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Complementary Currencies and Liquidity: The Case of Coca-Base Money*

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Abstract

In coca-growing villages of Colombia, where pesos are scarce, coca-base is not only used as the main input for cocaine production—it also acts as a complementary currency (CC), circulating locally as a medium of exchange for day-to-day transactions. This paper provides a clear rationale for the economically-motivated adoption of a CC in a small open economy underprovided with official currency. An equilibrium currency shortage arises endogenously in our model, whereby shocks to the local supply of currency have a real impact on local trade and welfare. We show how a CC can mitigate the underprovision of liquidity and derive general insights relating the CC's characteristics to its ability to supplement the official currency. In an application, we quantify the unintended consequences of various anti-narcotic policies pursued by the Colombian government on liquidity provision in coca-growing villages and identify the least-harmful policy tools given the policy objectives at stake.

JEL codes: E40; E41; E51; O23

Keywords: complementary currency; local currency; money supply; commodity money; money shortage; liquidity; anti-narcotic policies

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1 Introduction

In coca-growing villages of Colombia, where coca-base serves as the primary input for cocaine production, it is also sometimes used as a medium of exchange in daily transactions. For instance, in describing this practice, the photo-journalist Villalón [2004] writes,

> The customer ahead of us had put a bag of cocaine base on the counter to pay his bill. I soon learned that merchants all over the region accepted base as payment for purchases, weighing out the right amount and handing back the remainder of the base in change.

More generally, the phenomenon has been extensively documented by journalists and academic researchers, showcasing its prevalence across numerous coca-growing regions in Colombia for decades.[1] Available evidence emphasizes that the use of coca-base as money becomes prominent when the local supply of pesos depletes, often leading locals to express their frustration over the shortage of official currency. For instance, Espinosa [2010, free translation, emphasis added] describes the situation as follows,

> Mrs. Cristal sells beef. [...] [A]s *the money in circulation is scarce*, the prices of beef, wages, supplies, food and many other items in the region are measured in coca[-base] grams.[...] People pay Mrs. Cristal in coca-base grams for beef, and she pays the original owner of the cow in the same manner.

Likewise, Turkewitz [2021, emphasis added] remarks that,

> The bad roads prevent them from getting other crops to market, residents said, and a *lack of cash* shuts them out of the mainstream economy. The town's store accepts cocaine base as payment, instead of coins and bills.

These two quotes further emphasize that when used as money, coca-base circulates extensively within local communities, changing hands numerous times during informal transactions among villagers as well as transactions conducted at local brick-and-mortar stores.

[1] The illegal character of cocaine production and trafficking, along with the fact that cocaine production takes place in remote areas of the country, makes it difficult to precisely quantify the use of coca-base money across coca-growing regions. However, in the last twenty years, the phenomenon has been reported by at least nine different journalistic and ethnographic sources in five Colombian departments: Caquetá [Villalón, 2004, Cárdenas, 2007], Guaviare [ElTiempo, 2007, Turkewitz, 2021], Meta [Espinosa, 2010, Cardona, 2021, Álvarez and Forero, 2023], Nariño [LeFigaro, 2007], and Vichada [McDermott, 2008], which together concentrated 67% of the total coca crops in 2004, 51% en 2014, and 33% in 2021. Appendix F.2 offers additional textual evidence about the use of coca-base as money. In quote 5, Álvarez and Forero [2023] refer to the phenomenon as "an undeniable reality" and "dynamics that have been used for years in these territories."

Several characteristics intuitively make coca-base a naturally suitable currency: (1) as a friable paste that can be readily weighed and exchanged by the gram, it offers easy divisibility; (2) given its local production, villagers possess expertise in visually and olfactorily discerning its quality, making it recognizable;[2] (3) it entails minimal storage costs and exhibits relatively good durability, maintaining its quality over an extended period; (4) due to its use as an input for cocaine production, it possesses commodity value. However, the commodity's illegal character restricts its use to transactions that are not subject to institutional scrutiny, preventing its widespread use outside coca-growing villages. In serving as a medium of exchange, in specific markets only, alongside the official currency, coca-base acts as a complementary currency (CC thereafter) [Amato and Fantacci, 2020].

Historically, the emergence of CCs has also often been attributed to the scarcity of official currency [Labrot, 1989, Cameron et al., 1993], e.g., during the Great Depression [Fisher, 1933, Blanc, 2000]. In recent years, there has been a proliferation of local CCs worldwide.[3] Although ethical and environmental considerations may underlie the modern development of some current CCs, economic necessity remains the main rationale [Peacock, 2014]. Indeed, many modern communities adopt a CC on account of a shortage of official currency, while others purport that such a currency shall stimulate the local economy. Be that as it may, the adoption of a CC seems to be motivated by the belief that its use will have a positive economic impact on the local community.[4]

From the standpoint of monetary theory, the notion of a currency shortage, as well as the related idea that a CC may positively impact the local economy, may appear obscure. If the official currency is divisible but not sufficient for trade in a local economy, we should expect its value to simply adjust to the market-clearing level. For the same reason, even if the local money supply is increased through a CC, we may expect prices to rise, eliminating any real effect on the local economy in accordance with the postulate of money neutrality.

The paper's first main contribution is to clarify this puzzle by providing a clear rationale for the economically-motivated adoption of a CC in a small open local economy, using coca-base as a case study. Doing so requires developing a model where (i) an equilibrium money shortage that has real effects on local outcomes can arise and (ii) the addition of a CC such as coca-base can mitigate some of these effects. Our second main contribution lies in leveraging our model of CC to explore the connection between the specific features of

[2]When doubts about the quality remain, they burn a small fraction. If the resulting oil is clean, then coca-base is considered to be of good quality. The coca-base holder loses the coca-base burned in the process.

[3]See, e.g., *Créditos* in Argentina, *Chiemgauer* in Germany, *BerkShares* in the United States, *La sol-violette* in France, and *Ora* in South Africa.

[4]Empirically, Colacelli and Blackburn [2009] find that *Créditos* adopters in Argentina enjoyed a non-negligeable income boost relative to non-adopters.

a CC—e.g., supply, holding costs, or commodity value—and its ability to supply liquidity. Note that the insights derived from these first two main contributions apply to a broader context. Indeed, they apply to small marketplaces that rely on liquidity for decentralized trade and are open to larger economies.[5] Our third and last main contribution is to offer a policy application of the model to highlight and quantify the unintended consequences of the anti-narcotic policies pursued in Colombia on liquidity and trade in coca-growing villages.

Our model is designed as follows. The local economy, which constitutes the theoretical analog to a remote coca-growing village, is modeled following the New Monetarist tradition [Lagos et al., 2017]. Importantly, recording and enforcement frictions make money essential for trade among villagers, making explicit the liquidity role played by money locally. As a result, money is priced endogenously to reflect the liquidity services it provides. Such micro-foundations are crucial if one hopes to explain the role that a CC can play when liquidity is dry.[6] More specifically, we build on the workhorse model of Lagos and Wright [2005], which we expand by linking the local economy to a larger economy. The latter represents the large urban centers where legal economic activity takes place. Local villagers get infrequent access to that market, where we assume that they can purchase goods at a fixed price in terms of the official currency. In other words, the demand from villagers has no impact on the price level in the large economy, effectively making the local economy a small open economy. We then show how, in this simple environment, the nominal supply of official currency can impact trade in the local economy in real terms.

Such an equilibrium regime occurs when the local supply of money is in an intermediate range. If it is too low, the value of money in local trade is too high for villagers to choose to use it in the larger economy, in which case the local economy operates in autarky as in a typical Lagos and Wright [2005] model. Money is only valued for its local liquidity services, and the supply of money is neutral. Indeed, although its rate of growth matters by driving the inflation rate, a one-time shock to money supply has no impact on local real outcomes, as it is entirely offset by a change in prices. At the other extreme, if the supply of money is high enough, local liquidity needs can be satiated and money is then only valued, at the margin, for its purchasing power in the large economy—which is impervious to changes in money supply. When money supply is in an intermediate range, it is both priced for the liquidity services it provides in the village and for the benefits resulting from its use in the larger economy. Since the latter are independent of money supply, the local value of money becomes less reactive to changes in money supply than it would be in a closed economy.

[5]For example, our analysis also rationalizes the benefit of tokens in peer-to-peer online marketplaces that otherwise rely on a government-issued currency.

[6]In contrast, more reduced-form approaches such as money in the utility function may be appropriate when considering CCs as desirable for social and environmental reasons.

Hence, the option for villagers to spend their currency at a fixed price, however infrequently, is sufficient to break money neutrality locally. In sum, opening the economy and giving money a fixed real value outside the village allows us to rationalize the concept of a money shortage, whereby a negative shock to the inflow of official currency into the local economy, or a positive shock to the outflow, can negatively impact local trade and local welfare.

Next, we show that upon its introduction to the local economy, coca-base acts as a complement to the official currency by providing liquidity services that enhance local trade.[7] In particular, we demonstrate that local trade is always larger with a positive supply of coca-base in addition to the official supply of currency, and strictly so when the local economy is originally in the shortage regime. Then, changes in the supply of coca-base impact local trade similarly to changes in the supply of official currency.

Having demonstrated the liquidity role played by a CC in a small open economy, we use the model to investigate how the specific characteristics of a CC impact its ability to provide extra liquidity services. CCs display notable heterogeneity regarding features such as their circulating quantity, issuance, holding costs and benefits, or redeemability [Blanc, 2011, Martignoni, 2012]. This heterogeneity in attributes is likely a contributing factor to the varying levels of success observed across different CCs in providing complementary liquidity services. We first show that total liquidity provision is determined by two main factors: the aggregate supply of the currency and the net marginal benefit derived by the currency holder. We then show how the specific attributes of the CC impact these two factors.

For example, consider the case of coca-base, which is subject to seizures from the government due to its illegal character. An increase in the rate of seizures not only decreases the net marginal benefit of holding the CC, everything else equal, due to the risk of loss, but it also decreases the local supply of coca-base. Both effects compound each other in harming local liquidity. We also remark that in the environment we study—that of a small open economy with a liquidity shortage, while a CC need not carry any commodity value to be valued in exchange alongside the original currency, it must carry at least some commodity value to effectively supplement liquidity and mitigate the shortage. Interestingly, however, we also show that more commodity value may not always be desirable to maximize local liquidity. On one hand, an increase in the commodity value increases the value of holding the currency, supporting liquidity provision. On the other hand, it may also increase the

[7] While we use the word "complement" here to stick to the language commonly used in the literature about CCs, note that we do not necessarily mean that official currency and coca-base are complementary in the typical economic meaning of complementary goods and services. In Section 3, we show that it is more precise to call coca-base a supplement of official currency. Fisher [1933] pioneered the description of CCs as a supplement to official currency. From now on, we will use "complement[ary]" and "supplement[ary]" interchangeably.

consumption of the currency, reducing its supply. Overall, the aggregate liquidity impact then depends on the magnitude of these two opposite effects.

After deriving general insights regarding CCs, we extend the model to more carefully examine two attributes specific to coca-base relative to other historically-documented CCs. A first distinctive characteristic of coca-base is that its commodity value can only be realized sporadically, through sales to intermediary dealers when they visit the region. As a result, coca-base plays a crucial role for local liquidity provision not only directly as a CC but also indirectly as a significant—if not the primary—source of official currency within the community. This magnifies the liquidity impact of shocks that result in a reduction in coca-base sales, such as government crackdowns on intermediaries. The second specific attribute we study is that coca-base is privately produced locally. We extend our model to endogenize production and better understand how the private production of a CC matters for its ability to provide liquidity and respond to shocks.

Finally, we use our micro-founded model for a topical policy application, where we evaluate the effects of anti-narcotic policies pursued in Colombia on liquidity and trade in coca-growing villages. While the adverse effects of these policies on farmers' income are widely recognized, their impact on the local economy due to liquidity effects has typically been overlooked. We calibrate the model using data from a specific coca-producing region of Colombia named Guaviare, matching targets such as the pesos value of coca-base in local trade, the pesos value of coca-base when it is sold to intermediaries, the aggregate quantity of coca-base seizures, GDP per capita, and the elasticity of coca production to coca-base seizures. We specifically focus on ranking the desirability of various policy instruments by quantitatively assessing the trade-off between a targeted policy goal, such as reducing coca-base sales or production, and the unintended adverse effects on local liquidity and trade. The three policy instruments we consider are coca-base seizures, coca-base production reduction through aerial spraying, and crackdowns on intermediary dealers.

We show that relatively small changes in policies lead to sizable effects on our outcomes of interest. For example, according to our calibrated model, a 10% increase in the seizure rate decreases the quantity of coca-base produced by 7.9% and the quantity of coca-base sold to intermediaries by 5.2%, but simultaneously harms liquidity in the village and reduces local trade by 8.5%. We can also make use of our model to quantify the importance of the different channels that underlie the aggregate provision of liquidity. We find that, in this example, a large part of the negative liquidity impact comes from the 8.1% decrease in the local supply of pesos that follows the increase in seizures. Keeping the local pesos supply fixed, the increase in seizures would only reduce local trade by 2.7%, i.e., only about a third of the true impact. Around half of this drop could then be attributed to the decrease in coca-base production.

We also show that regardless of whether the policy goal is to decrease the amount of coca-base sold to intermediaries or the amount of coca-base produced, increasing seizures is the least desirable policy instrument in view of its disproportionately negative impact on liquidity. Whether targeting intermediaries or coca-crops is more desirable, however, depends on the policy objective.

Literature review. There is a considerable body of literature on CCs that does not depend on formal models and delves into a wide array of monetary perspectives from within and beyond economics. Most of these works primarily rely on individual-level surveys focused on specific case studies to explore the motivations of users of CCs, analyze their functioning, and evaluate their overall impact.[8] A strand of this literature is focused on discussing the benefits CCs may bring to the communities who adopt them [Lietaer, 2012, Michel and Hudon, 2015, Fare and Ahmed, 2017, Blanc, 2018, Marshall and O'Neill, 2018, Gómez, 2022, Larue, 2022]. When examining the liquidity benefits, a question arises as to whether CCs substitute the liquidity provided by official currencies [Evans, 2009], maintaining overall liquidity constant, or whether they instead supplement it, thereby enhancing overall liquidity available to users [Blanc, 2017]. Recognizing the significance of this question, we assert that it can be properly examined through a micro-founded model of CCs where different types of money may circulate endogenously as a medium of exchange. Therefore, we offer a formal model that outlines the specific conditions under which a CC only substitutes liquidity, as well as the conditions under which a CC leads to an expansion of liquidity. Furthermore, we resort to our model to show how different features of a CC impact its ability to provide extra liquidity services.

Our research builds on several strands of research in monetary economics. Methodologically, the model we build follows the New Monetarist tradition [surveyed in Lagos et al., 2017]. More specifically, it expands on the workhorse model of Lagos and Wright [2005]. While we are not aware of research in monetary economics that explicitly models CCs, there exists both empirical and theoretical research on closely-related concepts. Colacelli and Blackburn [2009] propose an empirical investigation of Argentinian *Créditos*, which they refer to as a "secondary currency." First, they show that the data supports the predictions derived from a search model of money based on Kiyotaki and Wright [1993]: the acceptability of the secondary currency decreases with its transaction cost, the ease of finding trade partners, and the supply of the primary currency. Second, they estimate that the individual benefit from trading with the secondary currency is 15% of the average income. To our

[8]For a review of the main topics, methodologies, and results in this literature, see articles in the Special Issue of the International Journal of Community Currency Research edited by Blanc [2012], Michel and Hudon [2015], and Silva et al. [2023].

knowledge, this is the only paper that directly investigates the benefits of CCs and frames it in the context of a shortage of the primary currency. The theoretical model they use as a base for the empirical investigation, however, relies on the indivisibility of money to explain why changes in the money supply may have real effects and why an economy may be underprovided with money. While indivisibility may be a contributing factor, we propose the rationale of price rigidities in a small economy context as an alternative story that may be more compelling in a contemporary setting, where individuals do not rely as much on indivisible cash.

Craig and Waller [2000] provide an overview of the money search literature related to "dual-currency economies." Although they focus on explaining how a foreign currency can endogenously coexist with a domestic currency using search models of money, they mention in the introduction cases of dual-currency economies that fall under the umbrella of CCs (e.g., in the US during the Great Depression). More generally, there is a substantial sub-literature concerned with the coexistence of multiple currencies. Our paper shares similarities, in particular, with Curtis and Waller [2000], Lotz and Rocheteau [2002], and Lotz [2004], all of which feature the coexistence of a legal (domestic) and an illegal (foreign) currency. Specifically, these pieces focus on the decision to adopt new fiat money when the old money is declared illegal by the government. In our model, coca-base is also "illegal" and can be seized when held by local agents. In addition, its illegal character precludes its trade in the outside economy, which acts as an additional downside relative to the official currency. In line with the three papers mentioned above, our model helps understand the effects of government policies aimed to fight the use of a CC. However, in our application to coca-base, the government does not seek to fight against coca-base as a CC per se, but only because of its narcotic usage. Hence, we offer a quantitative exercise to evaluate the unintended consequences of anti-narcotic policies on liquidity and trade in villages that rely on coca-base as a CC. We then quantify the trade-off faced by the government between anti-narcotic objectives and liquidity provision objectives.

More importantly, the theoretical literature on dual-currency economies cited thus far primarily concentrates on the adoption of a new currency and the conditions for the coexistence of multiple currencies with different features. However, it falls short in formalizing the liquidity benefits that an economy can derive from the additional currency, in particular when there is a scarcity of the original currency. This is a key question of interest when it comes to the study of CCs and the guiding question of our paper.

Our approach to studying the liquidity benefits of a CC starts with establishing an equilibrium where the official currency is in shortage, in line with the reported experience of villagers in coca-growing villages and other localities having launched CC projects. In doing so, we relate to the literature on money shortages [Hardy and Lahiri, 1996, Wallace and Zhou, 1997, Cuadras-Morató, 2009, Rocheteau and Nosal, 2017]. We contribute by providing a novel model in which a small open economy experiences a shortage of money that arises neither from the stickiness of deposits' real interest rate nor from the indivisibility of currency, as is common in this literature. Instead, our model exploits that the village's internal market is significantly smaller than the outside market and assumes that prices are fixed in the latter—effectively considering the local economy a small open economy. As the value of money inside the village is impacted by the fixed value of money in the outside market, it will not adjust as perfectly as it would in autarky.

This formalization of the official currency having a fixed value in the large outside economy gives it some real value. For this reason, the mechanisms at work in our model share many similarities with those described in the New Monetarist literature that investigates the liquidity role of real assets, sometimes alongside currency [Geromichalos et al., 2007, Lagos and Rocheteau, 2008, Lagos, 2011, Jacquet and Tan, 2012, Lester et al., 2012, Li et al., 2012, Nosal and Rocheteau, 2013, Rocheteau and Wright, 2013, Geromichalos and Herrenbrueck, 2016, Rocheteau and Nosal, 2017]. In this literature, a change in the supply of real assets can impact liquidity provision and real outcomes. A key result of our model is that under some conditions, changes in the local supply of government-issued currency can have real effects—in which case the official currency behaves as a real asset. However, this is not always the case, as the official currency may also behave as fiat money, endogenously, depending on the circumstances. For example, when the supply of official currency is low enough, it is only valued for its liquidity services (not its real value), and marginal changes in supply have no impact on liquidity provision (even though liquidity needs). We assess the similarities and differences with the literature on the liquidity of real assets in more detail in Section 2.3.

In an extension of our model, we study the case where the CC can be privately produced. Other papers, such as Fernández-Villaverde and Sanches [2019], have focused on currency competition when currencies can be privately-produced. One of the questions they seek to answer is whether such competition leads to a socially optimum amount of money. Our focus instead is to show how endogenous production matters for the ability of a CC to respond to shocks to liquidity provision. In addition, in our model, the liquidity provision role of the CC is at odds with the government's desire to eradicate the CC's production and sales because of its illegal character as a commodity.

Relatedly, our paper also speaks to the literature that studies commodity money [Kiyotaki and Wright, 1989, Velde et al., 1999, Burdett et al., 2001, Bignon and Dutu, 2017]. This literature has mainly focused on two aspects. First, the conditions under which a commodity, rather than consumed, is used as a medium of exchange. Second, the effects of actions that reduce either money's commodity value or agents' ability to recognize it. By contrast, we focus on a money-shortage economy and study the role that the commodity value of coca-base plays in its ability to supplement liquidity as a CC. In particular, our model shows that while having a non-zero commodity value is not necessary for a CC to circulate in trade, it does require at least some positive commodity value for the CC to be able to mitigate the local underprovision of liquidity.

2 An equilibrium money shortage

In this section, we demonstrate how a small local economy open to infrequent trade with a larger economy, e.g., a remote village with sporadic access to a larger town, can experience a situation similar to the currency shortage described in coca-growing villages in Colombia. We describe the model environment in Section 2.1. In Section 2.2, we solve for the equilibrium and show that in that environment, at odds with the postulate of money neutrality, shocks that impact the local supply of money have real effects on local trade and consumption. We further discuss model mechanisms and implications in Section 2.3.

2.1 Environment

Time is discrete and continues forever. We consider a (small) local economy with a measure one of villagers. Every period is divided into three sequential stages. We describe the last stage first and proceed backward to describe the other two.

In the third and last stage, a fraction $\alpha \in (0, 1]$ of villagers can access the *outside market*, denoted OM. In that market, villagers are able to purchase the OM good, y^o, at a fixed unit price in terms of the government-issued currency. The price is taken as given by the small economy, which we assume has no impact on aggregate demand in the large outside economy. For simplicity, one unit of the OM good translates to one util.

The second stage comprises a *decentralized market*, which we refer to as DM. Trade in this market exclusively occurs through bilateral meetings. Villagers can produce on the spot a good q, denoted the DM good, at cost $c(q)$, where $c'(.) > 0$, $c''(.) > 0$, and $c'(0) = 0$. We assume that villagers all produce different varieties of the DM good and that they do not enjoy consuming their own variety. With probability $\sigma \in (0, 1/2)$, a villager gets to trade with another villager whose variety he enjoys and is therefore labeled a *buyer*. He then values q units of the DM good as $u(q)$, with $u'(.) > 0$, $u''(.) < 0$, and $u'(0) = +\infty$. With the same probability, the villager gets to trade with another villager who enjoys the variety he himself produces, and is thus labeled a *seller*. With probability $(1 - 2\sigma)$, the villager does not have the opportunity to trade in the DM.[9] The first best amount of trade between a buyer and a seller is $\bar{q}$, defined by $u'(\bar{q}) = c'(\bar{q})$.

