Policies for Transactional De-Dollarization: A Laboratory Study*

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Abstract

Partial currency substitution typically occurs in small open economies amid economic crises. The local currency loses some of its essential functions, and a foreign currency, usually the US Dollar, becomes widely adopted. Interestingly, the coexistence of the two currencies often persists even after macroeconomic stability returns. This persistence imposes challenges to the conduct of monetary policy. Central banks have responded by applying de-dollarization policies. We extend the model in Matsuyama et al. (1993) and implement an experiment to study the effectiveness of two de-dollarization interventions: (1) taxes on transactions in foreign currency among domestic agents and (2) a reduction in the storage costs of local currency. We contribute to the theoretical literature by characterizing a new circulation regime for small open economies where agents use the foreign currency (FC) solely for international trade purposes and settle domestic transactions exclusively in local currency (LC). Our experimental evidence suggests that taxes (treatment 1) and storage cost (treatment 2) can foster de-dollarization as they reduce foreign currency acceptance and reinforce the use of local currency. However, we find that the impact of a reduction in the storage costs of local currency is more significant and more robust. It lowered the acceptance rate of FC by more than 20% and increased the acceptance of LC by more than 30%. The tax policy only reduced foreign currency acceptance by a smaller amount and only for encounters with foreign agents.

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1 Introduction

The coexistence of two currencies in an economy opens significant challenges to central banking. Empirical evidence, mainly from emerging economies, shows that the mass adoption of alternative currencies arises when the local currency loses at least one of its functions as a result of severe fiscal and monetary disequilibria (Yeyati and Ize, 2005).

Dollarization is a process that usually exhibits a well-defined pattern that starts with the foreign currency used as a reserve of value, then as a medium of exchange, and finally as a unit of account. This pattern defines three interrelated types of currency substitution: Financial dollarization (assets and liabilities), transaction dollarization, and price or invoicing dollarization. When the domestic currency loses its function as a reserve of value, agents often change their portfolios towards dollar-denominated assets/liabilities and start using dollars (in the form of bank deposits and cash) for durable goods transactions. Banks notice that a higher fraction of their deposits are denominated in dollars and begin lending in dollars as well. By this mechanism, firms also start saving and borrowing in dollars too and ultimately decide to set their prices in the foreign currency as well. The more agents get used to buying and selling goods in foreign currency, the more agents will save and lend in such currency (Calvo and Vegh, 1992).

Interestingly, in many countries, the coexistence of two currencies persists even after the economy has returned to macroeconomic stability, and the local currency has recovered its fundamental attributes. In several Latin American economies, for example currency, price and financial dollarization are still prevalent in different magnitudes (Yeyati and Ize, 2005; Colacelli and Blackburn, 2009). Dollarization, in this context, is an important phenomenon because it can be socially suboptimal. When agents choose to dollarize their assets, liabilities, and invoicing, they do not internalize the aggregate risks associated with such decisions. These risks include currency mismatches in balance sheets and foreign currency liquidity risks. In this sense, dollarization may place the financial system to be more exposed to unanticipated sharp movements in the exchange rate.

Furthermore, dollarization limits the role of the central bank as a lender of last

resort. In turn, this generates significant vulnerabilities to financial stability and the payment system as a whole. That is, dollarization reduces the effectiveness of monetary policy in episodes where international turbulence and capital outflows affect the domestic value of the foreign currency. Consequently, it might be optimal for central banks to deploy policies that make agents internalize those risks and discourage some types of dollarization. In fact, under this rationale, several governments and central banks have started implementing de-dollarization policies, even though there is insufficient research and evidence on the relative effectiveness of the available policy options.

This paper extends existing theory and uses laboratory experiments to study the impact of a set of relevant policies on currency dollarization. In particular, we focus on exploring the transactional role of money in a bimonetary small open economy where two policies, taxes on transactions in foreign currency among domestic agents and differential storage costs for the foreign currency, might affect the acceptance rate of foreign currency. To our knowledge, this is the only well-known instance of this type of policy. Prior attempts did not materialize. Notably, between 2000 and 2010, the European Commission discussed the Financial Transaction Tax, whose objective was to reduce currency volatility (Peterson and Galliano, 1999; Schmidt, 2008; Mcculloch and Pacillo, 2011). The first policy, taxes on domestic transactions in foreign currency, is partly motivated by a tax implemented in Argentina, aimed to reduce dollarization and foreign exchange arbitrage. This tax applies to specific types of domestic transactions, e.g., purchases of items listed in dollars with credit cards with an 8% rate for digital payments and 30% for other operations[1]. The second policy we study, asymmetric storage costs for the domestic and foreign currency, is a modelling abstraction of policies aimed to alter the cost of using domestic currency relative to foreign currency. Although there are different approaches to alter this relative cost, we think of it as the efforts of macroprudential offices such as the monetary authority and the banking regulator agency to improve the functioning and accessibility of the domestic payment system which ultimately may discourage agents to rely on the foreign currency to settle domestic transactions (Camera et al., 2016).

Our model builds on Matsuyama et al. (1993), a two-country and two-currency monetary search model with indivisible tradable objects (money and consumption goods). The circulation patterns of each currency are determined by the relative size of the two economies and the degree of trade integration. In particular, we study a small economy

[1]This tax is called "Impuesto para una Argentina Inclusiva y Solidaria (PAIS)" due to its nominal redistributional purposes. Although in practice, the tax aims to disincentivize the demand for dollars in the black market. Commercial banks (in coordination with the tax authority) apply the tax automatically, excluding international trade operations and health and education services payments.

that trades with a large foreign country. Agents of big economies do not accept small countries' currencies for international trade (e.g., Colombian citizens cannot use pesos for transactions with US agents). Accordingly, we focus on equilibria where the foreign economy never accepts the domestic currency.

We extend the model in two main directions. First, we include a government in the small open economy that deploys policies to discourage foreign currency acceptance in domestic transactions. Second, from the perspective of the small open economy, three circulation regimes for the foreign currency may emerge: (1) a national currency regime where domestic agents always reject the foreign currency, (2) an international currency regime where domestic agents always accept the foreign currency, and (3) a conditional acceptance currency regime where the foreign currency is accepted in international transactions but rejected in domestic transactions. This last regime is novel and is intended to represent a small open economy with a healthy macroeconomic equilibrium but persistent currency dollarization. As in Matsuyama et al. (1993) and Jiang and Zhang (2018), our set-up excludes prices and exchange rates from the analysis to focus on the policies that directly affect the decision to accept foreign currency in a stable economy.

Our laboratory experiment closely resembles the environment in the model, except that the trader population is countable and finite (the domestic economy is size eight, the foreign economy is size 20), and the time horizon is finite (100 periods, in expectation) [2]. Our empirical results are partially consistent with the theoretical predictions of our model. First, both policies, asymmetric storage costs between domestic and foreign currency holdings and taxes on specific transactions, impact currency acceptance decisions. Specifically, reducing the storage costs of local currency relative to foreign currency holdings deter the acceptance of foreign currency in all types of encounters (international and domestic). The introduction of taxes in domestic transactions with foreign currency diminish foreign token acceptance in international transactions, which is a departure from the theoretical predictions of model that we interpret as domestic agents anticipating the difficulties of using the foreign currency in subsequent transactions that arise due to existing storage costs. We interpret the above mentioned results as evidence of the proposed taxation system's challenges to induce the conditional acceptance regime. Domestic agents might start rejecting all their transactions with foreigners to avoid paying future taxes or avoid losing potential matches with other domestic traders. Second, our results suggest that unlike what is predicted by

[2]Although the experiment has a finite number of rounds, our analysis of the dynamics of traders' behavior reveals that acceptance rates of the treatment and control groups do converge. Consequently, we argue our results can be interpreted as equilibrium outcomes.

the theoretical model, both policies increase the acceptance rate of the local currency. In this case, the policy of reducing the storage cost of the local currency substantially increases the acceptance of the local currency. The latter is consistent with an improvement of the domestic payment system that encourage domestic agents to rely on the local currency for domestic transactions. We consider this results are indicative that the policy instruments analyzed in our experiment might reduce currency dollarization in small open emerging economies with macroeconomic stability but with some degree of persistent dollarization.

The rest of the paper is organized as follows. Section 2 presents the related literature, and section 3 describes the model and its predictions. Section 4 details the experimental design as well as hypotheses and the laboratory procedures. Section 5 presents a discussion of the results. Finally, section 6 concludes.

2 Related Literature

Our work is inspired and contributes to three bodies of economics literature: (1) theoretical and empirical literature on dollarization and dual-currency economies, (2) theoretical models of search and matching in monetary economics, and (3) laboratory experiments studying monetary phenomena.

There are different approaches to study and explain dollarization, its persistence, and the associated monetary policies. In the currency substitution approach, dollarization occurs as a migration to a safe coin as a consequence of sustained high rates of inflation in a small economy (Sahay and Végh, 1995; Savastano, 1996; Armas, 2016; Rossini, 2016). However, this view is not sufficient to explain why dollarization often persists after the inflationary period ends and the economy has stabilized. Other three approaches aim to explain this persistence (see Levy Yeyati (2006), and Hippolyte Balima (2017) for a discussion). First, the portfolio hypothesis highlights the differences in return and volatility between currencies (Ize and Yeyati, 2003; Hippolyte Balima, 2017). Second, the market development view emphasizes that dollarization is reinforced by market failures such as the absence of sufficient investment alternatives and financial instruments in the local currency (Yinusa, 2009; Hippolyte Balima, 2017; Christiano et al., 2021). Third, the institutional view focuses on political or economic uncertainty, which deters confidence in the local currency (Nicoló et al., 2005; Hippolyte Balima, 2017). Some papers combine more than one of these views in their theoretical and empirical work on dollarization. For instance, Rappoport (2009) explains the phenomenon

as an insurance demand in case of a real crisis that fosters exchange rate depreciation, more common in emergent economies. Similarly, Vieira et al. (2012) characterize dollarization empirically (using a cross-country estimation) and document it as an insurance response in an environment of high domestic debt, inflation, and default risk. Winkelried and Castillo (2010), models an emerging country's economy and argues that dollarization arises as a result of heterogeneous information processing among agents in that economy. Finally, Imam and Corrales (2019) estimated a panel data model to explain the financial dollarization of households and firms across countries. They find that variables associated with market development (e.g financial deepening, access to external debt) have the most significant joint explanatory power.

