opportunities to faster competitors, causing sellers to sell packages at too low prices. Additionally, there is miscoordination if some sellers may allocate most of their packages, for instance, to the Bitcoin-denominated market, preventing buyers from spending their Dollar balances. As sellers cannot reallocate packages between markets during a trading period, they are unable to respond to unforeseen market conditions.

The persistence of currency hoarding is striking given the high impatience imposed by the experimental design. A termination probability of 1/6 per round corresponds to a discount factor of 5/6, implying that savings are unlikely to yield future returns. Such high impatience would typically incentivize higher consumption in the present, yet significant savings are still observed.

Figure 8 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").

5.5 Estimation Results

Because the underlying model of the experiment admits equilibria with a constant Dollar sales share (and an adjustment to central bank transfers via prices) as well as equilibria with a time-varying Dollar sales share (and an adjustment via currency substitution), we focus on identifying time variation in the main variables in the different treatments. The regression models reported in Table 5 reveal that the Dollar sales share decreases in all treatments but Tr. `infl-noCost`, and does so even more rapidly in Tr.`infl-cost` (Cols. I-II). Without costs, CB transfers leads to a higher Dollar sales share than without and this difference tends to increase over time. By contrast, under transaction costs, CB transfers produce a decrease in the Dollar sales share. Transaction costs do not affect the dynamics of the Dollar sales share in the absence of CB transfers.

The saving rate in Dollar (Cols. III-IV) and the Dollar price of a Bitcoin (Cols. VII-VIII) increase over time in the two treatments featuring CB transfers. Conversely, the saving rate in Bitcoin tends to decrease in all treatments (Col. V) and even more so in Tr.`infl-cost` (Col. VI). These different dynamics reflect the price stickiness pattern discussed above: as prices do not increase as fast as the CB inflation target, subjects accumulate Dollar currency holdings. They are also consistent with increasing trade volumes in Bitcoin in the presence of transaction costs and CB transfers, which leads to a faster decrease in the Bitcoin saving rate and a stronger hoarding on Dollar than in the three other treatments.

5.5.1 Estimating the asymptotic values

We have uncovered significant time variation in the main variables of the experiment but the sequences of play have a limited number of rounds in the lab out of both practicability concerns and coherence with the underlying model that relies on the hypothesis of impatient agents. What would the behavior of the main variables of interest have been had each sequence continued for a much longer period? To shed light on the matter, we estimate the long-run or asymptotic values of these variables using a convergence assessment method inspired by Duffy

	(1)	(2)	(1) vs. (2)	(3)	(4)	(3) vs. (4)
	Transaction costs			*Transaction costs*		
	No	*Yes*	$p-$value	*No*	*Yes*	$p-$value
	Panel A. Price paid in Market A (Dollars)			***Panel B. Price paid in Market B (Bitcoin)***		
(I) $m = 1$	0.829 (0.162)	1.247 (0.110)	0.041**	1.040 (0.377)	1.900 (0.585)	0.093*
(II) $m = 1.3$	2.153 (2.133)	1.502 (0.347)	0.589	1.951 (0.453)	1.394 (0.090)	0.310
p-value (I) vs. (II)	0.009***	0.589		0.026**	0.132	
	Panel C. Total chips consumption			***Panel D. Number of packages bought***		
(I) $m = 1$	56.040 (135.881)	37.960 (60.462)	0.009***	0.569 (0.016)	0.524 (0.016)	0.699
(II) $m = 1.3$	113.288 (4667.42)	54.756 (107.358)	0.026**	1.125(0.454)	0.780 (0.016)	0.700
p-value (I) vs. (II)	0.041**	0.026**		0.065*	0.015**	
	Panel E. Packages bought in Market A			***Panel E. Packages bought in Market B***		
(I) $m = 1$	0.640 (0.030)	0.647 (0.018)	0.937	0.984 (0.046)	0.764 (0.026)	0.132
(II) $m = 1.3$	1.395 (0.373)	0.972 (0.041)	0.180	1.056 (0.049)	0.890 (0.010)	0.240
p-value (I) vs. (II)	0.004***	0.015**		0.590	0.590	

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 groups; 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 2: Relative dispersion of buyers' prices and consumption levels

et al. (2016).[15] Table 3 displays these estimates and reports on the cross-treatment comparisons.[16]

In the absence of CB transfers, transaction costs do not significantly affect trade and currency competition; a little more over half of the trade occurs in Dollar (Panels A and B), which is consistent with the optimal allocation of packages given the cost structure and assuming a constant critical good equilibrium. Moreover, subjects converge towards saving about 20% of their currency holdings (Panels C and D) and prices on both markets are constant (Panels D and E).

The situation is significantly different when CB transfers are introduced. In the absence of transaction costs, subjects then substitute Dollar purchases for Bitcoin trade and almost three quarters of the trade end up in Dollar. Because considerable price stickiness causes Dollar inflation to settle on a positive yet below-target rate, subjects accumulate Dollar and a high fraction of their Dollar endowment ends up unspent. Interestingly, Dollar inflation also triggers Bitcoin inflation, in line with the conclusions of the seminal model of Kareken and Wallace (1981) and their formulation of the Gresham's law. By contrast, in the presence of costs, CB transfers have the opposite effects on currency substitution: the fraction of trade in Dollar is driven down (almost three quarters of the trade would end up in Bitcoin) while subjects end up saving less and trading more in Bitcoin. This dynamics is in line with the prediction of the SU model. No matter the cost structure, there

[15]To be precise, for each time series of interest in each group, we estimate autoregressive processes with and without intercept and with up to two lags (to account for the alternating pattern of trade in the model and in the lab). We then select the first stationary model that minimizes the BIC information criterion. If no stationary model fits the data, the variable is said to converge to its upper limit or to diverge.

[16]Given the inherent difficulty of collecting many independent observations in group experiments involving each 12 subjects, it is sometimes not possible to disentangle a true null effect from a lack of statistical power.

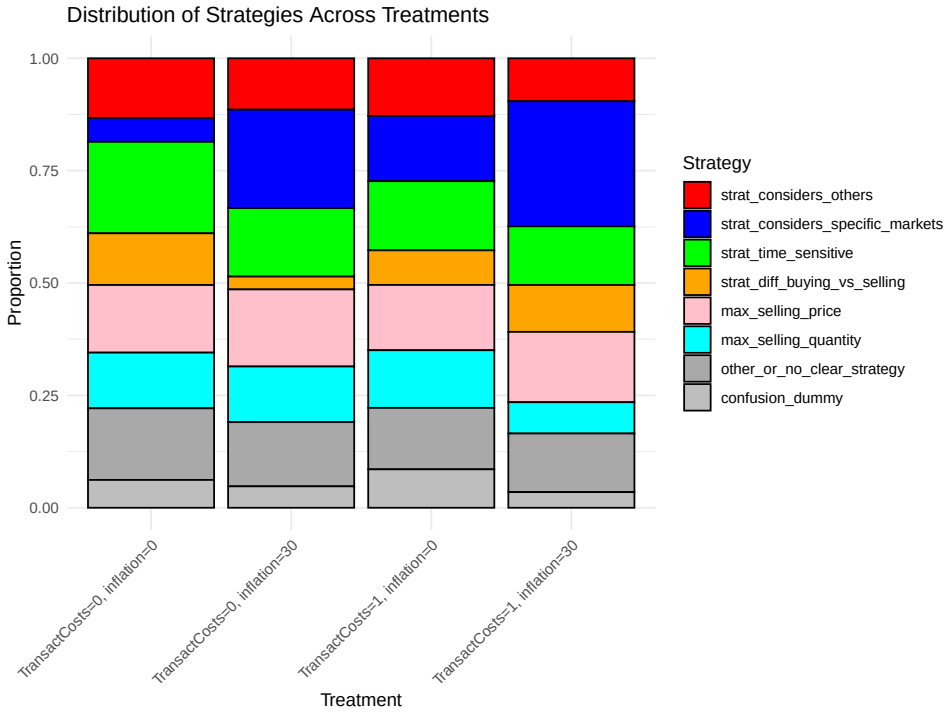
		(1)	(2)	(1) vs. (2)	(3)	(4)	(3) vs. (4)
		Transaction costs			*Transaction costs*		
		No	*Yes*	$p-$value	*No*	*Yes*	$p-$value
		Panel A. Dollar sales share			***Panel B. Dollar trade share (consumption) in Dollar***		
(I)	$m = 1$	0.548 (0.038)	0.548 (0.048)	0.818	0.550 (0.035)	0.465 (0.231)	0.937
(II)	$m = 1.3$	0.734 (0.143)	0.289 (0.317)	0.004^{***}	0.740 (0.139)	0.500 (0.248)	0.009^{***}
p-value (I) vs. (II)		0.004^{***}	0.387		0.002^{***}	0.418	
		Panel C. Saving rate in Dollar			***Panel D. Saving rate in Bitcoin***		
(I)	$m = 1$	0.180 (0.044)	0.172 (0.012)	0.485	0.232 (0.015)	0.232 (0.051)	0.937
(II)	$m = 1.3$	0.440 (0.151)	0.520 (0.194)	0.420	0.297 (0.082)	0.103 (0.119)	0.015^{**}
p-value (I) vs. (II)		0.002^{***}	0.002^{***}		0.145	0.067^{*}	
		Panel D. Inflation rate in Dollar			***Panel E. Inflation rate in Bitcoin***		
(I)	$m = 1$	0.002 (0.004)	0.0016 (0.025)	1.000	0.011 (0.027)	0.031 (0.044)	0.424
(II)	$m = 1.3$	0.204 (0.256)	0.070 (0.020)	0.329	0.066 (0.055)	0.005 (0.011)	0.061^{*}
p-value (I) vs. (II)		0.045^{**}	0.009^{***}		0.061^{*}	0.303	

