The Price of Traceability: E-Payments, Tax Compliance, and Policy[*]

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Abstract

Why do firms continue to rely on cash in economies where digital payments are widespread and electronic transaction costs are low? This paper shows that the answer lies in the interaction between payment technologies and tax enforcement. Using randomized experimental evidence from Kenyan small and medium-sized firms, we establish that the adoption of electronic payments causally increases tax compliance by raising transaction traceability. Moreover, SME survey evidence shows that tax evasion is associated with cash discounts. Motivated by these findings, we develop a microfounded general equilibrium model in which heterogeneous firms choose prices, payment acceptance, and tax evasion jointly. Cash facilitates evasion but exposes buyers to transaction risk, while electronic payments are safer yet traceable by third parties. These trade-offs generate endogenous cash discounts, selective rejection of digital payments, and coexistence of payment instruments in equilibrium. The calibrated model shows that when electronic payments are non–interest-bearing, inflation increases cash usage and tax evasion, overturning the standard prediction that inflation reduces cash use. We characterize the optimal policy mix and show that financial development, enforcement intensity, and inflation are tightly intertwined in maximizing government revenues and welfare.

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1 Introduction

Tax evasion represents a pervasive challenge for policymakers around the world, particularly in developing economies where limited enforcement capacity and weak institutional frameworks constrain the effectiveness of tax collection.[1] Promoting the digitization of payments through electronic money products has been widely advocated as a means to enhance tax compliance, given the greater traceability of digital transactions.[2] Yet the literature largely lacks a rigorous, microfounded framework that compares cash and digital payment instruments by jointly endogenizing firms' tax evasion and payment choices within the structural setting. This paper addresses that important gap by developing a general equilibrium framework in which firms choose their optimal payment methods mix under tax compliance frictions, and where fiscal and monetary policy jointly shape the aggregate payments composition and government revenues.

Building on the established view that tax-evading firms favor cash for its anonymity, our research emphasizes the contrasting role of electronic payments, which generate verifiable records that enhance traceability and limit evasion.[3] When alternative payment methods are available, small businesses — especially in developing countries — often offer discounts for cash transactions or set a minimum purchase amount for debit and credit card payments, as suggested by both anecdotal and empirical evidence.[4]

We ground our theoretical framework in micro-level evidence from a randomized controlled trial (RCT) in Kenya, showing that the adoption of a mobile-money based electronic payment instrument causally increases tax compliance at Small-and-Medium-Sized Enterprises (SMEs). While our study is generalizable to many countries across the globe, Kenya provides an ideal setting for this analysis due to its rapid pace of financial development and the transformative expansion of its mobile money ecosystem. This evolution created a unique window in which our data can be used to identify the causal effects of a new electronic payment instrument—Lipa Na M-Pesa—on tax compliance. We complement the RCT data with an enterprise survey, which allows to track additional correlates of mobile payment usage at SMEs.

The RCT underlying our study sought to reduce the adoption costs of an electronic payment system, Lipa Na M-Pesa, for small businesses to exogenously encourage e-payment uptake. While this system lowers transaction frictions, it also entails electronic transaction fees and, crucially for our analysis, all payments received through Lipa Na M-Pesa are digitally recorded and therefore traceable as business transactions, with po-

[1] La Porta and Shleifer (2014), Dzansi et al. (2022).

[2] Apeti and Edoh (2023), Kotsogiannis et al. (2025).

[3] Slemrod, Joel (2019).

[4] Bourguignon et al. (2014), Chodorow-Reich et al. (2020), Alvarez et al. (2022).

tential tax compliance implications. We conduct an intention-to-treat (ITT) regression analysis and show that, compared to the control group, treated businesses increase their tax payments by nearly 17%.[5] Although novel, this result aligns with the established argument that electronic payments are associated with increased tax compliance.

Further analysis with micro-level enterprise survey data shows that while higher tax compliance at the intensive margin is associated with lower cash discounts, at the extensive margin, higher tax compliance is linked with higher cash discounts. Lastly, cash discounts increase with firm size and productivity.

Building on the motivational micro evidence, we develop a monetary dynamic general equilibrium framework to study the co-existence of cash and electronic payments as competing media of exchange. In our framework, cash-based payments facilitate tax evasion relative to electronic (debit) payments; however, cash is subject to theft risk, representing an opportunity cost of holding liquidity, while debit payments involve bank transaction fees. These micro-founded tensions between different forms of liquidity are important concerns for many countries across the globe and thus constitute key considerations for financial development, monetary- and fiscal-policy interactions.

Our framework emphasizes the trade-off between between buyers' and sellers' incentives with respect to optimality of transacting with cash. On the one hand, the probability of theft implies that, absent any discount on cash transactions, buyers would like to use only debit as a method of payment and would avoid carrying around large cash balances. On the other hand, sellers are willing to accept debit as a payment method - but at a higher price, due to the presence of electronic transaction fees, and the desire to evade taxes. A key strength of our framework is that it captures the interplay between buyers' and sellers' incentives in determining the degree of digitization, which is crucial for optimal policy analysis.

The model features a continuum of buyers and a continuum of sellers. As in Lagos and Wright (2005) each period is divided in two sub-periods: a day market and a night market. In the former, all agents transact in a frictionless Walrasian market, and buyers choose how much cash and debit to carry into the night. In the latter, buyers and sellers trade in two competitive markets, segmented by the productivity of the seller, where buyers get randomly assigned to either a "high productivity market" or to a "low productivity market." Prices are allowed to endogenously differ across payment methods for each seller, and sellers differ in their productivity and, as a result, in their incentives to evade taxes.

The theoretical analysis shows that firms whose tax evasion is constrained by cash revenues tend to offer larger discounts for cash transactions. When both high- and low-

[5]IV analysis indicates roughly a 140% increase in compliance among the treated.

evasion-cost firms accept debit payments, low-cost firms offer larger cash discounts because their optimal level of tax evasion is higher. On the contrary, when low-evasion-cost firms accept only cash, they may offer smaller discounts if their evasion costs are sufficiently high, a pattern that rationalizes the empirical findings based on the micro survey evidence, which highlight differences between intensive and extensive tax evasion margins.

In the empirically relevant parameter space of the model, low-productivity sellers accept only cash payments, giving rise to a form of idle liquidity balance problem: debit remains unspent when buyers transact with low-productivity firms, whereas cash is universally accepted. This theoretical insight is important, as it highlights that when interest on debit accounts fails to sufficiently compensate for inflation during periods of inactivity, buyers may be discouraged from using debit in environments where fractions of sellers incentivize cash transactions due to tax evasion benefits.

We calibrate our model using (i) micro-level SME survey data, (ii) legal and institutional information on corporate taxation, enforcement, and e-payments, and (iii) macro statistics from Kenya. The data and the model's qualitative predictions align: more productive businesses are more likely to adopt and use electronic payment systems, are less likely to evade taxes, and offer larger cash discounts than the low-productivity, fully evading firms. The calibrated model also behaves well quantitatively in comparison to targeted and non-targeted moments.

Quantitative policy analysis based on the calibrated model shows that high inflation increases the use of cash by raising the opportunity cost of holding idle debit balances when transacting in low-productivity markets, where sellers are often unwilling to accept debit payments. This mechanism implies that high inflation does not necessarily reduce tax evasion; instead, it may exacerbate it in environments where sellers can endogenously discourage electronic payments by offering cash discounts. This result introduces a novel perspective to the literature on optimal policy in the presence of informality and tax evasion, complementing the contributions by Gomis-Porqueras et al. (2014), Ulyssea (2018), Aruoba (2021), and Erosa et al. (2023). The calibrated model also predicts the existence of a Laffer curve, indicating that tax revenues are non-monotone in tax rates. Additionally, increasing penalties leads to higher fine revenues and greater tax compliance. Overall, the government's revenue is maximized by a combination of low inflation, stringent penalties, and a tax rate of approximately 9%.

Our results indicate that in developing economies, technology-driven financial development policies should be coordinated with fiscal (and monetary) policy to enhance tax revenues. Tax rates and inflation crucially affect the degree of digitization and, as a result, tax compliance. Given the rapid global expansion of FinTech payment systems, our findings provide concrete quantitative guidance for policymakers—especially in environments where institutional frictions hinder tax collection and enforcement.

2 Related literature

Our paper sits at the intersection of microfounded money-fiscal interactions on the macro-literature side, while also relating to the micro-literature studying the implications of electronic payment (alternative payment) adoption on business outcomes. Our key contribution results from bringing these two lines of literature together and analyzing the optimizing payments choice of firms with tax evasion incentives and the response of monetary and fiscal policies in curbing such incentives.

In the microfounded money literature, we relate to the rapidly growing body of research on the essentiality of electronic money and its coexistence with traditional payment instruments. Recent studies highlight the electronic money's role as a medium of exchange (Chiu and Wong, 2015; Carli and Uras, 2024), the competitive dynamics among privately issued digital currencies (Fernández-Villaverde and Sanches, 2019), and the emerging role of the public sector in providing central bank digital currency (CBDC). This research agenda has also explored how CBDC issuance affects the banking sector (Andolfatto, 2021; Chiu et al., 2019; Fernández-Villaverde et al., 2021; Keister and Sanches, 2023), influences financial stability (Keister and Monnet, 2022; Williamson, 2022), and raises new considerations regarding user anonymity, data privacy, and illegal monetary activity (Kang, 2021; Parlour et al., 2022; Ahnert et al., 2022; Wang, 2023). We contribute to this line of work in two key ways: we develop a tractable model that captures the heterogeneous prices charged by firms across different payment instruments; and, we link these pricing decisions to the implementation and enforcement of tax policy and inform optimal policy design in that regard.

On the fiscal policy side, our paper relates to the macroeconomic literature on tax evasion. A large body of work models payroll tax evasion through informal hiring by both formal and informal firms, typically via a probabilistic cost of detection and punishment that increases with firm size, reflecting the empirically documented negative correlation between informality and firm size (Ulyssea, 2018; Erosa et al., 2023). Relatedly, Dzansi et al. (2022) show, using field experimental evidence from Ghana, that tax collectors optimally allocate enforcement effort—facilitated by new technologies—toward agents with higher expected compliance, particularly high-income households.

More closely related to our analysis, Gomis-Porqueras et al. (2014) estimates the size of the shadow economy in a cross-country setting using a calibrated general equilibrium model in which goods can be purchased with either cash or credit, and where cash facilitates tax evasion. Aruoba (2021) studies tax evasion and cash intensity in a general equilibrium framework with a Ramsey planner who chooses the least distortionary mix of taxes subject to institutional constraints. In their model, inflation discourages cash usage and informal activity by reducing the real value of cash holdings, while higher tax rates increase both, generating a trade-off between monetary and fiscal policy instruments. While this literature implies that inflation should reduce informality by discouraging cash usage—leaving interest-bearing deposits and credit largely unaffected—cross-country evidence instead documents a positive correlation between inflation and informality (Koreshkova, 2006; Aruoba, 2010). Our paper contributes to this debate by embedding firms' endogenous payment-method and tax-evasion choices into a microfounded monetary model with tax enforcement frictions. By endogenizing tax evasion, the framework captures its intensive margin—the dimension most responsive to digitization in our empirical analysis and a key determinant of cash discounts. Crucially, the model allows for economies in which the primary, less-anonymous alternative to cash is neither credit-based nor interest-bearing and is therefore equally exposed to the inflation tax. Combined with well-documented heterogeneity in firms' compliance incentives, this structure rationalizes the positive inflation–informality relationship observed in cross-country data. Within this setting, and guided by causal micro-level evidence, we examine whether the adoption of electronic payments can enhance tax compliance in developing economies.

Finally, our paper relates to the literature examining the impact of electronic payment adoption. Most research in this area relies on observational data (e.g., Humphrey et al., 1996; Schuh and Stavins, 2010; Bolt et al., 2010; Agarwal et al., 2019; Ghosh et al., 2022, Lahiri, 2020, Chodorow-Reich et al., 2020, Alvarez et al., 2022) or laboratory experiments (e.g., Camera et al., 2016; 2017, 2017). A notable exception is Dalton et al. (2024), whose RCT framework in the context of Lipa Na M-Pesa is referenced in our analysis. Building on their RCT framework, we empirically analyze how e-payment adoption influences tax compliance and utilize the institutional and data context of Lipa Na M-Pesa to develop a general equilibrium monetary model of e-payment adoption under tax evasion incentives.