Finally, in the first stage of each period, there is a perfectly competitive *centralized market* that can be accessed by all villagers. In this market, which we denote the CM, all can produce on the spot and at unit cost a good that will serve as the numéraire. All villagers also enjoy unit utility over the numéraire good.

We assume that there is no commitment device in the economy, so credit cannot occur.[10] Trade in the DM must therefore be financed with a medium of exchange. We assume that there exists a government-issued currency (i.e., cash). It is perfectly recognizable and non-counterfeitable. At the beginning of each period, villagers receive a lump-sum transfer of ψ units of the currency.[11] We denote M_t the supply of official currency in the economy after these transfers at the beginning of period t.

2.2 Equilibrium

We now show that under mild assumptions on parameters, the unique monetary equilibrium where the local economy described above is not in autarky (i.e., trade occurs with the larger town, in the OM) is such that decreases in the money supply can harm local trade within the village in real terms. A one-time decrease in the money supply would usually be expected to be neutral. However, the existence of an outside market where prices are fixed partially ties the real aggregate value of the local currency to its supply, impacting the volume of trade that it can support within the village.

Before solving for the equilibrium formally, it is helpful to provide an overview of the equilibrium trade patterns within a period. In the centralized market, agents can trade the numéraire good, which can be produced on the spot, for government-issued currency. The agents may enter this market with heterogeneous money holdings due to idiosyncratic trade opportunities in the previous period's DM and OM. An agent who wants to increase his balances of government-issued currency can do so by producing the numéraire, while an agent who wants to decrease her money holdings can do so by consuming the numéraire.

[9]This implies that the probability of double coincidence of wants, and therefore barter, is zero.

[10]Anecdotal evidence points to the fact that while this is not the norm, transactions sometimes occur through credit in small coca-growing villages. Some of it is unsecured, sustained by reputation, while some of it is collateralized by coca-crops (see reference to "chagra[s]," or coca plots, in Quote 5, Appendix F.2). We abstract from credit in this paper, both to keep the model more tractable and because we are not aware of a substitution away from cash towards credit during the liquidity shortages we are describing.

[11]For now, we do not specify what this flow represents. It could correspond to government transfers, family transfers, or income from another economic activity we abstract from in the model. The goal of this inflow is to ensure that there can be a steady-state quantity of money in the economy. In Section 3.4.1, after having added coca-base to the model, we micro-found the inflow of pesos into the village by assuming that it corresponds to the revenue from the sale of coca-base from villagers to dealers.

The price of the numéraire in terms of money in that market, p_t, will (inversely) indicate the value of money within the village. In the DM, some agents will have the opportunity to trade bilaterally the DM good, also produced on the spot, against the government-issued currency. The quantity of DM good traded between a buyer and a seller will be an important outcome, particularly in relation to how close it is to the quantity that would maximize the gains from trade between the two agents, $\bar{q}$. Finally, in the OM, some agents will be able to purchase OM goods from the outside economy, but only if they still carry government-issued currency (i.e., they have not spent it all in the DM). Agents will then enter the next period's CM with any remaining currency in their possession.

We focus on stationary equilibria where real balances are constant, meaning that $M_t/p_t = M_{t+1}/p_{t+1}$, and where the stock of money is constant, $M_t = M_{t+1} = M$. This implies that the price level in the village must be constant, $p_t = p_{t+1} = p$. As the inflation rate is equal to the growth rate of the money supply, which we assume is zero, the price level must be constant.

Bellman equations The lifetime discounted utility of an agent that carries m^- nominal units of money, which is equivalent to $z^- \equiv m^-/p$ units of real balances, at the beginning of a period can be written as

$$V^1(z^-) = \max_{x,z \geq 0} \left\{ x + V^2(z) \right\} \text{ s.t. } x + z = z^- + \frac{\psi}{p}, \tag{1}$$

where $V^2(z)$ is the lifetime utility of entering the second stage with z units of real balances. The first term of the objective function, x, corresponds to the utility (or cost) derived from the consumption (or production) of the numéraire good, and is the first choice variable. The second choice variable is z, the amount of real balances that the agent decides to carry into the second stage. The equation can be simplified as follows,

$$V^1(z^-) = z^- + \frac{\psi}{p} + \max_{z \geq 0} \left\{ -z + V^2(z) \right\}. \tag{2}$$

The value function is linear in the state variable z^-, thus it has no impact on the agent's portfolio decision. This feature is key in order to keep the model tractable despite the fact that agents may face different trading opportunities during a given period: any heterogeneity in trade history during period $t-1$ is erased after the CM of period t.

Having accumulated z real balances in the first stage, we can write an agent's second-stage lifetime discounted utility as follows,

$$V_2(z) = \sigma \left\{u[q(z)] + V_3[z - d(z)]\right\} + \sigma \mathbb{E}\left\{-c[q(z^b)] + V_3[z + d(z^b)]\right\} + (1 - 2\sigma)V_3(z), \quad (3)$$

where $V_3(z)$ is the lifetime discounted value of entering the OM with z real balances. With probability σ, the agent enters a bilateral match as a buyer. He gets to enjoy utility over the consumption of $q(z)$ units of DM good but relinquishes the real balances transferred as payment to the seller, $d(z)$. With the same probability, he can also get matched as a seller. In this case, he earns $d(z^b)$ real balances in exchange for producing $q(z^b)$ DM goods, where z^b is the quantity of real balances held by the buyer met at random. With the complementary probability, the agent does not get to trade in the DM. Note that to simplify the exposition, we made the conjecture that the terms of trade in a bilateral match are entirely determined by the real balances of the buyer (i.e., they are independent of those of the seller). We will verify this conjecture when we solve for the bargaining solution. To do so, we must first lay out the third-stage value function,

$$V_3(z) = \alpha \max_{y_o \in [0, pz]} \left\{ y_o + \beta V_1\left(z - \frac{y_o}{p}\right)\right\} + (1 - \alpha)\beta V_1(z). \quad (4)$$

If the agent accesses the OM, an event that occurs with probability α, she chooses how much of her currency to spend, y^o (expressed in nominal terms). She cannot spend more currency than the amount she carried from the second stage, z, thus $y^o \leq pz$. If the buyer does not get the opportunity to purchase from the OM, she simply moves to the next period. Making use of the linearity of V_1, we can rewrite (4) as

$$V_3(z) = \alpha \max_{y_o \in [0, pz]} \left[1 - \frac{\beta}{p}\right] y_o + \beta\left[z + V^1(0)\right] = \alpha \max\left\{p - \beta, 0\right\} z + \beta\left[z + V^1(0)\right]. \quad (5)$$

The objective function in the first term after the first equality sign is linear in the consumption of the outside good, so we directly obtain that the agent will spend all of her remaining currency in the outside market if $p > \beta$, none if $p < \beta$, and any amount if $p = \beta$. The intuition is that for each nominal unit of currency spent in the OM, the villager enjoys one util immediately. The alternative is to keep the money for the next period, when the villager will be able to purchase $1/p$ units of the numéraire good. After discounting, this alternative option is worth β/p utils. Hence, the higher the price level, the less valuable each nominal unit of currency locally. If p is high enough, the villager prefers to spend in the OM. The second equality follows and shows that V_3 is linear in z.

DM bargaining We can now turn back to determining the terms of trade in a DM bilateral match between a buyer carrying z units of real balances and a seller. The surplus received by a buyer who purchases q units of DM good against d units of currency, expressed in real terms, is

$$S^b \equiv u(q) + V^3(z-d) - V^3(z) = u(q) - [\alpha \max\{p-\beta, 0\} + \beta]\, d, \tag{6}$$

where the second equality follows from the linearity of V_3. We can define the surplus received by the seller, S^s, in a similar fashion, noting that the total surplus from trade is $S^b + S^s = u(q) - c(q)$. We assume that the terms of trade are determined by Kalai bargaining and that the buyer enjoys a bargaining power $\theta \in ((1-\beta)/(1-\beta+\beta\sigma), 1)$.[12] The terms of trade solve

$$\begin{aligned} \max_{q,d} \quad u(q) - c(q) \quad \text{s.t.} \quad & u(q) - [\alpha \max\{p-\beta, 0\} + \beta]\, d = \theta[u(q) - c(q)] \\ & \text{and } d \leq z. \end{aligned} \tag{7}$$

The first constraint allows us to solve for the payment, in real terms, as a function of the quantity traded,

$$d = [\alpha \max\{p-\beta, 0\} + \beta]^{-1}\, p(q), \tag{8}$$

where $p(q) \equiv (1-\theta)u(q) + \theta c(q)$. We denote $\tilde{z} \equiv [\alpha \max\{p-\beta, 0\} + \beta]\, z$ the forward-looking value of the money held by the buyer, taking into account its outside value in the upcoming OM and CM. The quantity of DM traded is then given by

$$q = \begin{cases} \bar{q} & \text{if } \tilde{z} \geq p(\bar{q}) \\ p^{-1}(\tilde{z}) & \text{otherwise.} \end{cases} \tag{9}$$

The first-best quantity is traded if the buyer carries enough real balances. Otherwise, she spends all of her real balances and the quantity traded is determined so as to split the total gains from trade in proportion to the agents' bargaining powers. Note that the terms of trade, (q, d), do not depend on the real balances of the seller, as we had conjectured earlier. We can now write the buyer's surplus as

$$S^b(z; p) = \begin{cases} \theta[u(\bar{q}) - c(\bar{q})] & \text{if } \tilde{z} \geq p(\bar{q}) \\ u[p^{-1}(\tilde{z})] - \tilde{z} & \text{otherwise.} \end{cases} \tag{10}$$

[12]The lower bound on θ ensures the existence of a monetary equilibrium for any quantity of money in the economy.

CM portfolio problem Finally, we can go back to the choice of real balances made by agents in the first stage. The third term on the right-hand side of (2) can now be written as

$$\max_{z \geq 0} \left\{ -z + \beta z + \sigma S^b(z;p) + \alpha \max \{p - \beta, 0\} z \right\}. \tag{11}$$

The first term represents the direct cost of accumulating real balances (thereby foregoing consumption of the numéraire). The second term represents the value of carrying real balances directly into the next period. The third and last terms represent the additional net surpluses that the agent can obtain by using the real balances in the DM and/or in the OM. The first-order condition for an interior solution is

$$1 = \beta + \sigma S^{b\prime}(z;p) + \alpha \max \{p - \beta, 0\}, \tag{12}$$

where

$$S^{b\prime}(z) = \begin{cases} 0 & \text{if } \tilde{z} \geq p(\bar{q}) \\ \left(u'[p^{-1}(\tilde{z})]/p'[p^{-1}(\tilde{z})] - 1\right)[\alpha \max\{p - \beta, 0\} + \beta] & \text{otherwise.} \end{cases} \tag{13}$$

The marginal benefit of carrying additional real balances into the DM is positive as long as the agent does not already carry enough to purchase the first-best quantity. The marginal benefit of real balances in the OM is positive as long as $p > \beta$ (i.e., as long as the agent would like to purchase the OM good).

Lemma 1 (Individual demand for real balances) *The first-order condition* (12) *admits a unique solution, denoted $z(p)$, if and only if $p < [1 - (1 - \alpha)\beta]/\alpha$. The solution is such that $\partial \tilde{z}/\partial p = 0$ if $p \leq \beta$ and $\partial \tilde{z}/\partial p > 0$ otherwise.*

Were the price level greater than $[1-(1-\alpha)\beta]/\alpha$, demand for real balances would be infinite. Note that when $p < \beta$, villagers prefer not to spend their money balances in the OM, in which case the price level does not impact their real consumption, and therefore it does not impact their demand for real balances ($z'(p) = \tilde{z}'(p) = 0$). However, when $p > \beta$, the price level directly impacts outcomes in the DM and in the OM. In this case, while the impact of p on $\tilde{z}$ is positive, the impact on z depends on parameter values.[13]

[13] On the one hand, as p goes up, the marginal benefit of real balances in the OM goes up since each additional unit of real balances is worth p pesos (and hence p utils) in the OM. On the other hand, the marginal benefit of real balances in the DM may go up or down. While a higher p means that each extra unit of real balances has a higher impact on the liquidity carried by the buyer ($\partial \tilde{z}/\partial z$ increases in p), a higher p also brings the DM quantity traded closer to the first-best level. This diminishes the marginal impact of additional units of z since the buyer's surplus is concave in z. Overall, $z'(p)$ may be positive or negative.

Money supply The money supply follows the law of motion

$$M_{t+1} = M_t + \psi - \alpha \tau_t M_t, \tag{14}$$

where τ_t is an endogenous object that represents the share of money holdings spent by villagers in the OM relative to the total quantity of money they hold, αM_t. It is given by

$$\tau_t = \begin{cases} 0 & < \\ \tau \in (0,1) \text{ if } p & = \beta. \\ 1 & > \end{cases} \tag{15}$$

The money supply at time $t+1$ is equal to the money supply at time t, plus the flow of currency into the economy, net of the flow of currency spent in the OM. In steady-state, $M = M_t = M_{t+1}$, so

$$\alpha \tau_t M = \psi. \tag{16}$$

Equilibrium definition *A monetary equilibrium consists in a list (p, z, q, τ, M) jointly satisfying (9), (12), (15), (16) and the market clearing condition $M = pz$.*

Although it is an equilibrium object, it is helpful to first describe equilibrium regimes as a function of the money supply, M.

Lemma 2 (Equilibrium regimes as a function of M) *Let $\underline{q} \equiv \{q : (1-\beta)/\beta = \sigma[u'(q)/p'(q) - 1]\}$, $\underline{M} \equiv p(\underline{q})$, $\bar{p} \equiv (1 - \beta + \alpha\beta)/\alpha$ and $\bar{M} \equiv \bar{p}p(\bar{q})$. All uniquely exist and $\bar{M} > \underline{M}$. In equilibrium:*

i. (Autarky) If $M < \underline{M}$, then $q = \underline{q} < \bar{q}$, $z = p(\underline{q})/\beta \equiv \underline{z}$, and $p = \beta M/p(\underline{q}) < \beta$.

ii. (Shortage) If $M \in [\underline{M}, \bar{M})$, then z is the unique solution to

$$\left[\alpha \frac{M}{z} + (1-\alpha)\beta\right]^{-1} - 1 = \sigma \left[\frac{u' \circ p^{-1}(\tilde{z})}{p' \circ p^{-1}(\tilde{z})} - 1\right], \tag{17}$$

where $\tilde{z} \equiv \alpha M + (1-\alpha)\beta z$. Then, $q = p^{-1}(\tilde{z})$ and $p = M/z \geq \beta$. Also, $\partial p/\partial M$, $\partial \tilde{z}/\partial M$, $\partial q/\partial M > 0$.

iii. (First best) If $M \geq \bar{M}$, then $q = \bar{q}$, $z = M/\bar{p}$, and $p = \bar{p} > \beta$.

Lemma 2 is illustrated by Figure 1. When the money supply is low, the village operates in autarky, as the price level is below the discount factor. In this situation, agents who have

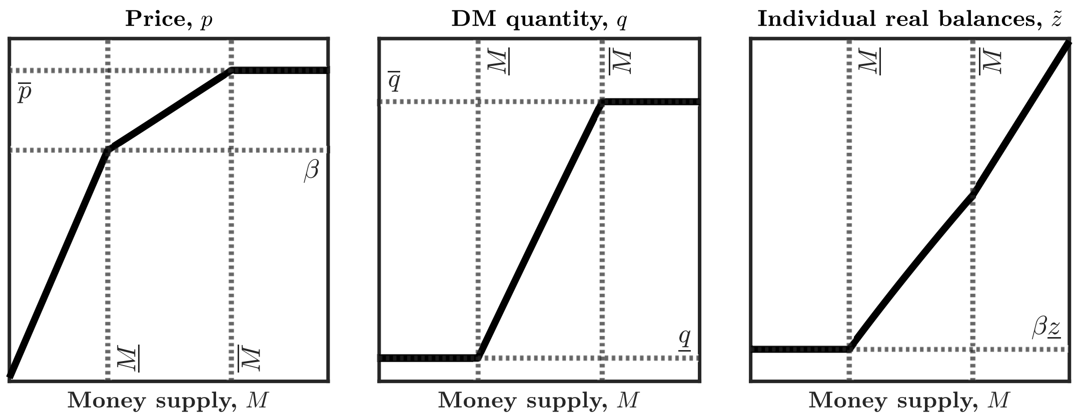

Figure 1: Equilibrium outcomes as a function of money supply in the economy without coca-base.

the opportunity to purchase OM goods prefer to hold onto their balances for the next CM instead. This outcome arises because a low money supply increases the value of money within the village, making the fixed-price OM goods less attractive to purchase. In this regime, the quantity of DM good traded among villagers is less than that of the first best due to a hold-up problem: the buyer incurs the entire cost of holding money while only obtaining a share θ of the gains from trade.[14] Notice that this quantity is independent of the stock of money in the economy, indicating that money is neutral in this regime. A single alteration in the money supply is exactly counterbalanced by a corresponding change in price, leaving the equilibrium real balances unaffected. This regime corresponds to the equilibrium obtained in the Lagos and Wright (2005) model, which can also be retrieved by setting α to zero in our environment.

When $M \geq \underline{\mathrm{M}}$, the OM can be active. When the inequality is strict, agents who access the OM will spend all of their real balances to purchase the OM good (otherwise, agents are indifferent between purchasing the OM good or not). Thus, money has now an additional benefit beyond enabling agents to trade in the DM. There are two subcases. When $M \geq \bar{M}$, the money supply is sufficient to meet liquidity needs in the DM, resulting in the first-best level of trade being achieved and bilateral bargaining surpluses being maximized. In this case, money does not play a liquidity role at the margin in the DM. Money is uniquely priced by its marginal value in the OM, which is constant, and thus the price level is also constant at its maximal value. Real balances adjust according to M, but they have effectively no impact on real outcomes within the village.

When the money supply is in the intermediate range, $M \in [\underline{\mathrm{M}}, \bar{M})$, it is not sufficient to

[14]This problem would be exacerbated by a growing stock of money, generating inflation from one period to another. On the other hand, it could be solved by running the Friedman rule, i.e., shrinking the money supply at a rate such that the value of money increases to exactly offset the discount factor.

achieve the first best in the DM. In this regime, an increase in the nominal money supply results in higher levels of trade and welfare in the DM.[15] Conversely, in this regime, a decrease in the aggregate supply of money (for example, when it is used to purchase goods from outside the village but not replenished by other means) leads to a decrease in real economic activity within the local economy. We interpret this regime as representing the empirical phenomenon that villagers have experienced and referred to as a currency shortage.

Intuitively, the positive relation between money supply and local trade is due to money being priced both by its marginal liquidity roles in both the DM and the OM, so that an increase in the local price level due to an increase in the money supply does not entirely offset the increase in the aggregate value of money holdings. While intuitive, this result is not necessarily straightforward. First, note that local trade, q, is determined by the quantity of pesos held by the buyer, m, and by the forward-looking value of each peso, $\alpha+(1-\alpha)(\beta/p)$. A share α of the real value of each peso is directly tied to the real value of the currency in the OM (where one peso yields one util), while a share $(1-\alpha)$ is related to the face value of pesos, whose real value depends on the local price level p.

When the nominal money supply increases, market clearing and symmetry imply that the pesos of all holders increase. Thus, on the one hand, the value of pesos holdings related to the OM, αM, necessarily increases, benefiting local trade. This mechanism is similar to that described in the New Monetarist literature that considers the liquidity role of real assets. On the other hand, one could expect the increase in pesos supply to put upwards pressure on the local price level, which adjusts in the CM to match pesos supply with pesos demand. Then, the value of pesos holdings linked to their face value, $(1-\alpha)(\beta/p)M$, may decrease, potentially offsetting the positive effect previously described. In a model without an OM (or, e.g., in the autarky regime), this effect is the only effect, and the increase in p exactly offsets the increase in M, leaving local trade unchanged. Thus, one needs to examine what happens to the total forward-looking value of aggregate holdings, $\alpha M+(1-\alpha)(\beta/p)M$. This is equal to $\alpha m+(1-\alpha)(\beta/p)m$ by market clearing, so we can simply study the CM portfolio problem of a villager. Think of the demand for pesos as demand for liquidity for local trade q. The first-order condition can be recast as

$$\frac{(1/p)}{\alpha+(1-\alpha)(\beta/p)} = 1+\sigma\left[\frac{u'(q)}{p'(q)}-1\right]. \tag{18}$$

The right-hand side is related to the marginal utility enjoyed by the buyer from an additional

[15] We focus on welfare in the DM since it would be inappropriate to include the welfare derived from the OM when looking at the impact of changes in the money supply. Obviously, a larger money supply increases welfare in the OM since the OM price is exogenously fixed. On the other hand, the real effects of a change in the money supply on DM outcomes are interesting since prices in that market are endogenous.

unit of DM trade. The left-hand side represents the cost of accumulating the extra liquidity necessary for this additional unit of trade (in the numerator), discounted by its option value if not used in the DM but instead carried into the OM or into the next CM (in the denominator). When the price level goes up, the value of pesos in the current CM reduces more than their value looking forward (combining the forthcoming OM and the next CM), since the OM value is independent of the local price level. Hence, the net marginal cost of more accumulating the liquidity necessary to increase DM trade is lower when p is higher, which leads to more local trade q when p goes up as a result of an increase in M (and vice versa).

Finally, we close the model by taking into account the equilibrium determination of the money supply. It allows us to endogenously determine whether the local economy experiences an underprovision of liquidity or not. We denote the DM trade welfare $\mathcal{W} \equiv \sigma[u(q) - c(q)]$.

Proposition 1 (Equilibrium with endogenous money supply) *When $\psi/\alpha = 0$, there is a continuum of steady-state monetary equilibria with $M \in (0, \underline{M})$ and $\tau = 0$. Conditional on M, equilibrium outcomes are described by case (i) in Lemma 2. When $\psi/\alpha > 0$, there is a unique steady-state monetary equilibrium. There are three subcases:*

(i) If $0 < \psi/\alpha \leq \underline{M}$, $\tau = \psi/(\alpha\underline{M})$, $M = \underline{M}$.

(ii) If $\underline{M} < \psi/\alpha \leq \bar{M}$, $\tau = 1$, $M = \psi/\alpha \in (\underline{M}, \bar{M}]$.