Notes: Each cell reports the estimated mean of the stationary auto-regressive process of up to two lags that minimizes the BIC information criterion on each time series in each session, averaged over the six independent groups; standard deviations are reported next in parentheses. Similarly, 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 3: Estimated asymptotic values of the main aggregate variables

is increased difficulty in coordination among subjects, as reflected by the higher standard deviations in the presence than in the absence of inflation.

5.5.2 Diving into the individual market behaviors



The Chi-squared test for equality of proportions only gives a cross-treatment statistically significant difference for the strategy 'consider specific markets' (p-value = 0.008): subjects are most indifferent between markets in the baseline treatment (since the two markets are perfectly symmetric), more have market-specific strategies once we introduce transaction costs but the highest proportion of market-specific strategies are observed with inflation (a third of them with inflation and transaction costs, versus about 5% in the baseline treatment).

Figure 9: Classification of the most common strategies per treatment

6 Conclusions

In this study, we examine currency competition between the Dollar and Bitcoin, focusing on the effects of central bank monetary policy and transaction costs. We find that the Dollar can increase its usage relative to Bitcoin through targeted monetary transfers, though its ability to control inflation is somewhat diminished when both currencies are in play. We also demonstrate that Dollar monetary policy indirectly drives Bitcoin inflation by crowding out Bitcoin trade, despite the absence of a central bank for Bitcoin. Additionally, we show that transaction costs can counteract the effectiveness of Dollar policy by encouraging sellers to shift trade to Bitcoin, where costs are more predictable. These transaction costs, however, exacerbate inflation in both currencies by reducing aggregate output.

Our findings offer insights into a future where currencies compete for usage, shaped by asymmetric monetary policies and transaction costs. In such a world, where transaction costs are unavoidable, Dollar monetary policy becomes less ef-

fective, as agents may bypass it by transacting in Bitcoin. This study highlights the challenges central banks face in maintaining currency dominance in an environment of increasing alternative currencies and rising transaction costs.

References

Maurice Allais. A restatement of the quantity theory of money. *The American economic review*, 56(5):1123–1157, 1966. 1

Jasmina Arifovic. Evolutionary dynamics of currency substitution. *Journal of Economic Dynamics and Control*, 25(3-4):395–417, 2001. 3

Pierpaolo Benigno, Linda M Schilling, and Harald Uhlig. Cryptocurrencies, currency competition, and the impossible trinity. *Journal of international economics*, 136:103601, 2022. 3

Bruno Biais, Christophe Bisiere, Matthieu Bouvard, Catherine Casamatta, and Albert J Menkveld. Equilibrium bitcoin pricing. *The Journal of Finance*, 78(2):967–1014, 2023. 3

Paul M Brown. Experimental evidence on money as a medium of exchange. *Journal of Economic Dynamics and Control*, 20(4):583–600, 1996. 5

Markus K Brunnermeier and Christian Julliard. Money illusion and housing frenzies. *The Review of Financial Studies*, 21(1):135–180, 2008. 2

Markus K Brunnermeier, Stefan Nagel, and Lasse H Pedersen. Carry trades and currency crashes. *NBER macroeconomics annual*, 23(1):313–348, 2008. 2

Gabriele Camera and Marco Casari. The coordination value of monetary exchange: Experimental evidence. *American Economic Journal: Microeconomics*, 6 (1):290–314, 2014. 5

Gabriele Camera and Dean Corbae. Money and Price Dispersion. *International Economic Review*, 40(4):985–1008, 1999. 5

Gabriele Camera, Charles Noussair, and Steven Tucker. Rate-of-return dominance and efficiency in an experimental economy. *Economic Theory*, 22:629–660, 2003a. 5

Gabriele Camera, Charles Noussair, and Steven Tucker. Rate-of-return dominance and efficiency in an experimental economy. *Economic Theory*, 22:629–660, 2003b. 4

Gabriele Camera, Ben Craig, and Christopher J. Waller. Currency competition in a fundamental model of money. *Journal of International Economics*, 64(2):521–544, 2004. URL https://www.sciencedirect.com/science/article/pii/S0022199603001247. 3

Colin F Camerer. Behavioural studies of strategic thinking in games. *Trends in cognitive sciences*, 7(5):225–231, 2003. 5

Marcos Cardozo, Yaroslav Rosokha, and Cathy Zhang. On the emergence of international currencies: An experimental approach. *Journal of Economic Behavior & Organization*, 228:106744, 2024. 1, 2, 4, 5

Daniel L Chen, Martin Schonger, and Chris Wickens. oTree – An open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance*, 9:88–97, 2016. 26

Shuze Ding and Daniela Puzzello. Legal restrictions and international currencies: An experimental approach. *Journal of International Economics*, 126:103342, 2020. 4

John Duffy and Jack Ochs. Emergence of money as a medium of exchange: An experimental study. *American Economic Review*, 89(4):847–877, 1999. 5

John Duffy and Jack Ochs. Intrinsically Worthless Objects as Media of Exchange: Experimental Evidence. *International Economic Review*, 43(3):637–673, 2002. 5

John Duffy and Daniela Puzzello. Gift exchange versus monetary exchange: Theory and evidence. *American economic review*, 104(6):1735–1776, 2014a. 5

John Duffy and Daniela Puzzello. Experimental Evidence on the Essentiality and Neutrality of Money in a Search Model. In *Experiments in Macroeconomics, Research in Experimental Economics*. Emerald Group Publishing Ltd, Bingley, UK, 2014b. 5

John Duffy et al. *Macroeconomics: a survey of laboratory research*. eScholarship, University of California, 2016. 41

Martin Dufwenberg and Uri Gneezy. Measuring beliefs in an experimental lost wallet game. *Games and economic Behavior*, 30(2):163–182, 2000. 24

Ernst Fehr and Jean-Robert Tyran. Does money illusion matter? *American Economic Review*, 91(5):1239–1262, 2001. 2

Jesús Fernández-Villaverde and Daniel Sanches. Can currency competition work? *Journal of Monetary Economics*, 106:1–15, 2019. 4