3 Institutional Context

3.1 Mobile Money in Kenya: M-Pesa and Lipa Na M-Pesa

Kenya has been at the forefront of mobile money innovation, with the launch of M-Pesa by Safaricom in 2007 marking a turning point in financial inclusion across the country. Originally designed as a peer-to-peer (P2P) money transfer platform, M-Pesa quickly gained traction by addressing the needs of unbanked and underbanked populations. Its success laid the groundwork for a range of mobile financial services, including credit, savings, and insurance products. Against this backdrop, Lipa Na M-Pesa ("Pay with M-Pesa") was introduced in June 2013 as a merchant payment solution, enabling customers to make cashless payments directly to businesses using their mobile phones. To this day, Safaricom remains the monopolist provider of mobile phone–based electronic payments in Kenya. By regulation, Lipa Na M-Pesa—like M-Pesa itself—is fully backed by local currency, with customer funds held in a 100% ring-fenced account.

Unlike traditional P2P M-Pesa transactions, Lipa Na M-Pesa is designed for business-to-business (B2B) and business-to-consumer (B2C) interactions. Retailers are assigned a unique till number that allows them to receive payments directly into their business accounts, and they pay a 1% transaction fee when receiving payments on Lipa Na M-Pesa. This system provides several advantages for businesses compared to transacting with cash: it reduces cash-handling risks, such as theft, improves record-keeping, and facilitates faster transaction processing. For small and medium-sized enterprises (SMEs) Lipa Na M-Pesa offers a low-cost entry point into the digital economy.

The platform's growing adoption has also had important implications for fiscal governance. As digital payments leave an auditable trail, and in particular Lipa Na M-Pesa transactions get recorded as business activity, the payment instrument enhances business transparency and provides a foundation for formality. The Kenyan Revenue Authority (KRA) has increasingly leveraged this digital footprint to improve tax compliance and enforcement.[6] In doing so, Lipa Na M-Pesa plays a dual role—not only as a payment tool that enhances operational efficiency of retail transactions, but also as a mechanism for expanding the tax base and improving transparency in a traditionally cash-heavy and opaque retail sector. This dual role plays a pivotal role in our theoretical model.

For businesses, Lipa Na M-Pesa has emerged as a key institutional innovation in Kenya's digital and fiscal landscape, creating new opportunities to bridge the gap between informality and formal regulation—particularly through improved monitoring and data-driven enforcement. From the perspective of customers, the adoption of Lipa Na M-Pesa has been facilitated by several key features of the broader M-Pesa ecosystem. Most notably, using Lipa Na M-Pesa to make payments at registered merchants is free of charge for customers. Given the already widespread penetration of M-Pesa across Kenya — with adoption rates exceeding 80% of the adult population by the time Lipa Na M-Pesa was launched in 2013 (Suri and Jack, 2016) — there is little friction on the user side when it comes to leveraging the platform for everyday transactions.

[6] This newspaper article provides supporting evidence for this tax enforcement mechanism.

As another important institutional detail relevant for our theoretical analysis, M-Pesa is a non-interest-bearing stored-value instrument. This means that while customers can hold balances in their M-Pesa wallets, they do not receive any returns on these balances - as for the case of the traditional form of cash, which implies that M-Pesa and cash are subject to the same price inflation pressures.

3.2 Taxation and Tax Enforcement in Kenya

We focus on tax rules in Kenya that are effective for companies, and in particular for SMEs, over the period 2015–2017. In 2017, the standard corporate income tax rate in Kenya was 30% (KPMG East Africa, 2017).[7] Moreover, firms with revenues between KSh 500,000 and KSh 5 million per year were required to pay a turnover tax (ToT) of 3% over their gross sales and firms making over KSh 5 million per year are required to register for value-added tax (VAT) according to the Kenya Revenue Authority (2017). For companies below that threshold, registration is voluntary. Lastly, registration for VAT exempts firms from paying ToT, meaning that firms that meet the eligibility criteria for the latter, can instead opt for the former if it is more advantageous. These constitute the primary tax obligations applicable to the sample of small- and medium-sized enterprises during our study period. Further discussion on additional tax levies can be found in the Online Appendix Section A.1.1.

Penalties for tax evasion can be imposed as fixed amounts or as proportions of the tax shortfall. Of particular relevance is Section 84 of Kenya's Tax Procedures Act, which mandates a penalty of 75% of the unpaid tax in cases of deliberate or fraudulent misreporting, with statutory increases for repeat offenses and reductions for voluntary disclosure prior to audit (National Council for Law Reporting, 2015). Enforcement, however, remains imperfect: the Revenue Performance Report for fiscal year 2018/19 indicates that in concluded legal disputes the Kenya Revenue Authority (KRA) recovered only about 30% of the contested revenue, underscoring the high costs and limited effectiveness of judicial enforcement (Kenya Revenue Authority, 2019a). These limitations motivate the enforcement frictions embedded in both our experimental design and theoretical framework.

With respect to third-party audits of mobile money services—central to our analysis—Section 60 of the Tax Procedures Act grants the Commissioner, subject to a warrant, authority to access premises and records for enforcement purposes (National Council for Law Reporting, 2015). Although a 2018 High Court ruling initially constrained the KRA's ability to access M-Pesa account data, this decision was overturned on appeal in 2020. More recently, the Finance Act of 2023 introduced Section 59A, authorizing a data man-

[7] Special conditions are applicable for newly listed firms and companies in export processing or special economic zones.

agement and reporting system for the submission of detailed transactional information (Republic of Kenya, 2023). Together, these legal developments have strengthened the KRA's digital enforcement capacity, particularly with respect to mobile money transactions, and underpin recent efforts to improve tax compliance among SMEs.[8] The Online Appendix Section A.1.2 contains additional details on tax enforcement procedures.

4 Experimental and Empirical Evidence

In this section, we present micro-level evidence on electronic payment adoption and tax compliance, examining both the extensive and intensive margins in both variables. Our analysis draws on two data sources from Kenya—a country that, as highlighted earlier, is a global front-runner in the innovation and adoption of non-cash (electronic) payment systems. The first data source is a Randomized Controlled Trial (RCT) conducted in Kenya to identify the causal impact of electronic payments on business outcomes. The second is an enterprise survey administered to Kenyan SMEs that participated in the RCT. The survey provides detailed information on firms' use of various payment instruments—particularly cash, M-Pesa, and Lipa Na M-Pesa (LPN)—as well as a rich set of business characteristics and performance indicators.

In what follows, we first describe the data. We then use the enterprise survey to document patterns of e-payment usage, cash discounts, and their association with sales, productivity, and tax compliance. Finally, we present experimental evidence from the RCT to causally identify the presence of tax enforcement frictions among Kenyan SMEs.

4.1 Data

The randomized controlled trial (RCT) that we draw upon was conducted by Dalton et al. (2024) between 2015 and 2017 in Nairobi, Kenya. The study sample comprise 553 pharmacies and 669 restaurants—each classified as a small or medium-sized enterprise. These retailer businesses were randomly assigned within their respective sectors (pharmacies and restaurants) to treatment and control groups. The primary objective of the RCT was to evaluate the impact of electronic payment adoption on business finances. In this study, we leverage the Dalton et al. (2024) data to causally estimate the effect of electronic payment usage on tax compliance, thereby identifying the presence of tax enforcement frictions that electronic payments may help to mitigate.

Dalton et al. (2024) exploited the recent introduction of the Lipa Na M-Pesa (LPN) payment technology, which had been launched less than a year before their study began.

[8] See, for example, reports from the Business Daily, The Standard, and Techpoint.

At that time, adoption among Kenyan SMEs was low: only 9% of surveyed businesses having an LPN account. The RCT employed an encouragement design to promote technology adoption by reducing *short-run information frictions* —specifically those related to the benefits, usage know-how, and account registration — stemming from the technology's novelty in the market. Indeed, the presence of these short-run frictions in the *unique* e-payment context of Kenya was what enabled the researchers to identify the business outcome effects of the e-payment instrument. Specifically, the researchers encouraged adoption in the treatment group by 1) providing information on the technology and addressing common misconceptions; 2) offering to open LPN accounts on behalf of business owners[9]; and 3) explaining how to use the technology post-adoption. The intervention led to an exogenous 34% increase in LPN usage relative to the control group.[10]

4.2 Enterprise Survey Evidence

Dalton et al. (2024) conducted baseline and endline surveys with the businesses included in their study - in 2015 (baseline) and 2017 (endline). A discussion of descriptive statistics based on the survey data can be found in Section A.2 of the Online Appendix. In this section, we first document a set of empirical regularities from the enterprise survey that form the foundation for developing and quantifying the general equilibrium framework introduced in the next section. These stylized facts underscore key relationships between firm productivity, the adoption of electronic payments, tax compliance, and the provision of cash discounts among Kenyan firms.

4.2.1 Acceptance of mobile payments and productivity (Extensive margin)

The first set of survey-based results concerns the extensive margin of electronic payment adoption in business transactions and is reported in Online Appendix Section A.2.1. These results indicate that higher productivity is associated with a greater likelihood of accepting mobile payments. This finding is consistent with Beck et al. (2018), who, using alternative data from Kenya, also show that more productive firms are more likely to accept mobile money.

4.2.2 Cash discounts, productivity and tax compliance (Intensive margin)

We now turn to the determinants of discounts offered on cash payments (hereafter, cash discounts), a key decision margin through which firms discourage electronic payments

[9]During the experiment, Safaricom tightened LPN account-opening requirements by requiring an up-to-date business license, preventing some treated firms from fully benefiting from the assistance.

[10]For a comprehensive discussion of their experimental results, see Dalton et al. (2024).

at the intensive margin, even after adopting e-money at the extensive margin. The dependent variable in the regressions reported in Table 1 is the average ratio of cash to M-Pesa prices across the firm's three main products.[11] In the absence of baseline price data, we rely exclusively on endline survey observations. To capture tax compliance at the extensive margin, we consider a dummy equal to one if the firm reports paying positive taxes, and zero otherwise. The intensive margin is captured by the *tax share*, defined as

$$TaxShare_i := \frac{Taxes_i}{Sales_i}, \tag{1}$$

where taxes include PAYE, excise taxes, and the annual corporate income tax paid in installments. Panel A reports regressions of the average relative price on the tax compliance dummy and the tax share. Because the tax share reflects both compliance and firm size, we additionally control for the logarithm of sales. In subsequent panels, sales are replaced with the productivity measures defined above. All specifications include sectoral and enumerator fixed effects. Given the presence of price outliers, each column in Table 1 applies a different treatment. Column (1) trims the top and bottom 5% of observations; column (2) winsorizes at the 10% level; column (3) winsorizes at the 20% level; column (4) excludes firms offering discounts greater than 75% for either payment method; and column (5) reports estimates from a robust regression.[12]

We find that a 1% increase in sales is associated with at least a 1.9% lower cash discount. This relationship is fairly robust, becoming insignificant only in column (2). Revenue productivity shows a similar pattern, with somewhat larger effects. Profit and value-added productivity yield less precise estimates, though the coefficients retain the expected sign and are significant at the 10% level in about half of the specifications. Consistent with the extensive-margin adoption results, productivity also influences firms' intensive-margin behavior, as more productive firms are less inclined to offer cash discounts that would discourage electronic payment use.

With regard to tax compliance; since a one-unit increase in the tax share corresponds to moving from paying 0% to 100% of revenues in taxes, the estimated coefficients should be divided by 100 for a more meaningful interpretation. The results in Panel A indicate that a 1% higher intensive-margin tax compliance is associated with roughly a 0.9–2% reduction in cash discounts, with the effect becoming insignificant only under 10% win-

[11] A higher ratio implies a smaller discount on cash transactions. Not all firms reported prices for all products; in such cases, the average is computed over the available observations. The sample size is smaller in this specification, as the ratio is undefined for firms that do not accept mobile payments.

[12] The robust regression is implemented using Stata's built-in *rreg* command, which drops observations with large Cook's distance and iteratively down-weights those with large residuals, combining Huber and biweight loss functions for improved stability and convergence.

sorization. Panel B shows a similar pattern and comparable p-values, while Panel C yields weaker significance overall.

Greater tax compliance along the extensive margin (a higher value of the compliance dummy) is associated with a higher cash discount of 5.3%–9.1%, and the effect is highly significant in all but one specification. Overall, the results suggest that larger and more productive firms tend to offer smaller cash discounts encouraging the use of electronic payments, while the relationship between tax compliance and discounting behavior depends critically on the margin of evasion. As to be discussed later, our model replicates and rationalizes these empirical patterns.