(iii) If $\bar{M} < \psi/\alpha$, $\tau = 1$, $M = \psi/\alpha > \bar{M}$.

In these three subcases, (q, p, z) are respectively given by cases (i), (ii), and (iii) in Lemma 2. Also, for all $\psi/\alpha \in (\underline{M}, \bar{M})$,

$$\frac{\partial M}{\partial(\psi/\alpha)}, \frac{\partial p}{\partial(\psi/\alpha)}, \frac{\partial \tilde{z}}{\partial(\psi/\alpha)}, \frac{\partial q}{\partial(\psi/\alpha)}, \frac{\partial \mathcal{W}}{\partial(\psi/\alpha)} > 0. \tag{19}$$

Proposition 1 is illustrated by Figure 2. If there is no inflow of money in the economy, $\psi/\alpha = 0$, a steady-state equilibrium requires no outflow of money, meaning that the economy must be in autarky. This entails $p < \beta$, which we know from Lemma 2 is supported by any $M < \underline{\mathrm{M}}$. As soon as there is a non-zero inflow of money in the economy, however minimal, the unique monetary steady-state equilibrium features an active outside market.

More specifically, when $\psi/\alpha \in (0, \underline{M}]$, the inflow of money into the village is smaller than the outflow of money that would occur were those villagers who access the OM spending all of their currency there. In such an equilibrium, the stock of money would always be decreasing, precluding a steady state. Instead, there always exists a unique steady-state equilibrium where villagers only spend a share of their currency in the OM when they get

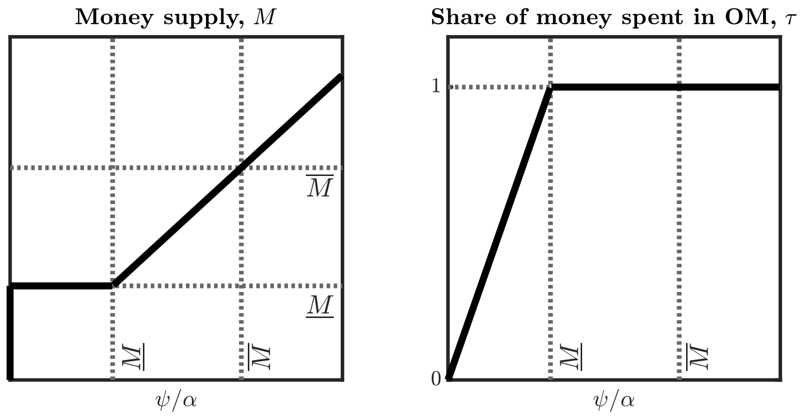

Figure 2: Equilibrium money supply and share of money spent in the OM as a function of the relative frequencies of intermediary coca sales and OM trade, ψ/α.

the chance, $\tau \in (0, 1)$. This share is determined such that $M = \underline{M}$ and the quantity of local trade is identical to that in autarky, $q = \underline{\mathrm{q}}$.

Finally, when $\psi/\alpha > \underline{M}$, the steady-state money supply in the economy exceeds $\underline{\mathrm{M}}$, even when villagers spend all their currency when accessing the OM. We know from Lemma 2 that when $M > \underline{\mathrm{M}}$, the local price level is such that $p > \beta$ so that villagers always strictly prefer to spend their money in the OM. Thus, the equilibrium must feature $\tau = 1$ and the economy behaves exactly like in cases (ii) and (iii) from Lemma 2, where M is substituted with ψ/α.

The local village is in the shortage regime when $\psi/\alpha \in (\underline{M}, \bar{M}]$. In that case, both a decrease in money inflows, ψ, and an increase in access to the OM, α, lead to a decrease in the official money supply. Thus, the purchasing power of villagers reduces, who will undergo a more severe underprovision of liquidity. Note that when $\psi/\alpha > \bar{M}$, an increase in ψ/α also increases the money supply, but it does not impact local trade since the first-best trade is already achieved. When $\psi/\alpha < \underline{M}$, an increase in ψ/α is exactly offset by an increase in the share of currency spent in the OM, τ, leaving the money supply unchanged at $\underline{M}$ and real activity unaffected.

2.3 Discussion

We now discuss some of the mechanisms and model implications, starting with the underlying reason for the existence of equilibrium money shortages in our environment. Fundamentally, note that such equilibrium money shortages are not due, at the individual level, to villagers spending their money in the OM and, consequently, not having enough on hand to purchase goods locally. This can be seen in several ways. Firstly, DM trade is determined before agents have access to the OM, and therefore before any currency has had the chance to flow out of the local economy. Secondly, the equilibrium shortages can arise even if OM trade becomes very rare (i.e., as α tends to zero), and thus only a small fraction of currency leaves out the village. Thirdly, the lowest quantity of local trade is achieved when the economy is in autarky, showing that money used to purchase OM goods does not inherently reduce trade locally.

Rather, the primary reason why shortages may arise is that the local value of money is influenced by the benefits of trade generated in the OM, where the price level is constant for the villagers. That is, given the local economy's linkage to a larger economy, money is not only priced according to the liquidity services it provides in the village but also by the trade benefits resulting from its use in the OM. In this regard, the very possibility that villagers are able to spend their currency at a fixed price in the OM, however rare, is sufficient to break money neutrality locally.[16] Under these conditions, a low supply of official money, due to low inflows or large outflows, can place the local economy in the shortage regime.

One may argue that the postulate of money neutrality is inadequate in our environment, as the existence of the OM where money has a fixed real value makes the currency we consider a real asset and not fiat money. Indeed, as mentioned earlier, our model is related to the New Monetarist literature that studies the liquidity role of real assets. In models of this literature, a change in the supply of real assets would impact the liquidity provision and thus real outcomes. Hence, if money is regarded locally as a real asset (with a liquidity premium due to its local liquidity value), it should not be surprising that a decline in the quantity of that real asset negatively impacts the local economy. A crucial novelty of our model, relative to this literature, is that the currency we consider is both a real and a nominal asset and that the importance of the real part relative to the nominal part is endogenous. When the price level is low, the OM is inactive and the currency is only valued for its local liquidity purposes. In that case, the real value of the currency in the OM plays no role (even as an option value) and money is neutral. When the price level is high enough, in expectation, a share α of the value of the currency stems from its real value in the OM, while the remaining share still comes from its nominal value. Only then is money non-neutral.

In addition, whenever the real option value of the currency is exercised (by using it in the OM), the holder must part with the currency—different from a more typical environment where the liquid asset remains in the hands of its holder, who can still use it for trade after it provides a real dividend. Hence, in our environment, the holder must make a decision between exercising the real value or keeping the asset for future trade. Another important

[16] Of course, the liquidity impact of changes in money supply is inversely related to the strength of the linkage between the village and the OM. When α is low, changes in money supply do not impact local trade as much as when α is high.

difference with the models cited above is that sale of the asset occurs with outsiders so such sales decrease liquidity within the village rather than simply being transfers among agents.

While we have studied a small remote village within a larger country, our setup and results could be transposed to other contexts featuring a small open economy using the same currency as the larger economy it is linked to. In addition to using the same currency, the key requirement for shortage equilibria to arise is that, from the point of view of the small economy, the currency has a fixed nominal value when trading with the large economy. Expanding the analogy, one could apply our findings to two-sided marketplaces where buyers and sellers exchange using an official currency, and where the redemption of that currency outside the platform is not frictionless. For example, one can think of an online decentralized platform where participants trade services among each other in a peer-to-peer fashion. Assuming that payment is in USD, which requires preloading an online wallet attached to the platform, and that redemption out of the platform has some cost (pecuniary or not), our analysis suggests that trade on the platform will be impacted, in real terms, by the nominal quantity of US dollars loaded on the platform.

Finally, our demonstration that a currency shortage in the local economy has a negative real impact on local trade in the environment we described should not necessarily be interpreted as a recommendation for increasing the money supply as a policy intervention. The model does not take into account the impact of a change in local money supply on the demand for goods and prices in the OM. Thus, such a policy intervention cannot be evaluated in the confines of our small open economy model. Instead, the takeaway is that the existence of an outside market where prices are fixed is sufficient to rationalize the phenomenon of villagers experiencing a currency shortage.

3 Coca-base as a CC

We now show how coca-base provides the small economy with extra liquidity—increasing DM trade and welfare—when it is in the shortage regime, thereby acting as a CC alongside the official supply of money. To do so, we first introduce coca-base to the model environment, as described in Section 3.1, and solve for the new equilibrium regimes in Section 3.2. In Section 3.3, we leverage the example of coca-base to further explore how the specific features of a CC impact its ability to offer extra liquidity services. After deriving these general insights, we examine more precisely two specific attributes of coca-base (i.e., it is a source of official currency and is privately produced locally) through model extensions in Section 3.4.

3.1 Changes to the environment

We assume that all agents get the opportunity to produce λ units of coca base at no cost at the beginning of each period, just before the CM.[17] Two additional events can occur at the beginning of each period, prior to production: first, agents who carry a positive amount of coca-base get all of their coca-base holdings seized by government agents with probability $\delta \in (0,1)$; second, agents who did not undergo a seizure get the opportunity to sell their holdings to an intermediary dealer against the numéraire good with probability $\phi \in (0,1)$. The unit price offered by intermediaries, $\nu > 0$, is exogenous, and it is paid in numéraire goods.[18] We also assume that, like the official currency, coca-base is perfectly divisible and storable. However, it is not recognizable by everyone: only the local producers and the intermediary dealers have the ability to recognize it. This precludes its use as a means of payment in the OM.

3.2 The liquidity role of coca-base in equilibrium

The Bellman equations representing this new environment are provided in Appendix A. The CM portfolio problem, which was given by (11) in the economy without coca-base, can now be written as

$$\max_{z,b} \left\{ -z - \frac{p^b}{p} b + \sigma S^b(z,b) + \tilde{z}(z) + \beta \left[\tilde{\phi}\nu + (1-\tilde{\phi}-\delta)\frac{p^b}{p} \right] b \right\}, \tag{20}$$

where $\tilde{\phi} \equiv (1-\delta)\phi$, b represents the chosen holdings of coca-base and p^b the CM price of coca-base in terms of the government-issued currency. The second term represents the cost, in terms of the numéraire, of purchasing b units of coca-base. The expected benefits show up in the expected surplus from being a buyer in the DM, $S^b(z,b)$, which now also depends on b, as well as in the last term. Unless the coca-base is seized, the agent will either be able to sell the coca-base to an intermediary or have it in her portfolio in the next CM.[19] The surplus obtained by a buyer in a DM match as a function of her portfolio is

$$S^b(z,b) = \begin{cases} \theta[u(\bar{q}) - c(\bar{q})] & \text{if } \tilde{z} + \tilde{b} \geq p(\bar{q}) \\ u[p^{-1}(\tilde{z}+\tilde{b})] - \tilde{z} - \tilde{b} & \text{otherwise,} \end{cases} \tag{21}$$

[17] We endogenize the production of coca-base in Section 3.4.2.

[18] We make this assumption for ease of comparison with the model without coca-base. In Section 3.4.1, we instead assume that sales to intermediaries are paid with the official currency, thereby driving the supply of official currency in the local economy. Also, we endogenize ν by formalizing the bargaining between an intermediary and a villager who holds coca-base in Appendix B.2.

[19] We will focus on equilibria where agents sell the coca-base to an intermediary if given the opportunity. It is rational to do so only if $\nu \geq p^b/p$, which we will have to verify in equilibrium.

where

$$\tilde{b} \equiv \beta \left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p} \right] b \tag{22}$$

is the forward-looking value of coca-base holdings during a DM negotiation. If the total value of assets held by the buyer is high enough, she purchases the first-best amount of DM goods.[20] Otherwise, she spends all of her assets and obtains $p^{-1}(\tilde{z} + \tilde{b})$ units of DM good. The first-order condition for an interior solution for z is identical to (12), replacing $S^{b\prime}(z)$ with $\partial S^b(z, b)/\partial z$. The first-order condition for an interior solution for b is

$$\frac{p^b}{p} = \sigma \frac{\partial S^b(z, b)}{\partial b} + \beta \left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p} \right]. \tag{23}$$

The left-hand side represents the marginal cost of accumulating coca-base in the CM. The right-hand side corresponds to the marginal benefits, which include the ability to purchase more DM good in a potential DM match (if the agent is liquidity-constrained), as well as the ability to resell the coca-base in the next CM or to an intermediary the following period, conditional on the substance not being seized in the meantime.

Next, denote M_t^b the supply of coca-base in the economy during period t (after seizures, sales to intermediaries, and production). Its law of motion is given by

$$M_t^b = [1 - \delta - \tilde{\phi}]M_{t-1}^b + \lambda. \tag{24}$$

In steady-state, $M_t^b = M_{t-1}^b = M^b$, so that the steady-state stock of coca-base in the economy must be

$$M^b = \frac{\lambda}{\delta + \tilde{\phi}}. \tag{25}$$

The steady-state stock of coca-base increases with the production rate but decreases with the probability of undergoing a seizure or meeting with an intermediary. Finally, the supply of official currency in the local economy is still determined by (16) with τ given by (15).

Equilibrium definition *A monetary equilibrium consists in a list* $(p, z, q, \tau, M, p^b, M^b)$ *jointly satisfying* (9) *(replacing* $\tilde{z}$ *with* $\tilde{z} + \tilde{b}$*),* (12) *(replacing* $S^{b\prime}(z)$ *with* $\partial S^b(z, b)/\partial z$*),* (15)*,* (16)*,* (21)*,* (23)*,* (25) *and the market clearing condition* $M = pz$*.*

Again, we start by describing the equilibrium regimes as a function of the official supply of currency, M.

[20] In this case, she is indifferent between paying with any combination of official currency and coca-base worth $p(\bar{q})$, where official currency and coca-base are respectively weighted by $[\beta + \alpha \max\{0, p - \beta\}]$ and $\beta \left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)p^b/p \right]$.

Lemma 3 (Equilibrium regimes as a function of M with coca-base) *Let $\bar{p}^b \equiv \beta\tilde{\phi}\nu/[1-\beta(1-\delta-\tilde{\phi})]\bar{p}$, $\bar{M}' \equiv \bar{p}p(\bar{q})-\bar{p}^b M^b < \bar{M}$, $\underline{(p^b/p)} \equiv \tilde{\phi}\nu/(\delta+\tilde{\phi})$, and $\underline{M}' \equiv p(\underline{q})-\beta\underline{(p^b/p)}M^b < \underline{M}$. All exist and are unique. In equilibrium:*

i. (Autarky) If $M < \underline{M}'$, $q = \underline{q}$, $z = p(\underline{q})/\beta - \underline{(p^b/p)}M^b \equiv \underline{z}' < \underline{z}$, $p = M/\underline{z}'$, $p^b/p = \underline{(p^b/p)}$.

ii. (Shortage) If $M \in [\underline{M}', \bar{M}')$, then $(z, p^b/p)$ is the unique solution that satisfies

$$\left[\alpha\frac{M}{z} + (1-\alpha)\beta\right]^{-1} - 1 = \sigma\left[\frac{u' \circ p^{-1}(\tilde{z}+\tilde{b})}{p' \circ p^{-1}(\tilde{z}+\tilde{b})} - 1\right], \tag{26}$$

and

$$\beta\left[\tilde{\phi}\nu + (1-\tilde{\phi}-\delta)\frac{p^b}{p}\right] = \left[\alpha\frac{M}{z} + (1-\alpha)\beta\right]\frac{p^b}{p}, \tag{27}$$

where $\tilde{z} \equiv \alpha M + (1-\alpha)\beta z$ and $\tilde{b} = \beta\left[\tilde{\phi}\nu + (1-\tilde{\phi}-\delta)(p^b/p)\right]M^b$. Then, $q = p^{-1}(\tilde{z}+\tilde{b})$ and $p = M/z \geq \beta$. Also, $\partial p/\partial M$, $\partial(\tilde{z}+\tilde{b})/\partial M$, $\partial q/\partial M > 0$, and $\partial(p^b/p)/\partial M < 0$. Finally, $\partial p^b/\partial M > 0$ if $\alpha < (\delta+\tilde{\phi})$, $= 0$ if $\alpha = (\delta+\tilde{\phi})$, and < 0 otherwise.

iii. (First best) If $M \geq \bar{M}'$, $q = \bar{q}$, $z = M/\bar{p}$, $p = \bar{p} > \beta$, $p^b/p = \bar{p}^b/\bar{p}$.

There still exist three regimes after the addition of coca-base, which again can be described as a function of the nominal supply of official currency, M, as illustrated in Figure 3. Note that both the new threshold under which the regime is in autarky, $\underline{M}'$, and the new threshold above which the economy achieves the first-best DM trade, $\bar{M}'$, are lower than their counterparts in the economy without coca-base. This is because liquidity is now determined by the combined value of official currency and coca-base, $M + p^b M^b$. Hence, if $p^b M^b > 0$, a lower M is required to achieve the real outcomes that would otherwise be obtained without coca-base.[21] In this regard, coca-base complements government-issued currency by augmenting the local provision of liquidity, which raises local trade.[22]

In the autarky regime, conditional on M, real activity with and without coca-base is identical since $q = \underline{q}$ and no goods are purchased in the OM. The price level, p, is higher with coca-base since the quantity of money (official and coca-base) is larger for the level of real demand, thereby reducing the value of the official currency. In the first-best regime, real activity within the village is also the same with and without coca-base, since it is at its

[21]Precisely, the difference between the thresholds for M with and without coca-base is equal to $p^b M^b$.

[22]Note that technically, paper money and coca-base do not behave like what economists typically call *complements*. A marginal increase in the nominal supply of coca-base always has exactly the same effect on real outcomes as a marginal increase in the supply of government-issued currency. In other words, for a given total quantity of liquidity, the combination of paper money and coca-base is irrelevant. It may then be more appropriate to refer to coca-base as a *supplement* to paper money.

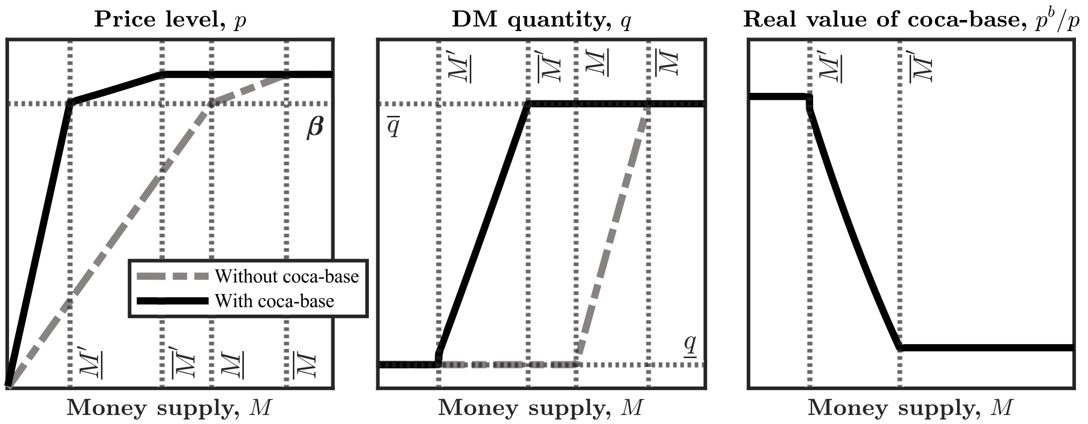

Figure 3: Example comparison of equilibrium outcomes as a function of money supply in an economy with and without coca-base.

peak. The price level is the same as well since it is pinned down by the value of the official currency in the OM and is therefore independent of the existence of the coca-base.

In the intermediary regime, the behavior of q and p is similar to what we described in the economy without coca-base: equilibria with higher supplies of official currency are associated with higher price levels, p, and higher DM trade, q. The intuition remains the same: the value of the official currency is partially determined by the outside market, so that the aggregate value of money holdings increases with money supply even though prices increase. Furthermore, the price of coca-base in terms of the numéraire, p^b/p, decreases. As more and more DM good is traded in bilateral meetings, the marginal benefit of carrying official currency or coca-base diminishes. However, the former does not diminish as much as the latter because it is partially determined by the constant purchasing power in the OM. The cost of carrying coca-base must therefore decrease relative to the cost of carrying official currency so as to guarantee their coexistence.

Interestingly, the behavior of the nominal price of coca-base, p^b, depends on the frequency of access to the OM relative to the frequency with which a villager meets with an intermediary or experiences a coca-base seizure. When $\alpha < \delta + \tilde{\phi}$, an increase in M increases p^b, and conversely. The intuition is as follows. Consider a villager in the CM, deciding whether to accumulate a marginal unit of official currency or an extra unit of coca-base. In equilibrium, their net marginal benefit must be equal for the two currencies to be held. Importantly, the nominal value of both assets positively depends on p: the revenues from selling the coca-base to intermediaries increase in p, as do the net benefit from purchasing OM goods with the official currency. Consider an increase in M, which we know increases p. When α is high, opportunities to consume in the OM are frequent relative to opportunities to sell the coca-base to intermediaries, and thus the marginal benefit of accumulating the official currency reacts more strongly than that of accumulating coca-base. Thus, the price of coca-base must adjust downwards to ensure demand for coca-base after an increase in the supply of official currency. Conversely, when $\tilde{\phi} + \delta$ is high, the benefit of coca-base reacts more strongly than that of official currency, and p^b must go up following an increase in the official currency supply.

Proposition 2 (Equilibrium with endogenous money supply and coca-base) *Proposition 1 still holds, substituting $\underline{M}$ with $\underline{M}'$, $\bar{M}$ with $\bar{M}'$, (q, p, z) with $(q, p, p^b/p, z)$, and references to Lemma 2 with references to Lemma 3. In addition, for all $\psi/\alpha \in (\underline{M}', \bar{M}')$,*

$$\frac{\partial \tilde{z} + \tilde{b}}{\partial(\psi/\alpha)} > 0, \frac{\partial \tilde{b}}{\partial(\psi/\alpha)}, \frac{\partial p^b/p}{\partial(\psi/\alpha)} < 0. \tag{28}$$

Also,

$$\frac{\partial p^b}{\partial(\psi/\alpha)} > 0 \textit{ if } \alpha < \tilde{\phi} + \delta, = 0 \textit{ if } \alpha = \tilde{\phi} + \delta, \textit{ and } < 0 \textit{ otherwise.} \tag{29}$$

We can still continuously map any $\psi/\alpha > 0$ into a unique M, which determines unique equilibrium outcomes according to Lemma 3. Hence, Proposition 2 provides the counterpart to Proposition 1 in an environment with coca-base.