Frank Whitson Fetter. Some Neglected Aspects of Gresham's Law. *The Quarterly Journal of Economics*, 46(3):480–495, 1932. 2

Guillaume R Fréchette and Sevgi Yuksel. Infinitely repeated games in the laboratory: Four perspectives on discounting and random termination. *Experimental Economics*, 20:279–308, 2017. 24

Milton Friedman. Studies in the quantity theory of money. *(No Title)*, 1956. 1

Milton Friedman. Quantity theory of money. In *Money*, pages 1–40. Springer, 1989. 1

Rodney Garratt and Neil Wallace. Bitcoin 1, bitcoin 2,....: An experiment in privately issued outside monies. *Economic Inquiry*, 56(3):1887–1897, 2018. 3

Robert L. Greenfield and Hugh Rockoff. Gresham's Law in Nineteenth-Century America. *Journal of Money, Credit and Banking*, 27(4):1086–1098, 1995. 2

Janet Hua Jiang and Cathy Zhang. Competing currencies in the laboratory. *Journal of Economic Behavior & Organization*, 154:253–280, 2018. 4

Janet Hua Jiang, Daniela Puzzello, and Cathy Zhang. How long is forever in the laboratory? three implementations of an infinite-horizon monetary economy. *Journal of Economic Behavior & Organization*, 184:278–301, 2021. 26

Janet Hua Jiang, Daniela Puzzello, and Cathy Zhang. Inflation, output, and welfare in the laboratory. *European Economic Review*, 152:104351, 2023. 5

John Kareken and Neil Wallace. On the Indeterminacy of Equilibrium Exchange Rates. *The Quarterly Journal of Economics*, 96(2):207–222, 1981. 3, 5, 14, 29, 31, 32, 42

Nobuhiro Kiyotaki and Randall Wright. On money as a medium of exchange. *Journal of political Economy*, 97(4):927–954, 1989. 5

Robert E Lucas. Two illustrations of the quantity theory of money. *The American Economic Review*, 70(5):1005–1014, 1980. 1

Robert E Lucas Jr. Adaptive behavior and economic theory. *journal of Business*, pages S401–S426, 1986. 5

Rodolfo E Manuelli and James Peck. Exchange rate volatility in an equilibrium asset pricing model. *International Economic Review*, pages 559–574, 1990. 3

Ramon Marimon and Shyam Sunder. Indeterminacy of equilibria in a hyperinflationary world: Experimental evidence. *Econometrica: Journal of the Econometric Society*, pages 1073–1107, 1993. 5

Ramon Marimon and Shyam Sunder. Expectations and learning under alternative monetary regimes: an experimental approach. *Economic Theory*, 4(1):131–162, 1994. 5

Adib J Rahman. Deflationary policy under digital and fiat currency competition. *Research in economics*, 72(2):171–180, 2018. 4

Justin Rietz. Secondary currency acceptance: Experimental evidence with a dual currency search model. *Journal of Economic Behavior & Organization*, 166:403–431, 2019. 4

Arthur J. Rolnick and Warren E. Weber. Gresham's Law or Gresham's Fallacy? *Journal of Political Economy*, 94(1):185–199, 1986. 2

Thomas J Sargent and Paolo Surico. Two illustrations of the quantity theory of money: Breakdowns and revivals. *American Economic Review*, 101(1):109–128, 2011. 1

Linda Schilling and Harald Uhlig. Some simple bitcoin economics. *Journal of Monetary Economics*, 106:16–26, 2019a. 1, 3, 4, 5, 6, 7, 8, 11, 15, 33, 34, 55

Linda M Schilling and Harald Uhlig. Currency substitution under transaction costs. In *AEA Papers and Proceedings*, volume 109, pages 83–87. American Economic Association, 2019b. 3, 5, 6, 7, 9, 15, 55

Eldar Shafir, Peter Diamond, and Amos Tversky. Money illusion. *The quarterly journal of economics*, 112(2):341–374, 1997. 2

Vernon L. Smith. Markets as Economizers of Information: Experimental Examination of the 'Hayek Hypothesis'. *Economic Inquiry*, 20(2):165–79, 1982. 24

Pedro Teles, Harald Uhlig, and João Valle e Azevedo. Is quantity theory still alive? *The Economic Journal*, 126(591):442–464, 2016. 1

John B Van Huyck, Raymond C Battalio, and Richard O Beil. Tacit coordination games, strategic uncertainty, and coordination failure. *The American Economic Review*, 80(1):234–248, 1990. 5

Johar Arrieta Vidal, David Florián Hoyle, Kristian López Vargas, and Valeria Morales Vásquez. Policies for transactional de-dollarization: A laboratory study. *Journal of Economic Behavior & Organization*, 200:31–54, 2022. 4

Yu Zhu and Scott Hendry. Monetary policy in a digital economy. *Available at SSRN 3318915*, 2018. 4

A Appendix

A.1 Theoretical Analysis

Proof. [Proof Lemma 3.1] 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.

□

[Proof Lemma 3.1]

A.1.1 Setting (Benchmark): no Transaction costs

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

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

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

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

As before, 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 a buyer buys some packages using Bitcoin and Dollars in every period, $q_t^D, q_t^B > 0$. Note again, 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 a deviation from the Kareken Wallace result,

$$
\frac{P_{t+1}}{P_t} = m \frac{\hat{P}_{t+1}}{\hat{P}_t} \tag{54}
$$

i.e., the inflation rates on Dollars, on the left, must equal the Bitcoin inflation rate times the Dollar multiplier m, at any point in time. Put differently, from one period to the other, the Dollar inflation is m times larger than the Bitcoin inflation. Writing this equilibrium condition in terms of the exchange rate, We have

$$
Q_{t+1} = m\, Q_t \tag{55}
$$

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

$$
0 \leq \hat{\lambda}_{14,t} = \frac{1}{P_t} u'(c_t) - \beta^2 m^2 \frac{1}{P_{t+2}} u'(c_{t+2}) \tag{56}
$$

and

$$
0 \leq \hat{\lambda}_{13,t} = \frac{1}{\hat{P}_t} u'(c_t) - \beta^2 \frac{1}{\hat{P}_{t+2}} u'(c_{t+2}) \tag{57}
$$

If not all Bitcoind 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, as we observe in the experiment, then $\hat{\lambda}_{13,t} = 0 = \hat{\lambda}_{14,t}$. In that case, FOC VIII and IX yield the consumption-Euler equations for consumption

purchased in Bitcoins

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \frac{u'(c_{t+2})}{u'(c_t)} \tag{58}$$

and Dollars

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2 \frac{u'(c_{t+2})}{u'(c_t)}. \tag{59}$$

Market clearing In the Monetary policy treatment, we hold the Bitcoin supply constant, and the Dollar supply grows at rate m, $D_t = mD_{t-1}$. From above, in equilibrium, clearing of both goods markets requires

$$Y \equiv Y_t = 30 = \sum_{i=1}^{6} y_{ti} = \frac{D_t V_t^D}{P_t} + \frac{B V_t^B}{\hat{P}_t} + \sum_{i=1}^{6} \ell_{ti} \tag{60}$$

$$= m \frac{D_{t-1} V_t^D}{P_t} + \frac{B V_t^B}{\hat{P}_t} + \sum_{i=1}^{6} \ell_{ti} \tag{61}$$

In equilibrium, the number of unsold packages is zero, $\sum_{i=1}^{6} \ell_{ti} = 0$ for any t. Because output Y is constant across time, sequential market clearing requires

$$0 = Y_t - Y_{t+1} = D_t \left(\frac{V_t^D}{P_t} - \frac{mV_{t+1}^D}{P_{t+1}} \right) + B \left(\frac{V_t^B}{\hat{P}_t} - \frac{V_{t+1}^B}{\hat{P}_{t+1}} \right) \tag{62}$$