4.3 Randomized-Controlled-Trial Evidence

4.3.1 Regression Specification for the RCT

We utilize the unique context of the RCT design and identify the effect of LPN e-payment instrument on tax compliance. A distinctive feature of the Lipa Na M-Pesa is that all transactions conducted through LPN are electronically documented as business transactions. Consequently, businesses in the treatment group that are averse to transparency, as noted by Dalton et al. (2024), tend to avoid adopting the technology. This feature and the adoption compliance further motivates the novel intention-to-treat analysis we present in this paper, which explores the impact of transaction traceability, enabled by Lipa Na M-Pesa, on tax compliance.

Specifically, in our baseline specification, we adopt the analysis of covariance (ANCOVA) regression model using the RCT data. More specifically, we estimate:

$$Y_{i2} = \alpha + \beta' T_i + \zeta' Y_{i1} + \lambda' Controls_{i1} + \mu_j + \eta_i + \epsilon_i, \tag{2}$$

where i indexes the business, Y_{i1} and Y_{i2} are, respectively, the baseline and endline values of the dependent variable, T_i is the treatment dummy, μ_j are sectoral fixed effects, and η_j are enumerator fixed effects.[13] The dependent variables we consider are the compliance dummy and the tax share, as defined at (1). With respect to the additional controls, we follow Dalton et al. (2024) and include variables that are unbalanced in the baseline survey both in the full sample, with both pharmacies and restaurants, and in the sector-specific subsamples. The balance test results can be found in Online Appendix C. In all regressions, we include as controls those variables that are unbalanced in the relevant sample at the 10% significance level.

We complement our analysis with treatment-on-treated (TOT) regressions that follow a specification similar to the baseline model. In the main TOT specification, we

[13]The enumerator fixed effects also control for location fixed effects, as enumerators were sent out to survey businesses based on their location.

Table 1: Average Relative Prices, Evasion and Size in Kenya

	(1)	(2)	(3)	(4)	(5)
			Panel A: Sales		
Tax Share	1.375***	1.926	0.926*	1.928*	0.865*
	(0.512)	(1.517)	(0.551)	(0.997)	(0.519)
Evasion	-0.079***	-0.078**	-0.077***	-0.058***	-0.060***
	(0.023)	(0.039)	(0.019)	(0.018)	(0.016)
Log Sales	0.028**	0.039	0.021**	0.019**	0.020**
	(0.013)	(0.026)	(0.008)	(0.009)	(0.008)
N	278	305	305	270	305
Mean	0.888	4.634	4.634	0.914	4.634
			Panel B: Revenue Productivity		
Tax Share	1.427***	1.757	0.901	2.226*	0.978*
	(0.520)	(1.559)	(0.547)	(1.148)	(0.519)
Compliance	-0.078***	-0.072*	-0.075***	-0.063***	-0.061***
	(0.024)	(0.039)	(0.019)	(0.019)	(0.016)
Log Revenue Productivity	00.032**	0.033	0.022**	0.034***	0.027***
	(0.015)	(0.024)	(0.010)	(0.010)	(0.009)
N	278	305	305	270	305
Mean	0.888	4.634	4.634	0.914	4.634
			Panel C: Profit Productivity		
Tax Share	0.838*	1.347	0.524	1.853	0.580
	(0.506)	(1.498)	(0.516)	(1.168)	(0.511)
Evasion	-0.067***	-0.063	-0.068***	-0.056***	-0.053***
	(0.023)	(0.038)	(0.019)	(0.020)	(0.016)
Log Profit Productivity	0.012	0.023	0.007	0.031**	0.016*
	(0.014)	(0.023)	(0.010)	(0.014)	(0.009)
N	273	300	300	265	300
Mean	0.888	4.697	4.697	0.915	4.697
			Panel D: Value Added Productivity		
Tax Share	1.179**	1.798*	1.241***	0.995**	0.986*
	(0.482)	(1.007)	(0.425)	(0.403)	(0.590)
Evasion	-0.081***	-0.116***	-0.091***	-0.058***	-0.065***
	(0.024)	(0.034)	(0.020)	(0.018)	(0.017)
Log Value Added Productivity	0.011	0.020	0.016*	0.022***	0.021**
	(0.010)	(0.013)	(0.009)	(0.008)	(0.008)
N	245	265	265	238	264
Mean	0.893	1.680	1.680	0.910	1.036

Notes: All regressions include enumerator and sectoral fixed effects and contain endline data only. Dependent variables are logged. The panels indicate the dependent variables. The columns stand for alternative ways of dealing with price outliers: (1) removing 5% from the top and 5% from the bottom of the distribution; (2) winsorizing at 10%; (3) winsorizing at 20%; (4) removing any observation with a discount of more than 75% on either payment method; and (5) robust regression.
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

instrument changes in the use of LPN for receiving payments between baseline and endline with treatment assignment. The endogenous variable equals 1 if the firm received LPN payments at endline but not at baseline, -1 if the firm received such payments at baseline but not at endline, and 0 otherwise. For robustness, we also analyze the case of a nonlinear first stage and bivariate probit.[14]

4.3.2 RCT Results

Next, we document the causal effects of the adoption of electronic payments on tax compliance at extensive and intensive margins. Table 2 reports results for the extensive margin, where the dependent variable is a dummy equal to one if the firm pays a positive amount of taxes. Panel A presents the ITT estimates, and Panel B reports the TOT (IV) results, as defined earlier. Standard errors are shown in parentheses.[15] In all cases, we find no significant effect along the extensive margin.

Table 3 reports results for the intensive margin, where the dependent variable is the firm's tax share, defined in (1). Because this measure reflects both intensive- and extensive-margin behavior, we include two additional controls to isolate the treatment effect on the *intensive margin*: baseline tax compliance and the change in the compliance dummy between baseline and endline.[16] These controls absorb variation in the tax share driven by extensive-margin changes—which, as shown above, are unaffected by the treatment—thereby isolating the treatment effect on the component of the tax share orthogonal to extensive-margin movements. We also include an interaction between the treatment and the change in tax compliance to capture heterogeneity among firms that begin or cease paying taxes between baseline and endline. Finally, we do not employ a bivariate probit model in the IV analysis, as the dependent variable is no longer binary.[17]

Our results show a positive treatment effect that is statistically significant at the 5% level in 14 of the 18 specifications. Significance fails only in two of the baseline IV regres-

[14] For that end, we use LPN payment acceptance as the endogenous variable and delete any observation that had already adopted LPN by the baseline.

[15] In the TOT analysis, we estimate a bivariate probit model, given the binary nature of the dependent variable.

[16] It takes the value of 1 when firm pays some taxes in the endline but not in the baseline, -1 in the opposite case, and 0 otherwise.

[17] We observe several outliers in firms' tax share outcomes. Unlike in previous cases, these appear plausible rather than driven by reporting error. As shown in the table, the mean tax share in the control group is around 0.01, implying that firms pay, on average, roughly one-fifteenth of their owed taxes.[18] Such low averages suggest that a small number of highly compliant firms may disproportionately affect linear estimates. Accordingly, in both baseline and IV specifications, we use the logarithm of the tax share as the dependent variable. Since the tax share can be zero, we approximate it by $\log(1 + \text{tax expenses}) - \log(\text{sales})$, noting that adding one shilling is negligible.

Table 2: ITT and TOT Estimates for Compliance in Kenya

	(1)	(2)	(3)
Panel A: ITT Analysis			
Treatment	-0.022	-0.024	-0.024
	(0.035)	(0.036)	(0.039)
N	802	773	802
Panel B: IV Analysis			
Shift in Lipa Payments	-0.3414		
	(0.533)		
Lipa Payments Acceptance		0.2469	0.7785
		(0.352)	(0.734)
N	801	695	722
Kleibergen-Paap statistic	6.469	12.045	.
Anderson-Rubin χ^2 *p-value*	0.508	0.471	.

Notes: All regressions include enumerator and sectoral fixed effects. They also include controls for variables unbalanced in the baseline for either case. Panel A contains the baseline ITT regressions; and Panel B displays the IV analysis. For Panel A, the columns stand for alternative ways of dealing with price outliers: (1) retains all observations; (2) drops observations with discounts above 75% on either payment method; and (3) uses robust regression. For Panel B, we present three different specifications of the IV regressions: (1) 2SLS; (2) Probit on the first stage and 2SLS with the fitted values as instruments on the sample of firms that did not accept LPN payments in the baseline; and (3) bivariate probit.
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

sions, likely due to instrument weakness; however, the corresponding Anderson–Rubin χ^2 statistics remain significant at the 5% level, confirming robustness when instrument strength is accounted for. In terms of magnitude, the baseline specification yields an ITT estimate of 16.8% and a treatment-on-the-treated (TOT) effect of roughly 140% (based on the IV regressions in columns (3)–(6)) along the intensive margin. These magnitudes are plausible given the high baseline tax evasion. The TOT effect is consistent with expectations: among firms not receiving LPN payments at baseline, adoption rose to 12.9% in the control group and to 19.8% in the treatment group, implying an increase of 0.0686 and a local average treatment effect roughly 15 times the ITT estimate. Finally, the interaction term is insignificant in most specifications, except for two; in both cases, it enters with a negative sign, suggesting that, conditional on starting to pay taxes, treated firms were more likely to comply.

Table 3: ITT and TOT Estimates for Tax Share in Kenya

	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: ITT Analysis			
Treatment	0.1684**	0.1735**	0.0022*	0.0023*	0.0005***	0.0008***
	(0.075)	(0.076)	(0.001)	(0.001)	(0.000)	(0.000)
Treatment × Shift		0.1603		0.0022		0.0008***
		(0.123)		(0.002)		(0.000)
N	721	721	694	694	721	721
Control Mean	.	.	0.010	0.010	0.009	0.009
Control StDev	.	.	0.019	0.019	0.019	0.019
			Panel B: IV Analysis			
Shift in Lipa Payments	2.7412	2.8717				
	(1.687)	(1.757)				
Lipa Payments Acceptance			1.3786**	1.4153**		
			(0.689)	(0.687)		
Treatment × Shift		0.2476		-0.2447*		
		(0.181)		(0.141)		
N	720	720	620	620		
Kleibergen-Paap statistic	5.219	5.054	15.359	15.522		
Anderson-Rubin χ^2 p-value	0.022	0.020	0.021	0.017		

Notes: All regressions include enumerator and sectoral fixed effects. They also include controls for variables unbalanced in the baseline for either case. Panel A contains the baseline ITT regressions; and Panel B displays the IV analysis. Even-numbered columns contain an interaction between treatment assignment and the shift along the extensive margin. For Panel A, the columns stand for alternative ways of dealing with outliers: (1) — (2) approximate the dependent variable as $log(1 + tax\ expenses) - log(sales)$; (3) — (4) drop any observation with a discount of more than 90% on either payment method; and (5) — (6) use robust regression. For Panel B, we present three different specifications of the IV regressions of the logged tax share: (1) — (2) 2SLS; (3) — (4) Probit on the first stage and 2SLS with the fitted values as instruments on the sample of firms that did not accept LPN payments in the baseline. Standard errors in parentheses.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

These results indicate that the treatment increased tax compliance only along the intensive margin—that is, among firms already paying taxes at baseline—and that the effect was substantial. Since extensive-margin compliance is likely correlated with transparency, this finding is consistent with Dalton et al. (2024), who show that LPN adoption in the treatment group is associated with transparency aversion. This pattern also helps explain why our treatment assignment acts as a weak instrument for changes in LPN acceptance. A linear first stage does not capture the relationship well. Moreover, because LPN payments are more easily monitored by tax authorities, many firms may be discouraged from adopting them despite the reduction in information frictions, transaction costs, and knowledge barriers induced by the treatment. This points to a substantial *tax enforcement friction* that undermines compliance, while also highlighting the potential of mobile money adoption to mitigate this challenge.

4.4 Taking Stock of the Experimental and Empirical Findings

This section used data from a randomized controlled trial to show that mobile payments increased tax compliance in Kenya, highlighting tax enforcement frictions associated with cash-based transactions. Complementary enterprise-survey evidence indicated that more productive firms and those with greater adoption of electronic payments were more likely to comply with tax obligations and to offer smaller cash discounts. To rationalize and quantitatively replicate these patterns, the next section develops a general equilibrium monetary model with tax enforcement frictions and endogenous payment and pricing decisions. This structure is essential for translating the causal micro evidence into an empirically grounded, microfounded policy analysis that accounts for government policy, private technology choices, and general equilibrium effects.

5 The Model

We develop a microfounded monetary model in which the use of electronic payments by firms and their tax evasion decisions are jointly determined, accounting for the equilibrium responses of households, the cost of electronic payments, and public policy instruments, including monetary and fiscal policy. The joint determination of e-payments and tax evasion at the firm level generates novel theoretical insights and yields important policy implications in general equilibrium.