Interestingly, although these papers highlight the main determinants of dollarization, there is little research on the impact of specific policies that affect circulation patterns of the dollar. One exception is Castellares and Toma (2020) who study the case of Peru where the passing of a law that demanded sellers to post their prices in local currency increased menu costs for firms who originally priced their goods in foreign currency. They find this law diminished both the exchange rate passthrough and the degree of price dollarization. Castillo et al. (2016) and Contreras et al. (2019) study the use of the unconventional monetary policy of raising the relative reserve requirements and the expansion of the local currency liquidity relative to the dollar. These policies increased the cost of providing credits and deposits in foreign currency, and therefore incentivized the credit supply in local currency. This resulted in lower financial dollarization.[3]

To our knowledge, there are no experimental studies of the impact of policies on dollarization. There is, however, a good deal of prior theoretical and experimental work that is extensible to this purpose. In particular, an important branch of theoretical work in monetary economics studies the main functions of money using search and matching models. In two seminal papers, Kiyotaki and Wright (1993) introduce theoretical search models to highlight the welfare-enhancing attributes of money as a means of payment. In this setting, the difficulty of barter and the associated problem of "double coincidence of wants" endogenously generates the emergence of fiat money, which facilitates trade. These models admitted the possibility of equilibria with multiple currencies circulating simultaneously. Still, they focused on a single, closed economy with an exogenous money supply of these currencies and similar intrinsic properties (e.g., rates of return, flow yields, or dividends). Matsuyama et al. (1993) extended the framework to include two economies and two intrinsically worthless currencies that "compete" to serve as a

[3]This was known as the Financial De-Dollarization Program (2013-2017).

medium of exchange. In this environment, each possible equilibrium depicts a circulation pattern that depends on two fundamental parameters: the economies' relative size and their degree of trade integration. In this paper, we extend this setting to characterize an instance of a small open economy and study the impact of two government policies on reducing the acceptance rate of the foreign currency, taxes on domestic transactions settled in foreign currency, and policies that reduce the storage or usage costs of the local currency.

A growing body of research has studied these models and environments experimentally testing their main assumptions and predictions. Notably, Duffy and Ochs (2002) empirically tested the theoretical predictions on money emergence of Kiyotaki and Wright (1993) finding that lowering transaction costs does incentivize agents to accept a worthless token as a medium of exchange. In a paper that is particularly relevant to ours, Jiang and Zhang (2018) conduct an experiment based on the model of Matsuyama et al. (1993) to study the currency circulation patterns in an environment with two economies and two currencies. Their findings highlight the relative size of the economies and their degree of trade integration as determinants of the acceptance rates of the two currencies. Importantly, this paper also studies the government's role in providing a coordination device aimed to achieve a higher relative preference for the domestic currency. In particular, the government is an automated agent that is always willing to trade but only accepts the local currency.

Our paper extends this environment to study the effect of government policies on reducing foreign currency circulation and whether they act as a coordination device among multiple equilibria. We find that these policies reduce foreign currency circulation and, more interestingly, foster local currency circulation, a novel result and an alternative coordination device respect to Jiang and Zhang (2018).

There is some recent experimental work on a second currency circulating along with the local "official" one and the policies aimed to impact their circulation patterns. Rietz (2019) study a closed economy where there is an additional coin (representing a cryptocurrency) circulating partially in the sense that it might not be accepted in all trades. The official currency is always accepted. The author examines the circulation pattern of the second currency by experimentally comparing a barter economy to a non-barter economy. He finds that as theory predicts, in a non-barter economy, the secondary currency would allow further trades as it diminishes transaction cost. In the barter economy, there are no incentives to accept the cryptocurrency and its circulation is limited. Ding and Puzzello (2020) study a two-economies, two-currencies search model and evaluate government policies aimed to make a currency to circulate internationally.

In their experiment, each economy had buyers and sellers, where a seller could be from the private sector (able to accept any currency) or from the Government (accepting only the local currency). Accepting the foreign currency has a cost. To evaluate whether the government can modify the circulation, the experiment implemented one treatment where the government accepted the foreign currency. They also implemented a treatment with a lower cost of accepting the foreign currency. Their experimental evidence shows that these policies are not effective in altering the circulation regime to make a currency to become international. However, they do find that these policies improve aggregate welfare (as there are more transactions) and allow for more stable prices.

We construct on these models to characterize how policies might, on the other hand, deter the convergence to an International circulation regime in a similar environment in a two-country, two-currency search model.

3 The Model

Our theoretical predictions, as well as our experimental design, are based on the two-country, two-currency search model of Matsuyama et al. (1993). This framework is helpful to explore the transactional role of money in the presence of multiple currencies. The circulation patterns of each currency are determined endogenously by two fundamental factors: the relative size of the two economies and the degree of trade integration. We can also extend the model to include the role of a government that implements policies to deter the circulation of foreign currency.

Time is discrete and agents are infinitely lived. There are two economies: *Red* (r) and *Blue* (b); and the mass of agents in each of them has measure n_i, where $i \in \{r, b\}$. Without loss of generality, we define n as the fraction of agents that live in the Red economy (i.e., $n = \frac{n_r}{n_r+n_b}$). All agents have an intertemporal discount rate of $\delta \in (0, 1)$ and discount factor $\beta = \frac{1}{1+\delta}$.

Economies are defined by a *matching technology* that depends on the relative size of their populations, n, and the degree of trade integration, $\rho \in [0, 1]$. This technology determines the probability, α_{ij}, that an agent from economy i meets an agent from economy j. Table 1 summarizes the mapping from n, ρ to matching probabilities.

There are three indivisible objects in the model: a consumption good and two intrinsically worthless tokens labeled by color, red and blue. Each agent can costlessly produce a variety of consumption goods. However, agents only consume the varieties others produce, which provides a positive flow utility, $u > 0$. After consumption, agents

Table 1: Matching probabilities

	Red agent	Blue agent
Red agent	$\alpha_{rr} = 1 - \rho(1-n)$	$\alpha_{rb} = \rho(1-n)$
Blue agent	$\alpha_{br} = \rho n$	$\alpha_{bb} = 1 - \rho n$

engage in production to restore their inventories. The absence of *double coincidence of needs* eliminates the existence of barter, and the lack of record-keeping makes cooperation unsustainable. Tokens are used solely as a medium of exchange. These are useless for production and do not provide utility to their holders. That is, both currencies represent fiat money.

In each economy, i, a fraction $M_i \in (0,1)$ of agents (henceforth buyers) is initially endowed with a unit of their Local Currency. The remaining fraction of agents (henceforth sellers), $1-M_i$, is given a unit of the consumption good. Subsequently, we assume that the per-capita supply of tokens remains constant. Additionally, we rule out the possibility of currency exchange between agents.

There is a trade opportunity whenever a buyer matches with a seller. In that case, both agents in the pair must decide, simultaneously, whether to make the exchange. Trade occurs only when there is mutual agreement, and agents swap inventories and roles reverse. The buyer consumes the good, gains utility flow $u > 0$, and engages in production immediately after, becoming a seller. Similarly, the new currency holder begins the subsequent period as a buyer. As a direct consequence of the trading rules, agents never hold more than one object at a time.

3.1 Policy Instruments

In this model, the government can deploy policy instruments aiming to alter the cost of using the foreign currency relative to the domestic currency, and by doing so, to change the currencies' circulation patterns. These instruments include taxes on domestic transactions with foreign currency and policies aiming to make holding domestic currency cheaper relative to holding foreign currency. More specifically, the following policy options are available in economy $i \in \{r, b\}$:

- **Taxes:** τ_i^0 and τ_i^j denote, respectively, a lump-sum tax levied on domestic sellers and buyers of economy i for using the foreign currency in a domestic transaction.[4] This policy applies only when a local buyer holding foreign currency meets a local

[4]Superscripts denote object and foreign currency, respectively.

seller with a consumption good and agrees to trade.

- **Storage costs:** c_i^i and c_i^j denote the per-period storage costs incurred by domestic buyers when holding a local and foreign currency unit, respectively. If a local buyer cannot trade when holding a domestic (foreign) currency unit and must keep the token for an additional period, she pays c_i^i (c_i^j).

The first policy, taxes on transactions in foreign currency among domestic agents, is partly motivated by a tax implemented in Argentina, aimed to reduce dollarization and foreign exchange arbitrage. This tax applies to specific types of domestic transactions, e.g., purchases of items listed in dollars with credit cards with an 8% rate for digital payments and 30% for other operations.

The second one, differential storage costs for the domestic and foreign currency, is an abstraction of policies aimed to alter the cost of using domestic currency relative to foreign currency. One important way these policies materialize is the improvement of payment systems. Agents, for example, engage in cash transactions, but storing coins and bills is costly because of the associated risks of loss, theft, and counterfeit. By developing or improving digital payments (e.g., investing in digital infrastructure and mobile banking), regulatory policies might facilitate settlements in local currency and erase these costs to a large extent (Camera et al., 2016). Often, these improvements are only applicable to the domestic currency, thereby lowering its storage cost relative to the foreign currency.

3.2 Monetary Equilibrium

The state of the economy is completely determined by the distribution of assets among its agents, $\mathbf{m} = (m_{ij})$. In each period, there is a fraction of agents in economy i, m_{ik}, with currency $k \in \{r, b\}$; and a fraction, m_{i0}, of sellers. Since currencies are indivisible and agents can only hold one object at a time, equation (1) is always satisfied.

$$m_{ir} + m_{ib} + m_{i0} = 1 \tag{1}$$

Additionally, the total supply of currency i must equal its aggregate demand. That is, equation (2) must hold.

$$n_i M_i = n_i m_{ii} + n_j m_{ji} \tag{2}$$

Following Matsuyama et al. (1993) and Jiang and Zhang (2018), we focus on symmetric and stationary equilibria in pure strategies, where agents from the same country follow the same trading rule and the distribution of tokens remains constant over time. In this model, a token holder (buyer) who is matched with a good holder (seller) always attempts to trade. Moreover, we focus on candidate equilibria where sellers always accept the local currency. The central issue is whether sellers from economy i accept to trade and receive currency $j \neq i$. Let λ_{ij} be a dummy variable defined as $\lambda_{ij} = 1$ if sellers from country i accept the foreign currency when paired with buyers from country j, and 0 otherwise. The regimes we study are completely characterized by $\lambda = (\lambda_{rr}, \lambda_{rb}, \lambda_{br}, \lambda_{bb})$. A currency is said to be an *international currency* if it is accepted by all sellers in both countries and a *national currency* if it is only accepted by sellers from its economy of origin. Importantly, in this paper, we introduce a new attribute for a currency: the ***conditional acceptance***. We say a currency is conditionally accepted if it is used for international trade but not for local transactions outside its economy of origin. Formally, currency i is *conditionally-accepted* if it is accepted by sellers from i, irrespective of the buyer's nationality, and by sellers from $j \neq i$ *only if* it is handed over by a buyer from i.