We now build on Proposition 2 to examine the impact of the presence of coca-base in an economy experiencing a shortage of official currency.

Proposition 3 (Complementary liquidity of coca-base) *Consider two economies perfectly identical except for their supplies of coca-base, $M_1^b > M_2^b = 0$. Denote $(q^1, \mathcal{W}^1)$ and $(q^2, \mathcal{W}^2)$ the outcomes respectively obtained in those economies. Then $(q^1, \mathcal{W}^1) \geq (q^2, \mathcal{W}^2)$, and the inequality is strict if $\psi/\alpha \in (\underline{M}_1', \bar{M}_2)$.*

In the shortage regime, the introduction of coca-base strictly increases local trade and welfare. Such a positive impact on trade and welfare can thus be seen, empirically, as a rationale for the adoption of a CC in a small economy that suffers from a shortage of official currency.

In summary, we were able to show that coca-base is not only used as a means of exchange, but it can also alleviate the real costs of the currency shortage experienced by villagers. Note that these two results are not necessarily linked. As we can see in the autarky regime, coca-base can be used as a substitute for money without impacting real activity. Also note that the insights on the role of coca-base as a supplement to official currency also apply to the alternative interpretations that one may give to the environment described in this paper, as discussed in Section 2.3. For example, thinking of two-sided online marketplaces, our results provide an additional rationale for the development of platform-specific tokens as a

	Benefit of holding CC	Agg. supply of CC	**Total impact on liquidity**
$\downarrow$ **Supply** (λ)	x	-	**-**
$\uparrow$ **Storage costs** (δ)	-	-	**-**
$\downarrow$ **Commodity value 1** (ϕ)	-	+	**?**
$\downarrow$ **Commodity value 2** (ν)	-	x	**-**

Table 1: Impact of CC characteristics on liquidity provision, decomposed between the impact on holding benefits and the impact on the supply of CC. The last column provides the aggregate impact on liquidity. Note that 'x' means there is no impact, and '?' means that the sign is ambiguous.

CC, boosting trade on the platform if the supply of official currency held by users on the platform is not sufficient.[23]

3.3 CC's features and liquidity

Empirically, CCs exhibit significant heterogeneity in characteristics. This diversity is likely a crucial factor in the varying levels of success observed across complementary currency projects. We leverage our theoretical model to explore the connection between the specific features of a CC and the liquidity services it renders when there is a shortage of official liquidity. Specifically, we consider the CC's supply, its storage costs, its commodity value, and its redeemability.

Supply Proposition 3 showed that in the shortage regime, and everything else equal, an economy with coca-base fares strictly better than an economy without coca-base. We now consider the impact on local liquidity of marginal changes in the supply of coca-base, M^b. In our model, the supply of coca-base is determined endogenously by the balance between the flow of coca-base into the economy through endowments (λ) and the flow out of the economy through seizures at rate δ and sales to intermediaries at rate ϕ. We argue that to isolate the impact of an exogenous change in supply, it is appropriate to consider the impact of a change in λ, keeping δ and ϕ fixed. Indeed, contrary to these two latter parameters, λ does not impact any other element of the model directly. In other words, a change in M^b driven by a change in λ can be interpreted as a "pure" exogenous change in coca-base supply in the local economy, analog to a change in the supply of a CC in a local economy where the supply of CC is entirely determined by a planner. Mathematically, for any endogenous

[23] Other rationales typically brought forward invoke the revenue generated from the original issuance of these tokens as well as the positive effect of tokens on platform adoption. See, e.g., Bakos and Halaburda [2019] or Cong et al. [2022].

variable x in our model, $(\partial x/\partial M^b)_{|\delta,\phi} = (\delta + \tilde{\phi})(\partial x/\partial \lambda)$. We prove in the appendix that for any $\psi/\alpha = M \in (\underline{M}', \bar{M}')$,

$$\frac{\partial q}{\partial \lambda}, \frac{\partial \mathcal{W}}{\partial \lambda}, \frac{\partial p}{\partial \lambda} > 0. \tag{30}$$

A decrease in coca-base supply negatively impacts the total amount of liquidity in the economy, which reduces local trade and welfare. Conversely, the larger the supply of CC, the better the impact on local liquidity. Note that this effect only works through the general equilibrium impact of the change in coca-base supply on the value of currency both in real terms and in terms of the coca-base. In partial equilibrium, the change in coca-base supply does not impact money demands given p and p^b since M^b (and for this reason, λ) do not appear in the portfolio problem faced by villagers, (20). Finally, if the supply of coca-base grows sufficiently large, the local economy can reach the first-best level of trade. These results are summarized in the first line of Table 1.

Storage costs We now consider the impact of storage costs, which we use as an umbrella term to include any cost that the CC holder may incur from holding onto the asset from one period to another. In general, this could include literal storage costs, depreciation, risk of theft, etc. In the case of coca-base, the risk of government agents seizing the asset, at a rate δ, constitutes such a cost.[24] For any $\psi/\alpha = M \in (\underline{M}', \bar{M}')$,

$$\frac{\partial q}{\partial \delta}, \frac{\partial \mathcal{W}}{\partial \delta}, \frac{\partial p}{\partial \delta} < 0. \tag{31}$$

An increase in the seizure rate negatively impacts local liquidity. This goes through two channels. First, an increase in seizures reduces the supply of coca-base M^b, which we know has a negative general equilibrium impact on liquidity. This would extend to any kind of storage costs that reduces the quantity of complementary currency available for trade. The second channel operates directly through the portfolio problem of villagers. If the risk of seizures goes up, the real value of holding a unit of coca-base decreases, ceteris paribus. In others words, this decreases the expected benefit from holding the currency, which also negatively impacts liquidity. This result would apply to any storage cost that impacts the value of holding a CC, regardless of whether the storage cost has an effect on the supply of CC.

Commodity value While villagers cannot directly derive utility from consumption of coca-base, we can argue that in the environment we describe, it is effectively *as if* they

[24] While we do not formalize it, another such cost for coca-base could be the cost of maintaining its quality so that it can eventually be sold as an input for cocaine production.

could: villagers can sell coca-base at a fixed real value, ν, to intermediaries, thereby enjoying ν utils. The opportunity to do so arises at the rate $\tilde{\phi}$, hence we consider $\tilde{\phi}\nu$ the commodity value of one unit of coca-base. A first question of interest is whether coca-base could indeed play a role as a complementary currency, augmenting local liquidity, if it did not carry a commodity value, $\tilde{\phi}\nu = 0$. In our environment, the answer is no. Recall first that in order to be positively valued in local exchange, coca-base must compete with official currency. Absent the possibility to sell coca-base to intermediaries, rate-of-return equality requires $\beta + \alpha \max\{p - \beta, 0\} = \beta(1 - \delta)$. This equality cannot hold if $\delta > 0$. Then, coca-base will not be valued, and the equilibrium will not be impacted by the positive supply of coca-base. If $\delta = 0$, then coca-base will be positively valued, but $p \leq \beta$. In such an equilibrium, local trade is equal to $\underline{q}$, and thus coca-base plays no liquidity role in addition to that played by official currency. In other words, a CC with no commodity value cannot coexist with an official currency with a strictly positive advantage in the OM. In any equilibrium where the two coexist, that advantage must be zero, i.e., there is no net benefit from trading in the OM relative to trading locally. In addition, in this context, the CC must not have storage costs larger than those of the official currency.

We now consider the impact of marginal changes in ν and ϕ on the liquidity provided by coca-base. For any $\psi/\alpha = M \in (\underline{M}', \bar{M}')$,

$$\frac{\partial q}{\partial \nu}, \frac{\partial \mathcal{W}}{\partial \nu}, \frac{\partial p}{\partial \nu} > 0. \tag{32}$$

A decrease in the real sale price of coca-base to intermediaries negatively impacts local liquidity. Since ν has no impact on the supply of coca-base (as long as it is high enough for coca-base to be sold to intermediaries), the liquidity effects entirely go through the impact of a reduction in ν on the value for a villager of carrying units of coca-base. Everything else equal, a lower ν means the commodity value of coca-base is lower, which negatively impacts its liquidity value. The impact of a change in ϕ is more subtle. There exists a unique $\phi^* > 0$ such that, for any $\psi/\alpha = M \in (\underline{M}', \bar{M}')$,

$$\frac{\partial q}{\partial \phi}, \frac{\partial \mathcal{W}}{\partial \phi}, \frac{\partial p}{\partial \phi} > 0 \text{ if } \phi < \phi^* \text{ and } < 0 \text{ if } \phi > \phi^*. \tag{33}$$

Hence, a reduction in the frequency of meetings with intermediaries can have a positive impact on liquidity if the original frequency of meetings is large enough. When the frequency of meetings is already small, further reductions harm liquidity. This results from a horse race between two opposite effects. On one hand, a decrease in ϕ increases the supply of coca-base, which is positive for liquidity. On the other hand, it reduces the expected gain from holding coca-base (just like a reduction in ν). When ϕ is large, the impact on supply more than offsets the impact on the commodity value of coca-base, and vice versa.

Redeemability Many complementary currencies are designed with a guaranteed redeemability, or convertibility, in terms of the official currency. In the case of coca-base, there is no such guarantee. Agents can trade coca-base for the official currency locally, where the terms of trade are endogenously determined by supply and demand. Generically, in equilibrium, $p^b \neq 1$, so that coca-base and official currency are not traded at par in the village. As a thought experiment, consider the existence of a facility where villagers would be able to exchange coca-base for pesos, at a guaranteed rate of x pesos per unit of coca-base, in the first stage of every period. Ignoring the impact of such an arrangement on the local supplies of coca-base and pesos, arbitrage would lead to $p^b = x$ in equilibrium. Then, the system of equilibrium conditions would be over determined, and an equilibrium where coca-base and official currency coexist would, generically, not exist. In other words, for coca-base to be valued alongside money (and provide additional liquidity), their relative exchange rate must be able to adjust endogenously.

3.4 Extensions

Coca-base displays two distinctive attributes relative to many other CCs. First, it is able to impact the local provision of official currency: through the sales of coca base, the local economy replenishes itself with official currency. Second, it is produced by the members of the community where it circulates. Changes in the values of certain variables may thus induce changes in the coca-base production. In Section 3.4.1, we provide an extension where the sales of coca-base are a source of official currency. Furthermore, to explore the response of coca-base production to parameter shocks, we offer a second extension in Section 3.4.2 where the production of coca-base is private and endogenous.

3.4.1 Coca-base sales as a source of official currency

The key role played by the sales of coca-base to intermediaries in replenishing the local stock of official currency is described by Le Figaro [2007, free translation]:

> [Villagers] hang onto visits from "bosses," the drug dealers who purchase the coca-base. A villager explains "The bosses come from the city by boat, well-escorted, with bags of cash, and everyone runs to sell their coca-base." In just a few hours, hundreds of kilograms of paste can change hands.

Thus, we now assume that intermediaries pay villagers with official currency instead of numéraire goods. Then, the supply of official currency in the local economy is still determined by (16) with τ given by (15), but substituting the flow of currency into the economy, ψ, by the revenues from coca sales, $\tilde{\phi}\nu p M^b$.[25] Hence, the steady-state supply of official currency is

$$M = \frac{\tilde{\phi}\nu p}{\alpha\tau} M^b = \frac{\nu p \lambda \tilde{\phi}}{\alpha\tau(\tilde{\phi}+\delta)}. \tag{34}$$

Conditional on the price level p, an increase in the revenue from coca-base sales raises the stock of official currency that can be used locally. This can be due to a higher rate of coca-base production, more frequent opportunities to sell coca-base, a higher real sale price, or fewer seizures.

Assumption 1 *The economy is such that, when $M^b = 0$, $\partial z/\partial M > 0$ for $M \in (\underline{M}, \bar{M})$. Equivalently, the solution to (12) increases in p.*

This assumption ensures that higher price levels are associated with higher real balances (i.e., when M goes up, the price level does not go up as much).[26] At the individual level, this means that the higher the price level, the more valuable every additional unit of liquidity is. Without this assumption, we cannot guarantee that the equilibrium is unique. Indeed, (34) maps the exogenous object $\tilde{\phi}\nu M^b/\alpha$ into the endogenous object M/p. We know that M/p is constant in M when $M < \underline{M}'$ and strictly increasing in M when $M > \bar{M}'$. It also needs to be strictly increasing between $\underline{M}'$ and $\bar{M}'$ to ensure that any $\tilde{\phi}\nu M^b/\alpha$ maps into a single M/p. Assume instead that there exists a $\tilde{\phi}\nu M^b/\alpha$ equal to both M_1/p_1 and M_2/p_2, with $M_1 > M_2$. Then, there would exist two equilibria consistent with the same parameter values. The first one would be characterized by a larger money supply and price level. The larger price level leads to larger flows of official currency into the local economy (each unit of coca base is sold for $p\nu$ pesos). In turn, a high money supply is then consistent with a high price level. Conversely, the second equilibrium would be characterized by both a relatively smaller money supply and price level, also consistent with each other. Importantly, the two equilibria would differ in terms of real outcomes. We avoid this outcome by imposing Assumption 1.

Proposition 4 (Equilibrium with endogenous supply of money and coca-base) *When $\tilde{\phi}\nu M^b/\alpha = 0$, there is a continuum of steady-state monetary equilibria with $M \in (0, \underline{M}')$ and $\tau = 0$. Conditional on M, equilibrium outcomes are described by case (i) in Lemma 3. Un-*

[25] We assume that there are no other inflows of currency into the local economy, for simplicity.

[26] Footnote 13 explained why this may not necessarily be true for any set of parameter values.

der Assumption 1, when $\tilde{\phi}\nu M^b/\alpha > 0$, there is a unique steady-state monetary equilibrium. There are three subcases:

(i) If $0 < \tilde{\phi}\nu M^b/\alpha \leq \underline{M}'/\beta$, $\tau = \tilde{\phi}\nu M^b\beta/(\alpha\underline{M}')$, $M = \underline{M}'$.

(ii) If $\underline{M}'/\beta < \tilde{\phi}\nu M^b/\alpha \leq \bar{M}'/\bar{p}$, $\tau = 1$, $M = \tilde{\phi}\nu M^b p/\alpha \in (\underline{M}', \bar{M}']$.

(iii) If $\bar{M}'/\bar{p} \leq \tilde{\phi}\nu M^b/\alpha$, $\tau = 1$, $M = \tilde{\phi}\nu M^b\bar{p}/\alpha > \bar{M}$.

In these three subcases, $(q, p, z, p^b/p)$ are respectively given by cases (i), (ii), and (iii) in Lemma 3.

We recover a unique equilibrium that resembles that described in Proposition 2, with the difference that the equilibrium regime is now determined by $\tilde{\phi}\nu M^b/\alpha$ rather than ψ/α.

An important implication is that the supply of coca-base M^b now impacts liquidity not only directly, as described in Section 3.3, but also indirectly through its impact on the supply of official currency, M. If the supply of coca-base is low, sales of coca-base must also be low, drying up the flow of official currency into the local economy. This compounds the negative effect of a drop in coca-base supply on local liquidity. Similarly, a decrease in the real price of coca-base for dealers (ν) in the frequency of meetings with dealers ($\tilde{\phi}$) not only impacts liquidity by reducing the liquidity of coca-base, it also reduces the flow of official currency into the local economy, aggravating the negative impact on local liquidity. In sum, the local inflow of pesos due to coca-base sales constitutes a second channel through which shocks to coca-base impact local liquidity.[27]

3.4.2 Endogenous production of coca-base

Assume that instead of being endowed to all agents at the beginning of each period, coca-base can be produced. The production technology is available to all villagers during the first stage, and it is such that k units of the numéraire good generate $f(k)$ units of coca-base. We show in Appendix B.1 that when interior, the choice of k satisfies the first-order condition

$$\frac{p^b}{p} f'(k) = 1. \tag{35}$$

The left-hand side represents the marginal benefit of production in terms of the numéraire: an extra unit of numéraire used for production generates $f'(k)$ additional units of coca-base, each being worth p^b/p goods in the CM. The right-hand side represents the opportunity

[27]Since this channel works through changes to the local supply of pesos, it may look like an income effect, but it truly is a liquidity effect. Indeed, there are no income constraints in the model, as villagers can always produce more of the numéraire good in the DM.

cost: consuming the extra unit of numéraire on the spot would be worth one util. Hence, a reduction in the real value of coca-base, p^b/p, would lead to a reduction in production, and vice versa.

Denote $\underline{k}$ and $\bar{k}$ the levels of effort devoted by villagers to coca-base production when the real value of coca-base is respectively $\underline{(p^b/p)}$ and $\bar{p}^b/\bar{p}$. The corresponding supplies of coca-base are $\underline{M}^b \equiv f(\underline{k})/(\delta+\tilde{\phi})$ and $\bar{M}^b \equiv f(\bar{k})/(\delta+\tilde{\phi})$. Finally, let $\underline{M}'' \equiv p(\underline{\mathrm{q}})-\beta\underline{(\mathrm{p}^b/p)M}^b$ and $\bar{M}'' \equiv \bar{p}p(\bar{q}) - \bar{p}^b\bar{M}^b$.

Proposition 5 (Equilibrium with endogenous production of coca-base) *Proposition 2 still holds, substituting $\underline{M}'$ with $\underline{M}''$, and $\bar{M}'$ with $\bar{M}''$. The equilibrium is still defined by the same set of equations, replacing λ by $f(k^*)$, where k^* is the solution to (35). In addition, for all $\psi/\alpha \in (\underline{M}'', \bar{M}'')$,*

$$\frac{\partial M^b}{\partial(\psi/\alpha)} < 0. \tag{36}$$

Interestingly, the endogenous production of coca-base mitigates the impact of changes in the supply of official currency. When ψ/α (and therefore M) goes up, the real value of coca-base falls, reducing incentives to produce coca-base and eventually reducing its supply. This mitigates the increase in liquidity due to the increase in the supply of official currency. This works in favor of villagers in times of shortages: when the official money supply goes down, the production of coca-base picks up, mitigating the adverse impact of the official currency shortage.

The elasticity of coca-base production also matters following shocks to the seizure rate or shocks to the frequency of meetings with intermediaries. For example, we saw in Section 3.3 that an increase in seizures would negatively impact liquidity both through its direct impact on the supply of coca-base and through its negative impact on the benefits of coca-base for its holders. With endogenous coca-base production, a decrease in the real value of coca-base would also lead to a reduction in production, adding to the downwards pressure on coca-base supply. This channel would then exacerbate the negative liquidity impact of the policy. We also saw that a crackdown on intermediary meetings would have an ambiguous effect on liquidity, since it would prop coca-base supply up while reducing its value for holders. Again, allowing for the production of coca-base to respond, the reduction in coca-base value would lead to a reduction in production, countering the direct positive impact of the policy on the supply of coca-base. Whether this counter-effect would offset the direct effect is a quantitative question.

4 The unintended consequences of anti-narcotic policies on liquidity in coca-growing villages

In this last section, we present an empirical policy application of our micro-founded model of CC. Our aim is to evaluate the unintended consequences of the anti-narcotic policies pursued in Colombia on liquidity and trade in local coca-growing villages.

The country became a crucial location in the U.S. war on drugs during the late 1980s, leading to substantial investment in financial and military resources by both governments to reduce the supply of cocaine. For instance, in 1999, the Colombian government unveiled a collaborative strategy with the U.S. known as Plan Colombia, aiming to combat illegal drugs and organized crime. Between 2000 and 2008, the military aspect of Plan Colombia received an average annual funding of US$540 million from the U.S. government [Mejía, 2015]. Additionally, the Colombian government allocated approximately US$812 million per year. These combined expenditures accounted for approximately 1.2 percent of Colombia's average annual GDP during the same period.

In particular, two different types of policies aimed at curbing the supply of cocaine has been implemented. The first attacks coca cultivation by aerial spraying campaigns and manual eradication of illegal crops. The second, in contrast, attacks the later stages of production and trafficking through interdiction strategies such as the seizures of coca-base or cocaine and crackdowns on intermediaries. Aerial spraying has been the main strategy to control the cocaine supply, however, in the last decade interdiction strategies have been strengthened.

The harmful impact of these policies on the incomes of farmers has been widely recognized. However, the policies' effect on local trade and welfare in coca-growing villages caused by their nefarious impact on local liquidity has often been overlooked in policy discussions. Such unintended consequences are to be expected in light of the results derived in the previous section, where we demonstrated the liquidity role that coca-base plays locally in coca-growing villages. We also explained how shocks to attributes such as the rate of seizures, the efficiency of production, or the resalability to intermediary dealers—shocks that can easily be matched to anti-narcotic policies pursued in Colombia—matter for the ability of coca-base to supplement local liquidity.

Calibrating the model now allows us to go further and precisely quantify the magnitude of the loss of local liquidity following policy shocks. Specifically, we consider as policy instruments the rate at which coca-base can be produced (e.g., crop destruction through aerial spraying or manual eradication), the rate at which coca-base is seized by government officials and the frequency of being able to sell the coca-base to intermediaries (e.g., crackdowns on intermediary networks). We can also disentangle the role played by each theoretical channel—in particular, we can assess to which extent the impact of an anti-narcotic policy shock on local liquidity is due to the decrease in the production of coca-base (and its supply), the decrease in official currency, or the decrease of their respective value in trade. Finally, we also derive policy possibility frontiers to compute and compare, across different policy instruments, the trade-off between local outcomes and anti-narcotic policy goals. We consider two different potential policy goals: decreasing the production of coca-base and decreasing the sales of coca-base.

4.1 Calibration

The reports by ElTiempo [2007], Espinosa [2010], Cardona [2021], Turkewitz [2021], and Álvarez and Forero [2023] describe the phenomenon of coca-base money as occurring in a region named Meta-Guaviare. Due to data availability, we focus specifically on the department of Guaviare as a reference for our calibration. According to the maps by UNODC [2021], there are currently two concentration areas of coca crops in that department. We consider these areas as the local markets where coca is produced and accepted in exchange among villagers. This is in contrast with the capital city of Guaviare, San José del Guaviare, which we use as representing the OM in our model. Farmers from villages in the areas of crop concentration sporadically go there to buy supplies and take them back to their villages.