In the model, firms are referred to as sellers, and households as buyers. There is a unit mass of buyers and a unit mass of sellers. Buyers are homogeneous, while sellers are of two types: high-productivity sellers, H, and low-productivity sellers, L. Seller types change over time and are subject to i.i.d. shocks.

Time is discrete and indexed by t, extending indefinitely. In each period, agents first transact in a centralized, frictionless *day* market. They then trade in a segmented but competitive *night* market, where agents assume their specialized roles as $buyers$ and $sellers$. Segmentation in the night market assigns all high-productivity sellers to one market and all low-productivity sellers to another, while buyers are randomly matched to one of the two markets — limiting arbitrage across markets. In the night market, money is essential for buyers to settle transactions with sellers; accordingly, buyers accumulate monetary balances in the day market to finance their night purchases.

The supply of money is controlled by the central bank (operated by the government). Central bank money (m) can be held in its original paper form (*cash*, c) or converted at zero cost to traceable electronic money (*debit*, d), operated by a private bank whose revenues are fully taxed by the government. This convertibility implies that e-money functions as a stablecoin, backed by central bank money. Cash and debit differ along several dimensions. Cash is an anonymous asset and is therefore subject to theft risk, which we assume is borne by buyers. Debit payments, by contrast, are secure from theft but involve a private transaction fee. Moreover, because debit is a transparent and traceable payment method, payments received via debit are fully taxable, where as we will specify later the enforcement of tax compliance through cash receipts is limited. The costs associated with debit-based payments are borne by sellers. As a result, buyers prefer to pay with debit, while sellers prefer to receive payments in cash. This divergence creates a central tension in the model and generates endogenous seller responses, including the denial of debit payments and the offering of discounts for cash transactions. In what follows, we describe the timing of transactions in the day and night markets, abstracting from time subscripts when this entails no loss of theoretical consistency. Figure OA2 in Online Appendix C provides a flow chart for the timing of events.

Transactions in the Day. At the beginning of the day, agents enter the market with money balances carried over from the previous period, denoted by m_{-1}. Before any trading takes place, the government implements a lump-sum transfer γ to both buyers and sellers: this transfer redistributes tax revenues collected in the previous night market from sellers and the bank and incorporates injections of new money. We denote the money supply at time t as $\bar{M}_t$. Since we focus on stationary equilibria, we assume a deterministic money-supply path in the form of $\bar{M}_{t+1} = (1+\pi)\bar{M}_t$, where π is the time-invariant *monetary policy rule* that determines the growth rate of the money supply.[19]

Next, sellers draw their idiosyncratic productivity levels z^t, that are independently and identically distributed — with $t \in \{H, L\}$ and $z^H > z^L$. These productivity realizations govern production opportunities in the subsequent night market.

Once these preliminary steps are completed, the day goods market opens. Buyers simultaneously choose their day-market consumption x and labor supply h (producing the centralized market output at the rate of 1-to-1), as well as how to allocate their monetary balances between cash c and debit d to carry to the night market. These

[19]We assume that the government always re-injects the quantity of money that is stolen.

portfolio choices determine their future purchasing power and payment options at night-market transactions.

Sellers, conditional on their productivity type z^t, choose their own day-market consumption x^t and labor supply h^t. In contrast to buyers, sellers do not carry money into the night market, reflecting their role as producers rather than purchasers in that stage. After all consumption, labor, and portfolio decisions are made, the day market closes, and the economy transitions to the night market.

Transactions in the Night. At the beginning of the night market, buyers incur a loss on their cash holdings: a fraction $1-\delta$ of the cash they carried from the day market gets stolen.[20] This loss represents an opportunity cost of using cash relative to debit and captures the idea that cash is subject to storage and transaction risks, while debit balances are not.[21]

Following the realization of cash theft, the night goods markets open. Buyers then observe their submarket assignment—either the high-productivity or low-productivity sellers' market—interpretable as a location-preference shock that pins down the set of feasible trading partners in the night market. Given the cash and debit prices posted by sellers, p_c^t and p_d^t, buyers choose quantities q_c^t and q_d^t purchased with each payment method, which in turn determines sellers' labor input l^t under the linear production technology $y^t = z^t l^t$. In this formalization, sellers may choose not to accept debit payments, which is equivalent to setting an arbitrarily high debit price that effectively discourages their use.

Debit-based revenues are fully traceable and thus subject to full enforcement of the ad valorem tax τ under the government's *fiscal policy rule*. Cash-based revenues are also subject to the same tax rate τ. However, because cash transactions are anonymous, tax compliance on cash revenues is not fully enforceable. Sellers may evade taxes on cash revenues and are detected with probability $P^t(e^t)$, where $P_e^t(\cdot) > 0$, $P^H(\cdot) > P^L(\cdot)$ $\forall\, e \in [0,1]$, and e^t denotes the fraction of taxes evaded. If not detected, evaded taxes are retained as additional revenue. If detected, a penalty tax rate τ^P is fully enforced. The functional form implies that the probability of being caught increases with tax evasion intensity and it is higher for high-productivity sellers for a given level of evasion intensity.

In addition, debit transactions incur a proportional fee $\alpha \in (0,1)$, paid by sellers to the debit provider (the bank) and applied to the pre-tax value of the transaction. Once

[20] Cash stolen does not re-enter the night market. We do not consider the welfare of "thieves" as part of the subsequent welfare analyses we conduct.

[21] We assume that money is stolen with certainty in order to ensure that the uncertainty in the model stems from payment method usage at different submarkets, which is what we are explicitly modeling. Theft is not only a common storage/transaction cost associated to cash utilization, but also, as will be shown in the Section 7 section, it is a substantial problem in the economy we will calibrate the model to.

all trades are completed, the night goods markets close and buyers convert their unused debit units into cash before carrying forward monetary holdings to the next period. The government then collects tax revenues from the bank by fully taxing the fee income from debit transactions.[22]

Optimization Programs. We denote nominal variables with uppercase letters but focus throughout on their stationary counterparts, expressed in lowercase after dropping time subscripts. Specifically, c, d, p_c^t, p_d^t, and m_{-1} correspond to $C_t/\bar{M}_t$, $D_t/\bar{M}_t$, $P_c^t/\bar{M}_t$, $P_d^t/\bar{M}_t$, and $M_{t-1}/\bar{M}_t$, respectively.

In the day, the optimization program of the buyers is given by:

$$W^B(m_{-1}^{B,t_{-1}}) = \max_{x,h,c,d} U(x) - h + \sum_{t\in\{H,L\}} f(z^t)V^B(c,d,z^t) \tag{3}$$

$$\text{subject to} \quad \phi\left(\frac{c}{\delta} + d\right) + x \leq h + \phi\left(\frac{m_{-1}^{B,t_{-1}}}{1+\pi} + \gamma\right), \tag{4}$$

$$x, h, c, d \geq 0, \tag{5}$$

where $W^B(\cdot)$ and $V^B(\cdot)$ correspond to the value function of the buyer in the day and night markets, respectively; $U(\cdot)$ is the day-time utility function, satisfying $U'(\cdot) > 0$ and $U''(\cdot) \leq 0$; ϕ is the real price of money; $f(z^t) \in (0,1)$ is the fraction of sellers with productivity z^t (with $f(z^H) + f(z^L) = 1$); and the superscript on $m_{-1}^{B,t_{-1}}$ indicates that the buyer had a seller with productivity t_{-1} at the previous night.[23] The standard budget constraint argument implies that (4) binds. Constraint (5) indicates the non-negativity of consumption, labor and monetary holdings in its two forms (cash and debit).

Similarly, the day market problem of a seller with productivity draw t is given by:

$$W^S(m_{-1}^{t_{-1},p}, z^t) = \max_{x^t,h^t} U(x^t) - h^t + V^S(z^t) \tag{6}$$

$$\text{subject to} \quad x^t \leq h^t + \phi\left(\frac{m_{-1}^{t_{-1},p}}{1+\pi} + \gamma\right), \tag{7}$$

$$x^t, h^t \geq 0, \tag{8}$$

where $W^S(\cdot)$ and $V^S(\cdot)$ denote the seller's value functions in the day and night markets, respectively; and the superscript on $m_{-1}^{t_{-1},p}$ indicates that the seller had the productivity draw t_{-1} in the previous period. The superscript $p \in \{P, NP\}$ corresponds to whether the seller was charged with a tax penalty at the end of the previous night - based on

[22] A fully taxed bank is equivalent to a publicly held bank in our economy, since tax revenues collected from the bank are rebated to agents.

[23] As a standard property, money leftover from the previous period loses value due to inflation. Formally, $\frac{M_{-1}^{B,t_{-1}}}{\bar{M}_{t+1}} = \frac{M_{-1}^{B,t_{-1}}}{\bar{M}_t}\frac{\bar{M}_t}{\bar{M}_{t+1}} = \frac{m_{-1}^{B,t_{-1}}}{1+\pi}$.

their detected tax evasion behavior. The resource constraint (7) naturally binds and (8) indicates the non-negativity of goods purchased and labor supplied.

At night, upon entering the submarket with sellers of productivity z^t, buyers face the following problem:

$$V^B(c,d,z^t) = \max_{q_c^{B,t}, q_d^{B,t}} u(q^{B,t}) + \beta W^B_{+1}(m^{B,t}) \tag{9}$$

$$\begin{aligned}
\text{subject to} \quad & q^{B,t} = q_c^{B,t} + q_d^{B,t}, && (10)\\
& m^{B,t} = c - p_c^t q_c^{B,t} + d - p_d^t q_d^{B,t}, && (11)\\
& p_c^t q_c^{B,t} \leq c, \qquad [\mu_c^t] && (12)\\
& p_d^t q_d^{B,t} \leq d, \qquad [\mu_d^t] && (13)\\
& q_c^{B,t}, q_d^{B,t} \geq 0, \qquad [\Phi_c^{B,t}, \Phi_d^{B,t}] && (14)
\end{aligned}$$

where $u(\cdot)$ is buyers' night-time utility function, satisfying $u'(\cdot) > 0$ and $u''(\cdot) < 0$; and $q^{B,t}$ is total purchases of the good produced by the seller, on cash and/or debit. In this specification, equation (10) indicates the perfect substitutability between goods purchased with cash and debit. Equation (11) is the flow of money carried forward to the next period. Constraints (12) and (13) are cash and debit constraints. Finally, (14) ensures the non-negativity of goods purchased on cash and debit. The Lagrange multipliers associated with key constraints are identified in square brackets.

At night, the problem of a seller with productivity z^t is given by:

$$V^S(c,d,z^t) = \max_{l^t, q_c^t, q_d^t, e, e_c^t} -l^t + \beta \sum_{t+1 \in \{H,L\})} \sum_{p \in \{P,NP\}} f(z^{t+1}) \mathbb{P}^{t,p}(e^t) W^S_{+1}(m^{t,p}, z^{t+1}) \tag{15}$$

$$\begin{aligned}
\text{subject to} \quad & q_c^t + q_d^t \leq z^t l^t, && (16)\\
& m^t = (1-(1-e_c^t)\tau) p_c^t q_c^t + (1-\alpha-\tau) p_d^t q_d^t \\
& \qquad - \mathbb{1}_{p=P} \tau^P e^t (p_c^t q_c^t + p_d^t q_d^t), && (17)\\
& e_c^t p_c^t q_c^t = e^t (p_c^t q_c^t + p_d^t q_d^t), \qquad [\kappa^t] && (18)\\
& q_c^t, q_d^t \geq 0, \qquad [\Phi_c^t, \Phi_d^t] && (19)\\
& e^t, e_c^t \geq 0, \qquad [\bar{\lambda}^t, \bar{\lambda}_c^t] && (20)\\
& e^t, e_c^t \leq 1, \qquad [\underline{\lambda}^t, \underline{\lambda}_c^t] && (21)
\end{aligned}$$

where as noted previously, e^t corresponds to the fraction of total sales over which the seller evades taxes. The variable e_c^t is the fraction of transactions on cash over which no taxes are paid; and as also previously captured $P^t(e^t)$ stands for the probability of being caught evading taxes, which depends only on e^t and is type-specific. Moreover, $\mathbb{P}^{t,P}(e^t) = P^t(e^t)$ for penalized firms and $\mathbb{P}^{t,NP}(e^t) = 1 - P^t(e^t)$ for not penalized ones, while $\mathbb{1}_{p=P}$ takes the value of one if the firm is penalized and zero otherwise. In this optimization program,

(16) represents seller's production possibility dictated by the technology frontier and the substitutability of output sold in cash and debit. Equation (17) describes the flow of money carried forward to the next period, accounting for evaded taxes and, if detected, tax penalty payments. Equation (18) determines the relationship between tax evasion intensity from cash revenues and the overall intensity of tax evasion. Constraints (19)-(21) indicate the non-negativity of quantities produced and evaded taxes. Again, we identify the relevant Lagrange multipliers in square brackets.[24]

Equilibrium. Since the submarkets at night are competitive, prices are set by a Walrasian auctioneer within each to ensure market clearance, *i.e.* $\int_0^1 q_c^{B,t} di = \int_0^1 q_c^t dj$ and $\int_0^1 q_d^{B,t} di = \int_0^1 q_d^t dj$ for $t \in \{H, L\}$. Competitive equilibrium implies that sellers' profits on average are zero:

$$\Pi^t = -\frac{q_c^t}{z^t} - \frac{q_d^t}{z^t} + \beta\phi_{+1}[(1-(1-e_c^t)\tau)p_c^t q_c^t + (1-\alpha-\tau)p_d^t q_d^t - P^t(e^t)\tau^P e^t(p_c^t q_c^t + p_d^t q_d^t)] = 0. \tag{22}$$

In our equilibrium analysis, we focus on a region of the parameter space in which $p_c^H < p_c^L$ and $p_d^H < p_d^L$. That is, differences in the tax-evasion between high- and low-productivity types are not large enough to induce low productivity sellers to offer night-market goods at prices lower than those charged by more productive sellers.