When two agents of different nationalities are matched, $i \neq j$, the stationarity conditions of currency holdings are given by equations (3) and (4). These are built on the fact that local transactions do not alter the aggregate distribution of assets in the economy, $\mathbf{m}$. According to (3), the outflow of currency i from country j must equal the inflow of currency i to country j. Similarly, condition (4) shows that the inflow of currency j to country i must equal the outflow of currency j from country i.

$$\underbrace{m_{i0}m_{ji}}_{\text{outflow of currency } i \text{ from country } j} = \underbrace{m_{ii}m_{j0}\lambda_{ji}}_{\text{inflow of currency } i \text{ to country } j} \tag{3}$$

$$\underbrace{m_{i0}m_{jj}\lambda_{ij}}_{\text{inflow of currency } j \text{ to country } i} = \underbrace{m_{ij}m_{j0}}_{\text{outflow of currency } j \text{ from country } i} \tag{4}$$

Let V_{i0} denote the lifetime utility of a seller from economy i, and V_{ik} represent the lifetime utility of a buyer from country i who holds currency $k \in \{r, b\}$. The flow value of a seller from economy i is given by

$$\delta V_{i0} = \underbrace{(\alpha_{ii}m_{ii} + \alpha_{ij}m_{ji})(V_{ii} - V_{i0})}_{\text{expected trade surplus when seller meets buyer with local currency}} \tag{5}$$

$$+ \underbrace{(\alpha_{ii} m_{ij} \lambda_{ii} + \alpha_{ij} m_{jj} \lambda_{ij})(V_{ij} - V_{i0})}_{\text{expected trade surplus when seller meets buyer with foreign currency}} - \underbrace{\alpha_{ii} m_{ij} \lambda_{ii} \tau_i^0}_{\text{expected tax payment of seller}} .$$

Equation (5) has three terms. The first one is the probability of meeting a buyer, either local or foreign, holding local currency times the resulting trade surplus. Similarly, the second term is the probability of meeting a local or foreign buyer holding foreign currency times the corresponding trade surplus. The third is the probability of meeting a local buyer holding foreign currency times the tax levied on sellers who agree to trade. The flow value of a buyer from country i holding local currency is expressed by

$$\delta V_{ii} = \underbrace{(\alpha_{ii} m_{i0} + \alpha_{ij} m_{j0} \lambda_{ji})(u + V_{i0} - V_{ii})}_{\text{expected trade surplus of buyer with local currency in local and foreign meetings}} . \tag{6}$$

$$- \underbrace{(1 - \alpha_{ii} m_{i0} - \alpha_{ij} m_{j0} \lambda_{ji}) c_i^i}_{\text{expected storage cost of buyer with local currency}}$$

The first term in equation (6) corresponds to the probability of meeting a seller, either domestic or foreign, times the associated gains from trade. The second term represents the probability of holding a local currency unit for an additional period times the corresponding storage cost.

The value flow of a buyer from country i holding foreign currency can be written as

$$\delta V_{ij} = \underbrace{(\alpha_{ii} m_{i0} \lambda_{ii} + \alpha_{ij} m_{j0})(u + V_{i0} - V_{ij})}_{\text{expected trade surplus of buyer with foreign currency in local and foreign transactions}} \tag{7}$$

$$- \underbrace{\alpha_{ii} m_{i0} \lambda_{ii} \tau_i^j}_{\text{expected tax payment of buyer}} - \underbrace{(1 - \alpha_{ii} m_{i0} \lambda_{ii} - \alpha_{ij} m_{j0}) c_i^j}_{\text{expected storage cost of buyer with foreign currency}}$$

Equation (7) is comprised by three terms. The first one is the probability of meeting a seller, either domestic or foreign, times the resulting gains from trade. The second term is the probability of meeting a local seller times the tax levied on buyers who use foreign currency in domestic transactions. The third is the probability of holding a unit of the foreign currency for an additional period times the corresponding storage cost.

From the expressions above, it should be apparent that, in the absence of policy instruments, every buyer would *always* attempt to trade with a seller, local or foreign, since the value of obtaining the consumption good would be higher than the value of keeping a unit of currency $k \in \{r, b\}$, $u + V_{i0} > V_{ik}$.

We focus on equilibria where policy instruments fail to deter buyers' willingness to

use foreign currency in local transactions, $u+V_{i0}-\tau_i^j > V_{ij}-c_i^j$. Furthermore, we should note that storage costs encourage domestic buyers holding foreign currency to attempt to trade to avoid incurring in a penalty of c_i^j. Whether trade occurs ultimately depends on the seller's decision. In our candidate equilibria, sellers *always* accept their domestic currency. However, the acceptance of foreign currency may vary across regimes and is endogenously determined by the following incentive compatibility constraint, written for a seller from economy i who meets a buyer from economy $k \in \{i, j\}$

$$\lambda_{ik} = \begin{cases} 1 & \text{if } V_{ij} - \tau_i^0 \mathbf{1}_{\{k=i\}} > V_{i0} \\ 0 & \text{if } V_{ij} - \tau_i^0 \mathbf{1}_{\{k=i\}} \leq V_{i0}, \end{cases} \tag{8}$$

where $\mathbf{1}_{\{.\}}$ is an indicator function. According to equation (8), a seller accepts foreign currency from a local buyer, $k = i$, if the value of holding foreign money net of tax payment, $V_{ij} - \tau_i^j$, exceeds the value of remaining a seller, V_{i0}. The same reasoning applies when the meeting involves a foreign buyer, $k = j$, except no taxes are charged to the seller if trade takes place.

3.3 Currency Regimes

A circulation regime is a symmetric and stationary equilibrium $(\mathbf{m}, \lambda, \mathbf{V})$ that satisfies conditions (3)-(8). We focus on equilibria where **sellers from the *Blue* economy *always reject* the *Red* currency**, $\lambda_{bb} = \lambda_{br} = 0$. Since *Red* is a *national currency* that only circulates domestically, $m_{rr} = M_r$ and $m_{br} = 0$. Table 2 summarizes the currency regimes we discuss in this paper, which differ in the extent to which *Red* sellers accept the *Blue* currency.

Table 2: Currency Regimes

Regime	Circulation pattern of *Blue* currency
N	National currency
I	International currency
C	Conditional acceptance currency

For each candidate equilibrium, we solve equations (3)-(7) and verify if it is incentive-compatible according to condition (8). In every case, we assume **policy instruments are only available to the Red government**. Furthermore, we assume that the *Red* economy has a smaller population than the *Blue* country (n is low). Then, from the perspective of the *Red* economy, three circulation regimes for the foreign currency

may emerge: (1) a national currency regime (N) where domestic agents always reject the foreign currency, (2) an international currency regime (I) where domestic agents always accept the foreign currency, and (3) a conditional acceptance currency regime (C) where the foreign currency is accepted in international transactions but rejected in domestic transactions. In steady state, both regimes I and C exhibit the same degree of currency dollarization, since the same measure of foreign tokens are in permanent circulation within the local economy. However, the foreign currency remains more valuable in regime I, while regime C is intended to represent a small open economy with a healthy domestic currency but persistent dollarization.

In Figure 1, we provide the typology of equilibria under each treatment in our design, as well as the parameterization used in the experiment.

3.3.1 Regime N: *Blue* currency is *national*

In this regime, *Red* sellers **always reject** the *Blue* currency, $\lambda_{rr} = \lambda_{rb} = 0$, which in turn implies $m_{bb} = M_b$ and $m_{rb} = 0$. The flow values of agents from economy i collapse to

$$\begin{aligned}
\delta V_{i0} &= \alpha_{ii} M_i (V_{ii} - V_{i0}), \\
\delta V_{ii} &= \alpha_{ii}(1 - M_i)(u + V_{i0} - V_{ii}) - \mathbf{1}_{\{i=r\}} \left[1 - \alpha_{ii}(1 - M_i)\right] c_i^i, \\
\delta V_{ij} &= \alpha_{ij}(1 - M_j)(u + V_{i0} - V_{ij}) - \mathbf{1}_{\{i=r\}} \left[1 - \alpha_{ij}(1 - M_j)\right] c_i^j.
\end{aligned}$$

For both economies, we verify whether the incentive compatibility constraints in (8) are satisfied. In the *Red* economy, taxing sellers τ_r^0 reduces the trade surplus they obtain when accepting foreign currency from domestic buyers, relative to the case where transactions involve a foreign counterpart. Therefore, if *Red* sellers reject the *Blue* money from *Blue* buyers, they will also reject it when offered by *Red* citizens. As a result, it is sufficient to show $V_{ij} \leq V_{i0}$, which occurs if:

$$\begin{aligned}
&\left[\alpha_{ii}^2 M_i (1 - M_i) - (\delta + \alpha_{ii}) \alpha_{ij} (1 - M_j)\right] u \qquad (9) \\
&- \mathbf{1}_{\{i=r\}} \alpha_{ii} M_i \left[1 - \alpha_{ii}(1 - M_i)\right] c_i^i + \mathbf{1}_{\{i=r\}} (\delta + \alpha_{ii}) \left[1 - \alpha_{ij}(1 - M_j)\right] c_i^j > 0
\end{aligned}$$

Equation (9) gives the existence conditions for Regime N in terms of the relative size of the *Red* economy, n, the degree of trade integration, ρ, and the storage costs on the *Red* and *Blue* currencies imposed by the *Red* government, c_r^r and c_r^b, respectively. Other

things being equal, decreasing the storage cost of the local currency relative to that of the foreign currency discourages the acceptance of foreign money, which translates into an increase in the set of pairs (n, ρ) that support this equilibrium.

3.3.2 Regime I: *Blue* currency is *international*

This equilibrium arises when *Red* sellers **always accept** the *Blue* currency, $\lambda_{rr} = \lambda_{rb} = 1$. Moreover, by solving equations (2) and (4), we find that the fraction of agents holding *Blue* money in the *Red* and *Blue* economy, respectively, are given by

$$m_{rb} = \frac{(1-n)(1-M_r)M_b}{1-nM_r},$$

$$m_{bb} = \frac{(1-n)M_b}{1-nM_r}.$$

For *Red* agents, flow values of simplify to

$$\delta V_{r0} = \alpha_{rr} M_r (V_{rr} - V_{r0}) + \alpha_{rr} m_{rb} (V_{rb} - \tau_r^0 - V_{r0}) + \alpha_{rb} m_{bb} (V_{rb} - V_{r0}),$$

$$\delta V_{rr} = \alpha_{rr} m_{r0} (u + V_{r0} - V_{rr}) - [\alpha_{rr}(M_r + m_{rb}) + \alpha_{rb}]\, c_r^r,$$

$$\delta V_{rb} = \alpha_{rr} m_{r0} (u + V_{r0} - \tau_r^b - V_{rb}) + \alpha_{rb} m_{b0} (u + V_{r0} - V_{rb}) - [\alpha_{rr}(M_r + m_{rb}) + \alpha_{rb} m_{bb}]\, c_r^b.$$

Conversely, for *Blue* citizens, the value functions may be written as

$$\delta V_{b0} = (\alpha_{bb} m_{bb} + \alpha_{br} m_{rb})(V_{bb} - V_{b0}),$$

$$\delta V_{bb} = (\alpha_{bb} m_{b0} + \alpha_{br} m_{r0})(u + V_{b0} - V_{bb}),$$

$$\delta V_{br} = \alpha_{br} m_{r0} (u + V_{b0} - V_{br}).$$

For the *Red* economy, we verify that sellers accept the *Blue* currency from domestic buyers, $V_{rb} - \tau_r^0 > V_{r0}$, hence ensuring they will also accept it from foreign citizens. Next, we show that *Red* sellers still accept the *Red* token, which implies $V_{rr} > V_{r0}$[5].