From above, in any equilibrium it holds $Q_{t+1} = m\,Q_t = m^t Q_1$, and thus

$$\hat{P}_{t+1} = \frac{1}{m} P_{t+1} \frac{\hat{P}_t}{P_t} = \frac{1}{m^t} P_{t+1} \frac{\hat{P}_1}{P_1} \tag{63}$$

Replacing $\hat{P}_{t+1}$ in the sequential market clearing constraint, (**??**),

$$0 = Y_1 - Y_{t+1} = D_1 \left(\frac{V_1^D}{P_1} - \frac{m^t V_{t+1}^D}{P_{t+1}} \right) + B \left(\frac{V_1^B}{\hat{P}_1} - \frac{V_{t+1}^B}{\hat{P}_{t+1}} \right) \tag{64}$$

$$= D_1 \left(\frac{V_1^D}{P_1} - \frac{m^t V_{t+1}^D}{P_{t+1}} \right) + \frac{B}{\hat{P}_1} \left(V_1^B - \frac{m^t V_{t+1}^B P_1}{P_{t+1}} \right) \tag{65}$$

If not all Bitcoins and Dollars are spent in every period (which we observe in the experiment), in a symmetric equilibrium it holds $c_{ti} = y_{ti} = y_{t+2,i} = c_{t+2,i}$, and thus

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \frac{u'(c_{t+2})}{u'(c_t)} = \beta^2 \tag{66}$$

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2 \frac{u'(c_{t+2})}{u'(c_t)} = \beta^2 m^2 \tag{67}$$

Thus, we require

$$\hat{P}_{t+2} = \beta^2 \hat{P}_t \leq \hat{P}_t \tag{68}$$

$$P_{t+2} = \beta^2 m^2 P_t \tag{69}$$

That is, the Bitcoin price should weakly decline. But the Dollar price may increase across time if $\beta m > 1$, i.e. if m is large enough. In the experiment, this is clearly the case.

A.1.2 Setting: Transaction costs Economy

We next introduce monetary policy in addition to transaction costs.

We analyze again green agent's optimization problem. A red agent's optimization is the same, with consumption shifted one time period ahead. Green agents are buyers and hence consume in even periods, and are sellers in odd periods. Let $\xi_t = 1$ when t is even, and zero when odd. The Lagrangian reads

$$\begin{aligned}
L = \sum_{t=0}^{\infty} \xi_t \beta^t \Big[& u(c_t) + \lambda_{13,t}(\hat{P}_t q_t^B) + \hat{\lambda}_{13,t}(b_t - \hat{P}_t q_t^B) && (70)\\
& + \lambda_{14,t}(P_t q_t^D) + \hat{\lambda}_{14,t}(d_t - P_t q_t^D) && (71)\\
& + \lambda_{15,t}(r_t(q_t^D)\, q_t^D + r^B\, q_t^B - c_t) && (72)\\
& + \lambda_{16,t}(b_t - \hat{P}_t q_t^B - b_{t+1}) && (73)\\
& + \lambda_{17,t}(m(d_t - P_t q_t^D) - d_{t+1}) \Big] && (74)\\
+ (1-\xi_t)\beta^t \Big[& \lambda_{19,t}(y_t - x_t - z_t) && (75)\\
& + \lambda_{20,t}(b_t + \hat{P}_t x_t - b_{t+1}) && (76)\\
& + \lambda_{21,t}(m(d_t + P_t z_t) - d_{t+1}) && (77)\\
& + \lambda_{22,t} x_t + + \lambda_{23,t} z_t \Big] && (78)
\end{aligned}$$

If t is even and $t+1$ is odd,

$$\begin{array}{lll}
I. & \frac{\partial L}{\partial c_t} & = u'(c_t) - \lambda_{15,t} = 0\\
II. & \frac{\partial L}{\partial q_t^D} & = \lambda_{14,t} P_t - \hat{\lambda}_{14,t} P_t + R(q_t^D)\, \lambda_{15,t} - \lambda_{17,t}\, m P_t = 0\\
III. & \frac{\partial L}{\partial q_t^B} & = \lambda_{13,t} \hat{P}_t - \hat{\lambda}_{13,t} \hat{P}_t + R^B\, \lambda_{15,t} - \lambda_{16,t} \hat{P}_t = 0\\
IV. & \frac{\partial L}{\partial x_{t+1}} & = -\lambda_{19,t+1} + \lambda_{20,t+1} \hat{P}_{t+1} + \lambda_{22,t+1} = 0\\
V. & \frac{\partial L}{\partial z_{t+1}} & = -\lambda_{19,t+1} + \lambda_{21,t+1}\, m P_{t+1} + \lambda_{23,t+1} = 0\\
VI. & \frac{\partial L}{\partial b_t} & = \hat{\lambda}_{13,t} \beta^t + \lambda_{16,t} \beta^t - \lambda_{20,t-1} \beta^{t-1} = 0\\
VII. & \frac{\partial L}{\partial d_t} & = \hat{\lambda}_{14,t} \beta^t + \lambda_{17,t}\, m\, \beta^t - \lambda_{21,t-1} \beta^{t-1} = 0\\
VIII. & \frac{\partial L}{\partial b_{t+1}} & = -\lambda_{16,t} \beta^t + \lambda_{20,t+1} \beta^{t+1} = 0\\
IX. & \frac{\partial L}{\partial d_{t+1}} & = -\lambda_{17,t} \beta^t + \lambda_{21,t+1}\, m\, \beta^{t+1} = 0
\end{array} \tag{79}$$

As before, assuming 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, and that a buyer buys some packages using Bitcoin and Dollars in every period, $q_t^D, q_t^B > 0$, it holds $\lambda_{13,t} = \lambda_{14,t} = \lambda_{22,t} =$

$\lambda_{23,t} = 0$. After solving for the Lagrange multipliers, the FOCs IV and V yield

$$R^B \frac{P_{t+1}}{P_t} = m\, R(q_t^D)\, \frac{\hat{P}_{t+1}}{\hat{P}_t}. \tag{80}$$

Writing this equilibrium condition in terms of the exchange rate, we obtain

$$Q_{t+1} = m\, \frac{R(q_t^D)}{R^B}\, Q_t \tag{81}$$

The initial exchange rate Q_0 remains undetermined. One obtains

$$0 \leq \hat{\lambda}_{14,t} = \frac{1}{P_t} u'(c_t) R(q_t^D) - \beta^2 m^2 \frac{1}{P_{t+2}} u'(c_{t+2}) R(q_{t+2}^D) \tag{82}$$

and

$$0 \leq \hat{\lambda}_{13,t} = \frac{R^B}{\hat{P}_t} u'(c_t) - \beta^2 \frac{R^B}{\hat{P}_{t+2}} u'(c_{t+2}) \tag{83}$$

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, as we observe in the experiment, then $\hat{\lambda}_{13,t} = 0 = \hat{\lambda}_{14,t}$. In that case, FOC VIII and IX yield the consumption-Euler equations for consumption purchased in Bitcoins

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \frac{u'(c_{t+2})}{u'(c_t)}. \tag{84}$$

Since the marginal Bitcoin transaction cost is contant in the number of packages purchased, it cancels out and does not affect the pricing equation. For Dollars,

$$\frac{P_{t+2}}{P_t} = \beta^2\, m^2\, \frac{R(q_{t+2}^D)}{R(q_t^D)}\, \frac{u'(c_{t+2})}{u'(c_t)}. \tag{85}$$

the transaction costs and the multiplier jointly affect the pricing equation.