Based on this equilibrium specification, we define the stationary equilibrium of the economy and distinguish two subclasses: mixed-payment equilibria, in which payment methods coexist, and single-payment equilibria, in which only one payment method is used in the night market. We focus on the conditions under which mixed-payment equilibria arise - the empirically relevant benchmark for the quantitative analysis that follows.

Definition 1 (Stationary equilibrium)**.** *A stationary equilibrium is a collection of day market real prices of money ϕ, consumption allocations $\{x, \{x^t\}_{t\in\{H,L\}}\}$, labor effort $\{h, \{h^t\}_{t\in\{H,L\}}\}$, payment method choices $\{c, d\}$ and lump-sum transfers γ, and night market prices $\{p_c^t, p_d^t\}_{t\in\{H,L\}}$, consumption allocations $\{q_c^t, q_d^t\}_{t\in\{H,L\}}$, tax evasion levels $\{e_c^t, e^t\}_{t\in\{H,L\}}$ and labor effort $\{l^t\}_{t\in\{H,L\}}$ such that:*

1. *$\{x, h, c, d\}$ solves the problem of the buyers in the day market, (3), given ϕ;*
2. *$\{x^t, h^t\}_{t\in\{H,L\}}$ solves the problem of the sellers in the day market, (6), given ϕ;*
3. *Given p_c^t and p_d^t, $q_c^{B,t}$ and $q_d^{B,t}$ solve the buyers' problem (9);*
4. *Given p_c^t and p_d^t, q_c^t and q_d^t solve the sellers' problem (15);*

[24]We would like to note that the total revenue, $p_c^t q_c^t + p_d^t q_d^t$ does not need to differ across types, as in equilibrium the buyer may decide to leave the night market with no idle money balance in both submarkets. In that case, revenues would be identical for both seller types.

5. *The day market clears, i.e.* $x + \sum_{t \in \{H,L\}} x^t = h + \sum_{t \in \{H,L\}} h^t$*;*

6. *The night submarkets clear, i.e.* $\int_0^1 q_a^{B,t} di = \int_0^1 q_a^t dj$ *for* $a \in \{c, d\}$ *and* $t \in \{H, L\}$*;*

7. *The money stock is conserved, i.e.*

$$\gamma = \frac{1}{1+\pi} \left\{ (1-\delta)c + \pi + \sum_{t \in \{H,L\}} \left[(1-e_c^t)\tau p_c^t q_c^t + (\tau + \alpha) p_d^t q_d^t + P^t(e^t)\tau^P e^t (R_c^t + R_d^t) \right] \right\} \tag{23}$$

Definition 2 (Mixed-payment equilibrium)**.** *A mixed-payment equilibrium is a stationary equilibrium where* $c, d > 0$*, and* $q_c^t > 0$ *and* $q_d^s > 0$ *for* $t, s \in \{H, L\}$*.*

Definition 3 (Single-payment equilibrium)**.** *A single-payment equilibrium is a stationary equilibrium where either* $q_c^t = 0\ \forall t \in \{H, L\}$ *or* $q_d^t = 0\ \forall t \in \{H, L\}$*.*

6 Theoretical Results

We begin the equilibrium analysis by characterizing the demand and price schedules in general terms.

Proposition 1. *In any submarket, for an* $a \in \{c, d\}$*,* $a' \in \{c, d\} \setminus a$ *and optimal consumption level* q^{t*}*, the demand schedule is given by:*

$$q_a^t = \begin{cases} 0 & \text{if } p_a^t > u'(q_{a'}^t)(1+\pi)/\beta\phi_{+1} \geq p_{a'}^t \text{ for } q_{a'}^t = \min\left(q^{t*}, \frac{a'}{p_{a'}^t}\right) \\ (u')^{-1}\left(\frac{\beta\phi_{+1}}{1+\pi} p_a^t\right) & \text{if } q^{t*} \leq a/p_a^t \text{ and } p_a^t < p_{a'}^t \\ \left[0, \min\left(q^{t*}, \frac{a}{p_a^t}\right)\right] & \text{if } p_a^t = p_{a'}^t \\ (u')^{-1}\left(\frac{\beta\phi_{+1}}{1+\pi} p_a^t\right) - \frac{a'}{p_{a'}^t} & \text{if } a'/p_{a'}^t < q^{t*} \leq a/p_a^t \text{ and } p_a^t > p_{a'}^t \\ a/p_a^t & \text{if } q^{t*} > a/p_a^t + \mathbb{1}_{p_a^t > p_{a'}^t} a'/p_{a'}^t \end{cases} \tag{24}$$

where $\mathbb{1}_{p_a^t > p_{a'}^t}$ *takes the value 1 when* $p_a^t > p_{a'}^t$ *and 0 otherwise. In every submarket* $t \in \{H, L\}$*, there is an optimal level of tax evasion* e^{t*} *satisfying:*

$$\left[P_e^t(e^{t*})e^{t*} + P^t(e^{t*})\right]\tau^P = \tau, \tag{25}$$

and a multiplier that takes the value of $\bar{\lambda}_c^t > 0$ *if* $e^{t*} > \frac{p_c^t q_c^t}{p_c^t q_c^t + p_d^t q_d^t}$*, and it is more likely to bind for low-productivity sellers. Moreover, the relative price is given by:*

$$\frac{p_c^t}{p_d^t} = \frac{1 - \alpha - \tau + \tau e^t - P^t(e^t)e^t\tau^P - \frac{1+\pi}{\beta\phi_{+1}}\left(\frac{\bar{\lambda}_c^t}{p_c^t q_c^t} - \frac{\Phi_d^t}{p_d^t}\right)}{1 - \tau + \tau e^t - P^t(e^t)e^t\tau^P + (1-e^t)\frac{1+\pi}{\beta\phi_{+1}}\frac{\bar{\lambda}_c^t}{p_c^t q_c^t}} < 1. \tag{26}$$

Lastly, any mixed-payment equilibrium is characterized by $e^t > 0$ *for* $t \in \{H, L\}$ *and:*

$$\sum_{t=\{H,L\}} f(z^t)\mu_c^t > \sum_{t=\{H,L\}} f(z^t)\mu_d^t, \tag{27}$$

implying that $p_c^t < p_d^t$ *for some* $t \in \{H, L\}$.

Proof. *All proofs are provided in Online Appendix B.*

By the demand schedule, buyers always spend first with the payment instrument offering the lower effective price, switching to the more expensive one only after the cheaper asset is exhausted. A buyer may optimally refrain from using a payment method $a \in \{c, d\}$ for two reasons. First, the optimal night-time consumption level q^{t*} may be attainable using only the strictly cheaper method, rendering any spending with a strictly dominated. Second, even if the cash-in-advance constraint on the cheaper method binds, the price p_a^t may be sufficiently high that the buyer prefers to carry unspent balances of a to the next day market, where they relax the labor-effort margin. In this case, buyers rationally forgo night-time consumption when the price in terms of a exceeds the future value of holding the asset.

This discontinuous demand schedule allows the model to generate equilibria in which some firms optimally do not accept debit payments, consistent with the data. This occurs when the debit price in the low-productivity submarket is sufficiently high that consumers fully spend cash while carrying debit balances to the next day market.

Turning to tax evasion, the optimal concealment choice equates the marginal benefit of hiding sales with its marginal cost. Because evasion yields a strictly positive payoff, sellers optimally evade a positive amount in mixed-payment equilibria. The evasion constraint is particularly relevant for low-productivity sellers, who face stronger incentives to underreport revenues and a lower probability of detection. When binding, the associated multiplier $\bar{\lambda}_c^t > 0$ captures the seller's desire to evade beyond what is permitted by the share of cash transactions.

A binding evasion constraint has direct price implications. When sellers are restricted from evading as much as they would like, they are willing to accept cash at a larger discount, with a higher $\bar{\lambda}_c^t$ implying a stronger discount. Thus, relative price distortions arise endogenously from limited evasion capacity. Finally, (27) implies that, because cash entails storage costs due to theft risk, buyers must be compensated through lower cash prices for $c > 0$ to be optimal. Consequently, sellers accepting cash have lower cash-prices; accordingly, cash transactions are settled at a discount relative to debit transactions.

6.1 Special case: A centralized night market

Next we analyze the special case where there is only one type of seller, whose productivity is set at z. This implies that the night market is not segmented, and it is a standard competitive market. This structure allows us to capture the important property that mixed-payment equilibria - in general - require the presence of heterogeneous sellers.

To build intuition, the next proposition assumes that the optimal tax-evasion level characterized by (25) satisfies $e^* \leq 1$.[25] Moreover, we assume logarithmic utility for buyers' night-time utility. Lastly, we have shown above that zero evasion is suboptimal in the presence of $c > 0$, meaning that there is some $\varepsilon > 0$ such that $e_c = 1$ for $c < \epsilon$. By continuity, it is then natural to assume that $e_c = 1$ when $c = 0$. We would like to note that this admits the possibility of no tax evasion ($e = 0$), allowing us to obtain the following proposition.

Proposition 2. *Given α, the economy can be at either of the following three situations:*

i. For $\alpha > (1-\delta)\left(1-\tau+e^*\tau - P(e^*)e^*\tau^P\right)$, $c^* = \min\{m/\delta, q_c^*\}$;

ii. For $\alpha \in \left[1-\tau-\delta\ ,\ (1-\delta)\left(1-\tau+e^*\tau-P(e^*)e^*\tau^P\right)\right]$, $c^*, d^* > 0$; and

iii. For $\alpha < 1-\tau-\delta$, $c^* = 0$,

where the upper bound corresponds to the "knife-edge" case where $e = e^*$. Moreover, in mixed-payment equilibria, we must have

$$\frac{p_c}{p_d} = \delta. \tag{28}$$

Lastly, all of the mixed-payment equilibria are indeterminate.

Proposition 2 shows that payment methods coexist when the debit technology fee lies in the interval $\alpha \in \left[1-\tau-\delta\ ,\ (1-\delta)\left(1-\tau+e^*\tau-P(e^*)e^*\tau^P\right)\right]$. If α falls below this range, the equilibrium features $c^* = 0$; if α exceeds the relevant range, we have $c^* = \min\{m/\delta, q_c^*\}$. Interpreting α as a measure of financial underdevelopment, the proposition implies that more financially developed economies rely less on cash, while cash is more prevalent when payment services linked to deposits are costly. Moreover, in equilibria with payment-method coexistence, buyers must be exactly compensated for theft risk, as implied by (28).

The proposition further establishes that all mixed-payment equilibria are indeterminate. When $p_c/p_d = \delta$, converting one unit of money into either cash or debit yields the

[25] This assumption is not needed for the remaining propositions nor for the quantitative results.

same night-market consumption. Buyers are therefore indifferent between the two instruments, so any $c \in [0, m/\delta]$ is admissible. In a (non-segmented) centralized night market, this indifference generates a coordination failure, as no force pins down the equilibrium cash–debit mix. Therefore, we next consider a segmented market with heterogeneous sellers and show that, in that environment, the equilibrium is determinate and features the coexistence of payment methods.