On the other hand, we verify that *Blue* sellers always reject the *Red* currency, which requires $V_{br} \leq V_{b0}$ and thus

$$\alpha_{br} m_{r0} (\delta + \alpha_{bb} m_{b0} + \alpha_{br} m_{r0}) \leq \alpha_{bb} m_{b0} (\alpha_{bb} m_{bb} + \alpha_{br} m_{rb}). \tag{10}$$

According to equation (10), it should be relatively easier for *Blue* buyers to meet *Blue* rather than *Red* sellers.

[5]We use Matlab to compute analytical solutions in the (n, ρ) locus. These expressions shape the circulation patterns presented in Figure 1 of Section 4.

3.3.3 Regime C: *Blue* currency is the *conditional acceptance currency*

This equilibrium emerges when *Red* agents reject the *Blue* token in domestic transactions, but accept it in international meetings, $\lambda_{rr} = 0$ and $\lambda_{rb} = 1$. The fraction of agents holding *Blue* currency in the *Red* and *Blue* economy, respectively, are given by

$$m_{rb} = \frac{(1-n)(1-M_r)M_b}{1-nM_r},$$

$$m_{bb} = \frac{(1-n)M_b}{1-nM_r}.$$

In the *Red* economy, value functions may be written as

$$\delta V_{r0} = \alpha_{rr} M_r (V_{rr} - V_{r0}) + \alpha_{rb} m_{bb} (V_{rb} - V_{r0}),$$

$$\delta V_{rr} = \alpha_{rr} m_{r0} (u + V_{r0} - V_{rr}) - [\alpha_{rr}(M_r + m_{rb}) + \alpha_{rb}]\, c_r^r,$$

$$\delta V_{rb} = \alpha_{rb} m_{b0} (u + V_{r0} - V_{rb}) - (\alpha_{rr} + \alpha_{rb} m_{bb}) c_r^b.$$

In the *Blue* economy, flow values coincide with those in *Regime I*. Therefore, equation (10) is an equilibrium condition for this regime as well. Next, we verify *Red* sellers reject the *Blue* token from local buyers, $V_{rb} - \tau_r^0 \leq V_{r0}$, but accept it from foreign citizens, $V_{rb} > V_{r0}$. That is, *Red* sellers are willing to hold foreign currency as long as no tax payment, τ_r^0, is incurred upon. As a consequence, this trading rule may only arise when $\tau_r^0 > 0$. Finally, we show *Red* agents always accept the local token, $V_{rr} > V_{r0}$[6].

3.4 Welfare

The steady state welfare of the *Red* economy, which is the main focus of our study, depends on the model's parameterization and the endogenous currency regime. In order to assess the welfare implications of each dedollarization policy, we use the same parameters as in our experimental design, extensively discussed in the next section. We assume the same money supply for both economies ($M_R = M_B = 0.5$), a mild degree of trade integration ($\rho = 0.35$), a relatively small size for the *Red* economy ($n = 8/28$), a utility flow equal to 10 ($u = 10$), and a discount rate equal to 0.01 ($\delta = 0.01$). We use different combinations of policy parameters to define our treatments.

Table 3 shows that steady state welfare of the red economy in each currency regime and treatment. We can see that the highest welfare is reached in the national currency regime in all treatments.

[6]We use Matlab to compute analytical solutions in the (n, ρ) locus. These expressions shape the circulation patterns presented in Figure 1 of Section 4.

Table 3: Steady state welfare for the *Red* economy across regimes and treatments

Treatment	Regime N	Regime I	Regime C
Baseline $(\tau_r^0 = \tau_r^b = 0, c_r^r = c_r^b = 0.25)$	177.9	170.5	-
Taxes on transactions in FC $(\tau_r^0 = \tau_r^b = 0.4, c_r^r = c_r^b = 0.25)$	177.9	166.9	124.3
Costly storage of FC $(\tau_r^0 = \tau_r^b = c_r^r = 0, c_r^b = 0.25)$	185.6	180.2	-

4 Experiment Design

The experimental environment closely follows the model described above, where citizens of two economies repeatedly interact with each other and citizens of the other economy. The Blue country is the larger economy, and the Red country represents a small open economy whose government implements policies to discourage the domestic use of foreign currency. Our study focuses on the small open economy, represented by the Red economy, and often refers to its currency as the "domestic" or "local" currency.

Since we study policies deployed in the Red economy and its outcomes, the experiment's human participants interact as citizens of this economy, and we automate the citizens of the Blue country. The size of the population in the Blue economy is twenty, and the size of the Red economy is eight. These groups of eight human participants are formed with random grouping at the beginning of the session and remain as a fixed group for the whole session.

In each period, individuals participate in the same exchange game described in the theoretical section. Each agent holds one of three objects: a consumer good, a blue token, or a red token. Then, each participant is randomly matched with another agent, and is informed about this other player's color and held object. Participants must decide whether they want to attempt to exchange objects with their partner. Trade attempts occur simultaneously and privately. Once both matched players submit their decisions, these are revealed and the exchange occurs only if there is a mutual willingness to trade objects. As in the model, bartering between sellers (good holders) is not allowed. The same is true for the exchange of tokens. The automated agents of the Blue economy always use a trading rule in which they only accept blue tokens in exchange for a consumption good and are always willing to trade when holding a token. This rule is public information.

In either country –Red or Blue– half of the agents receive their corresponding domestic currency as an initial endowment, and the remaining half receives a consumption

good. That is, using the model's notation: while $n_b > n_r$, we have $M_b = M_r = 0.5$. We calibrate the integration level so that the following holds. (a) For the red citizens, there is a higher probability of meeting with another domestic agent ($\alpha_{rr} = 0.75, \alpha_{rb} = 0.25$). (b) For blue automated citizens, it is almost certain they will meet with another blue agent ($\alpha_{bb} = 0.9, \alpha_{br} = 0.1$).

As explained above, we use a discount factor of $\beta = 0.99$ when calculating our theoretical equilibria. This discount factor is consistent with a random stopping rule with a continuation probability of 99 percent.

Moreover, each human participant starts the first period with an endowment, W, of 50 points, and the consumption utility service, u, is 10 points. The payoff for the session adds up the earnings of all periods plus the initial endowment.

There are two additional notes related to departures of the experimental environment from the theoretical model presented above. First, the experiment uses a finite horizon ($T < \infty$) while in the model, time is infinite. Similar to the case of Jiang and Zhang (2018), we should note that in our environment, there exists monetary equilibria even for the finite horizon.[7] Second, in the model, the population of both countries is modeled as a continuum (with uncountable citizens). In the experiment, we are restricted to work with a finite population in both countries. We chose the appropriate parameters so that the relevant probabilities are compatible with the discreteness of the population. Furthermore, we set population sizes to be at least as large as those in Jiang and Zhang (2018). They show through simulations that if the sizes of the economies are sufficiently large and parameters of the environment are properly chosen, the finite-population model shares relevant equilibria with the infinite population model.

4.1 Policy Treatments

Our experiment follows a between-group design, where each group of eight participants interacted under a single condition (policy treatment). We implemented the following two policy treatments along with the baseline condition.

Baseline Condition

Each group of eight human participants represents the Red economy. In each group, agents play approximately 100 rounds of the game described above, amongst

[7] Other experimental evidence on monetary economies with a finite number of periods also suggests that money emerges as a medium of exchange in most sequential games with multiple equilibria (Davis et al., 2019).

themselves and with 20 automated Blue bots. The rest of the parameters are: $\alpha_{rr} = 0.75$, $\alpha_{bb} = 0.90$, $W = 50$ points, $u = 10$ points. Storage costs of either token in the Red economy are equal to 0.25 points, $c_r^r = c_r^b = 0.25$. Taxes on transactions are null, $\tau_r^0 = \tau_r^b = 0$ points.

Treatment 1: Taxes on domestic transactions with foreign currency
In this treatment, we maintain the setting of the baseline condition but implement taxes to domestic transactions in foreign currency. The taxes are set to $\tau_r^0 = \tau_r^b = 0.40$ points.

Treatment 2: Local currency storage cost reduction
In this treatment, we maintain the setting of the baseline condition but implement asymmetric storage costs of: $c_r^r = 0$ and $c_r^b = 0.25$. Agents can freely store the local token but pay 0.25 points to carry over the foreign token for each additional round.

4.2 Hypotheses

In Figure 1, we present the classification of equilibria for all conditions. In particular, each panel depicts the regions of the fundamental parameters (relative size, n, and degree of integration, ρ) that support each of the three different equilibrium regimes we study: international currency regime (I); national currency regime (N); and conditional acceptance currency regime (C).[8]

Panel (a) shows this typology for the baseline condition; Panels (b) and (c) show the typology for treatments 1 and 2, respectively. This exercise illustrates the theoretical impact of the proposed de-dollarization policies. Taxes reduce the areas of parameter combinations that sustain regime I relative to the baseline condition and introduce a small region where regime C is also supported (the band in Panel (b) of Figure 1). [9] On the other hand, reducing the storage costs of the domestic currency expands the area of regime N relative to baseline. It causes a significant reduction of the scope of regime I, as expected. However, since storage costs are not conditional on who provided the Blue token, regime C does not emerge under this policy. These diagrams also show the

[8]See Appendix C for the impact of the tax level on the regions of fundamental parameters that support different circulation regimes.

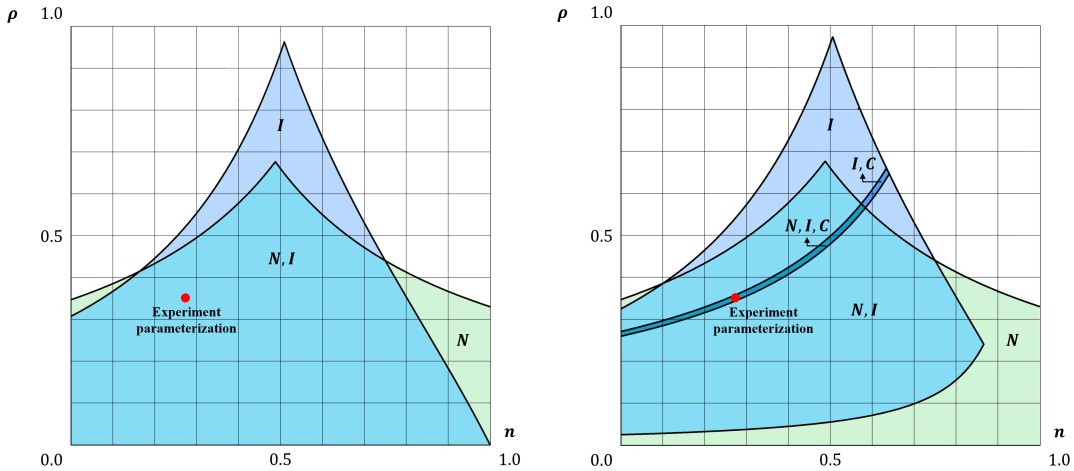
[9]Taxes reduce the value of accepting the foreign currency in local transactions, which are significantly more frequent than international, cross-border encounters. As a result, higher taxes shrink the area of regime I, where the foreign currency is a universal medium of exchange and is thus more valuable than the local currency. Furthermore, increasing the size of the taxes also enlarges the area of regime C, where local agents only accept the foreign currency in international transactions.

parameterization we implemented in all treatments of the experiments regarding the degree of trade integration and the relative size of the economies (red dot, $n = 8/28$ and $\rho = 0.35$). As mentioned earlier, this parameterization supports regimes I and N in all treatments. However, only under a non-zero tax policy (treatment 2) regime C emerges as a possible equilibrium.