Market clearing with transaction costs and monetary policy means that aggregate consumption is below the aggregate production, due to frictions and the Dollar supply grows by factor m per period. As before, let q_t^D the number of packages bought with Dollars, whereas $r_t(q_t^D) q_t^D$ is the consumption afforded with Dollars after accounting for transaction costs. Likewise, let q_t^B the number of packages bought with Bitcoins, whereas $0.75 q_t^B$ is the consumption afforded with Bitcoins after accounting for transaction costs. We define the aggregate transaction costs as

$$\sum_{i=1}^{6} TraCo_{ti} = \sum_{i=1}^{6} (1 - r_t(q_{ti}^D))\, q_{ti}^D + (1 - r^B) q_{ti}^B \tag{86}$$

In equilibrium, clearing of both goods markets requires

$$Y \equiv Y_t = 30 = \sum_{i=1}^{6} y_{ti} = \sum_{i=1}^{6} c_{ti} + \sum_{i=1}^{6} TraCo_{ti} + \sum_{i=1}^{6} \ell_{ti} \tag{87}$$

$$= \underbrace{r_t(q_t^D)\,\frac{D_t\,V_t^D}{P_t} + r^B\,\frac{B\,V_t^B}{\hat{P}_t}}_{\text{consumption after costs}} + \underbrace{(1-r_t(q_t^D))\,\frac{D_t\,V_t^D}{P_t} + (1-r^B)\,\frac{B\,V_t^B}{\hat{P}_t}}_{\text{lost consumption due to frictions}} + \sum_{i=1}^{6} \ell_{ti} \tag{88}$$

$$= \underbrace{m\,r_t(q_t^D)\,\frac{D_{t-1}\,V_t^D}{P_t} + r^B\,\frac{B\,V_t^B}{\hat{P}_t}}_{\text{consumption after costs}} + \underbrace{m\,(1-r_t(q_t^D))\,\frac{D_{t-1}\,V_t^D}{P_t} + (1-r^B)\,\frac{B\,V_t^B}{\hat{P}_t}}_{\text{lost consumption due to frictions}} + \sum_{i=1}^{6} \ell_{ti} \tag{89}$$

$$\tag{90}$$

Sequential market clearing requires

$$0 = Y_t - Y_{t+1} = D_t\left(r_t(q_t^D)\,\frac{V_t^D}{P_t} - m\,r_{t+1}(q_{t+1}^D)\,\frac{V_{t+1}^D}{P_{t+1}}\right) + r^B\,B\left(\frac{V_t^B}{\hat{P}_t} - \frac{V_{t+1}^B}{\hat{P}_{t+1}}\right) \tag{91}$$

$$+ D_t\left((1-r_t(q_t^D))\,\frac{V_t^D}{P_t} - m\,(1-r_{t+1})(q_{t+1}^D)\,\frac{V_{t+1}^D}{P_{t+1}}\right) + (1-r^B)\,B\left(\frac{V_t^B}{\hat{P}_t} - \frac{V_{t+1}^B}{\hat{P}_{t+1}}\right) \tag{92}$$

and

$$0 = Y_1 - Y_{t+1} = D_1\left(r_1(q_1^D)\,\frac{V_1^D}{P_1} - m^t\,r_{t+1}(q_{t+1}^D)\,\frac{V_{t+1}^D}{P_{t+1}}\right) + r^B\,B\left(\frac{V_1^B}{\hat{P}_1} - \frac{V_{t+1}^B}{\hat{P}_{t+1}}\right) \tag{93}$$

$$+ D_1\left((1-r_1(q_1^D))\,\frac{V_1^D}{P_1} - m^t\,(1-r_{t+1})(q_{t+1}^D)\,\frac{V_{t+1}^D}{P_{t+1}}\right) + (1-r^B)\,B\left(\frac{V_1^B}{\hat{P}_1} - \frac{V_{t+1}^B}{\hat{P}_{t+1}}\right) \tag{94}$$

A.1.3 Comparison with a single-currency economy

Consider the contrast between our framework and classic monetary models featuring a single currency. The quantity theory and sequential market clearing imply:

$$Y - Y = 0 = \left(\frac{mD_{t-1}V_t^D}{P_t} - \frac{D_{t-1}V_{t-1}^D}{P_{t-1}}\right) = D_{t-1}\left(\frac{mV_t^D}{P_t} - \frac{V_{t-1}^D}{P_{t-1}}\right). \tag{95}$$

An increase in the Dollar supply by factor m affects buyers' consumption-savings decisions, altering velocity V_t^D. However, with output constant and a single currency (Dollar) market for goods, scarcity effects are absent, and the increase

in good supply fully passes through to the Dollar price:

$$P_t = m \frac{V_t^D}{V_{t-1}^D} P_{t-1}. \tag{96}$$

In contrast, with currency competition, as shown in Section 3.1, an increase in the Dollar supply at a given multiplier may induce a shift in trade volume toward the Dollar market, $\Delta_t = Y_t^D - Y_{t-1}^D > 0$. Consequently, constant aggregate output does not necessarily imply proportional Dollar inflation: $\Delta_t = D_{t-1}\left(\frac{mV_t^D}{P_t} - \frac{V_{t-1}^D}{P_{t-1}}\right)$, implies

$$P_t = m\frac{V_t^D}{V_{t-1}^D}\left(\frac{V_{t-1}^D D_{t-1}}{\Delta_t P_{t-1} + V_{t-1}^D D_{t-1}}\right) P_{t-1}. \tag{97}$$

For $\Delta_t \neq 0$, monetary policy pass-through to Dollar prices is dampened by the bracketed term, $\left(\frac{V_{t-1}^D D_{t-1}}{\Delta_t P_{t-1} + V_{t-1}^D D_{t-1}}\right) \in (0,1)$, which equals one only when $\Delta_t = 0$.

Thus, currency competition and trade reallocation toward the Dollar market partially weaken the effectiveness of Dollar monetary policy. Hence, constant aggregate output does not necessarily imply proportional Dollar inflation. Similar inflation-deterring behavior is documented in Schilling and Uhlig (2019a), where symmetric Dollar transfers can induce Bitcoin deflation instead of Dollar inflation. Further, Schilling and Uhlig (2019b) show that an increased Dollar supply may shift the "critical good" at which buyers switch from using Dollars to Bitcoin for purchases.

A.2 Explicit forms of the quantity-dependent transaction costs in the experiment

In the experiment, since only integer numbers of packages are traded, the quantity-contingent package content $\gamma(q_{i,t}^D)$ in the Dollar-denominated market takes the form of a step function.

We employ the Gauss formula – the sum of the numbers from $1,\ldots,n$ equals $n(n+1/2)$. – to adjust Equation (11) to the lab environment. Buyer i's average consumption per Dollar-financed package (after costs) in round t equals:

$$r(q_{i,t}^D) = \frac{10\times 11 - (10 - q_{i,t}^D)(10+1-q_{i,t}^D)}{2\times 10\times q_{i,t}^D} = \frac{21 - q_{i,t}^D}{20}, \qquad q_{i,t}^D \leq 10. \tag{98}$$

The marginal increase in Dollar-financed consumption (12), adjusts to

$$R(q_{i,t}^D) \equiv \frac{\partial}{\partial q_{i,t}^D}\left(r(q_{i,t}^D) q_{i,t}^D\right) = \frac{\partial r}{\partial q_{i,t}^D} q_{i,t}^D + r(q_{i,t}^D) = \frac{21 - 2q_{i,t}^D}{20} = r(2q_{i,t}^D), \qquad q_{i,t}^D \leq 10. \tag{99}$$

Table 4 summarizes the average after-cost consumption $R(\cdot)$ and the incremen-