6.2 Segmented market

We conclude our theoretical analysis by studying the equilibrium payment choice in the case of a segmented market with heterogeneous sellers - constituting the generalized case of our model. For this purpose we define additional objects. Assuming that the functions $P(\cdot)$, $u(\cdot)$ and $U(\cdot)$ are fully parametric, let $\Omega \subset \mathbb{R}^k$ be the space of feasible parameter values, where k is the number of parameters in the structure. Moreover, let $\Omega^{MP} \subset \Omega$ be the region of the parameter space that generates mixed-payment equilibria. The typical element of this region, $\omega \in \Omega^{MP}$, is a k-dimensional parameter vector that produces payment method coexistence in equilibrium. Given this notation, we refine our mixed-payment equilibrium concept.

Definition 4 (Robust mixed-payment equilibrium)**.** *The mixed-payment equilibrium associated to the parameter vector $\omega \in \Omega^{MP}$ is robust if, and only if, there is $\varepsilon > 0$ such that an open ball with radius ε centered around ω satisfies $B(\omega, \varepsilon) \subset \Omega^{MP}$.*

According to this definition, a robust mixed-payment equilibrium sustains the coexistence of payment methods even under small perturbations of the model's parameters. This excludes mixed-payment equilibria located on the boundary of Ω^{MP} or those arising from knife-edge parameter constellations. Such non-robust equilibria depend on special parameter values that are unlikely to occur. For expositional clarity, we therefore focus on robust mixed-payment equilibria, characterized in the following results.

Lemma 1. *In equilibria where $q_d^t > 0$ for all $t \in \{H, L\}$, the following statements hold for sellers for whom the tax evasion constraint binds:*

$$1) \quad \frac{\partial \frac{p_c^t}{p_d^t}}{\partial e^t} > 0,$$

$$2) \quad \mathcal{E}^H_{<\delta} \subset \mathcal{E}^L_{<\delta} \quad \textit{for } \mathcal{E}^t_{<\delta} := \left\{ e \in [0,1] \;\middle|\; \frac{p_c^t}{p_d^t} < \delta \textit{ and } \bar{\lambda}_c^t > 0 \right\}.$$

Lemma 1 reveals that, for sellers that accept debit payments and that are constrained in their level of tax evasion, the low-productivity sellers are the ones who are more likely to give a large discount on cash transactions for any $e = \frac{c}{c + p_d^t q_d^t} \in [0, 1]$. This theoretical finding rationalizes the empirical pattern we documented with Kenyan enterprise survey for tax complying firms, where among sellers that accept mobile payments, the more productive ones charge larger premiums for their debit transactions. We reiterate that this does not mean that the actual discount is always larger for the least productive agents, as will be seen in Proposition 4. Moreover, as the level of tax evasion increases, sellers become less constrained, which allows them to give a lower discount on cash.

Proposition 3. *In every robust mixed-payment equilibrium, the general equilibrium payment mix $\{c, d\}$, is inefficient in each submarket.*

According to Proposition 3, buyers adopt a payment portfolio in the day market, which is always ex-post inefficient, in the night. The reason for this is that there is heterogeneity in relative prices across night-time submarkets. In other words, if buyers knew with certainty which submarket they would trade in each period, they would choose to use either cash or debit exclusively. However, since matching is random, they choose a payment mix that makes them dissatisfied *ex post*, one way or another. Lastly, Proposition 4 reconnects to our empirical findings and presents a sufficient condition for fully evading sellers giving lower cash discounts than their non-fully evading counterparts.

Proposition 4. *In robust mixed-payment equilibria where $e^t = 1$ for some $t \in \{H, L\}$ and $e^s < 1$ for some $s \in \{H, L\} \setminus \{t\}$, if the multiplier of the constraint $e_c^L \geq 1$ satisfies:*

$$\bar{\lambda}_c^L < \frac{\beta\phi_{+1}p_c^L q_c^L}{1+\pi}\left[\left(1 - P^L(1)\tau^P\right)(1-\delta) - \alpha\right] \tag{29}$$

then $\frac{p_c^t}{p_d^t} > \frac{p_c^s}{p_d^s}$ with $t = L$ and $s = H$.

Proposition 4 implies that firms paying no taxes may offer lower cash discounts than tax-paying firms in equilibrium if their tax evasion constraint is weakly binding. Since these firms already evade fully, they cannot increase their tax evasion further. However, if their probability of detection is sufficiently high, cash becomes less attractive for them compared to more productive firms, whose ability to evade is limited by their lower share of cash transactions.

6.3 Taking Stock of the Theoretical Findings

Our model is consistent with the qualitative patterns observed in the empirical and experimental evidence presented in Section 4. Specifically, it replicates the finding that more productive sellers offer lower cash discounts and, consequently, are less inclined to discourage buyers from using debit payments, reflecting their weaker tax evasion incentives relative to less productive firms. In addition, the model yields new insights—most notably the emergence of an ex-post wallet-portfolio inefficiency on the buyer's side, which interacts nontrivially with policy. In the next section, we calibrate the model using both micro- and macro-level evidence to quantify these mechanisms and examine the resulting equilibrium behavior of buyers and sellers to evaluate the response of the economy to policy changes.

7 Calibration

7.1 Functional Forms

Before calibrating the model, we specify three functional forms: the utility functions, $U(\cdot)$ and $u(\cdot)$, for the day and night markets respectively, and the probability of detection by tax inspectors, $P^t(\cdot)$. For the utility functions, we assume

$$U(x_t) = \ln(x_t), \tag{30}$$

$$u(q_t) = \Theta \frac{q_t^{1-\sigma}}{1-\sigma}, \tag{31}$$

where $\sigma > 0$ is the coefficient of relative risk aversion in the night, and Θ is a preference shifter adapted to facilitate calibration. For the probability of detection, we assume

$$P^t(e) = \theta^t e^{\zeta}, \tag{32}$$

where θ_t differs for types $t \in \{L, H\}$. Tax evasion costs are convex, *i.e.*, $\zeta > 1$.

7.2 Data

We fix a subset of parameters using readily available empirical evidence and calibrate the remaining parameters to match key moments, drawing on the enterprise surveys presented in Section 4 and macroeconomic data for Kenya. The calibration period spans 2012–2019, covering the introduction of LPN M-Pesa and the RCT, and ensuring consistency in tax revenue data prior to COVID-19 disruptions. CPI inflation and real interest rates are obtained from the World Bank. The penalty rate is taken from the Kenyan Tax Procedures Act (National Council for Law Reporting, 2015). Tax revenue data come primarily from the Kenyan Economic Surveys (2017–2022), which report corporate income, value-added, turnover, and excise taxes; these are aggregated to construct total domestic tax receipts. For excise and turnover taxes, we supplement these data with *Revenue Statistics in Africa* and cross-validate the series using *Revenue Performance Reports*.

Although these surveys report fine revenues, they appear to understate the full extent of enforcement. To obtain a more comprehensive estimate of recovered taxes—including revenues from completed court cases—we use data from the 2018/2019 fiscal year reported in the *Revenue Performance Report* (Kenya Revenue Authority, 2019a), which yields a substantially higher implied tax penalty. We also draw on microdata from the 2016 *Small and Medium Enterprises Survey* (of Statistics, 2016) to estimate the fraction of firms that reported paying fines. The remaining calibration moments are disciplined using data from Kenyan restaurants and pharmacies (SMEs) in our study sample.

7.3 Model Calibration

Table 4 summarizes the parameter values along with the corresponding empirical evidence and calibration targets. In our framework, "debit" encompasses both Lipa Na M-Pesa and the regular M-Pesa and the debit fee, α, matches the transaction fee charged to sellers under Lipa Na M-Pesa. The discount factor, β, and the money growth rate, π, are calibrated to match, respectively, the average annual real interest rate and inflation rate observed between 2012 and 2019. We model time at an annual frequency, reflecting that one of the main taxes we consider is the corporate income tax, which is assessed on a fiscal-year basis; accordingly, tax-evasion decisions are naturally annual.[26]

When selecting calibration targets, we exclude firms with missing sales data. Non–tax-paying firms account for 47% of the sample, so we set the share of low-productivity sellers, $f(z_L)$, accordingly. High productivity is fixed at $z_H = 1.5$, while low productivity, z_L, is calibrated. A key requirement is that low-productivity sellers do not accept debit payments, which in our simulations necessitates a coefficient of relative risk aversion below one. Intuitively, a high intertemporal elasticity of substitution makes consumers willing to tolerate small intertemporal distortions in consumption, so they optimally leave debit balances idle when trading in the low-productivity submarket. Computationally, we find it more efficient to fix the coefficient of relative risk aversion at $\sigma = 0.7$ and calibrate the preference shifter Θ in the night-market utility function to match the relevant moment.

Building on the discussion in the previous subsection, we consolidate the various taxes that could apply to Kenyan firms in our sample into a single turnover tax. To calibrate the model, we need to determine the tax rate on revenues, τ, that would ensure firms, on average, pay an amount equivalent to their current tax obligations. To achieve this, we need to calculate the taxes owed by each firm in our sample. Unfortunately, we lack

[26]Additionally, we assume that when indifferent between consuming an additional unit in the current night market or in the subsequent day market, buyers choose the latter. Moreover, when $q_c^t = 0$ or $q_d^t = 0$ for a given productivity level z^t, the conditions above do not uniquely pin down the corresponding price p_c^t or p_d^t. In these cases, we assume without loss of generality that $p_a^t = u'(q_a^t)/(\beta\phi_{+1})$ for $a \in \{c, d\}$, that is, the auctioneer sets a price low enough to leave the buyer indifferent between purchasing in the night market and postponing consumption to the day market. This normalization does not affect equilibrium allocations, as buyers still optimally choose not to transact using the corresponding payment method, and the price is too low for sellers to accept.

Parameter	Value	Target
		Fixed parameters
α	0.01	Rate paid by sellers on LPN transactions: 1%
β	0.925	Avg. annual real interest rate between 2012-2019: 8.15%
π	0.066	Average annual inflation rate between 2012-2019: 6.6%
τ	0.15	Effective tax rate of 15%
τ^P	0.2625	Penalty rate of 75% over owed taxes
σ	0.7	Fixed at a value below 1
$f(z_L)$	0.47	Fraction of fully evading sellers in the sample
z_H	1.5	Fixed at a certain level
		Calibrated parameters
z_L	0.4	Aggregate tax/GDP ratio
Θ	0.85	Chosen to ensure that $q_d^L = 0$
δ	0.9	Avg. discount on cash payments among non-fully evading sellers
ζ	4	Average probability of paying fines
θ^L	0.0286	Total evasion for low-productivity sellers
θ^H	0.0857	Average evasion among non-fully evading sellers

Table 4: Parameter values and targets

data on VAT or ToT registration as well as annual revenues. Our approach to addressing this gap is as follows: we first estimate the likely annual revenues for each firm, and then determine which firms are eligible or required to register for either tax.

To account for seasonality, we draw on data from Kenya National Bureau of Statistics (2018) on the quarterly output of wholesale and retail trade in 2017. The endline survey took place in the first quarter of 2017, with the order of interviews unrelated to firm size. Thus, we calculate the average monthly and quarterly sales for each sector separately during this period. We then use these figures to extrapolate monthly sales into annual revenues. Furthermore, for simplicity, we assume that all firms with yearly turnover between KSh 500,000 and KSh 5 million pay ToT, rather than VAT. We can then compute:

$$\tau = \frac{0.3 * Profits + \mathbb{1}_{ToT} 0.03 * Revenues + \mathbb{1}_{VAT} 0.16 * (Revenues - Input\ Costs)}{Revenues}, \tag{33}$$

where $\mathbb{1}_{ToT}$ and $\mathbb{1}_{VAT}$ identify, respectively, firms that are registered for ToT and VAT. The average effective tax rate we obtain is $\tau \approx 0.1498$ and, thus, we set $\tau = 0.15$. As a result, we fix $\tau^P = 1.75 * \tau = 0.2625$.

Finally, we calibrate $\{z_L, \Theta, \delta, \zeta, \theta^L, \theta^H\}$ to match the targeted moments. The average discount on cash transactions in our sample is 11%.[27] Furthermore, for firms that paid

[27] The discount is only observable for firms that accept M-Pesa payments. As a result, we target an 11% cash discount among high-productivity sellers. Furthermore, as discussed in the empirical section, to obtain this figure we disregard relative prices below the 5^{th} percentile and above the 95^{th}.

taxes, the average evasion rate in our sample is 90%. The average tax/GDP ratio during 2012-2019 for domestic taxes is 0.0656[28]. We match that value by computing the total amount of taxes collected, including the taxes retrieved through enforcement measures but excluding fines of $\tau^P - \tau$. Lastly, the average fraction of small and medium sized businesses that reported paying fines is 3.48%.

Although the assumed fraction of money lost to theft, $1 - \delta = 0.1$, may appear large, the likelihood of theft in Kenya is substantial and consistent with this calibration. According to Stavrou (2002), between May 2000 and April 2001, 37% of Nairobi residents were victims of robbery, and about 22% experienced theft.