The primary outcome we study is the acceptance rate of foreign currency. At the individual level, this outcome emerges from the binary decision to accept a foreign token in exchange for the consumption good. At the economy-period level, the metric is the percentage of citizens who take the foreign currency in exchange for a good. Given that the focus of this paper is transactional (de)dollarization, we distinguish -when relevant- the acceptance of foreign currency in international trade (matches between red and blue agents) from the acceptance of foreign currency in domestic transactions (matches between two red agents). Another metric associated with efficiency and welfare is the percentage of participants who decide to trade. We use the theoretical predictions of the model to form the following hypotheses about the experimental results.

> **Hypothesis I:** The introduction of taxes to domestic transactions in a foreign currency will reduce the acceptance rate of foreign currency. Relative to baseline, more red economies will move away from the international regime (dollarization) toward the national or conditional acceptance regimes.
>
> This hypothesis has two mechanisms at work: a direct effect on local meetings and an indirect (anticipated) effect on meetings with foreign agents. With taxes, red sellers want to reject the blue currency from other local buyers because the tax increases the immediate cost of holding blue tokens. Beyond this direct effect, agents might also consider the future expected value of receiving a foreign currency unit. If a red citizen accepts a blue token, it might be less likely to use that token in subsequent transactions unless everyone else operates as if they are in the international regime. Furthermore, since this environment considers a finite population, each decision to accept a blue token significantly increases the money supply of these coins in the red economy, decreasing red agents' lifetime expected utility. For these reasons, we expect the acceptance rate of the foreign currency will decrease, favoring the national or conditional acceptance regimes.

> **Hypothesis II**: The introduction of asymmetric storage costs, $c_r^b > c_r^r$, will reduce the acceptance rate of foreign currency, whether the partner is local or foreign. Relative to the baseline, the Red economy will move towards the national currency regime (blue token is not accepted in the Red economy).



(a) Baseline Condition

(b) Taxes on trade in foreign currency

(c) Local currency cost reduction

Figure 1: Typology of equilibria in all three conditions. These graphs represent the regions of fundamentals (relative size, n, and degree of integration, ρ) that support the three different equilibria we study: international circulation of the blue token (I); National circulation of the blue token (N); and conditional acceptance of Blue token (C). Panel (a) shows the typology for the baseline condition; Panels (b)-(c) show the typology for treatments 1 and 2, respectively. These diagrams also show the parameterization utilized in the experiment (red dot, $n = 8/28$ and $\rho = 0.35$).

Hypothesis III: In all conditions (baseline and treatments), the acceptance rate of local currency is 100%. Since there is always a higher probability of matching local citizens than foreign ones, accepting the domestic currency is always a dominant strategy.

Hypothesis IV: The acceptance ratio of the consumption good remains constant throughout the control and treatment sessions. This hypothesized behavior is a rationality test for experiment participants. Attempting to exchange when holding a token is a strictly dominant strategy for buyers. Hence the acceptance rate should be around 100%.

4.3 Procedures

The experiment software was mainly developed at the LEEPS Lab of the University of California Santa Cruz using the oTree framework (Chen et al., 2016), and deployed on Heroku servers.[10] Appendix A contains a screenshot of the interface.

We deployed online sessions using the subject pools maintained by the Experimental Economics Laboratory of the Pontifical Catholic University of Peru and E2LabUP from Universidad del Pacífico, both in Lima, Peru. We conducted a total of 21 sessions with eight participants each.[11] [12]

Each session was structured as follows. Each subject who had previously signed up for a session received an email with the session-specific URL and participant ID to enter the virtual room. Our software checked whether the subject was using a desktop computer and not a mobile device.[13]. Once the session started, participants read the instructions page.[14] Then, participants solved incentivized control questions. The experimenters answered any questions in private web-based chat or over the phone. Once we answered all questions, the interaction started.

Each round consisted of a screen showing participants their current state, their matched partner's state, and a table with the complete history of their transactions in all previous rounds. This table included the color of the counterpart in each period and their object (token or consumption good). After all interaction rounds, subjects

[10]The code source is in this public repository `https://github.com/elip12/dedollarization`, or upon request from the authors.

[11]Both laboratories administer their subject pools using an ORSEE server Greiner (2015).

[12]We do not find a significant difference between locations (subjects from Pontifical Catholic University of Peru and Universidad del Pacífico)

[13]The interface was not optimized for mobile devices

[14]Please see Appendix B for the English translation of the experiment instructions.

answered a brief survey where, among other things, we asked for their feedback and a description of their strategies. The duration of a session ranged from one hour to one and a half hours.

Participants received payments based on their performance equal to the value of their accumulated points over the 100 periods. The exchange rate in the experiment was one PEN (Peruvian currency) for every 50 experimental points (1 point = 0.02 PEN). The participation fee was 5.00 PEN.[15] We initiated the payment processing immediately after the session. We used direct bank deposits and three of the most popular mobile payment applications in Peru as our payment methods. Most subjects earned between 15 and 20 PEN – on average, 18 PEN.

5 Results

We divide the results section into three subsections: (1) a brief discussion of our experimental data and results in a descriptive manner; (2) a formal econometric analysis; and (3) a discussion of the dynamics and convergence patterns across treatments.

5.1 Descriptive Analysis

Our analysis focuses on the acceptance rate of currencies and consumption goods. We define the acceptance rate of currency i as the proportion of red sellers facing an i token holder who attempts to trade. For example, the denominator of the acceptance rate of the foreign currency is the number of encounters between red sellers and any buyer with a blue token, while the numerator is the number of those matches in which the seller attempted to trade. Furthermore, in the case of the foreign currency, following the insights from the model, we distinguish the acceptance rate in encounters with other domestic (red) agents from that in meetings with foreign (blue) agents. We also document the impact of policies on two relevant auxiliary outcomes: the proportion of encounters with successful trades; and the experiment payoffs as an empirical measure of agents' wellbeing.

Table 4 shows the descriptive results of the primary outcomes under the baseline and both treatment conditions. We first discuss the effects considering all periods, and,

[15] Peruvian currency is called the "Sol", and its IBAN international code is "PEN". At the moment of the experiment, the exchange rate between PEN and the US Dollar was approximately 3.8 PEN for 1 USD.

Table 4: Descriptive Statistics

	Baseline	Tax FC trans. (Treatment 1)	LC cost reduc. (Treatment 2)
All periods			
FC acceptance rates:			
FC All encounters	46,61	36,34	22,77
FC Encounters w/ locals	46,67	38,12	17,19
FC Encounters w/ foreign	46,57	35,06	25,36
LC acceptance rate	42,37	60,66	73,85
C. good acceptance rate	92,98	87,21	91,71
Trade success rate	35,09	40,03	49,14
Average Payoffs (points)	131,11	153,31	182,35
$Period > 50$			
FC acceptance rates:			
FC All encounters	43,50	34,26	18,52
FC Encounters w/ locals	36,27	36,84	14,93
FC Encounters w/ foreign	51,02	32,23	20,13
LC acceptance rate	37,84	61,04	77,25
C. good acceptance rate	93,28	86,73	92,97
Trade success rate	30,99	41,06	51,56
Average Payoffs (points)	131,11	153,63	182,80

Notes: This table reports the acceptance rate of the foreign currency (FC) and local currency (LC). In the case of FC acceptance, we also report the rates distinguishing the origin of the buyer (local or foreign). We also report the acceptance rate of the consumption good, the success rate of encounters where a trade was possible, and the payoffs in points.

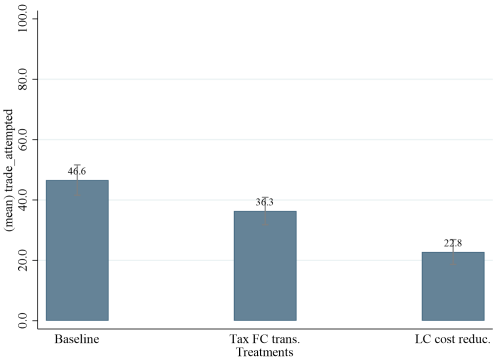
when relevant, we add comments regarding the results focusing only on the second half of the experiment. The following subsection reports our formal statistical and econometric tests.

In the baseline condition, the acceptance rate of foreign currency (FC) is around 47% regardless of the type of encounter (with a local or a foreign agent). It is interesting to note that the acceptance rate of the local currency, which in theory should be 100%, is also low: 42%. The only outcome closer to its theoretical value is the consumption-good acceptance rate, 92.98% in our experimental data. Finally, the trade success rate reaches 35.09%.

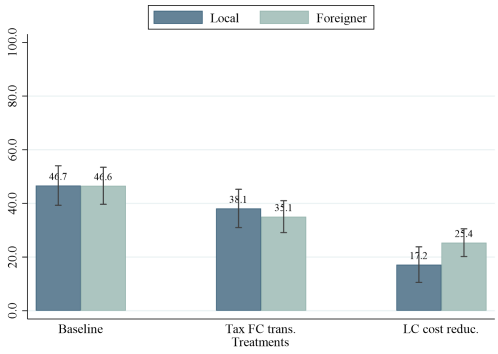
The table also reports changes associated with policy treatments. We observe that the primary outcomes vary in the same direction under both policies. Most notably, the acceptance rate of foreign currency decreases in encounters with either local or foreign agents. It is worth noting that the magnitude of these changes is significantly higher under the storage costs treatment. Indeed, when considering encounters with both local and foreign buyers, the acceptance rate of the foreign currency lowers to 22.77% under said policy, while the tax treatment just decreases it to 36.84%. Moreover, the influence of the type of buyer differs between both interventions, with local buyers experiencing a sharper decrease in the acceptance rate under the storage cost treatment (reaching 17.19%) and foreign agents facing a slightly lower acceptance rate under the tax treatment (reaching 36.84%). Figure 2 summarizes these findings as well. The top two panels depict the acceptance rates of the foreign currency, and the bottom panels show the acceptance rate of local currency and the consumption good, respectively. These plots also report the confidence interval of the mean estimate and display a pattern consistent with the results reported in the regression analysis of the next subsection (Tables 5 and 6). These results are indicative that both policy treatments might reduce transactional dollarization and induce domestic agents to settle domestic transactions in local currency.