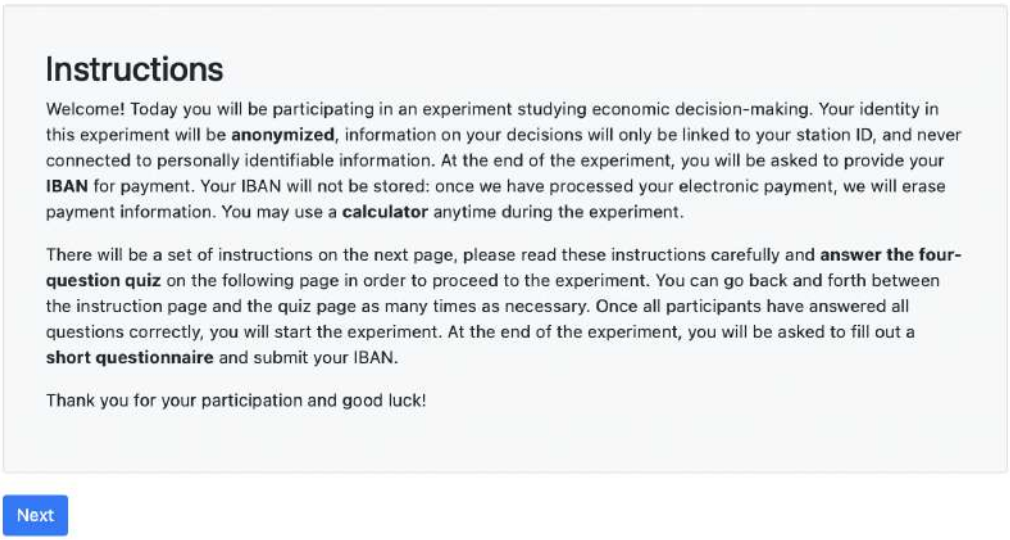
tal increase in consumption per package $r(\cdot)$ depending on the currency used.

No. of packages $(q^D_{i,t}, q^B_{i,t})$		1st	2nd	3rd	4rd	5th	$\cdots$	10th
In Dollar	$r(q^D_{i,t})$	1	0.95	0.9	0.85	0.8	$\cdots$	0.55
	$R(q^D_{i,t})$	0.95	0.85	0.75	0.65	0.55	$\cdots$	0.05
In Bitcoin	$r(q^B_{i,t}), R(q^B_{i,t})$	0.75	0.75	0.75	0.75	0.75	$\cdots$	0.75

Table 4: Consumption after transaction costs per package purchased using Dollar and Bitcoin

B Experimental material

B.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).

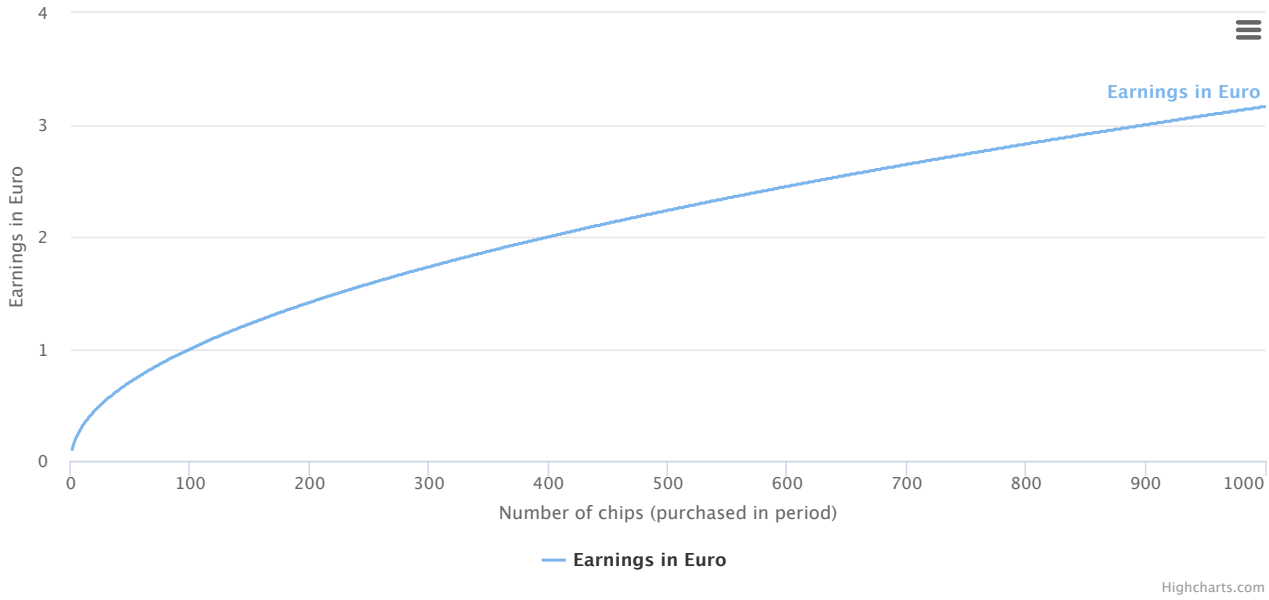
- A trade is finalized every time there is an ask price equal or less than a bid price.
  - The transaction price is the seller's asking price and the number of packages exchanged is the minimum between the number of packages offered by the seller, and desired by the buyer.
  - As a buyer, if no packages 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?

----

3. which one of the following applies?

Next

B.2 Graphical user interfaces (GUI)

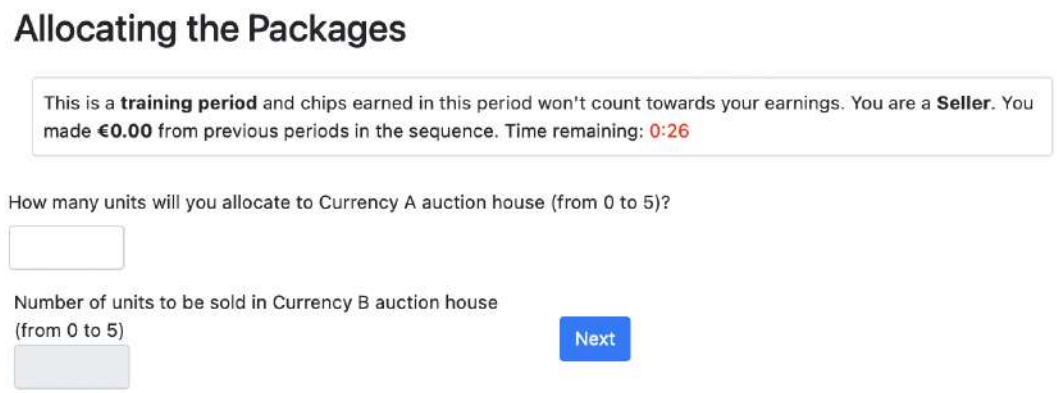


Figure 10: Screen of the sellers' allocation page of packages between the two markets