We calibrate the full model, with both endogenous money supply driven by the sale of coca-base to intermediaries (Section 3.4.1) and endogenous production of coca-base (Section 3.4.2), at the weekly frequency. The DM utility and cost functions respectively take the form $u(q) = q$ and $c(q) = a_c q_c^{\eta}$, with $\eta_c > 1$. The functional form for the utility function is set to match the utility received by agents who consume the OM. In other words, we interpret the OM and DM goods are perfect substitutes for the consumer. What differentiates them is only the time at which they are purchased (and thus consumed). The coca-base production function is such that k units of the numéraire allow for the production of $f(k) = Ak^{\gamma}$ units of coca-base. We need to calibrate the following list of 10 parameters: β, σ, α, ϕ, ν, δ, a_c, η_c, A and γ. We provide a summary of our calibration strategy below. A more detailed description can be found in Appendix C. The resulting parameter values are reported in Table 2, alongside a selection of non-targeted equilibrium outcomes.

The discount factor and the probabilities of DM trade and OM trade are calibrated externally. Then, we calibrate jointly the remaining parameters, $(\nu, \delta, \phi, a_c, \eta_c, A, \gamma)$. We use five targets and two ad-hoc restrictions. The targets are the pesos value of coca-base in local trade, the pesos value of coca-base when it is sold to intermediaries, the aggregate

Parameter	Description	Value
	Externally calibrated	
β	Discount factor	0.9992
σ	Probability of DM match	0.5000
α	Probability of OM access	0.0577
	Internally calibrated	
ν	Coca-base sale price to intermediary	3241.26
δ	Probability of coca-base seizure	0.0423
ϕ	Probability of meeting intermediary	0.1168
a_c	DM cost function scalar	0.9447
η_c	DM cost function elasticity	1.0042
A	Coca-base production function efficiency	0.0128
γ	Coca-base production function elasticity	0.6500
	Equilibrium outcomes	
M	Official money supply (COP)	131,891
$p^b M^b$	Nominal value of coca-base supply (COP)	49,220
$M/(M + p^b M^b)$	Share of liquidity from official supply	73%

Table 2: Calibrated parameter values and equilibrium outcomes.

quantity of coca-base seizures, GDP per capita, and the elasticity of coca production to coca-base seizures. The first ad-hoc restriction is that the CM price level, p, is fixed arbitrarily so that the equilibrium regime corresponds to case (ii) (the shortage regime). There is a range of values that could satisfy this condition: p must belong to $[\beta, (1 - \beta + \alpha\beta)/\alpha] = [0.9992, 1.0123]$. We pick the average value in this interval, yielding $p = 1.0058$. The second ad-hoc restriction is that we arbitrarily set the quantity of trade in a DM match relative to its first-best level, $q/\bar{q}$. In the results reported below, we picked $q/\bar{q} = 0.7$. The choice of $q/\bar{q}$ is not without loss of generality. Indeed, by determining how efficient the economy is relative to the first best, it also determines the marginal welfare gains (or losses) that can occur away from the calibrated steady-state. Because welfare is not linear in q in our model, picking $q/\bar{q}$ impacts any quantitative welfare results we obtain. However, robustness checks described later show that these two ad-hoc restrictions have little impact when we compute the effect, in percentage terms, of anti-narcotic policies on outcomes of interest such as the quantity of DM trade, the quantity of coca-base produced, or the quantity of coca-base sold.[28] We focus on the latter and leave quantifying real outcomes in the utility (welfare) plane to future research.

[28] Significant differences in results between two calibrations corresponding to different choices of $q/\bar{q}$ or p only arise if a shock is large enough for the economy to switch to the autarky or first-best regime, in which case the impact on q is no longer linear, in one calibration and not in the other.

4.2 Quantitative results

Table 3 quantifies the impact of a 10% policy shock on DM trade (q), the supply of pesos (M), the supply of coca-base (M^b), the quantity of coca-base produced ($f(k^*)$), and the quantity of coca-base sold to intermediaries ($\tilde{\phi}M^b$). Figures 4 and 5 below, as well as Figures D1, D2, D3, and D4 in Appendix D show the response of equilibrium outcomes to a wider range of policy shocks.

For each outcome of interest, we present results for the full model (used for the calibration), as well as counterfactual results obtained by sequentially shutting down some of the channels present in the full model. In the first counterfactual, we fix the pesos supply, M, to its calibrated value. This is akin to assuming that coca-base shocks do not impact the flows of pesos supply into and out of the local economy. In the second counterfactual, we additionally fix the production of coca-base, $f(k^*)$, to its calibrated value. This implies that not only is the pesos supply independent of coca-base shocks, but so is the flow of coca-base into the local economy. Finally, in the third counterfactual we also fix the coca-base supply, M^b, to its calibrated value. Hence, not only is the pesos supply independent of coca-base shocks, but so is the flows of coca-base into and out of the local economy.

To help with intuition, the difference between the impact of a given policy under the full model and under the first counterfactual can be attributed to the change in the supply of pesos. The difference between results under the first counterfactual and the second counterfactual can be attributed to the impact of the policy on coca-base production. Finally, the difference between the second and the third counterfactual can be interpreted as the role of coca-base supply, independent of its production. Note that we do not present results under the second and third counterfactual models when we study shocks to A because changes in the efficiency of production only apply when coca-base production (and hence coca-base supply) is free.

We first notice that relatively small changes in policies, such as a 10% shock, produce sizable effects on our outcomes of interest. For example, let us consider a 10% increase in the seizure rate. This policy is expected to decrease the quantity of coca-base produced by 5.2% and the quantity of coca-base sold to intermediaries by 7.9%. This would simultaneously impact liquidity in the village by decreasing local trade by 8.5%. A large part of this negative liquidity impact comes from the 8.1% decrease in the supply of pesos that follows the increase in seizures. The latter is due both to the decrease in the volume of coca-sales (since there is less coca-base to sell) and the sale price (since the value of money goes up in the village following the monetary contraction). Were the pesos supply unchanged, local trade would only drop by 2.7%, i.e., only about a third of the true impact. Almost half of the 2.7% drop could then be attributed to the decrease in coca-base production.

	DM trade	Pesos supply	CB supply	CB sold	CB produced
10% $\uparrow$ in δ					
Full model	-8.5	-8.1	-7.5	-7.9	-5.2
Counter. 1	-2.7	0	-7.6	-8	-5.3
Counter. 2	-1.4	0	-2.4	-2.9	0
Counter. 3	-0.8	0	0	-0.5	0
10% $\downarrow$ in ϕ					
Full model	-6.3	-8.3	2	-8.2	-5.4
Counter. 1	-0.3	0	1.9	-8.3	-5.5
Counter. 2	1.2	0	7.9	-3	0
Counter. 3	-0.8	0	0	-10	0
10% $\downarrow$ in A					
Full model	-25.7	-26.2	-25.8	-25.8	-25.8
Counter. 1	-6.9	0	-26	-26	-26

Table 3: Impact of a 10% shock to δ, ϕ and A on equilibrium outcomes (expressed in %), both under the full model and under counterfactual assumptions.

Next, we saw in the theory section that the impact of a shock to the intermediary meeting rate, ϕ, may be ambiguous. A decrease in the meeting frequency puts upwards pressure on the coca-base supply, but it also decreases the value of coca-base for its holders, which also negatively impacts its production. Table 3 shows that under the full model specification, the negative effects would dominate. While the decrease in coca-base production does not entirely offset the decrease in coca-base outflows (coca-base supply increases by 2% on net), the decrease in value is such that overall, local trade drops by 6.3%. We can check with Counterfactual 2 that indeed, were the supply of pesos and the production of coca-base fixed, the decrease in ϕ would be beneficial to local trade due to the 7.9% predicted increase in coca-base supply.

Another interesting result to note is that the impact of a given policy on the two goals we consider (reducing coca-base supply and sales) is virtually identical in the full model and under Counterfactual 1.[29] This implies that from the point of view of a policymaker, a given goal can be achieved regardless of the impact of a policy on the local supply of pesos. Hence, the decrease in pesos supply, while largely damaging to local trade, is not required per se to achieve the policy goals of reducing coca-base production and sales. This implies that designing policies to replace the local loss in official currency due to anti-narcotic policies

[29]This is also visible graphically, since in Figures 5, D3, and D4, the dashed blue lines and black lines almost perfectly overlap.

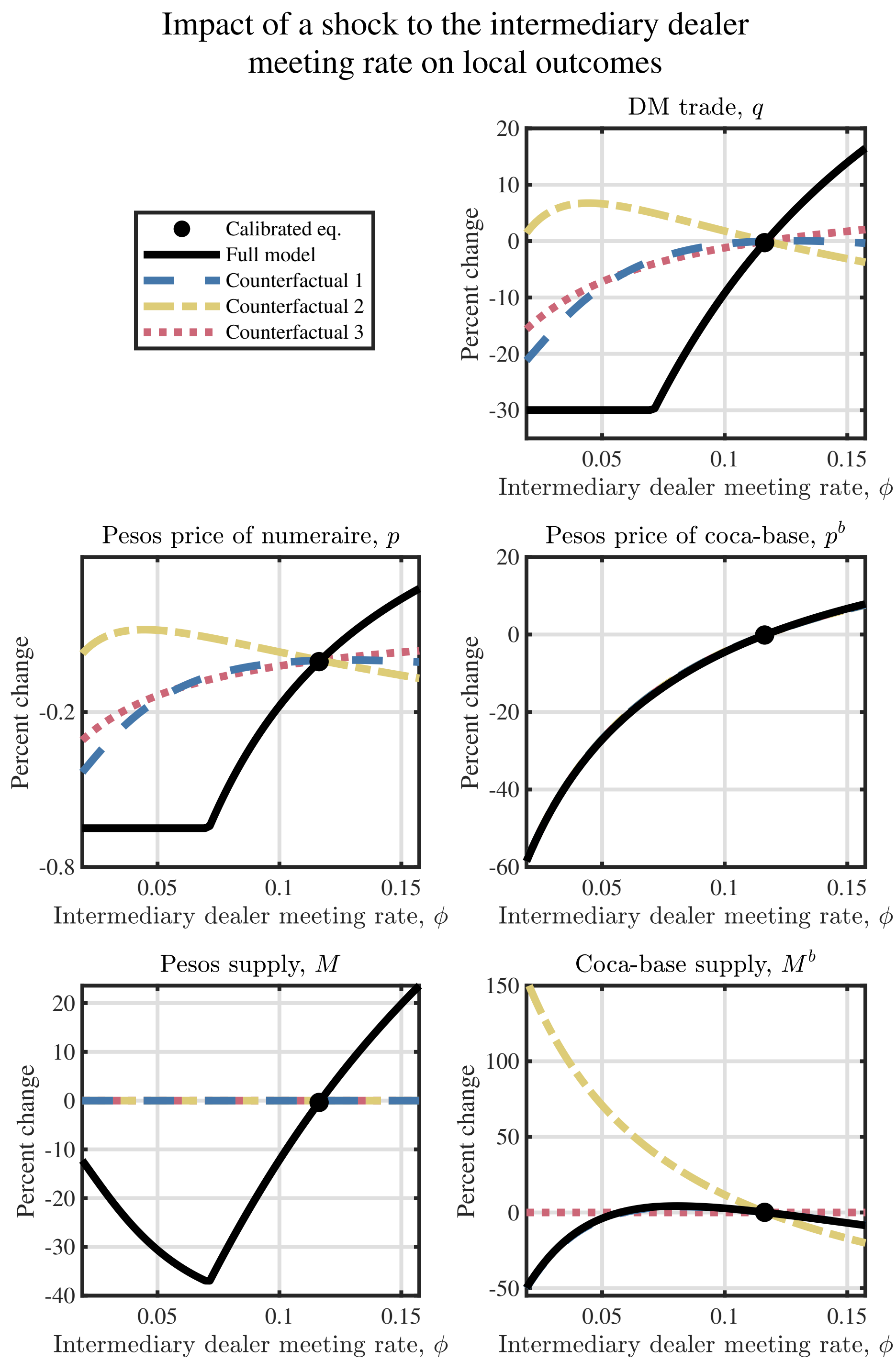

Figure 4: Local equilibrium outcomes as a function of the probability of meeting intermediaries.

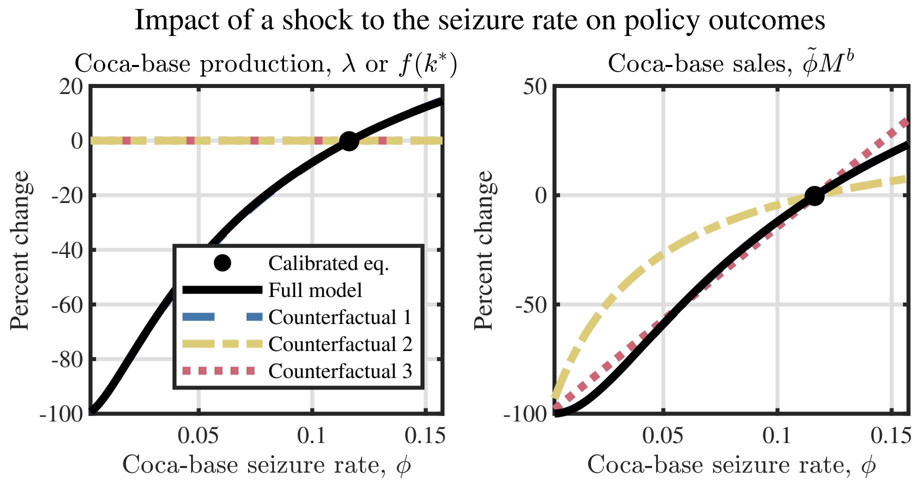

Figure 5: Policy outcomes as a function of the probability of meeting intermediaries.

should be a key focus, as it would not go in the way of anti-narcotic goals. While this may be obvious from an "income" point of view, our results show that this also holds from a "liquidity" point of view.

Last but not least, note that the impact of a policy on the pesos price of coca-base, p^b, is almost identical under the full model and the counterfactuals. Graphically, the four curves almost perfectly overlap in the middle-right panels of Figures 4, D1, and D2. Hence, the role played by the local value of coca-base is almost independent of the specification under consideration.

Now, the results presented above do not allow us to easily compare the liquidity impact across different policies, since the policy instruments do not have the same impact on policy goals in the first place. We would like to be able to compare, e.g., the liquidity impact of decreasing the production of coca-base by 1% when using seizures as a tool rather than intermediary crackdowns. We do so by producing policy possibility frontiers, represented in Figure 6. Each curve represents the equilibrium quantity of trade achieved inside the village against the equilibrium quantity of coca-base sold to intermediaries (left panel) or the equilibrium level of coca-base production (right panel), as policymakers vary either the degree of crop destruction (shock to A), seizures (shock to δ) and crackdown on intermediaries (shock to ϕ).

We can see that whether the policy goal is to decrease the amount of coca-base sold to intermediaries or the amount of coca-base produced, increasing seizures is the least desirable policy instrument. Indeed, for any given policy objective, achieving that objective through seizures leads to the largest drop in local trade. The intuition is that an increase in seizures negatively impacts all the channels that determine the liquidity of coca-base (holding costs,

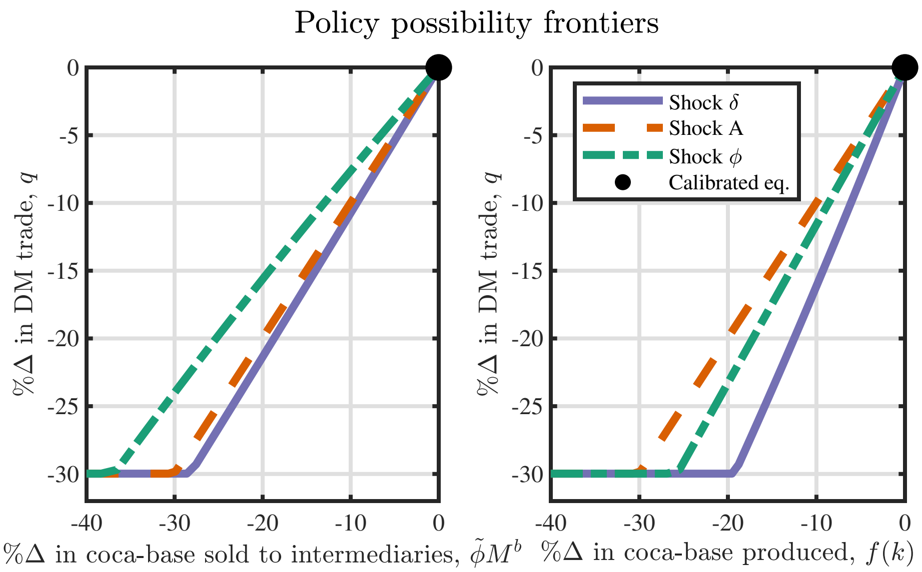

Figure 6: Policy possibility frontiers: percent change in the DM quantity traded, q, against the percent change in the quantity of coca-base sold to intermediaries (left panel) and the coca-base produced (right panel), across different policy instruments.

production, supply), while the other instruments have narrower effects. In other words, increasing seizures has an overly large impact on local trade relative to its impact on anti-narcotic objectives.

Next, determining whether targeting intermediaries or coca-crops is more desirable, however, depends on the policy objective. As one would expect, a policymaker who prioritizes reducing the production of coca-base should focus on coca crops destruction to minimize the impact on local liquidity, while a policymaker who prioritizes reducing coca sales should focus efforts on cracking down on intermediaries. Such focused policies allow achieving a given policy goal while minimizing the local impact on liquidity.

References

Massimo Amato and Luca Fantacci. Complementary currencies. *Handbook of the History of Money and Currency*, pages 501–522, 2020. doi: 10.1007/978-981-13-0596-2_50.

Yannis Bakos and Hanna Halaburda. The role of cryptographic tokens and icos in fostering platform adoption. *CESifo Working Paper*, 2019. doi: 10.2139/ssrn.3426940.

Vincent Bignon and Richard Dutu. Coin assaying and commodity money. *Macroeconomic Dynamics*, 21(6):1305–1335, 2017. doi: 10.1017/s1365100515000875.

Jérôme Blanc. *Les monnaies parallèles: unité et diversité du fait monétaire*. l'Harmattan, Paris, 2000.

Jérôme Blanc. Classifying “ccs”: Community, complementary and local currencies' types and generations. *International Journal of Community Currency Research*, 15, 2011.

Jerome Blanc. Thirty years of community and complementary currencies: a review of impacts, potential and challenges. *International Journal of Community Currency Research*, 16, 2012. URL https://shs.hal.science/halshs-00716906.

Jérôme Blanc. Unpacking monetary complementarity and competition: a conceptual framework. *Cambridge Journal of Economics*, 41(1):239–257, 2017. doi: 10.1093/cje/bew024.

Jérôme Blanc. *Les monnaies alternatives*. La Découverte, 2018. doi: 10.3917/dec.blanc.2018.02.

Kenneth Burdett, Alberto Trejos, and Randall Wright. Cigarette money. *Journal of Economic Theory*, 99(1-2):117–142, 2001. doi: 10.1006/jeth.2000.2731.

Rondo E Cameron et al. *A concise economic history of the world: from Paleolithic times to the present*. Oxford University Press, USA, 1993.

Andrés Cardona. El precio de la vida cuando pagas con coca. *El País*, April 2021. URL https://elpais.com/elpais/2021/03/26/album/1616776232_002258.html.

Mariana Colacelli and David JH Blackburn. Secondary currency: An empirical analysis. *Journal of monetary economics*, 56(3):295–308, 2009. doi: 10.1016/j.jmoneco.2009.02.002.

Lin William Cong, Ye Li, and Neng Wang. Token-based platform finance. *Journal of Financial Economics*, 144(3):972–991, 2022. doi: 10.1016/j.jfineco.2021.10.002.

Juan Pablo Cote. The effect of interdiction on coca cultivation in colombia. *Documento CEDE*, 18, 2019. doi: 10.2139/ssrn.3449268.

Ben R Craig and Christopher J Waller. Dual-currency economies as multiple-payment systems. *Economic review*, 36(1):2–13, 2000. URL https://fraser.stlouisfed.org/title/1328#4661.

Xavier Cuadras-Morató. Circulation of private notes during a currency shortage. *The Manchester School*, 77(4):461–478, 2009. doi: 10.1111/j.1467-9957.2009.02104.x.

Elisabeth Soller Curtis and Christopher J Waller. A search-theoretic model of legal and illegal currency. *Journal of Monetary Economics*, 45(1):155–184, 2000. doi: 10.1016/s0304-3932(99)00042-2.

Fernando Cárdenas. Un pueblo donde el dinero es coca. *El Tiempo*, April 2007. URL https://www.eltiempo.com/archivo/documento/MAM-2484852.

ElTiempo. La paz, un pueblo colombiano en el que la comida se paga con coca. *El Tiempo*, April 2007. URL https://www.eltiempo.com/colombia/otras-ciudades/la-paz-vereda-en-guaviare-en-donde-su-moneda-es-la-pasta-de-coca-137600.

Nicolás Espinosa. *Política de vida y muerte: etnografía de la violencia diaria en la Sierra de la Macarena*. Instituto Colombiano de Antropología e Historia Bogotá, 2010.

Michael S Evans. Zelizer's theory of money and the case of local currencies. *Environment and Planning A*, 41(5):1026–1041, 2009. doi: 10.1068/a4144.

Marie Fare and Pepita Ould Ahmed. Complementary currency systems and their ability to support economic and social changes. *Development and Change*, 48(5):847–872, 2017. doi: 10.1111/dech.12322.

Jesús Fernández-Villaverde and Daniel Sanches. Can currency competition work? *Journal of Monetary Economics*, 106:1–15, 2019. doi: 10.1016/j.jmoneco.2019.07.003.

Irving Fisher. *Stamp scrip*. New York: Adelphi, 1933.

Athanasios Geromichalos and Lucas Herrenbrueck. Monetary policy, asset prices, and liquidity in over-the-counter markets. *Journal of Money, Credit and Banking*, 48(1):35–79, 2016. doi: 10.1111/jmcb.12290.

Athanasios Geromichalos, Juan Manuel Licari, and José Suárez-Lledó. Monetary policy and asset prices. *Review of Economic Dynamics*, 10(4):761–779, 2007. doi: 10.1016/j.red.2007.03.002.

Georgina M Gómez. Large-scale currency circuits as anti-crisis mechanism: the argentine redes de trueque. In *Central Banking, Monetary Policy and the Future of Money*, pages 221–244. Edward Elgar Publishing, 2022. doi: 10.4337/9781800376403.00016.

Daniel C Hardy and Ashok K Lahiri. Cash shortage in the former soviet union. *Journal of Comparative Economics*, 22(2):119–140, 1996. doi: 10.1006/jcec.1996.0014.