The trade success rate is higher under both treatments than in the baseline condition, arguably due to the significant increase in the local currency acceptance rate that both policies seem to trigger. As a result of these changes in the number of successful trades, the average pay-off increases significantly relative to the baseline scenario.

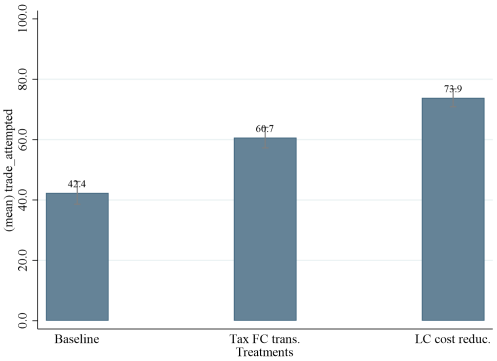
We also compute these statistics using the last 50 periods to assess any descriptive evidence of learning. We find evidence that behavior is slightly different in the second half of the experiment in the baseline condition. On average, the acceptance rate of the foreign currency is mildly lower in the last 50 periods compared to the sample with all periods. This change seems to be driven by a substantial reduction in the foreign cur-



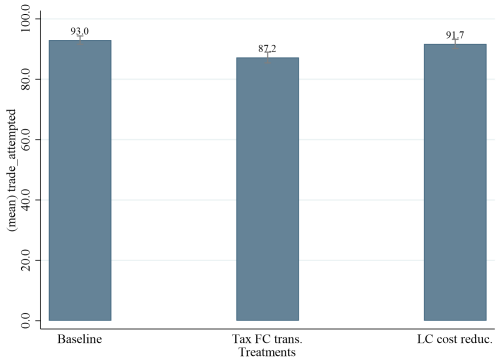
(a) FC acceptance rates



(b) FC by origin acceptance rates



(c) LC acceptance rates



(d) Consumption good acceptance rates

Figure 2: Principal outcomes acceptance rate (percentage). Whiskers on each bar depict the 95% confidence interval for the mean acceptance rate calculated using a normal distribution assumption.

rency acceptance rate in encounters with local agents. In contrast, the acceptance rate of the consumption good and the average pay-offs do not vary substantially. However, the trade success rate decreases from 35.09% to 30.99% when we compare all periods with the restricted sample. It is important to note this is an exploratory exercise as we provide a detailed discussion of the dynamics within the session in the last subsection.

5.2 Econometric Analysis

In this subsection, we focus on the formal econometric analysis of the impact of policies on our primary outcome variables: the acceptance of each currency and the consumption good. At the individual level, these outcomes are binary. For that reason, we estimate the effect of the policies using a Probit model.

We allow for the possibility of learning by including the number of the period as a regressor. We also have interactions between the treatment dummy variables and the period variable to account for possible heterogeneity in the learning pattern across conditions. As in the descriptive analysis, we used the whole sample with all periods and restricted the analysis to the last 50 periods. In the Probit model for the FC acceptance, we also conduct separate analyses for the samples of matches with locals and foreign agents. In all regressions, we clustered the standard errors at the group (economy) level. Formally, our specification is as in Equation 3.

$$Pr(Y_i = 1|X) = \Phi(\beta_1 T_{1i} + \beta_2 T_{2i} + \beta_3 Period_i + \beta_4 T_{1i} * Period_i + \beta_5 T_{2i} * Period_i + \epsilon_{i,g}) \quad (3)$$

where Y_i is an outcome variable (foreign currency acceptance, local currency acceptance, and the acceptance of the consumption good), Φ represents the Normal multivariate cumulative probability distribution. T_1 is the dummy for treatment 1 (tax levied on foreign currency transactions) and T_2 is the dummy for treatment 2 (local currency storage cost reduction). We estimate this at an individual Red citizen level, indexed by the i subscript. g indexes a group or economy. The results of this exercise are shown in Tables 5 and 6. In these two tables, we have two panels with two sets of results. At the top, in Panel A, we report the estimated Probit coefficients and, below, their standard errors in parenthesis. Below, in Panel B, we report the incremental effects of the treatments relative to the baseline condition in probability units. We also report the marginal effect of one additional period.

Table 5: Regression analysis on foreign currency acceptance rate (probit and marginal effects)

	(1)	(2)	(3)	(4)	(5)	(6)
		All Periods			*Period* > 50	
FC	All encounters	Encounters w/ locals	Encounters w/ foreign	All encounters	Encounters w/ locals	Encounters w/ foreign
Panel A: Probit estimation						
Tax FC trans.	-0.424	-0.819***	-0.172	-1.238	-0.570	-1.905*
	(0.283)	(0.176)	(0.385)	(0.914)	(1.372)	(1.107)
LC cost reduc.	-0.663***	-1.499***	-0.239	-3.156***	-3.925***	-3.048***
	(0.247)	(0.305)	(0.351)	(0.840)	(1.106)	(1.021)
Period	-0.00457	-0.0125***	0.00110	-0.0204**	-0.0176*	-0.0223*
	(0.00325)	(0.00174)	(0.00506)	(0.00893)	(0.0101)	(0.0114)
Tax FC trans.*Period	0.00305	0.0107***	-0.00255	0.0129	0.00713	0.0186
	(0.00398)	(0.00346)	(0.00581)	(0.0111)	(0.0168)	(0.0145)
LC cost reduc.*Period	-2.62e-05	0.0114	-0.00667	0.0316***	0.0423***	0.0285**
	(0.00537)	(0.00968)	(0.00581)	(0.0115)	(0.0129)	(0.0138)
Constant	0.152	0.607***	-0.140	1.400**	0.997	1.727**
	(0.234)	(0.130)	(0.329)	(0.684)	(0.785)	(0.870)
Panel B: Probit Marginal Effects						
Tax FC trans.	-0.104	-0.0974	-0.116*	-0.0978	-0.0156	-0.180**
	(0.0729)	(0.0925)	(0.0689)	(0.0834)	(0.121)	(0.0713)
LC cost reduc.	-0.237***	-0.306***	-0.209***	-0.254***	-0.222*	-0.302***
	(0.0647)	(0.0899)	(0.0618)	(0.0860)	(0.134)	(0.0699)
Period	-0.00123**	-0.00205***	-0.000726	-0.00238	-0.00250	-0.00196
	(0.000616)	(0.000768)	(0.000727)	(0.00152)	(0.00243)	(0.00173)
Observations	1,220	489	731	632	264	368

Group clustered standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Result 1

The introduction of taxes in domestic transactions with foreign currency does not change the acceptance rate of the foreign currency when considering both types of encounters. However, it does reduce the acceptance rate of the foreign currency in meetings with foreign agents.

As seen in Table 5, Panel B, this result holds for the whole sample, where the reduction is around 11%, and for the second half of the session, where the reduction in acceptance rate is around 18%. We interpret this result as partially consistent with Hypothesis 1. This hypothesis states that the tax will favor the national circulation regime N or C. However, we do not find evidence in favor of regime C. Participants do not reject FC in encounters with domestic agents more often than in encounters with foreign ones due to Treatment 1. We argue our results confirm the proposed mechanism in our first hypothesis. Domestic agents anticipate the difficulties of using the foreign currency in subsequent transactions, particularly among domestic agents. Considering they will have to hold a unit of foreign currency for more periods, they internalize the loss in expected lifetime utility arising from existing storage costs. Thus, the acceptance rate of foreign currency decreases even if we consider only the last 50 periods (see Table 5).[16]

Result 2

The policies to reduce the storage costs of the local currency lowers the acceptance rate of foreign currency, whether the match is local or foreign and whether we consider the whole sample or the second half.

As reported in Table 5, Panel B, this result holds for all any kind of encounter (local, foreign, or combined) and both samples (all periods and last 50). The size of the effect is rather consistent in the range of 20% to 30%. When considering all encounters, the effect is -23.7%, for the whole sample, and -25.5%, for the second half of the sessions. Again, these results favor the national currency regime (N) and therefore are consistent with Hypothesis II.

[16]We test whether there is a statistical difference in the impact on FC acceptance rate between encounters with local versus foreign agents. For this purpose, we estimate a similar probabilistic regression model as in column 1 of Table 5, except that we also include interactions between treatments and the origin of the buyer. We find that treatment 2 (local currency storage cost reduction) is the only treatment where the impact on acceptance is different. Specifically, the impact of treatment 2 for encounters with local agents is more negative.

Table 6: Regression analysis on local currency and consumption good acceptance rates (probit and marginal effects)

	(1)	(2)	(3)	(4)
	All Periods		*Period* > 50	
Variables	LC	Consumption good	LC	Consumption good
	Panel A: Probit estimation			
Tax FC trans.	0.219	-0.231**	-0.0870	-0.0446
	(0.206)	(0.110)	(0.840)	(0.410)
LC cost reduc.	0.269	-0.0726	-0.0346	1.156*
	(0.192)	(0.199)	(0.961)	(0.673)
Period	-0.00551	0.00266**	-0.0113	0.00343
	(0.00408)	(0.00132)	(0.00838)	(0.00335)
Tax FC trans.*Period	0.00523	-0.00219	0.00907	-0.00451
	(0.00522)	(0.00234)	(0.0105)	(0.00575)
LC cost reduc.*Period	0.0118**	-0.000318	0.0146	-0.0155*
	(0.00538)	(0.00291)	(0.0122)	(0.00876)
Constant	0.0647	1.345***	0.538	1.239***
	(0.127)	(0.0913)	(0.710)	(0.282)
	Panel B: Probit Marginal Effects			
Tax FC trans.	0.186*	-0.0575***	0.232	-0.0653**
	(0.107)	(0.0221)	(0.150)	(0.0303)
LC cost reduc.	0.316***	-0.0125	0.394***	-0.00397
	(0.0981)	(0.0176)	(0.137)	(0.0170)
Period	9.16e-05	0.000268	-0.00106	-0.000461
	(0.000700)	(0.000199)	(0.00156)	(0.000534)
Observations	2,310	3,981	1,103	1,943

Clustered group standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Result 3

Unlike what is predicted by the theoretical model, the acceptance rate of the local currency is significantly lower than 100%. Furthermore, this acceptance rate is substantially affected by reducing the storage cost of the local currency. Relative to the baseline, treatment 2 increases the LC acceptance by 31.6% (if we consider all periods) and by 39.4% (if we consider periods above 50; see Table 6). The impact of treatment 1 is smaller, 18%, and only significant at the 10% level. When considering the last 50 periods, this impact becomes statistically insignificant.