C Additional results

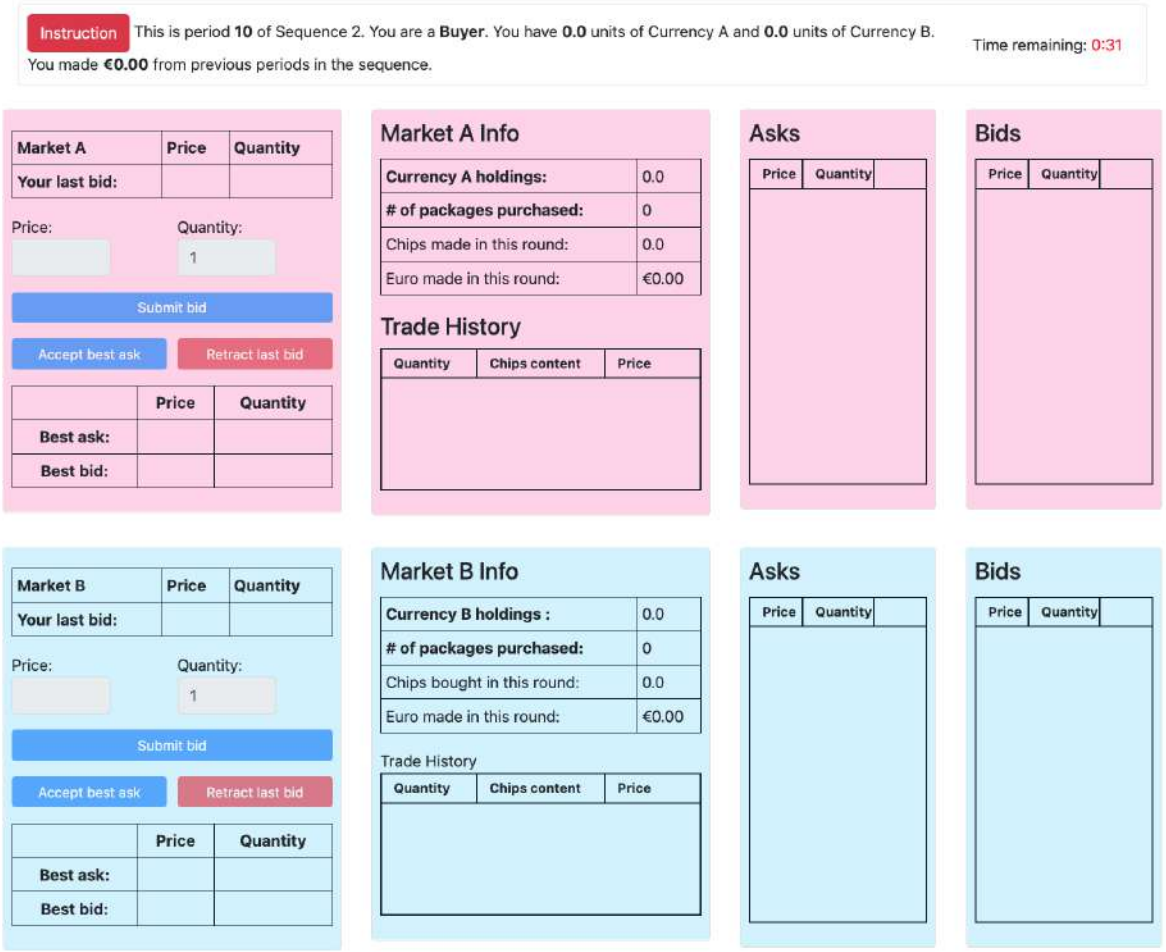


Figure 11: Graphical user interface of the buyer

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.

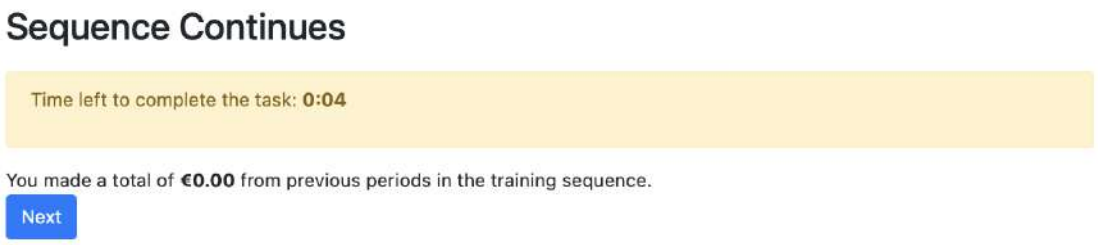


Figure 12: Screen indicating a continuing sequence

Dependent variable:	Dollar sales share		Saving rate in Dollar		Saving rate in Bitcoin		Exchange rate		Exchange rate growth	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Treatment dummy [omitted: Tr. `noInfl-noCost`]										
Tr. `noInfl-Cost`	−0.014	−0.023	−0.015	−0.004	−0.018	−0.004	0.063**	0.056**	0.049*	0.017
	(0.022)	(0.026)	(0.021)	(0.020)	(0.026)	(0.026)	(0.029)	(0.028)	(0.028)	(0.032)
Tr. `infl-noCost`	0.114***	0.107***	−0.056	−0.048	0.067**	0.073**	−0.047	−0.069	−0.115***	−0.190***
	(0.024)	(0.025)	(0.040)	(0.040)	(0.032)	(0.032)	(0.070)	(0.080)	(0.037)	(0.045)
Tr. `infl-cost`	0.071***	0.079**	−0.084***	−0.087***	−0.002	0.020	−0.028	−0.022	−0.061**	−0.129***
	(0.026)	(0.031)	(0.023)	(0.026)	(0.028)	(0.034)	(0.052)	(0.058)	(0.027)	(0.022)
round	−0.005***	−0.006***	−0.002	0.0005	−0.013***	−0.012***	0.002	0.002	0.004	0.006
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.005)	(0.006)	(0.006)	(0.006)
Tr. `noInfl-Cost`	0.001	0.002	0.002	−0.00004	0.003	0.001	0.001	0.002	−0.012*	−0.006
× round	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.006)	(0.006)	(0.007)	(0.007)
Tr. `infl-noCost`	0.006**	0.007**	0.034***	0.033***	0.001	−0.001	0.060***	0.064***	0.023***	0.036***
× round	(0.003)	(0.004)	(0.005)	(0.005)	(0.001)	(0.002)	(0.020)	(0.021)	(0.009)	(0.010)
Tr. `infl-cost`	−0.008***	−0.008**	0.041***	0.041***	−0.004	−0.007*	0.072***	0.073***	0.015**	0.031***
× round	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)	(0.013)	(0.014)	(0.007)	(0.007)
Constant	0.559***	0.566***	0.226***	0.205***	0.310***	0.318***	0.986***	0.994***	−0.052**	−0.144***
	(0.018)	(0.021)	(0.016)	(0.017)	(0.011)	(0.016)	(0.031)	(0.044)	(0.023)	(0.043)
R^2	0.324	0.375	0.343	0.478	0.088	0.168	0.351	0.413	0.031	0.451
Obs.	768	696	768	696	768	696	768	696	744	696
Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: OLS estimates. Clustered standard errors at the group level are reported between brackets. Dummy variables for the sequence number are always included; controls are the last two inflation rates in Dollar and in Bitcoin and the last two fractions of unsold goods in the two markets. *p<0.1; **p<0.05; ***p<0.01.

Table 5: Time variation in the main variables

Dependent variable	Bidding prices in Dollar			Bidding prices in Bitcoin			Dollar trade share (consumption)		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Treatment dummy [omitted: Tr. `noInfl-noCost`]									
Tr. `noInfl-cost`	0.16*	0.09	0.06*	0.06	0.09	0.09	0.12	0.10	0.12
	(0.10)	(0.08)	(0.03)	(0.08)	(0.09)	(0.07)	(0.09)	(0.10)	(0.08)
Tr. `infl-noCost`	−0.32	−0.43	−0.47**	0.07	0.07	−0.03	0.42***	0.31**	0.28**
	(0.28)	(0.28)	(0.23)	(0.16)	(0.15)	(0.10)	(0.11)	(0.14)	(0.12)
Tr. `infl-cost`	0.33**	0.24**	−0.06	0.46***	0.39***	0.19***	0.39***	0.31**	0.26**
	(0.15)	(0.12)	(0.07)	(0.09)	(0.10)	(0.07)	(0.10)	(0.14)	(0.12)
round	−0.003	−0.03***	−0.01**	−0.01*	−0.02***	−0.01**	−0.01	−0.003	−0.02*
	(0.01)	(0.01)	(0.01)	(0.004)	(0.004)	(0.003)	(0.01)	(0.01)	(0.01)
Tr. `noInfl-cost` × round	−0.02**	−0.02**	−0.01	−0.01	−0.01	−0.01	−0.01	−0.005	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Tr. `infl-noCost` × round	0.22***	0.16***	0.15***	0.03**	0.02*	0.03***	−0.003	−0.04*	−0.03
	(0.07)	(0.05)	(0.05)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)
Tr. `infl-cost` × round	0.15***	0.08***	0.10***	−0.01	−0.01	−0.002	−0.04***	−0.05**	−0.03
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Intra-period order	−0.0000	−0.0002	−0.001	0.001	0.001	0.001			
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)			
Dollar balance $t-1$		0.06	0.02		−0.03***	−0.05***		−0.01	−0.02
		(0.04)	(0.05)		(0.01)	(0.01)		(0.03)	(0.04)
Bitcoin balance $t-1$		−0.003	−0.03		0.18***	0.14***		−0.33***	−0.27***
		(0.01)	(0.02)		(0.02)	(0.01)		(0.03)	(0.04)
Dollar profits $t-2$		0.25***	0.25***		0.03*	0.06***		0.29***	0.37***
		(0.03)	(0.03)		(0.02)	(0.02)		(0.04)	(0.04)
Bitcoin profits $t-2$		0.09**	0.11***		0.04**	0.07***		−0.20***	−0.17***
		(0.04)	(0.03)		(0.02)	(0.02)		(0.05)	(0.05)
Dollar spending $t-1$		−0.02	−0.10***		0.04***	−0.002		−0.0001	−0.02
		(0.02)	(0.02)		(0.01)	(0.01)		(0.02)	(0.02)