Table 5 presents the model's fit to the targeted moments. Overall, the model replicates these moments closely. Higher average evasion among high-productivity sellers leads to a slightly lower tax/GDP ratio, though the deviations are minor. We also evaluate two non-targeted moments: the $fine/tax$ revenue ratio and the average revenue ratio between fully and non-fully evading sellers. In the model, the revenue gap between low- and high-productivity sellers reflects debit sales, making their ratio equal to the evasion level of high-productivity sellers. Consequently, the model successfully reproduces both the empirical low-to-high productivity revenue ratio of 0.77 and the fine-to-tax ratio.

Moment	Model	Data
Targeted moments		
Avg. discount on cash payments among non-fully evading sellers	10.86%	11%
Aggregate tax/GDP ratio between 2012-2019	0.0512	0.0656
Quantity sold on e-money by fully evading sellers	0	0
Average probability of paying fines	0.035	0.0348
Average evasion for low-productivity sellers	1	1
Average evasion among non-fully evading sellers	0.8299	0.9
Non-targeted moments		
$Fine/Tax\ Revenue$ for 2018	0.1557	0.1327
Ratio of average revenue by fully and non-fully evading sellers	0.8299	0.77

Table 5: Targeted and non-targeted moments

8 Quantitative Policy Analysis

Motivation for the policy analysis. Our model highlights a fundamental tension between e-money (debit) and cash. While debit is a superior store of value—protecting buyers against theft—cash is a more attractive payment instrument due to sellers' tax evasion incentives. This tension between storage efficiency and payment informality can

[28]This comprises the corporate income tax, the VAT, ToT and excise taxes. Payroll taxes are left out.

be shaped by monetary and fiscal policy to improve government revenue and overall welfare. This insight motivates the quantitative policy analysis presented in this section.

Roadmap for the policy analysis. For the quantitative analysis, we define a public policy vector $\mathbb{P} := \{\tau, \tau^P \pi\}$, which consolidates the government's three main policy instruments. The public policy vector encompasses both fiscal policy—captured by the tax rate and the tax penalty, and monetary policy—captured by the rate of money growth.[29] The analysis proceeds in two steps. We first examine the effects of public policy (fiscal and monetary) and then evaluate optimal public policy design from two perspectives: (i) maximizing government revenue and (ii) maximizing social welfare. Additionally, in Online Appendix Section A.3 we study the impact of the private policy parameter, α, representing the cost of debit set by the private technology provider.[30]

8.1 The Effects of Fiscal and Monetary Policy

In Figure 1, we study equilibrium outcomes for tax rates between 0% and 26%. Government revenues follow a Laffer-curve pattern. At low rates, sellers' cash discounts are too small to make cash holding attractive, so no cash is held below a 9% rate—rendering the relative price undefined and eliminating tax evasion. In this range, government revenues rise linearly with the tax rate. Once the rate exceeds 9%, the economy shifts to a mixed-payment equilibrium with increasing cash usage and growing tax evasion.

When the tax rate approaches the penalty rate $\tau^P = 0.26$, no taxes are collected, as all sellers optimally evade and pay the penalty, resulting in an all-cash equilibrium. The real value of money declines slightly as the tax rate increases because higher taxes raise night-market prices. Consequently, output falls modestly, as shown in Figure 1h, though this effect is partially offset by evasion. While the average probability of detection is zero under debit-only equilibria, it becomes positive and increasing in the tax rate when cash and debit coexist. Since low productivity sellers do not pay any taxes for any tax rate above 12%, this increase is pushed by their high-productivity counterparts.

At low tax rates, idle balances are largely insensitive to taxation, even though debit prices rise and output falls. This reflects a decline in day-market money demand induced by higher taxes, which lowers the real price of money. As money is worth less in the

[29]The government could also influence tax compliance by increasing audit intensity; however, focusing on changes in the penalty rate τ^P offers a simpler and more transparent means analyzing enforcement.

[30]The private policy vector excludes information-related adoption costs that were reduced in the RCT, since the quantitative analysis focuses on the stationary equilibrium, whereas those information frictions were short-run in nature, as discussed in Section 4. The debit fee (α) - determined by the technology provider - is a stationary object.

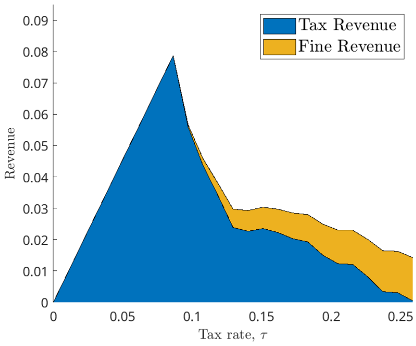
day-market, agents have weaker incentives to carry balances to the next period. Beyond a threshold, as higher taxes increase debit prices, cash becomes more attractive. In turn, lower debit holdings lead to decreasing leftover money. Moreover, the resulting slackening of the cash constraint in the low-productivity market produces lower cash discounts, while the higher tax burden increases discounts offered by high-productivity sellers, reversing relative prices across submarkets once the tax rate exceeds 15%.

Figure 2 presents the results for varying tax penalty rate within the interval $\tau^P \in [\tau, 1]$, where τ is the benchmark tax rate. Higher penalties raise government revenues primarily through voluntary tax payments by discouraging evasion. Unlike the previous case, some taxes are still collected even when $\tau = \tau^P$, provided the tax rate is sufficiently low. As penalties rise, the incentive to evade diminishes, reducing the attractiveness of holding cash. Intuitively, high-productivity sellers offer smaller cash discounts as their motivation to evade declines, which in turn weakens buyers' incentives to hold cash.

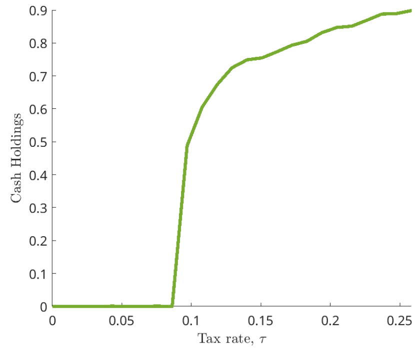
Interestingly, the discount on cash stations for both types of agents for penalty rates above 35%. In order to observe this, we would like to note that evasion affects i) the probability of being caught by tax authorities and ii) the value of the fine that must be paid after an audit. When the penalty rate is large, the latter effect dominates. As a result, the heterogeneity in tax evasion incentives begins to play a smaller role, and both the probability of being caught and the relative prices for both types of sellers converge. With less cash being held, for penalty rates above 40%, low-productivity agents begin accepting debit payments.

This shift lowers the revenues of low-productivity sellers, prompting them to offer larger cash discounts. Nevertheless, their output falls slightly, whereas output among high-productivity sellers increases as lower cash usage boosts monetary balances and mitigates theft losses. Idle balances initially rise with greater debit use in the night market but, as low-productivity sellers begin accepting debit payments, leftover money ceases to grow with the penalty rate. As a result, stronger enforcement seems to increase government revenues and debit usage - with minimal effects on output.

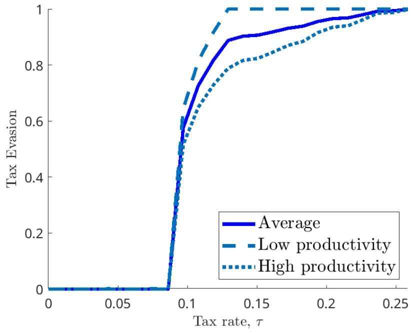
Next we analyze monetary policy by varying the inflation rate from -7% to 15%, with quantitative results shown in Figure 3. Cash usage increases with inflation because higher inflation raises the opportunity cost of holding idle debit balances carried over from the low-productivity market. This intriguing pattern is mirrored by the declining amount of money carried over from the night market as inflation rises. Consequently, as a novel theoretical finding in the literature, we observe that government tax revenues fall with higher inflation, as greater reliance on cash facilitates tax evasion, matching existing cross-country evidence on inflation and informality (Koreshkova, 2006; Aruoba, 2010). Notably, the increase in evasion occurs only in the high-productivity market, since



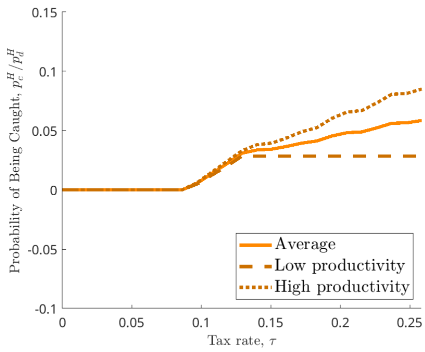
(a) Government revenues



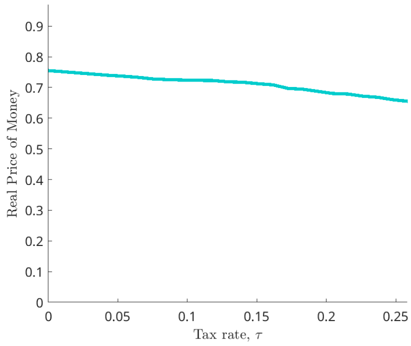
(b) Cash holdings



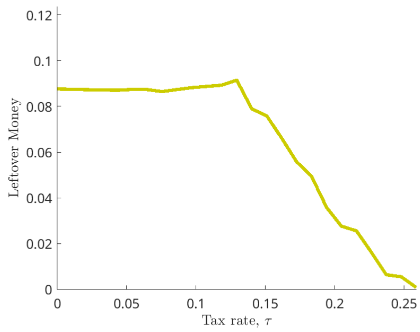
(c) Tax evasion



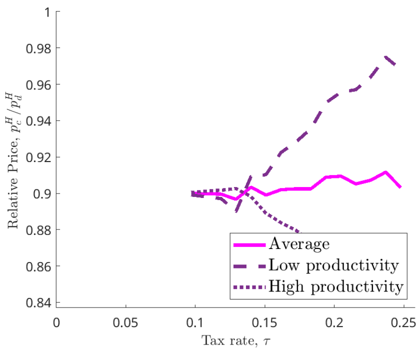
(d) Probability of being caught



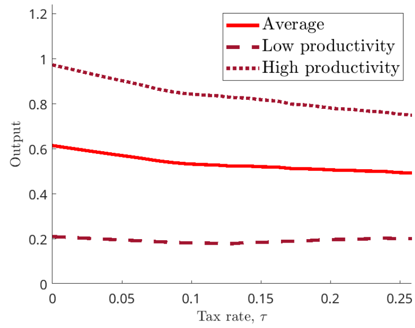
(e) Real price of money



(f) Leftover money

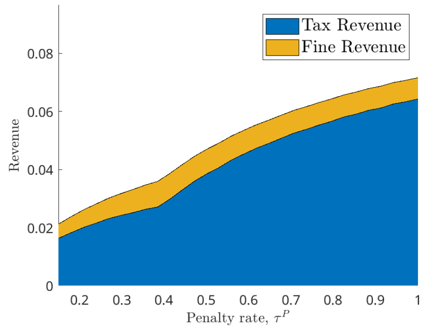


(g) Relative prices

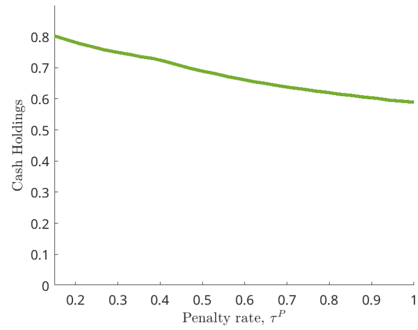


(h) Output

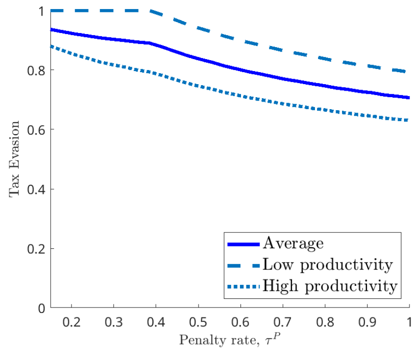
Figure 1: Effects of different tax rates