These results are inconsistent with Hypothesis 3 but constitute an essential and robust departure from our theory. First, as discussed in the previous section, all equilibria we study predict the complete acceptance rate of the local currency. However, the empirical acceptance rate of LC is under 50% in any sample of analysis. Interestingly, the cost reduction treatment has a substantial positive impact compared to the baseline. This pattern of results suggests a mild degree of currency substitution in the Baseline condition, where the foreign currency serves as a widely accepted medium of exchange in both domestic and foreign encounters –notice that the acceptance rate of the FC is higher than for LC (Calvo and Vegh, 1992; Hippolyte Balima, 2017; Jiang and Zhang, 2018). The usage of local currency is partly limited due to its lack of acceptance among foreign sellers and the presence of homogeneous storage costs. Put differently, while both currencies are equally costly to hold, the foreign one offers more trading opportunities and is thus preferred even by domestic agents. However, the introduction of taxes in domestic transactions in foreign currency or asymmetric storage costs breaks this mild substitution and increases the acceptance rate of local currency, in contrast with the proposal of Jiang and Zhang (2018). Between the two policies, the reduction of the storage cost of a local currency shows a greater impact than the introduction of taxes to the domestic transaction in FC.

Result 4

The acceptance ratio of the consumption good is below 100%. We reject Hypothesis 4. However, this rate remains around 90% for baseline and both treatments. Relative to the baseline condition, treatment 1 (tax) hurts the probability of accepting the consumption good. Treatment 2 does not have a statistically significant impact.

This result is another departure from the theory since the model predicts that participants will always accept the consumption good. In a sense, this is a rationality test, and we observe that in some conditions, participants miss more than one in 10

utility-gaining opportunities. The model does not explain why the tax treatment has an impact on this outcome either.

Robustness

We implemented a formal (more conservative) test of all hypotheses using a one-sided Wilcoxon Mann-Whitney, non-parametric test. This test used the mean acceptance rates for each independent economy. We obtain the seven independent values for each treatment and run the Mann-Whitney test between each pair of conditions using the corresponding 14 values.

In Table 7, we report the p-values of all these tests. As before, we study two samples: all periods and the last 50 periods. The results are nearly perfectly consistent with the regression analysis. The baseline exhibits a higher foreign currency acceptance rate than treatment 2 (the local currency cost reduction). Also, the local currency has a higher acceptance rate in treatment two than in the baseline. Finally, there is a lower acceptance rate of the consumption-good in treatment one compared to the baseline condition.

Table 7: Wilcoxon Mann-Whitney tests

	Baseline vs. Tax FC trans.	Baseline vs. LC Cost reduc.	Tax FC trans. vs. LC Cost reduc.
All periods			
FC All Encounters	0,180	0,018 (B)	0,225
FC Encounters w/ Locals	0,565	0,025 (B)	0,025 (LCr)
FC Encounters w/ Foreign	0,110	0,035 (B)	0,277
Local Currency	0,277	0,025 (LCr)	0,338
Consumption good	0,064 (B)	0,655	0,225
$Period > 50$			
FC All Encounters	0,277	0,025 (B)	0,055 (LCr)
FC Encounters w/ Locals	0,949	0,031 (B)	0,043 (LCr)
FC Encounters w/ Foreign	0,035 (B)	0,025 (B)	0,125
Local Currency	0,180	0,018 (LCr)	0,225
Consumption good	0,110	0,848	0,142

Note: This table reports the p-values. The characters inside the parentheses denote the condition with the higher statistic: (B) represents Baseline, (T) Tax FC trans. and (LCr) LC Cost reduc.

5.3 Dynamics

Our model assumes all studied equilibria are stationary. Agents are entirely rational and forward-looking, and equilibrium outcomes converge to stable equilibria in our model. In the experiment, however, we departed from the infinite population and time horizon assumptions. It is crucial to examine the economies' dynamics more carefully and measure how they converge in this context. Prior experimental work has discussed this finiteness and convergence matters before. See, for example, Duffy and Puzzello (2014); Jiang and Zhang (2018); Davis et al. (2019).

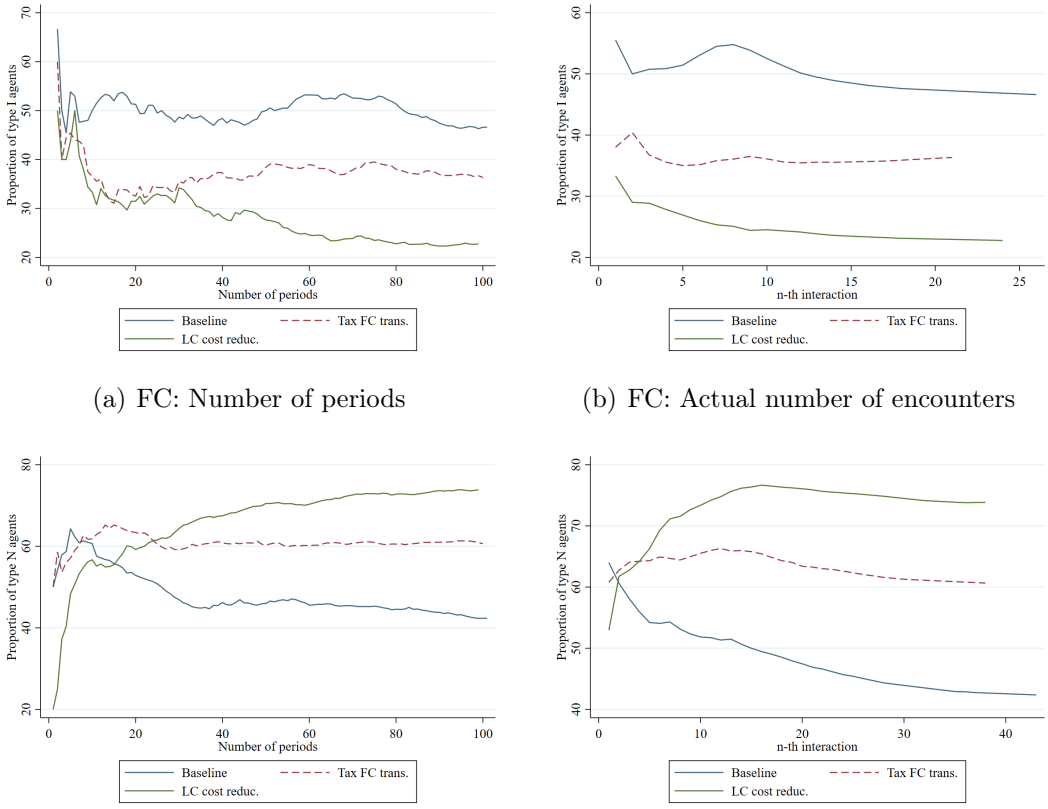
In this subsection, we study the dynamics of the acceptance rate of FC and LC. We document the evolution of the acceptance rate in two different ways. The first is the standard measure of acceptance per period, while the second is a new, alternative measure. In this new measure, the numerator is the number of agents willing to accept a foreign currency at their n-th encounter with a foreign currency. The denominator is the number of possible matches at that n-th interaction with a foreign token. This variable reduces the acceptance rate volatility. For instance, an agent might have ten meetings with FC holders at the first 25 periods, while another might have only two meetings, which would account for less experience in those encounters.

Figure 3 summarizes the evolution of the average foreign currency acceptance rate through all the periods for all treatments. In panel (a), we observe the foreign currency acceptance rate using the standard measure, while panel (b) shows the acceptance rate using the alternative measure. At the beginning of the experiment, acceptance rates were high, above 60% and 50% for the baseline under the standard and alternative measures respectively; likewise, acceptance rates under the local currency cost reduction treatment and the foreign currency tax treatment were around 50% and 60% respectively when using the standard measure, while their counterparts using the alternative measure were around 35% and 40%.

Panel (a) shows that acceptance rates reach their stability around the 20th period for each treatment (tenth for actual encounters, in panel b). They converge to approximately 50% for the baseline, 40% for the tax foreign currency transaction treatment, and 23% for the local currency cost reduction treatment. These figures are 45%, 38%, and 22% for the measurement considering actual encounters, respectively (see panel b). Hence, we can infer that the policies' implementation might be one factor in reducing the initial higher acceptance rates, despite the initial volatility related to the learning effect of participants.

We extend this analysis for the local currency acceptance rates. See panels (c) and (d). We observe that the acceptance rates increase progressively for the local currency

until they converge to 40% in the baseline, 60% in the tax foreign currency transaction treatment, and 75% in the local currency cost reduction treatment. Panel (d) also shows a progressively higher acceptance rate when considering the number of actual interactions. While these results show a learning process in the first ten or 20 periods, the experiment stabilizes in most conditions.



(a) FC: Number of periods

(b) FC: Actual number of encounters

(c) LC: Number of periods

(d) LC: Actual number of encounters

Figure 3: Local and Foreign Currency Acceptance rate dynamics

6 Discussion and Conclusion

We extend the model in Matsuyama et al. (1993) to study the effectiveness of policy instruments intended to discourage transactional dollarization. This study generates relevant insights for policy-making in contexts of partial currency substitution, relatively common in emerging markets. Interestingly, currency dollarization has not been as widely documented as financial dollarization (Yeyati and Ize, 2005; Armas, 2016).

To our knowledge, our study is the first one studying policies to reduce dollarization using the experimental approach.

We focus on two policies: (1) taxes on transactions in foreign currency among domestic agents; and (2) reducing the costs of holding the domestic currency compared to foreign currency. We contribute to the theoretical literature by characterizing the equilibria with these policies. We also find and document a new circulation regime that distinguished the trading partner's origin. In this regime, domestic agents accept the foreign currency in international transactions (encounters with foreign agents) but reject it when meeting other local agents.

Our experimental evidence is partly in line with our theoretical predictions. Imposing taxes on domestic transactions settled in foreign currency and reducing the storage costs of local currency relative to foreign do impact the decisions to accept foreign currency. Reducing the storage costs of the local currency relative to the foreign currency deter the acceptance of foreign currency in all types of encounters (international and domestic). Taxes on domestic transactions with foreign currency diminish foreign token acceptance in international transactions, which is a departure from the model that we interpret as agents seeking to avoid shifting the foreign currency supply in the domestic economy. We interpret this result as evidence of the proposed taxation system's challenges to induce the conditional acceptance regime. Domestic agents might start rejecting all their transactions with foreigners to avoid paying future taxes or avoid losing potential matches with other domestic traders.

The most relevant yet surprising result is that both policies substantially increase the acceptance rate of the local currency. Although we initially conjectured the studied policies would diminish the adoption of the foreign currency, we found that the effect in favor of de-dollarization occurs through an increase in the acceptance of the domestic currency. This result is a first-order departure from the theoretical model, and we plan to study these patterns further in future research.

From the monetary policy standpoint, our findings highlight that measures that make the local currency slightly less costly to hold and use than the foreign currency can significantly de-dollarize transactions.