Dependent variable	Bidding prices in Dollar			Bidding prices in Bitcoin			Dollar trade share (consumption)		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Bitcoin spending $t-1$		0.04^{***}	-0.02		0.03^{***}	-0.02^{**}		-0.06^{***}	-0.02
		(0.01)	(0.01)		(0.01)	(0.01)		(0.02)	(0.03)
Dollar inflation $t-1$		-0.45^{***}	-0.12		-0.08	0.09		0.01	0.05^{*}
		(0.08)	(0.15)		(0.10)	(0.09)		(0.02)	(0.02)
Bitcoin inflation $t-1$		0.20^{**}	0.27^{**}		-0.16^{**}	-0.12^{**}		-0.09^{***}	-0.14^{***}
		(0.08)	(0.11)		(0.06)	(0.06)		(0.02)	(0.03)
Exchange rate in $t-1$		0.68^{***}	0.56^{***}		0.07	-0.09		-0.06^{***}	-0.07^{*}
		(0.16)	(0.17)		(0.10)	(0.11)		(0.02)	(0.04)
Dollar price $t-1$			0.004			0.01^{***}			0.001
			(0.003)			(0.002)			(0.002)
Dollar price $t-2$			0.31^{***}			0.17^{***}			-0.49
			(0.07)			(0.04)			(0.86)
Bitcoin price $t-1$			0.002			0.0002			-0.004^{**}
			(0.002)			(0.002)			(0.002)
Bitcoin price $t-2$			0.01^{***}			0.01^{***}			-0.002
			(0.002)			(0.002)			(0.002)
Constant	-0.88^{***}	-1.18^{***}	-1.14^{***}	-0.43^{***}	-0.47^{***}	-0.56^{***}	-0.28	0.15	0.43^{**}
	(0.20)	(0.16)	(0.15)	(0.13)	(0.16)	(0.16)	(0.20)	(0.14)	(0.20)
Observations	17,479	15,400	11,964	13,059	11,623	9,966	4,448	3,349	2,697
Adjusted R^2	0.26	0.33	0.38	0.06	0.13	0.18	0.04	0.42	0.31

Table 6: Buyers' behaviors (standardized regressions)

Dependent variable	Asking prices in Dollar			Asking prices in Bitcoin			Dollar sales share		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Treatment dummy [omitted: Tr. `noInfl-noCost`]									
Tr. `noInfl-cost`	−0.004	−0.01	−0.02	0.0001	0.002	−0.004	−0.03	−0.05	0.07
	(0.01)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)	(0.06)	(0.07)	(0.07)
Tr. `infl-noCost`	0.04	0.05	0.06	0.01	0.02	−0.01	0.31***	0.27***	0.30***
	(0.03)	(0.05)	(0.06)	(0.01)	(0.02)	(0.01)	(0.07)	(0.09)	(0.08)
Tr. `infl-cost`	0.01	−0.01	−0.05	0.01	0.02	−0.02	0.19***	0.18**	0.30***
	(0.01)	(0.02)	(0.04)	(0.01)	(0.02)	(0.01)	(0.07)	(0.09)	(0.07)
round	−0.002	−0.01	−0.01	−0.001	−0.0005	−0.0000	0.0005	−0.001	0.001
	(0.002)	(0.01)	(0.01)	(0.001)	(0.001)	(0.001)	(0.01)	(0.01)	(0.01)
Tr. `noInfl-cost` × round	−0.002*	−0.001	−0.001	−0.0001	−0.0003	0.0000	0.003	0.01	−0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.01)	(0.01)	(0.01)
Tr. `infl-noCost` × round	0.01**	0.01**	0.01	0.002	0.002	0.002	0.02**	0.01	0.003
	(0.003)	(0.003)	(0.005)	(0.001)	(0.001)	(0.002)	(0.01)	(0.02)	(0.02)
Tr. `infl-cost` × round	0.004***	0.01*	0.01*	−0.0002	0.001	0.001	−0.02***	−0.02	−0.03***
	(0.001)	(0.003)	(0.01)	(0.001)	(0.002)	(0.001)	(0.01)	(0.01)	(0.01)
Intra-period order	0.0001	0.0002	0.0003	0.0000	0.0000	0.0002*			
	(0.0001)	(0.0002)	(0.0003)	(0.0001)	(0.0001)	(0.0001)			
Dollar balance $t-1$		−0.01	−0.01		−0.001	−0.002		0.002	0.01
		(0.01)	(0.01)		(0.002)	(0.002)		(0.02)	(0.01)
Bitcoin balance $t-1$		0.02	0.04		−0.01**	−0.003**		−0.002	−0.02
		(0.03)	(0.04)		(0.003)	(0.001)		(0.02)	(0.02)
Dollar profits $t-2$		0.01	0.01		−0.002	−0.004		0.05**	0.11***
		(0.01)	(0.01)		(0.003)	(0.005)		(0.02)	(0.03)
Bitcoin profits $t-2$		−0.01	−0.02		0.005	−0.002		−0.14***	−0.12***
		(0.01)	(0.02)		(0.004)	(0.002)		(0.03)	(0.03)
Dollar spending $t-1$		0.001	−0.01		−0.002	−0.002***		0.05***	0.04**
		(0.01)	(0.01)		(0.001)	(0.001)		(0.02)	(0.02)

Dependent variable	Asking prices in Dollar			Asking prices in Bitcoin			Dollar sales share		
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)	(IX)
Bitcoin spending $t-1$		0.03	0.03		−0.004	−0.01**		−0.07***	−0.06***
		(0.03)	(0.04)		(0.002)	(0.002)		(0.02)	(0.02)
Dollar inflation $t-1$		−0.04	−0.04		0.01	−0.0003		0.01	0.03
		(0.03)	(0.03)		(0.01)	(0.01)		(0.01)	(0.02)
Bitcoin inflation $t-1$		−0.02	−0.02		0.003	0.02		−0.03***	−0.04**
		(0.03)	(0.03)		(0.01)	(0.02)		(0.01)	(0.02)
Exchange rate in $t-1$		0.02	0.01		−0.02*	0.003		−0.06***	−0.07***
		(0.01)	(0.02)		(0.01)	(0.01)		(0.02)	(0.02)
Dollar price $t-1$			0.01*			−0.0003			−0.72
			(0.01)			(0.003)			(0.78)
Dollar price $t-2$			−0.01			0.24			0.01***
			(0.02)			(0.22)			(0.001)
Bitcoin price $t-1$			0.003**			0.001***			−0.002
			(0.001)			(0.0003)			(0.003)
Bitcoin price $t-2$			0.002**			0.002**			−0.002*
			(0.001)			(0.001)			(0.001)
Constant	−0.03	−0.02	−0.13	−0.04	−0.03	−0.12***	0.59***	0.66***	0.82***
	(0.04)	(0.06)	(0.08)	(0.03)	(0.03)	(0.05)	(0.17)	(0.16)	(0.16)
Observations	17,691	15,204	12,269	13,098	11,456	10,003	4,608	3,456	2,851
Adjusted R^2	0.003	0.005	0.01	0.01	0.01	0.05	0.08	0.19	0.17

Table 7: Sellers' behaviors (standardized regressions)

69