Nicolas L Jacquet and Serene Tan. Money and asset prices with uninsurable risks. *Journal of Monetary Economics*, 59(8):784–797, 2012. doi: 10.1016/j.jmoneco.2012.10.018.

Oscar Jansson. Tríadas putumayenses: relaciones patrón-cliente en la economía de la cocaína. *Revista Colombiana de Antropología*, 42:223–247, 2006.

Nobuhiro Kiyotaki and Randall Wright. On money as a medium of exchange. *Journal of Political Economy*, 97(4):927–954, 1989. doi: 10.1086/261634.

Nobuhiro Kiyotaki and Randall Wright. A search-theoretic approach to monetary economics. *The American Economic Review*, pages 63–77, 1993. URL http://www.jstor.org/stable/2117496.

J Labrot. *Une histoire économique et populaire du Moyen Âge: Les jetons et les méreaux*. Errance Paris, 1989.

Ricardo Lagos. Asset prices, liquidity, and monetary policy in an exchange economy. *Journal of Money, Credit and Banking*, 43:521–552, 2011. doi: 10.1111/j.1538-4616.2011.00450.x.

Ricardo Lagos and Guillaume Rocheteau. Money and capital as competing media of exchange. *Journal of Economic theory*, 142(1):247–258, 2008. doi: 10.1016/j.jet.2006.07.005.

Ricardo Lagos and Randall Wright. A unified framework for monetary theory and policy analysis. *Journal of political Economy*, 113(3):463–484, 2005. doi: 10.1086/429804.

Ricardo Lagos, Guillaume Rocheteau, and Randall Wright. Liquidity: A new monetarist perspective. *Journal of Economic Literature*, 55(2):371–440, 2017.

Louis Larue. The case against alternative currencies. *Politics, Philosophy & Economics*, 21 (1):75–93, 2022. doi: 10.1177/1470594x211065784.

LeFigaro. Colombie: quand la coca remplace les pesos. *Le Figaro*, 2007. URL https://www.lefigaro.fr/international/2007/10/06/01003-20071006ARTFIG90665-colombie_quand_la_coca_remplace_les_pesos.php.

Benjamin Lester, Andrew Postlewaite, and Randall Wright. Information, liquidity, asset prices, and monetary policy. *The Review of Economic Studies*, 79(3):1209–1238, 2012. doi: 10.1093/restud/rds003.

Yiting Li, Guillaume Rocheteau, and Pierre-Olivier Weill. Liquidity and the threat of fraudulent assets. *Journal of Political Economy*, 120(5):815–846, 2012. doi: 10.1086/668864.

Bernard Lietaer. *Money and sustainability*. Triarchy Press, 2012.

Sebastien Lotz. Introducing a new currency: Government policy and prices. *European Economic Review*, 48(5):959–982, 2004. doi: 10.1016/j.euroecorev.2003.12.005.

Sebastien Lotz and Guillaume Rocheteau. On the launching of a new currency. *Journal of Money, Credit and Banking*, pages 563–588, 2002. doi: 10.1353/mcb.2002.0003.

Adam P Marshall and Daniel W O'Neill. The bristol pound: A tool for localisation? *Ecological Economics*, 146:273–281, 2018. doi: 10.1016/j.ecolecon.2017.11.002.

Jens Martignoni. A new approach to a typology of complementary currencies. *International Journal of Community Currency Research*, 16(A):1–17, 2012.

Jeremy McDermott. Town where cocaine is the only currency. *The Telegraph*, 2008. URL https://www.telegraph.co.uk/news/worldnews/southamerica/colombia/2135436/Town-where-cocaine-is-the-only-currency.html.

Daniel Mejía. Plan colombia: an analysis of effectiveness and costs. *Washington, DC: Brookings Institution*, 2015.

Daniel Mejía and Daniel M Rico. *La microeconomía de la producción y tráfico de cocaína en Colombia*. Universidad de los Andes, Facultad de Economía, 2010.

Arnaud Michel and Marek Hudon. Community currencies and sustainable development: A systematic review. *Ecological economics*, 116:160–171, 2015. doi: 10.1016/j.ecolecon.2015.04.023.

MinComercio. Información: Perfiles económicos departamentales. *Informe de la Oficina de Estudios Económicos del Ministerio de Comercio basado en cifras del DANE*, 2022.

MinJusticia. Observatorio de drogas de colombia, n.d. Accessed on January 12, 2023.

Ed Nosal and Guillaume Rocheteau. Pairwise trade, asset prices, and monetary policy. *Journal of Economic Dynamics and Control*, 37(1):1–17, 2013. doi: 10.1016/j.jedc.2012.07.005.

Mark S Peacock. Complementary currencies: History, theory, prospects. *Local Economy*, 29 (6-7):708–722, 2014. doi: 10.1177/0269094214553174.

Policia-Nacional. Análisis del mercado de la cocaína 2020. *Informe del Centro Internacional de Estudios Estratégicos contra el Narcotráfico*, 2021.

Guillaume Rocheteau and Ed Nosal. *Money, payments, and liquidity*. MIT Press, 2017. doi: 10.7551/mitpress/10518.001.0001.

Guillaume Rocheteau and Randall Wright. Liquidity and asset-market dynamics. *Journal of Monetary Economics*, 60(2):275–294, 2013. doi: 10.1016/j.jmoneco.2012.11.002.

Bruno Nogueira Silva, Wesley Vieira da Silva, Alvaro Fabiano Pereira de Macêdo, Natallya de Almeida Levino, Luciano Luiz Dalazen, Fabíola Kaczam, and Claudimar Pereira da Veiga. A systematic review on social currency: a one-decade perspective. *Journal of Financial Services Marketing*, pages 1–17, 2023. doi: 10.1057/s41264-023-00231-x.

Julie Turkewitz. Five years after peace deal, colombia is running out of time, experts say. *The New York Times*, April 2021. URL https://www.nytimes.com/2021/09/26/world/americas/colombia-peace-deal-farc.html.

UNODC. *Monitoreo de Territorios Afectados por Cultivos Ilícitos 2020*. Oficina de las Naciones Unidas contra la Droga y el Delito, 2021.

François R Velde, Warren E Weber, and Randall Wright. A model of commodity money, with applications to gresham's law and the debasement puzzle. *Review of Economic Dynamics*, 2(1):291–323, 1999. doi: 10.1006/redy.1998.0037.

Carlos Villalón. Cocaine country. the colombian villages where coke is king. *National Geographic Magazine.*, Jul 2004.

Neil Wallace and Ruilin Zhou. A model of a currency shortage. *Journal of Monetary Economics*, 40(3):555–572, 1997. doi: 10.1016/s0304-3932(97)00053-6.

Lina Álvarez and Shirley Forero. Hambre e incertidumbre en territorios cocaleros. *El Cuarto Mosquetero*, April 2023. URL http://hambre-e-incertidumbre-en-territorios-cocaleros.elcuartomosquetero.com/.

Appendix A Proofs

Lemma 1 We first prove that the first-order condition (12) admits a solution, and that it is unique, if and only if $p < [1-(1-\alpha)\beta]/\alpha$. Rearrange the FOC as

$$1-\beta-\alpha\max\{p-\beta,0\} = \sigma S^{b'}(z;p). \tag{A1}$$

The left-hand-side is independent of z. The right-hand side is equal to $\sigma\theta[\alpha\max\{p-\beta,0\}+\beta]/(1-\theta)$ when $z=0$, 0 when $z \geq \bar{z}$ where $\bar{z} = \{z : p(\bar{q}) = \beta+\alpha\max\{p-\beta,0\}\}$, and it continuously decreases in between. It follows directly that there exists a solution, and that it is unique, if and only if $(1-\theta)/[1-(1-\sigma)\theta] \leq \beta+\alpha\max\{p-\beta,0\} < 1$. The first inequality is always true since we assumed that $\theta > (1-\beta)/(1-\beta+\beta\sigma)$. The second inequality is true as long as $p < [1-(1-\alpha)\beta]/\alpha$.

Second, we show that the solution to the FOC is such that $\tilde{z}(p)$ is weakly increasing in p. When $p > \beta$, the FOC can be rewritten as

$$\frac{1}{\alpha p+(1-\alpha)\beta} - 1 = \sigma\left\{\frac{u'[p^{-1}(\tilde{z})]}{p'[p^{-1}(\tilde{z})]} - 1\right\}. \tag{A2}$$

The left-hand-side decreases in p and the right-hand-side decreases in $\tilde{z}$, so $\tilde{z}$ and p are positively related. When $p \leq \beta$, the left-hand-side becomes $1/\beta - 1$, so that $\tilde{z}$ is independent of p.

Lemma 2 We first prove the existence and uniqueness of $\underline{q}$, $\underline{M}$, $\bar{p}$ and $\bar{M}$. Recall that $\underline{q}$ satisfies $(1-\beta)/\beta = \sigma\left[u'(q)/p'(q)-1\right]$ by definition. The left-hand side is constant. The right-hand side continuously decreases in q, it tends to 0 when q goes to ∞, and it tends to $\sigma\theta/(1-\theta)$ when q goes to 0. We know that $(1-\beta)/\beta > 0$ since $\beta \in (0,1)$, and $\sigma\theta/(1-\theta) > 1-\beta$ since we assumed that $\theta > (1-\beta)/(1-\beta+\beta\sigma)$. Therefore, $\underline{\mathrm{q}}$ exists and is unique. Next, $p(q)$ is well-defined on $\mathbb{R}$ and strictly increasing in q, therefore $\underline{\mathrm{M}}$ exists and is unique. The existence and uniqueness of $\bar{p}$ and $\bar{M}$ directly follow. Next, $\bar{M} > \underline{M}$ since $p(\bar{q}) > p(\underline{q})$ by definition and $\bar{p} > 1$.

Next, consider the autarky regime. It is such that $p < \beta$ (i.e., villagers who access the OM prefer not to buy the OM good). The first-order condition, (12), becomes $1-\beta = \sigma S^{b\prime}(z)$. This equation holds only if the right-hand side is greater than zero. According to (13), this requires or $\tilde{z} < p(\bar{q})$, in which case $S^{b\prime}(z) = \{u'[p^{-1}(\beta z)]/p'[p^{-1}(\beta z)]-1\}\,\beta$ (where we used $\tilde{z} = \beta z$). From (9), we also know that $q = p^{-1}(\beta z)$. Plugging these two elements into (12), we obtain that the solution to the first-order solution must be $q = p^{-1}(\beta z) = \underline{q}$, and $z = p(\underline{\mathrm{q}})/\beta$. Note that $\tilde{z} = p(\underline{q}) < p(\bar{q})$. Finally, by market clearing, $p = M/z = \beta M/p(\underline{q})$, so that the condition $p < \beta$ can be rewritten as $\beta M/p(\underline{q}) < \beta$, or $M < p(\underline{q})$, where the right-hand side thus defines the threshold $\underline{M}$.

Now consider equilibria such that the OM is active. Therefore, $p \geq \beta$. The first-order condition, (12), becomes $1 - \beta = \sigma S^{b\prime}(z) + \alpha(p - \beta)$. There are then two cases, depending on whether the first-best level of trade is achieved in the DM.

We start with the case where the first best is reached, i.e., $q = \bar{q}$. According to (13), $S^{b\prime}(z) = 0$. Thus, the first-order condition pins down the price level $p = (1 - \beta + \alpha\beta)/\alpha \equiv \bar{p}$. The market clearing condition then implies $z = M/\bar{p}$. Finally, from (9), this regime requires $\tilde{z} \geq p(\bar{q})$, which here is equivalent to $[\alpha(\bar{p} - \beta) + \beta]z \geq p(\bar{q})$. After plugging $\bar{p}$ in, we can rewrite the inequality as $M \geq \bar{p}p(\bar{q})$, where the right-hand side gives us the threshold $\bar{M}$.

Finally, we study the intermediate case, where the OM is active but $q < \bar{q}$. From, (9), the latter implies $\tilde{z} < p(\bar{q})$. Then, plugging in for (13) and the market clearing condition $M = pz$ into the first-order condition (12), the equilibrium can be summarized by a single equation with one unknown (z),

$$1 - \left[\alpha\frac{M}{z} + (1-\alpha)\beta\right] = \sigma\left\{\frac{u' \circ p^{-1}\left[\left(\alpha\frac{M}{z} + (1-\alpha)\beta\right)z\right]}{p' \circ p^{-1}\left[\left(\alpha\frac{M}{z} + (1-\alpha)\beta\right)z\right]} - 1\right\}\left[\alpha\frac{M}{z} + (1-\alpha)\beta\right]. \quad \text{(A3)}$$

The left-hand side is strictly increasing in z. Its limits as z tends to 0 and $+\infty$ are respectively $-\infty$ and $1 - (1-\alpha)\beta$. The right-hand side is decreasing in z, with a limit equal to zero when z grows large enough. Because $1 - (1-\alpha)\beta > 0$, (A3) admits a unique solution. Note that it is straightforward to check that when $M = \underline{M}$, the solution to (A3) is $z = \underline{z}$, so that $p = \beta$, and when $M = \bar{M}$, its solution is $z = M/\bar{p}$, so that $p = \bar{p}$. Hence, the intermediate case converges to the autarky case and to the first-best case when M goes to $\underline{M}$ and $\bar{M}$, respectively.

Last but not least, we need to show how equilibrium outcomes vary as a function of the parameter M in the intermediate regime where $M \in (\underline{M}, \bar{M})$. From the payment equation, $\tilde{z} = p(q)$, we directly obtain that $\tilde{z}$ and q move in the same direction. From the FOC, $1/[\alpha p + (1-\alpha)\beta] - 1 = \sigma[u'(q)/p'(q) - 1]$, we obtain that $\tilde{z}$ and p also move in the same direction. Making use of the definition of $\tilde{z}$ with the market clearing condition, we obtain $\tilde{z} = \alpha M + (1-\alpha)\beta/p$. Since $\tilde{z}$ and p move in the same direction, it must also be the case for M. Hence, we showed that $\tilde{z}$, p, and q all move in the same direction as M equilibrium. This also confirms that $p > \beta$ when $M > \underline{M}$.

Proposition 1 Lemma 2 provides equilibrium outcomes as a function of M. To prove Proposition 1, we need to establish the mapping between the parameters α/ψ and the endogenous variable M. In steady state, the money supply satisfies $\psi/\alpha = \tau(M)M$, where

$\tau(M)$ is given by (15). Hence, we can establish the correspondence

$$\frac{\psi}{\alpha}(M) = \begin{cases} 0 & \text{if } 0 \leq M < \underline{M} \\ \frac{\psi}{\alpha} \in [0, \underline{M}] & \text{if } M = \underline{M} \\ M & \text{if } M > \underline{M} \end{cases} \tag{A4}$$

We can invert this correspondence to get

$$M(\psi/\alpha) = \begin{cases} M \in [0, \underline{M}] & \text{if } \psi/\alpha = 0 \\ \underline{M} & \text{if } 0 < \psi/\alpha \leq \underline{M} \\ \psi/\alpha & \text{if } \psi/\alpha > \underline{M}. \end{cases} \tag{A5}$$

Proposition 1 then directly follows from combining this mapping with Lemma 2 (in particular, note that any $\psi/\alpha > 0$, is mapped to a unique $M \geq \underline{M}$).

Lemma 3 We first show how to obtain the portfolio problem given by (20). The lifetime discounted utility of entering the CM with a portfolio (z^-, b^-) (after seizures and meetings with intermediaries) is given by

$$V_1(z^-, b^-) = \max_{x,z,b} \{x + V_2(z, b)\} \text{ s.t. } x + z + \frac{p^b}{p} b = z^- + \frac{p^b}{p}(b^- + \lambda) + \frac{\psi}{p}. \tag{A6}$$

Hence,

$$V_1(z^-, b^-) = z^- + \frac{p^b}{p}(b^- + \lambda) + \frac{\psi}{p} + \max_{z,b} \left\{-z - \frac{p^b}{p} b + V_2(z, b)\right\}. \tag{A7}$$

Next, the lifetime discounted value of entering the DM with a portfolio (z, b) is

$$\begin{aligned} V_2(z, b) = {} & \sigma \left\{u[q(z, b)] + V_3[z - d^z(z, b), b - d^b(z, b)]\right\} \\ & + \sigma \mathbb{E} \left\{-c[q(\bar{z}, \bar{b})] + V_3[z + d^z(\bar{z}), b + d^b(\bar{b})]\right\} \\ & + (1 - 2\sigma) V_3(z, b), \end{aligned} \tag{A8}$$

where (d^z, d^b) are the transfers of official currency and coca-base from the buyer to the seller in a DM match and $(\bar{z}, \bar{b})$ is the seller's portfolio. The lifetime discounted utility of entering the third stage with a portfolio (z, b) is

$$\begin{aligned} V_3(z,b) = \alpha \max_{y_o \in [0,pz]} & \left\{ y_o + (1-\delta-\tilde{\phi})\beta V_1\left(z - \frac{y_o}{p}, b\right) + \delta\beta V_1\left(z-\frac{y_o}{p}, 0\right) \right. \\ & \left. + \tilde{\phi}\beta\left[V_1\left(z-\frac{y_o}{p},0\right) + \nu b\right] \right\} \\ & + (1-\alpha)\beta\left\{(1-\delta-\tilde{\phi})V_1(z,b) + \delta V_1(z,0) + \tilde{\phi}\left[V_1(z,0)+\nu b\right]\right\} \\ & = [\beta + \alpha\max(p-\beta,0)]z + \beta\left[\tilde{\phi}\nu + (1-\delta-\tilde{\phi})\frac{p^b}{p}\right]b + \beta V_1(0,0). \end{aligned} \tag{A9}$$

Plugging in for V_3 into V_2, then V_2 into V_1, we obtain (20), where the buyer's bargaining surplus is given by

$$\begin{aligned} S^b &\equiv u(q) + V^3(z-d^z, b-d^b) - V^3(z,b) \\ &= u(q) - [\beta + \alpha\max(p-\beta,0)]d^z - \beta\left[\tilde{\phi}\nu + (1-\delta-\tilde{\phi})\frac{p^b}{p}\right]d^b. \end{aligned} \tag{A10}$$

The seller's bargaining surplus is still given by $S^s = u(q) - c(q) - S^b$. We can then solve for the DM bargaining problem,

$$\max_{q,d^z,d^b} u(q) - c(q) \tag{A11}$$

subject to $d^z \le z$, $d^b \le b$ and $S^b = \theta[u(q)-c(q)]$. The solution is

$$q = \begin{cases} \bar{q} & \text{if } \tilde{z} + \tilde{b} \ge p(\bar{q}) \\ p^{-1}(\tilde{z}+\tilde{b}) & \text{otherwise,} \end{cases} \tag{A12}$$

and

$$(d^z, d^b) = \begin{cases} \{(d^z,d^b) \le (z,b) : \tilde{z}d^z/z + \tilde{b}d^b/b = p(\bar{q})\} & \text{if } \tilde{z}+\tilde{b} \ge p(\bar{q}) \\ (z,b) & \text{otherwise,} \end{cases} \tag{A13}$$

from which we obtain the surplus equation (21).

We now move onto deriving results for the autarky regime. The FOC with respect to z is

$$1 - \beta = \sigma\frac{\partial S^b(z,b)}{\partial z}, \tag{A14}$$

where

$$\frac{\partial S^b(z,b)}{\partial z} = \begin{cases} 0 & \text{if } \tilde{z}+\tilde{b} \ge p(\bar{q}) \\ \beta\left[\frac{u' \circ p^{-1}(\tilde{z}+\tilde{b})}{p' \circ p^{-1}(\tilde{z}+\tilde{b})} - 1\right] & \text{otherwise.} \end{cases} \tag{A15}$$

Thus, in a monetary equilibrium, we must have $\tilde{z} + \tilde{b} < p(\bar{q})$, and hence $q = p^{-1}(\tilde{z} + \tilde{b})$. Plugging these results into the FOC, we can see that $q = \underline{q}$. Next, note that

$$\frac{\partial S^b(z,b)}{\partial b} = \begin{cases} 0 & \text{if } \tilde{z} + \tilde{b} \geq p(\bar{q}) \\ \beta \left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p}\right] \left[\frac{u' \circ p^{-1}(\tilde{z}+\tilde{b})}{p' \circ p^{-1}(\tilde{z}+\tilde{b})} - 1\right] & \text{otherwise.} \end{cases} \tag{A16}$$

Thus, $\partial S^b(z,b)/\partial b = \left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p}\right] [\partial S^b(z,b)/\partial z]$, which we can use to simplify the FOC with respect to b, (23), to $p^b/p = \tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)p^b/p$. Solving this last equation, we obtain $p^b/p = (\underline{p^b/p}) < \nu$. Next, recall that the liquidity constraint is binding, hence $p(\underline{q}) = \beta z + \beta[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)(\underline{p^b/p})]b$. After plugging in for the market clearing condition $b = M^b$ and for $(\underline{p^b/p})$, we can solve for z and obtain $z = \underline{z}'$. It is smaller than $\underline{z}$ since $\tilde{\phi}\nu M^b/(\tilde{\phi} + \delta) > 0$. In addition, market clearing for paper money requires $pz = M$, so that $p = M/\underline{z}'$. Finally, we can derive the condition for the economy to be in this regime: $p < \beta$ is equivalent to $M/\underline{z}' < \beta$, which we can rearrange to $M < \underline{M}'$. The latter is smaller than $\underline{M}$ since $\beta(\underline{p^b/p})M^b > 0$.

We now turn to regimes where the local economy is not in autarky. We start with the case where first-best DM trade is achieved, $q = \bar{q}$, and thus $\partial S^b(z,b)/\partial z = \partial S^b(z,b)/\partial b = 0$. The FOC for z is $1-\beta = \alpha(p-\beta)$, so $p = \bar{p}$. The FOC for b is $p^b/\bar{p} = \beta[\tilde{\phi}\nu + (1-\tilde{\phi}-\delta)p^b/\bar{p}]$, from which we can solve for $p^b/\bar{p}$ and check that $p^b = \bar{p}^b$. Note that $\bar{p}^b/\bar{p} < \nu$ if and only if $\beta(1-\delta) < 1$, which always holds. Next, market clearing for paper money requires $z = M/\bar{p}$. Finally, the condition for this regime to hold is that liquidity needs are satiated, $\tilde{z} + \tilde{b} \geq p(\bar{q})$. Plugging in for $\bar{p}$ and $\bar{p}^b$, it is easy to show that $\tilde{z} = z$ and $\tilde{b} = (\bar{p}^b/\bar{p})b$. Thus, the condition for liquidity needs to be satiated can be written as $M/\bar{p} + (\bar{p}^b/\bar{p})M^b \geq p(\bar{q})$, where we made use of both the coca-base and the paper money market clearing conditions. Rearranging that equation yields $M \geq \bar{M}'$. The latter is smaller than $\bar{M}$ since $\bar{p}^b M^b > 0$.