Future research should focus on more detailed studies regarding the sensitivity to the size of cost reductions or tax increases and the effectiveness of other available policies, as we must also consider how the government should enforce this policies (Camera et al., 2016; Li and Wright, 1998). The local currency cost reduction might be enforced as development in the payment systems. Regulatory offices and the banking system might apply and be able to enforce this policy, while the Finance Ministry should apply the

taxes policies in coordination with financial system. These answers will be helpful in several ongoing debates. In particular, in guiding the efforts of Eastern European and Latin American countries to reduce the circulation of foreign currencies like the US dollar or the Euro and to strengthen the circulation of their local money.

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Appendix

A Experiment Interface

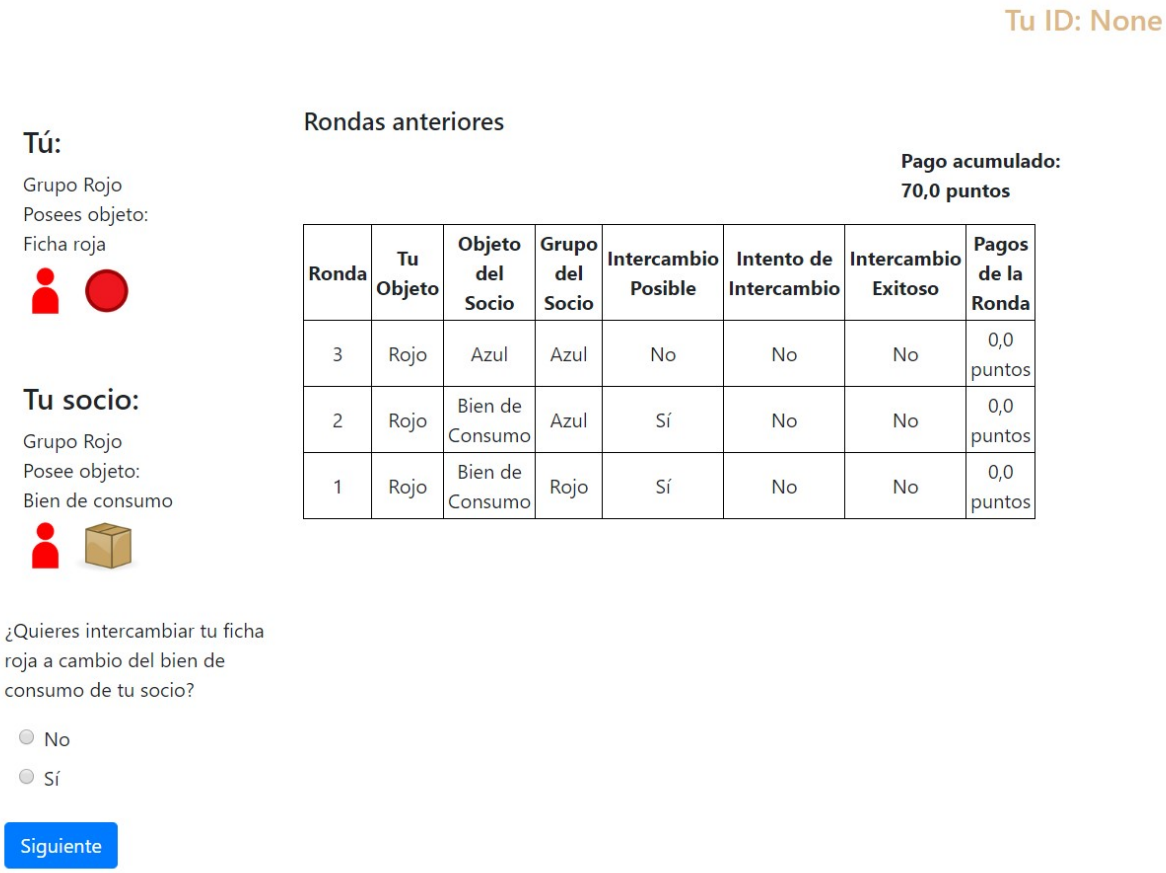


Figure 4: Experiment screenshot

B Instructions for Participants

(Translated from Spanish)

Read these instructions carefully: your decisions and those of the other participants in the experiment will determine your payment. Said payment will be proportional to the points that you accumulate throughout the experiment. Upon completion, the accumulated points will be converted into soles (S /) at the conversion rate of 1 point = S / 0.02. Additionally, you will be paid S / 5.00 just for participating.

Rounds and Groups The center block of this session consists of 100 rounds of the same type of interaction. At the start of the first round, groups will be formed at random. Each group will have 8 people. The groups are fixed; in other words, you will stay in the same group throughout the session. Your group will be called the red group. The people in your group interact with each other and with agents from the blue group, the latter of which are controlled by the computer (they are bots). There are 20 agents in the blue group.

Initial endowments Each participant in your group begins the first round with an endowment of 50 points and with one of two objects: a red token or a consumer good. Half of the members of the Red group receive a red token while the other half receives a consumer good. Who receives what is determined at random. The situation is analogous for the blue group, in which 10 agents randomly receive a blue token and 10 randomly receive a consumer good. The quantity of each object remains fixed throughout all rounds.

Random couples in each round At the beginning of each round, each member of the red group is randomly paired with someone from their group or from the blue group. The probability of matching with someone in the red group is 75%, while the probability of matching with someone in the blue group is 25%.

Exchange Decision In each round, the participant is informed of the object he owns and of his partner's group and object. Some meetings have the possibility of exchange and others do not. Exchange is possible only if one agent has a token and the other has a consumer good. On the contrary, if both have either consumer goods or tokens, they cannot exchange them (there is no barter).

When exchange is possible, both agents must decide whether they want to follow through/trade or not. Exchange only takes place if both agree. Agents in the blue group are programmed to always be willing to trade but also to never accept red tokens. The object with which you finish a round is the same with which you start the next.

Payments All participants start with 50 points. In each round, receiving a token

earns 0 points, regardless of whether it is red or blue. In contrast, receiving a consumer good from another participant earns you 10 points upon receipt. That is, the consumer good increases points only if it is obtained as a result of an exchange, regardless of which group it comes from. If you keep the same consumer good for more than one period, you do not receive additional points. If you keep a token for more than one period, you will pay a storage cost. If you keep a *Red* token, you'll pay 0.25 points. If you keep a *Blue* token, you will pay 0.25 points.

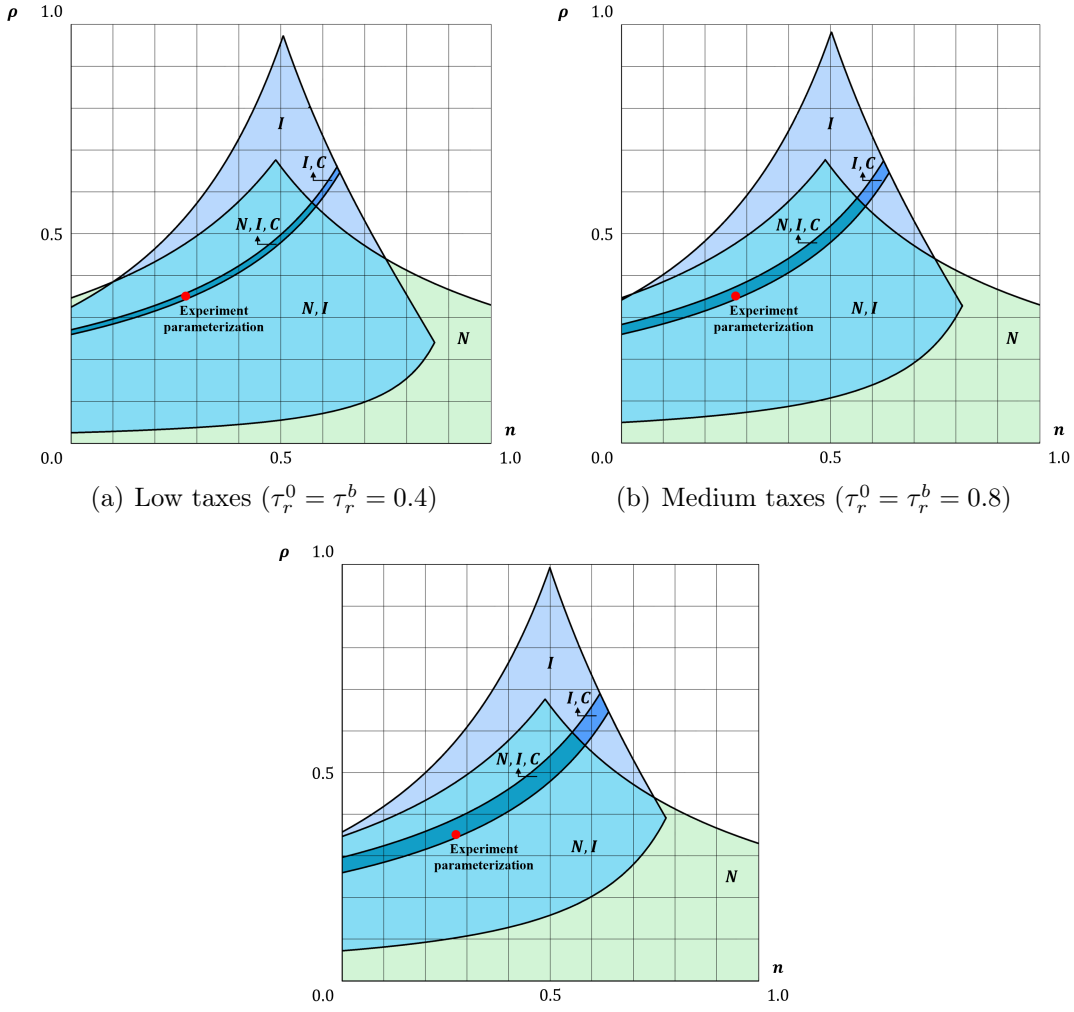
For the Tax FC transaction treatment: Usage of blue tokens by members of the red group is taxed. If you receive a blue token from another participant in the red group, you will pay a tax of 0.4 points. Similarly, if you exchange a blue token for a consumer good with another participant in the red group, you will pay a tax of 0.4 points.

For the Local cost reduction treatment: If you keep a token for more than one period, you will pay a storage cost. If you keep a *Red* token, you'll pay 0 points. If you keep a *Blue* token, you will pay 0.25 points.

During all rounds of interaction, your screen will display information referring to the previous rounds.

The payment of the session is the accumulated points of the 100 rounds of interaction.

C The theoretical impact of different taxes leves for domestic transaction in FC



(a) Low taxes ($\tau_r^0 = \tau_r^b = 0.4$)

(b) Medium taxes ($\tau_r^0 = \tau_r^b = 0.8$)

(c) High taxes ($\tau_r^0 = \tau_r^b = 1.2$)

Figure 5: Typology of equilibria across taxes size. The rest of the parameters follow from Treatment 1 (Section 4.1).