Finally, we solve for the case where the first-best DM trade is not achieved. The equilibrium triple $(q, p, p^b/p)$ satisfies

$$1 - [\alpha p + (1-\alpha)\beta] = \sigma[\alpha p + (1-\alpha)\beta] \left[\frac{u'(q)}{p'(q)} - 1\right], \tag{A17}$$

$$\frac{p^b}{p} - \beta\left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p}\right] = \sigma\beta\left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p}\right]\left[\frac{u'(q)}{p'(q)} - 1\right], \tag{A18}$$

and

$$p(q) = [\alpha p + (1-\alpha)\beta]\frac{M}{p} + \beta\left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p}\right]M^b. \tag{A19}$$

Now denote $\tilde{M} \equiv M + p^b M^b$ and $\mathcal{L} \equiv \tilde{M}/p$. Combining (A17) and (A18), we directly obtain

$$\beta \left[\tilde{\phi}\nu + (1 - \tilde{\phi} - \delta)\frac{p^b}{p} \right] = [\alpha p + (1-\alpha)\beta]\frac{p^b}{p}. \tag{A20}$$

Making use of this result into (A19), we can easily show that $p(q) = [\alpha p + (1-\alpha)\beta]\mathcal{L}$, and therefore $q = p^{-1}[(\alpha p + (1-\alpha)\beta)\mathcal{L}]$. Then, we can rewrite (A17) as

$$1 - \left[\alpha\frac{\tilde{M}}{\mathcal{L}} + (1-\alpha)\beta\right] = \sigma\left[\alpha\frac{\tilde{M}}{\mathcal{L}} + (1-\alpha)\beta\right]\left[\frac{u' \circ p^{-1}[(\alpha\frac{\tilde{M}}{\mathcal{L}} + (1-\alpha)\beta)\mathcal{L}]}{p' \circ p^{-1}[(\alpha\frac{\tilde{M}}{\mathcal{L}} + (1-\alpha)\beta)\mathcal{L}]} - 1\right]. \tag{A21}$$

We know from the proof of Lemma 2 that this equation admits a unique solution $\mathcal{L}(\tilde{M})$ for any $\tilde{M} \in [\underline{M}, \bar{M}]$. The solution is continuous in $\tilde{M}$, it is equal to $p(\underline{q})/\beta$ when $\tilde{M} = \underline{M}$ and $p(\bar{q})$ when $\tilde{M} = \bar{M}$. We also know that the solution $\mathcal{L}(\tilde{M})$ is such that $p = \tilde{M}/\mathcal{L}(\tilde{M})$ is continuously increasing in $\tilde{M}$ between $[\underline{M}, \bar{M}]$, with bounds β and $\bar{p}$ respectively.

Next, (A20) allows to solve for p^b/p as a function of p and exogenous parameters. When $\tilde{M}$ goes to $\underline{M}$, p goes to β and therefore p^b/p goes to $\underline{(p^b/p)}$. When $\tilde{M}$ goes to $\bar{M}$, p goes to $\bar{p}$ and therefore p^b/p goes to $\bar{p}^b/\bar{p}$. In between, p^b/p continuously decreases as a function of p, and thus it continuously decreases as a function of $\tilde{M}$.

The first-order condition with respect to z, (A17), allows us to solve for q as a function of p. When $\tilde{M}$ goes to $\underline{M}$, p goes to β and therefore q goes to $\underline{q}$. When $\tilde{M}$ goes to $\bar{M}$, p goes to $\bar{p}$ and therefore q goes to $\bar{q}$. In between, q continuously increases as a function of p, and thus it continuously increases as a function of $\tilde{M}$.

Finally, we can back out the supply of official currency, M, that is consistent with a given $\tilde{M}$ in equilibrium, using the payment equation (A19). When $\tilde{M}$ goes to $\underline{M}$, p goes to β and therefore M goes to $\underline{M}'$. When $\tilde{M}$ goes to $\bar{M}$, p goes to $\bar{p}$ and therefore M goes to $\bar{M}'$. To study what happens in between, note that the left-hand side increases in q, thus it increases in $\tilde{M}$. For a given M, the right-hand side decreases in p and increases in p^b/p, thus it decreases in $\tilde{M}$. Therefore, there is unique M solution to (A19) for a given $\tilde{M}$, and it is a continuously increasing function of $\tilde{M}$.

This concludes the proof that an equilibrium exists and is unique for any $M \in [\underline{M}', \bar{M}']$, and that it satisfies (A17), (A18) and (A20).

Having shown that an equilibrium exists and is unique when $M \in [\underline{M}', \bar{M}']$, we turn to comparative statics. The steps above already show that an increase in M increases q, and p but decreases p^b/p. This is also illustrated in Figure 7, which shows the construction of an equilibrium given M. In addition, the payment equation $p(q) = \tilde{z} + \tilde{b}$ implies a positive relation between q and $(\tilde{z} + \tilde{b})$.

Lastly, we use equation (A20) to establish the sign of $\partial p^b/\partial p$. Rearranging the equation,

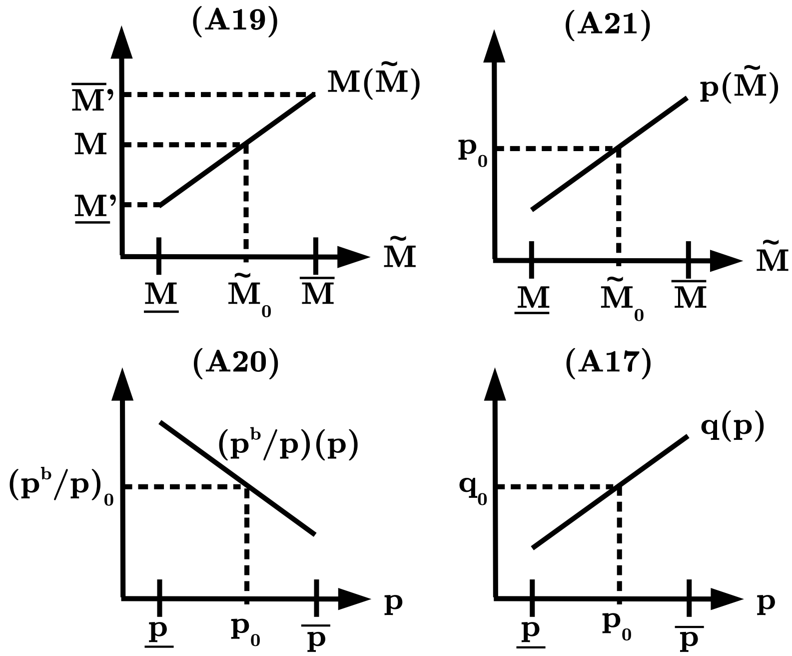

Figure 7: Construction of a coca-base equilibrium given M.

we obtain

$$p^b = \frac{\beta\tilde{\phi}\nu p}{\alpha(p-\beta)+\beta(\delta+\tilde{\phi})}. \tag{A22}$$

Taking the derivative with respect to p shows that p^b increases in p if and only if $\delta+\tilde{\phi} > \alpha$, is independent of p if and only if $\delta+\tilde{\phi} = \alpha$, and is decreasing in p otherwise. Since p is a continuously increasing function of M, these results extend to the relation between p^b and M.

Finally, we need to check that it is indeed always worth it for villagers to sell the coca-base to intermediaries when they meet them rather than keeping it for liquidity purposes. We showed that p^b/p is weakly decreases as a function of M, and it tends to $\underline{(p^b/p)} < \nu$ as M tends to 0. Hence, $p^b/p < \nu$ for $M > 0$, which concludes the proof.

Proposition 2 We follow a strategy similar to that used to prove Proposition 1. In steady state, the supply of official currency is still such that $\tau(M)M = \psi/\alpha$ where $\tau(M)$ is given by (15). Hence, we can establish the correspondence

$$\frac{\psi}{\alpha}(M) = \begin{cases} 0 & \text{if } 0 \le M < \underline{M}' \\ \frac{\psi}{\alpha} \in [0, \underline{M}'] & \text{if } M = \underline{M}' \\ M & \text{if } M > \underline{M}' \end{cases} \tag{A23}$$

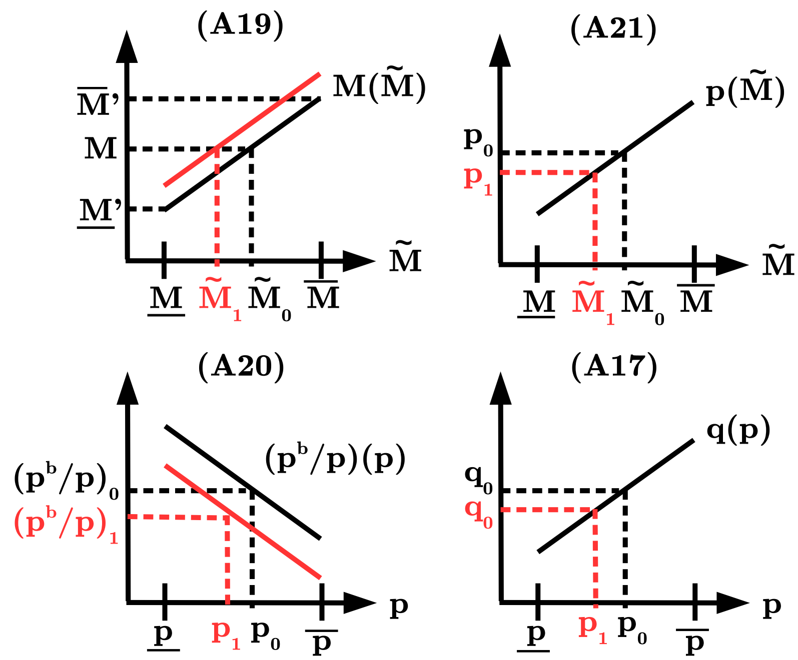

Figure 8: Impact of an increase in δ on equilibrium equations and outcomes.

We can invert this correspondence to get

$$M(\psi/\alpha) = \begin{cases} M \in [0, \underline{M}'] & \text{if } \psi/\alpha = 0 \\ \underline{M}' & \text{if } 0 < \psi/\alpha \leq \underline{M}' \\ \psi/\alpha & \text{if } \psi/\alpha > \underline{M}'. \end{cases} \tag{A24}$$

Proposition 2 then directly follows from combining this mapping with Lemma 3 (in particular, note that any $\psi/\alpha > 0$, is mapped to a unique $M \geq \underline{M}'$).

Proposition 3 First, note that everything else equal, $M_1^b > M_2^b = 0$ implies $\underline{M}_1' < \underline{M}_1 = \underline{M}_2$ and $\bar{M}_1' < \bar{M}_1 = \bar{M}_2$. Assume first that $\psi/\alpha \leq \underline{M}_1'$, Then, both economies trade at a level $\underline{q}$, and they have the same local welfare. Assume instead that $\psi/\alpha \geq \bar{M}_2$. Then, both economies trade at a level $\bar{q}$, the first best. Finally, assume that $\psi/\alpha \in (\underline{M}_1', \bar{M}_2)$. Then there are three subscases. If $\psi/\alpha \geq \bar{M}_1'$, economy 1 enjoys $q_1 = \bar{q}$ while economy 2 enjoys $q_2 < q_1$. If $\psi/\alpha \leq \underline{M}_2$, economy 2 enjoys $q_2 = \underline{q}$ while economy 1 enjoys $q_1 > \underline{q}$. If $\psi/\alpha \in (\underline{M}_2, \bar{M}_1')$, both economies are in the intermediate regime. Total liquidity in economy 1 is $\tilde{M}_1 = \psi/\alpha + p^b M_1^b$ while total liquidity in economy 2 is $\tilde{M}_2 = \psi/\alpha < \tilde{M}_1$. Then, $\mathcal{L}_1 > \mathcal{L}_2$ and thus $q_1 > q_2$. Rankings for $\mathcal{W}$ follow.

Results from Section 3.3 Consider a coca-base equilibrium with $M \in (\underline{M}', \bar{M}')$. We start by studying the impact of an increase in δ, as illustrated in Figure 8. Note first that the relation between $\tilde{M}$ and p and the relation between q and p, respectively given by (A21) and (A17), are unchanged. This implies that $q(\tilde{M})$ is not impacted. Graphically, the curves in the top- and bottom-right panels of Figure 8 is unchanged. The relation between p^b/p and p changes, however, as we can see from (A20). An increase in δ reduces p^b/p conditional on p (and thus reduces p^b/p given $\tilde{M}$). This is represented graphically by a downwards shift of the curve in the bottom-left panel of 8. Finally, we study the relation between M and $\tilde{M}$, given by (A19). The left-hand side is unchanged since $q(\tilde{M})$ is unchanged. On the right-hand side, p^b/p is smaller given $\tilde{M}$. The coca-base supply $M^b = \lambda/(\delta + \tilde{\phi})$ is also smaller for any $\tilde{M}$. The equality in (A19) can therefore only hold if $M(\tilde{M})$ increases given $\tilde{M}$, which is represented by an upwards shift of the curve in the top-left panel. We can then reconstruct the equilibrium following the increase in δ. Starting from the original money supply M, the corresponding total liquidity $\tilde{M}$ is now smaller (top-left panel). Thus, p is lower (top-right panel). This leads to a reduction in q, as shown in the bottom-right panel. The impact on p^b/p, shown in the bottom-left panel, is ambiguous.

Second, we consider a decrease in λ. Again, the relation between $\tilde{M}$ and p and the relation between q and p are unchanged, which would leave the curves in the top- and bottom-right panels of Figure 7 unchanged. In addition, the relation between p^b/p and p is unchanged as well, leaving the curve in the bottom-left panel of 7 unchanged. Regarding the relation between M and $\tilde{M}$, the only change is that the coca-base supply $M^b = \lambda/(\delta + \tilde{\phi})$ is smaller for any $\tilde{M}$. The equality in (A19) can therefore only hold if $M(\tilde{M})$ increases given $\tilde{M}$, which is represented by an upwards shift of the curve in the top-left panel. We can then reconstruct the equilibrium following the same method as above, and the comparative statics follow.

Third, we consider a decrease in ν. Again, the relation between $\tilde{M}$ and p and the relation between q and p are unchanged, which would leave the curves in the top- and bottom-right panels of Figure 7 unchanged. The relation between p^b/p and p changes, as we can see from (A20). An decrease in ν reduces p^b/p conditional on p (and thus reduces p^b/p given $\tilde{M}$). This would be represented graphically by a downwards shift of the curve in the bottom-left panel of 7. Regarding the relation between M and $\tilde{M}$, the only change is that p^b/p is lower for any given $\tilde{M}$, hence the equality in (A19) can only hold if $M(\tilde{M})$ increases given $\tilde{M}$. This would be represented by an upwards shift of the curve in the top-left panel of 7. We can then once again reconstruct the equilibrium following the same method as above, and the comparative statics follow.

Finally, we consider a decrease in ϕ. As before, this has no impact on the relation between $\tilde{M}$ and p and the relation between q and p, leaving the curves in the top- and bottom-right panels of Figure 7 unchanged. The relation between p^b/p and p changes, however. A decrease in ϕ reduces p^b/p conditional on p (and thus reduces p^b/p given $\tilde{M}$). This would be represented graphically by a downwards shift of the curve in the bottom-left panel of 7. Regarding the relation between M and $\tilde{M}$, given by (A19), changes again appear through p^b/p and M^b. However, while p^b/p is lower for any $\tilde{M}$ (as was the case after the increase in δ and the decrease in ν), M^b is higher conditional on $\tilde{M}$ (contrary to what occurred following the decrease in λ and the increase in δ). Therefore, the impact of a change in ϕ on the relation between M and $\tilde{M}$ depends on the sign of $\partial \left\{ \beta[\tilde{\phi}\nu + (1-\delta-\tilde{\phi})p^b/p]M^b \right\} / \partial\phi$. After some algebra, we can show that this object decreases with ϕ, and that there is a unique $\phi^* \geq 0$ such that the derivative is equal to 0. Hence, when $\phi < \phi^*$, $M(\tilde{M})$ increases given $\tilde{M}$, and comparative statics are similar to what we obtained following an increase in δ. However, when $\phi > \phi^*$, $M(\tilde{M})$ decreases given $\tilde{M}$. Then, the decrease in ϕ increases $\tilde{M}$, leading to both a higher p, a higher q, and a lower p^b/p.

Proposition 4 We follow a strategy similar to that used to prove Proposition 1, but we now establish the mapping between $\tilde{\phi}\nu M^b$ and M/p. In steady state, the supply of official currency is such that $\tau(M)M = \tilde{\phi}\nu p(M)M^b/\alpha$. Thus, $\tilde{\phi}\nu M^b/\alpha = M\tau(M)/p(M)$, where $\tau(M)$ and $p(M)$ are given by Lemma 3. Hence,

$$\frac{\tilde{\phi}\nu M^b}{\alpha} = \begin{cases} 0 & \text{if } M < \underline{M}' \\ \tilde{\phi}\nu M^b/\alpha \in [0, \underline{M}'/\beta] & \text{if } M = \underline{M}' \\ M/p(M) & \text{if } M > \underline{M}'. \end{cases} \tag{A25}$$

Under Assumption 1, z increases in M, and thus $M/p(M)$ increases in M. Then, when $M > \underline{M}'$, $\tilde{\phi}\nu M^b/\alpha$ increases in M. Therefore, we can inverse the correspondence to get

$$M(\tilde{\phi}\nu M^b/\alpha) = \begin{cases} M \in [0, \underline{M}'] & \text{if } \tilde{\phi}\nu M^b/\alpha = 0 \\ \underline{M}'/\beta & \text{if } 0 < \tilde{\phi}\nu M^b/\alpha \leq \underline{M}'/\beta \\ \tilde{\phi}\nu M^b p(M)/\alpha & \text{if } \tilde{\phi}\nu M^b/\alpha > \underline{M}'/\beta. \end{cases} \tag{A26}$$

Proposition 4 then directly follows from combining this mapping with Lemma 3 (in particular, note that any $\tilde{\phi}\nu M^b/\alpha > 0$, is mapped to a unique $M \geq \underline{M}'$).

Proposition 5 It is straightforward to adapt the proofs of Lemma 3 and Proposition 2 to allow for endogenous coca-base production. After substituting $\underline{M}'$ with $\underline{M}''$ and $barM'$ with $\bar{M}''$, the key step is to check that the mapping from any $\tilde{M}$ to a unique M, making use of

(A19), still holds. On the right-hand-side, M^b is now a function of p^b/p. Since M^b increases with p^b/p, the right-hand side is still an increasing function of p^b/b, and the rest of the proof follows.

Appendix B Model extensions

Appendix B.1 Endogenous production of coca-base (λ)

When coca-base is produced rather than endowed, the value of entering the CM with (z^-, b^-) changes to

$$\begin{aligned} V_1(z^-, b^-) &= \max_{x,z,b,k} \{x + V_2(z, b)\} \ \textbf{s.t.} \ x + k + \frac{p^b}{b} b = z^- + \frac{p^b}{p}[b^- + f(k)] + \frac{\psi}{p} \\ &= z^- + \frac{p^b}{p} b^- + \frac{\psi}{p} + \max_k \left\{ \frac{p^b}{p} f(k) - k \right\} + \max_{z,b} \left\{ -z - \frac{p^b}{p} b + V_2(z, b) \right\}. \end{aligned} \tag{B1.1}$$

The first maximization problem corresponds to the choice of how much coca-base to produce. Note that it is independent of the choice of how much coca-base to carry for the remainder of the period because there is a simultaneous spot market for coca-base.

Appendix B.2 Endogenous sales price of coca-base to intermediaries (ν)

In the baseline environment, it was assumed that agents who meet an intermediary can sell their coca-base at an exogenously fixed unit price. We now endogenize this price by assuming that it is the result of bilateral bargaining between the coca-base seller and the intermediary. Assume that the intermediary values coca-base at a real rate of ξ per unit. The meeting takes place just before the CM opens (seizures have already taken place), hence the agent values each of his b units of coca-base p^b/p in real terms. The two agents bargain over the following terms of trade: a quantity Q of coca-base sold by the villager to the intermediary, for a real payment P. The Kalai bargaining problem is

$$\max_{Q,P} (\xi - p^b/p)Q \text{ s.t. } Q \leq b \text{ and } P - \frac{p^b}{p} Q = \hat{\theta}(\xi - p^b/p)Q. \tag{B2.1}$$

The objective function is the total surplus. The second constraint imposes that the villager receives a share $\hat{\theta}$ of the total surplus, where $\hat{\theta} \in (0, 1)$ is the villager's bargaining power in this negotiation. As long as $\xi \geq p^b/p$, the solution to the bargaining problem requires that all coca-base changes hands, $Q = b$. The payment is

$$P = [(1 - \hat{\theta})\frac{p^b}{p} + \hat{\theta}\xi]b. \tag{B2.2}$$

Since the payment is linear in the quantity traded, we can also express it in terms of a unit sales price, $P/Q = [(1-\hat{\theta})p^b/p + \hat{\theta}\xi] \equiv \nu$. We can directly see that $\nu > p^b/p$ if and only if $\xi > p^b/p$, which means that the coca-base is sold to intermediaries whenever gains from trade exist.

Appendix C Calibration strategy

In this section, we provide more details on the steps undertaken to calibrate the model. We start with the parameters calibrated externally. The discount factor, β, is set to match a 4% yearly rate. The probability of DM trade, σ, is chosen to match the frequency at which villagers meet up to trade locally, which we estimate to be once every two weeks based on informal interviews with residents from the coca-growing regions of Guaviare. Similarly, the probability of accessing the OM, α, is set to match the frequency at which villagers visit San José del Guaviare, which occurs once every four months on average.

We now describe the internal calibration step by step. For simplicity of exposition, assume for now that the price level, p, is known. Then, data from Policia-Nacional [2021] suggest a sales price of coca-base from villagers to intermediary dealers of 3260 pesos per gram in 2020, which we use to obtain the real sales price of coca-base to intermediaries, $\nu = 3260/p$. Next, data from the reports by Cardona [2021] and Turkewitz [2021] suggest that when trading locally, villagers are able to use coca-base in lieu of pesos at the rate of 1 gram for 0.75 US dollars and 1 gram for 2100 pesos respectively. In conjunction with an exchange rate of 3491 pesos per US dollar (average for January 2021), and taking the average of the two data points, we obtain an exchange rate of 1 gram of coca-base being equivalent to 2359 pesos. Using the payment equation (A19), the corresponding exchange rate in the DM is $\beta[\tilde{\phi}\nu + (1-\tilde{\phi}-\delta)p^b/p]/\{[\beta+\alpha(p-\beta)]/p\}$. In equilibrium, this is also equal to the exchange rate in the CM, p^b, as we can see from equation (A20). Therefore, $p^b = 2359$.

Next, we solve for δ and ϕ to match the empirical quantity of coca-base seizures and GDP in Guaviare. According to MinJusticia [n.d.], the average quantity of coca-base seized in Guaviare between 2010 and 2022 was around 4,064.5 kilograms per year, i.e., 78,163.53 grams per week. Since the population in our model is normalized to one, we divide the aggregate quantity of seizures by the population of Guaviare, estimated to be 88,490 inhabitants [MinComercio, 2022], and get $\delta M^b = 0.8833$. Next, note that (A20) uniquely determines δ as a function of ϕ, thus the previous equation uniquely determines M^b as a function of ϕ. The equation for the steady-state level of pesos in the village then uniquely determines M as a function of ϕ since ν, p, and α are known. We can then solve for ϕ so as to match the empirical GDP in Guaviare given $\delta(\phi)$, $M^b(\phi)$, and $M(\phi)$. Intuitively, we can see ϕ as a key determinant of liquidity in the economy, which in turn, determines trade and GDP. GDP per capita in Guaviare was estimated to 2,533 USD per year in 2020 [MinComercio, 2022]. This is equivalent to 179,794 pesos using the average 2020 exchange rate of 3691 pesos per dollar. We derive the model equivalent to nominal GDP by adding nominal GDP in the DM and in the CM, respectively computed as

$$NGDP_{DM} = \sigma(M + p^b M^b) \tag{C1}$$

and

$$\begin{aligned}
NGDP_{CM} =& \sigma[(1-\alpha)M + p^b M^b] + \sigma\alpha\delta[(1-\alpha)M + p^b M^b] \\
&+ (1-2\sigma)\alpha\delta((1-\alpha)M + p^b M^b) + (1-2\sigma)\alpha(1-\delta-\tilde{\phi})[(1-\alpha)M] \\
&+ \sigma\alpha\tilde{\phi}\max[0,((1-\alpha)M + p^b M^b - 2\nu M^b] \\
&+ \sigma\alpha(1-\delta\tilde{\phi})\max[0,((1-\alpha)M + p^b M^b) - 2p^b M^b] \\
&+ \sigma(1-\alpha)\delta\max[0,((1-\alpha)M + p^b M^b) - 2M] \\
&+ (1-2\sigma)\alpha\tilde{\phi}\max[0,((1-\alpha)M + p^b M^b) - \nu M^b] \\
&+ (1-2\sigma)(1-\alpha)\delta\max[0,((1-\alpha)M + p^b M^b) - M].
\end{aligned} \tag{C2}$$

We obtain $\phi = 0.1168$. We can then back out $\delta = 0.0423$, $M^b = 20.8638$, $\lambda \equiv A(k^*)^\gamma = (\delta + \tilde{\phi})M^b = 3.2170$, and $M = 131,890.7394$. Thus, the official money supply, M represents roughly 2.7 times the pesos value of the coca-base supply, $p^b M^b$ (equivalently, roughly 73% of liquidity in the village comes from the official money supply).

Next, we calibrate A and γ using the first-order condition that governs the optimal production of coca-base, targeting an elasticity of log-elasticity of production with respect to seizure of 0.5% [Cote, 2019]. We obtain $A = 0.0128$ and $\gamma = 0.6500$.

We are left with the parameters related to the DM cost function, a_c, and η_c. Absent data on the real or nominal activity within villages, it is difficult to calibrate these two parameters by matching them to empirical targets, which is why we instead use the two "ad-hoc" restrictions. We use (A17) and (A19). There are two unknown variables, p, and q. By setting p equal to the midpoint value in the shortage range and q equal to 70% of its first-best value, we can solve for the two remaining parameters a_c and η_c. We obtain $a_c = 0.9447$ and $\eta_c = 1.0042$.

Appendix D Additional figures

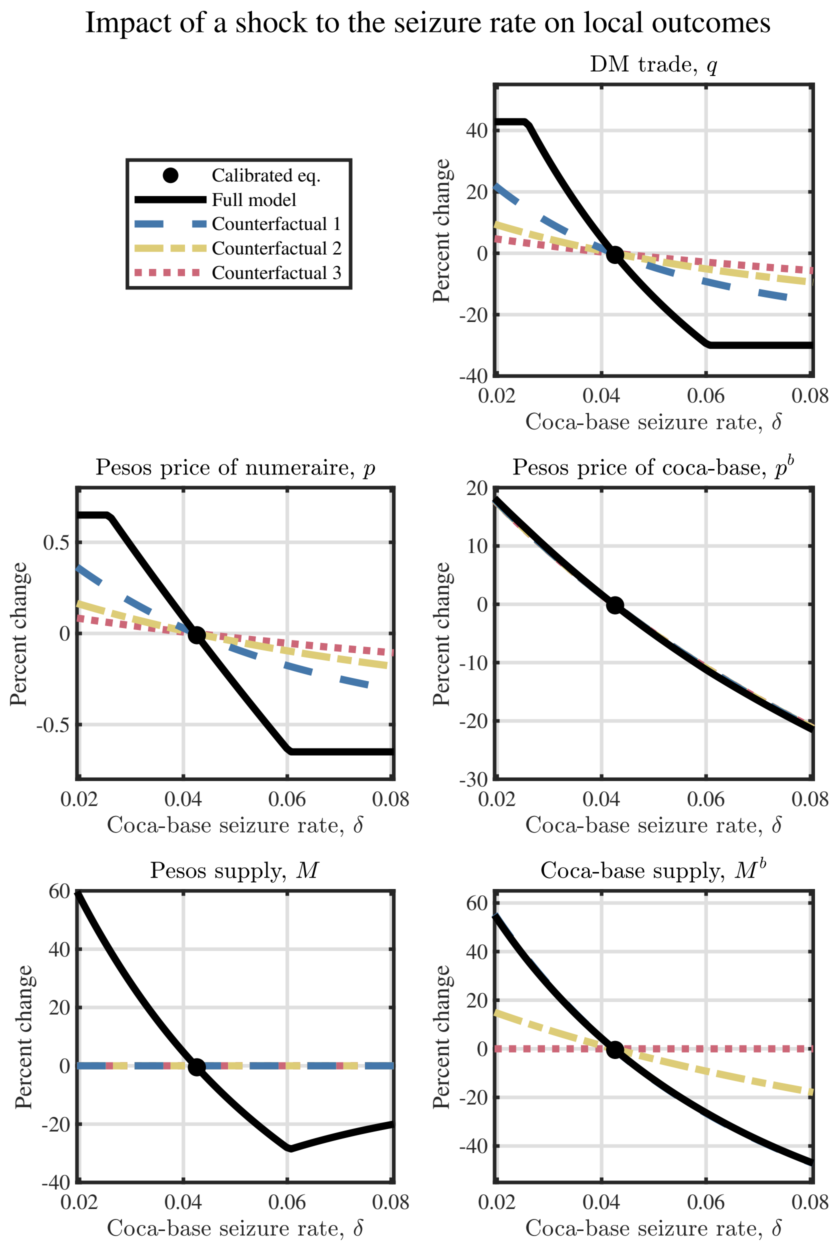

Figure D1: Local equilibrium outcomes as a function of the probability of coca-base seizures.

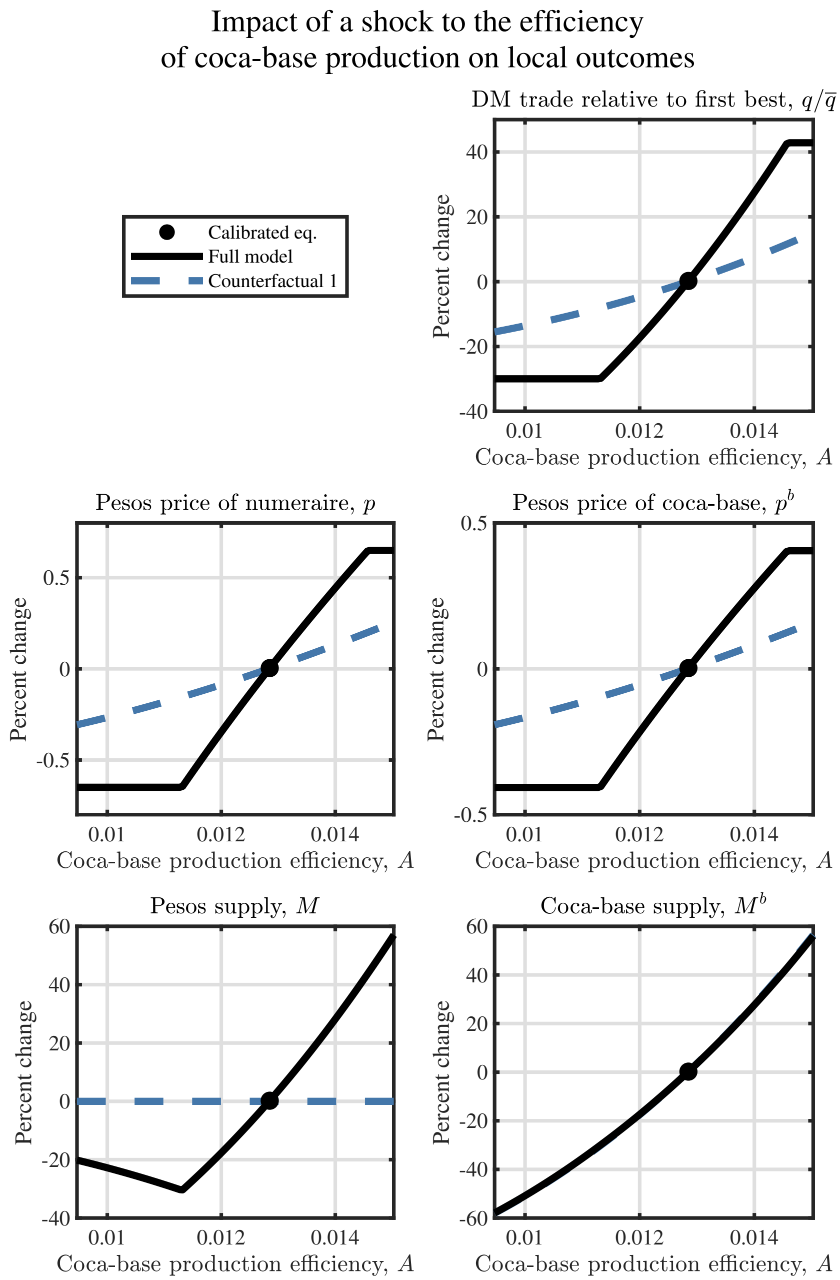

Figure D2: Local equilibrium outcomes as a function of efficiency of coca-base production.

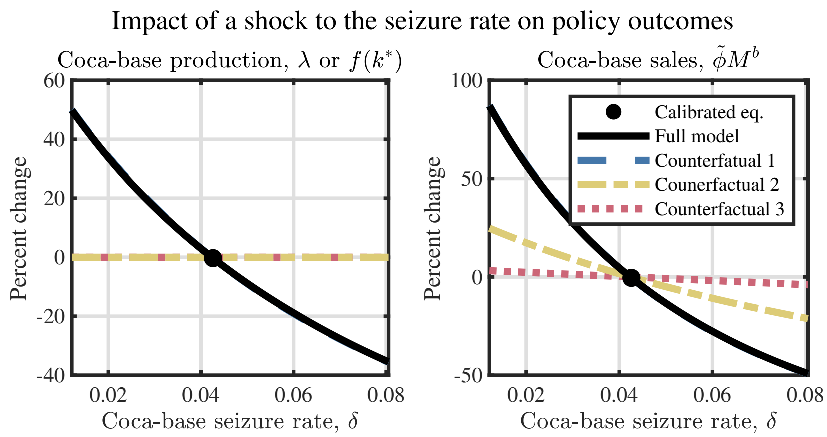

Figure D3: Policy outcomes as a function of the probability of coca-base seizures.

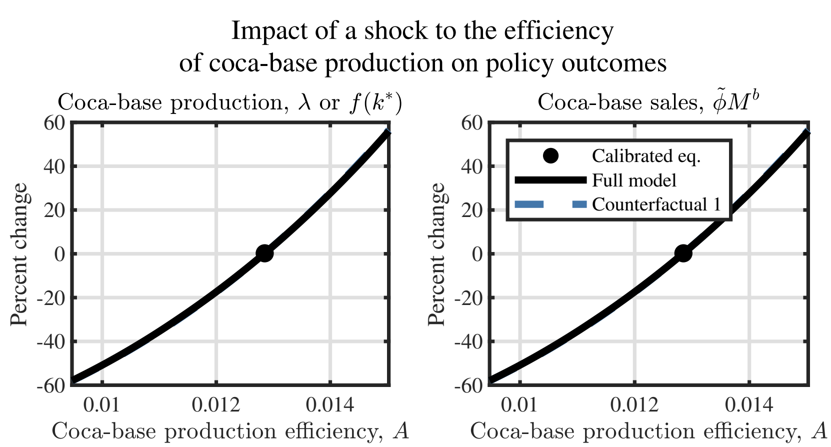

Figure D4: Policy outcomes as a function of the efficiency of coca-base production.

Appendix E Quantitative robustness checks

In this section we check the robustness of the quantitative results presented in Section 4.2 to changes in the two ad-hoc assumptions made in the calibration: the location of the price level p in $[\beta, (1-\beta+\alpha\beta)/\alpha]$ and the quantity of local trade relative to the first best quantity, $q/\bar{q}$. Recall that in the baseline calibration we set p equal the midpoint and $q/\bar{q}$ is set to 70%, which required the parameters of the DM utility function to equal $\eta_c = 1.0042$ and $a_c = 0.9447$.

We now consider four alternative calibrations:

1. Higher price: $p = \mathbf{0.7} * \beta + (1 - \mathbf{0.7}) * (1 - \beta + \alpha\beta)/\alpha = 1.0032$ and $q/\bar{q} = 0.7$, requiring $\eta_c = 1.0059$ and $a_c = 0.9234$.
2. Lower price: $p = \mathbf{0.3} * \beta + (1 - \mathbf{0.3}) * (1 - \beta + \alpha\beta)/\alpha = 1.0084$ and $q/\bar{q} = 0.7$, requiring $\eta_c = 1.0025$ and $a_c = 0.9664$.
3. More local trade: $p = 0.5 * \beta + (1 - 0.5) * (1 - \beta + \alpha\beta)/\alpha = 1.0058$ and $q/\bar{q} = \mathbf{0.9}$, requiring $\eta_c = 1.0143$ and $a_c = 0.8278$.
4. Less local trade: $p = 0.5 * \beta + (1 - 0.5) * (1 - \beta + \alpha\beta)/\alpha = 1.0058$ and $q/\bar{q} = \mathbf{0.5}$, requiring $\eta_c = 1.0022$ and $a_c = 0.9704$.

Results are presented in Table E1.

Overall, the sign and magnitude of results are robust to changes in the targets for a_c and η_c. Indeed the impact of changes in the four parameters we consider on the percent change in DM trade, coca supply, coca sold and coca produced are marginal for small and medium-sized shocks.

However, this breaks for large shocks—more specifically, when the shock is large enough for the equilibrium to hit a corner solution, that is, when it switches from the shortage regime to the autarky regime. In that case, the outcomes of interest become bounded, so that the impact of the policy, when expressed in percent terms, diverge (see, e.g., the impact of a 10% decrease in A on DM trade).

In sum, the ad-hoc assumptions made in our calibration have little impact on our quantitative estimates of the impact of diverse anti-narcotic policies on liquidity as long as the shocks are small enough for the local economy to remain in the original (shortage) regime.

			10% increase in δ		
	DM trade	**Pesos supply**	**CB supply**	**CB sold**	**CB produced**
Baseline	-8.5	-8.1	-7.5	-7.9	-5.2
Alt. 1	-8.6	-8.2	-7.6	-8	-5.3
Alt. 2	-8.5	-8	-7.5	-7.9	-5.2
Alt. 3	-8.5	-8.5	-7.6	-8	-5.3
Alt. 4	-8.6	-8.1	-7.6	-8	-5.2
			10% decrease in ϕ		
	DM trade	**Pesos supply**	**CB supply**	**CB sold**	**CB produced**
Baseline	-6.3	-8.3	2	-8.2	-5.4
Alt. 1	-6.3	-8.5	1.9	-8.3	-5.5
Alt. 2	-6.3	-8.3	2	-8.2	-5.4
Alt. 3	-6.3	-8.7	1.9	-8.4	-5.5
Alt. 4	-6.3	-8.3	2	-8.3	-5.4
			10% decrease in A		
	DM trade	**Pesos supply**	**CB supply**	**CB sold**	**CB produced**
Baseline	-25.7	-26.2	-25.8	-25.8	-25.8
Alt. 1	-14.2	-10	-26.2	-26.2	-26.2
Alt. 2	-25.8	-26.1	-25.9	-25.9	-25.9
Alt. 3	-10	-4.5	-26.7	-26.7	-26.7
Alt. 4	-25.9	-26.1	-25.9	-25.9	-25.9

Table E1: Robustness checks: impact of a 10% shock to the seizure rate, the intermediary meeting rate, and the efficiency of coca-base production in the benchmark model versus alternative calibrations.

Appendix F Background on the production and use of coca-base

Appendix F.1 A brief description of the stages of cocaine production and trafficking

The stages of cocaine production and trafficking span from the growing of coca leaf to the wholesale cocaine trade. The early stages of coca cultivation and coca-base production are mainly carried out by farmers, while the later stages of trafficking involve illegal armed groups and organized crime. In a great number of coca-growing regions, over half of coca-plant farmers do not sell the coca-leaf as-is but, instead, convert it into coca-base [Mejía and Rico, 2010, UNODC, 2021].

Coca is a small plant whose time until harvest takes between two and six months, depending on the variety. The process of transforming the coca leaf into coca-base starts with the coca growers baking the leaves under the sun. Once they are sufficiently dried, the leaves are minced and mixed, in several steps, with gasoline, cement, urea, and lime to extract the alkaloid (cocaine sulfate). The result of this first chemical process is a brown and gelatinous mix called coca-paste. In a second chemical process, the coca-paste is mixed with, among other inputs, gasoline, sulfuric acid, sodium carbonate, and ammonium to eliminate the impurities. The resulting product of this second process is the coca-base.

Available evidence collected before the peace agreement with the FARC (Fuerzas Armadas Revolucionarias de Colombia) guerrilla group reveals that the market for coca-base behaved as a monopsony in which the only buyer was the illegal armed group that exerts territorial control. Mejía and Rico [2010] pointed out that this market's feature could explain why, even with variations in supply, the price of coca-base has remained stable over the years. Illegal armed groups buy the coca-base from coca-plant farmers through intermediaries who visit the region regularly [Jansson, 2006]. Coca-base is then sold to large cocaine producers who transform it into cocaine, which is mainly shipped to markets in North America and in Europe.

Appendix F.2 Additional evidence on the use of coca-base as a complementary currency

Quote 1 [LeFigaro, 2007, free translation] "One quickly notices a precision scale on shop counters in the Patia region. Farmers handle coca paste—small, beige-colored, friable rocks—like nuggets. Some only have a few ounces at the bottom of a small plastic bag.

Others retrieve kilograms-worth of packages in their cheap backpacks. Chemical emanations float over the village. A strange business begins. Blocks of coca paste are weighed. Smelled. The drug is exchanged against anything that can be bought. Twenty grams for rubber boots, six grams for a meal at the local joint. Along the Patia river, even the the bets on cock fights are run with coca-money. [...] Prisoners from the drug economy, the FARC-run countryside lives under perfusion. They hang onto visits from "bosses," the drug dealers who purchase the coca-base. A villager explains "The bosses come from the city by boat, well-escorted, with bags of cash, and everyone runs to sell their coca-base." In just a few hours, hundreds of kilograms of paste can change hands. Then, the drug is lost in the secret of the jungle, on hidden pathways and never-ending canals, punctuated by armed countrymen. After the "bosses" visit, pesos reclaim their role. But, during wartime, the cartels' envoys do not take the risk to step into FARC-run territories. Too may army blockades. Then, coca paste ends up replacing pesos. Farmers stock their savings in coca-base, sometimes during months on end, until the narcos come by. This illegal money confines them to their coca-growing lands."

Quote 2 [**Cárdenas, 2007, free translation**] "In the most remote villages of Caquetá, money is no longer the medium of exchange. The farmers buy their groceries with grams of coca [base] and the shopkeepers, instead of a cash register, have an electronic scale. A breakfast is worth 1.5 grams and, without going any further, an ice cream costs half a gram of white powder."

Quote 3 [**McDermott, 2008, free translation**] "No money has reached Guerima for months and transactions are conducted in coca[-base], with one gram enough to buy a soft drink."

Quote 4 [**Cardona, 2021, free translation**] "In the Amazonian region of Guayabero (Colombia), where coca paste is grown and produced, grams of coca paste are bought and sold due to poverty and difficult access to the area. [...] Coca is the main economic factor, even though it is illegal. It is practically the money around here. It is called merchandise and is paid by the gram. 'We haven't seen a bill here for two or three years [...],' say the neighbors."

Quote 5 [**Álvarez and Forero, 2023, free translation**] "Coca [base] paste as a local currency in the regions of Colombia, especially those that depend exclusively on this income, is an undeniable reality. Whether the coca[-base] is exchanged with an electronic scale in hand for the corresponding cash value of the product being purchased, a practice known as ‘cambalache,’ or giving credit to someone who has a ‘chagra’ as a guarantee, these are dynamics that have been used for years in these territories and whose common denominator is the guarantee that it will later be converted into money.[...] Nearly six months without any purchase of coca base paste leaves a feeling of anguish and desperation in the air among the growers. [...] In the coca fields, the workers receive the coca base paste corresponding to what they have worked for. With this paste, [...] they can go to the stores to do their shopping.”