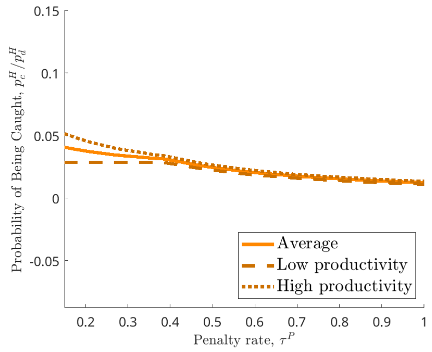
(a) Government revenues



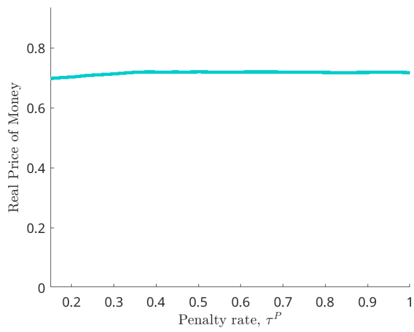
(b) Cash holdings



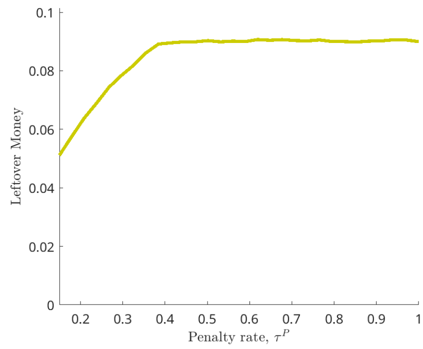
(c) Tax evasion



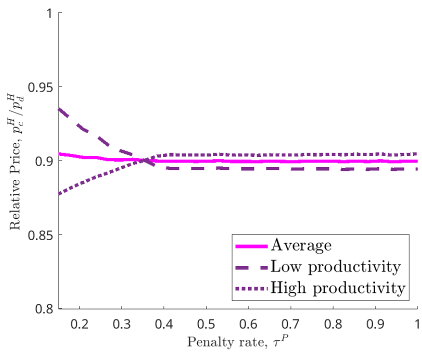
(d) Probability of being caught



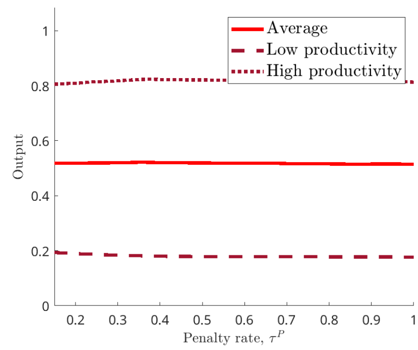
(e) Real price of money



(f) Leftover money



(g) Relative prices



(h) Output

Figure 2: Effects of different penalty rates

evasion is already at its maximum in the low-productivity market for all inflation levels. Although revenues from tax penalties increase with inflation, they fail to fully offset the decline in overall tax revenues—implying that low inflation maximizes government revenue in mixed-payment equilibria.

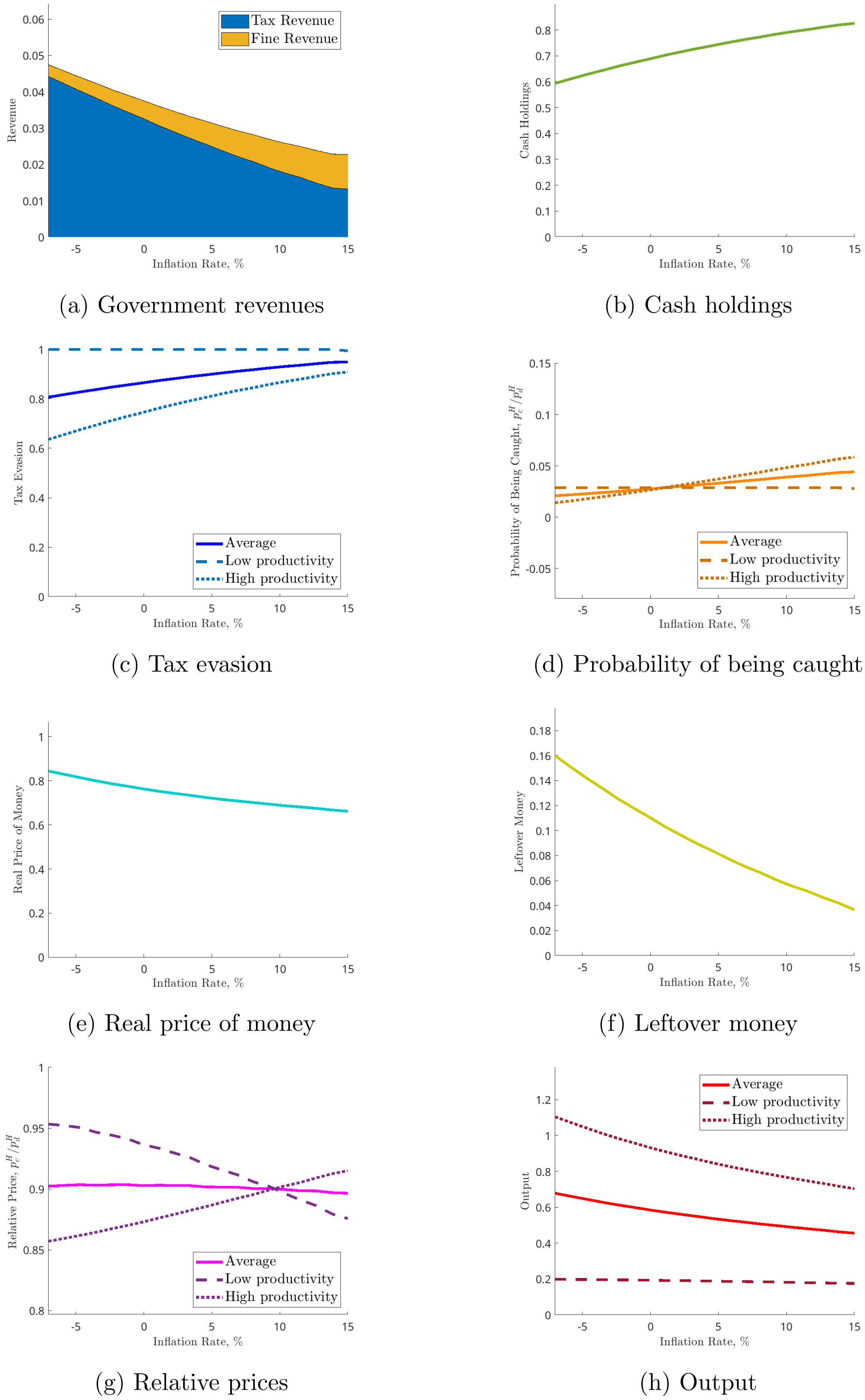
Higher inflation also reduces money demand via the "hot potato effect." Under low inflation, high-productivity sellers offer larger discounts on cash transactions than low-productivity sellers, whereas the pattern reverses under high inflation. The mechanism works as follows: when inflation is low, agents have a greater incentive to carry idle money balances forward. The cash constraint therefore does not bind in the low-productivity submarket, leaving some cash unspent and reducing the equilibrium cash discount. Intuitively, cash is preferred for transactions in both markets, but debit serves as the preferred store of value between day and night markets, being immune to theft — a key tension in our framework. Furthermore, in a deflationary environment, low-productivity agents have a higher probability of being subject to an audit since the evasion level by high-productivity agents is constrained at a low level by the amount of cash revenues.

Under high inflation, high-productivity sellers approach their optimal level of tax evasion and consequently offer smaller cash discounts. Hence, the mixed-payment equilibrium features a higher cash discount in the low-productivity submarket, where buyers aim to spend cash more rapidly due to the "hot potato effect." Importantly, under our baseline calibration, the model reproduces the empirical pattern in our data: fully-evading sellers offer lower cash discounts.

As shown earlier, no cash is used at low tax rates. Figure 4 presents the comparative statics for inflation when the tax rate is low, *i.e.*, $\tau = 0.05$. In this debit-only regime, the "hot potato effect" operates in the opposite direction: higher inflation encourages spending, and since no cash is used, this translates into a modest increase in government revenues. Output declines with rising inflation under both low- and high-tax regimes. Relative prices are undefined due to the lack of debit usage and the probability of being caught is stuck at zero. Overall, inflation exerts contrasting effects across regimes—reducing revenues in mixed-payment economies by promoting cash use and evasion, but enhancing revenues in cashless economies by stimulating spending.

8.2 Optimal Monetary and Fiscal Policy

We now turn to the analysis of the optimal mix of monetary and fiscal policies, where we consider two alternative policy objectives. First, we examine the policy mix that maximizes the revenues of the government. Second, we analyze a central planner who selects policy parameters to maximize social welfare.



(a) Government revenues

(b) Cash holdings

(c) Tax evasion

(d) Probability of being caught

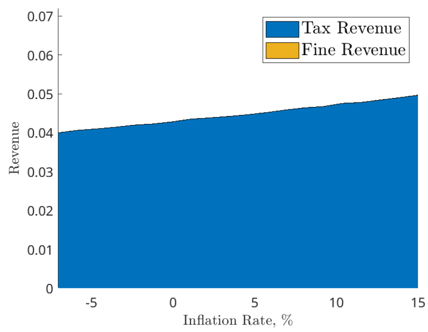
(e) Real price of money

(f) Leftover money

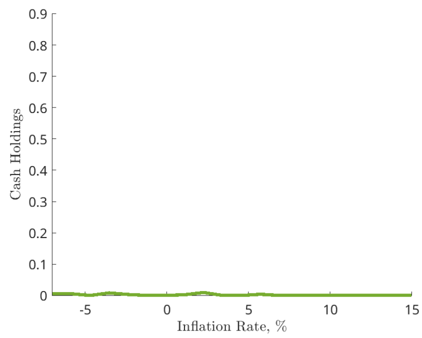
(g) Relative prices

(h) Output

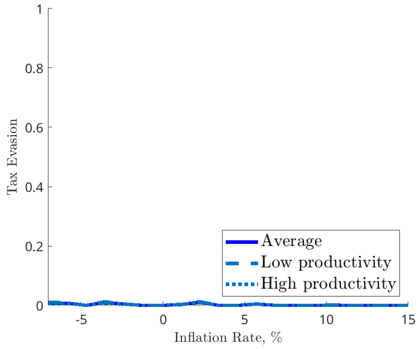
Figure 3: Effects of different inflation rates



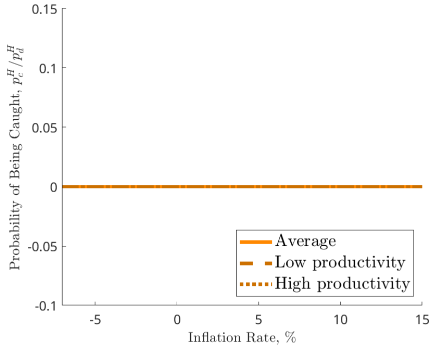
(a) Government revenues



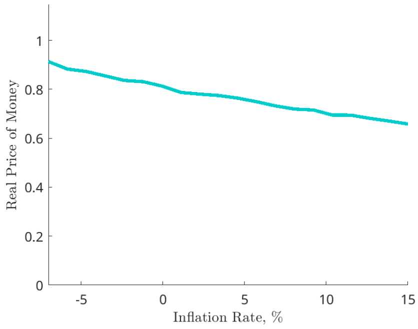
(b) Cash holdings



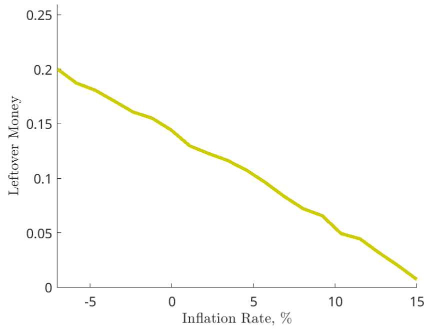
(c) Tax evasion



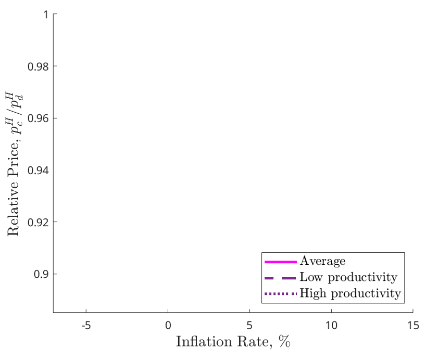
(d) Probability of being caught



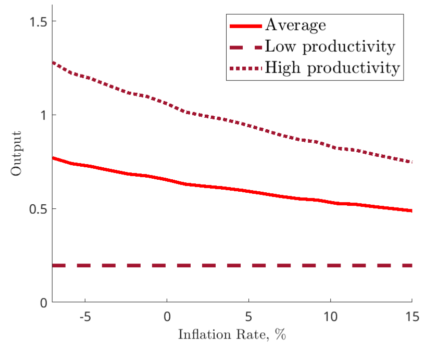
(e) Real price of money



(f) Leftover money



(g) Relative prices



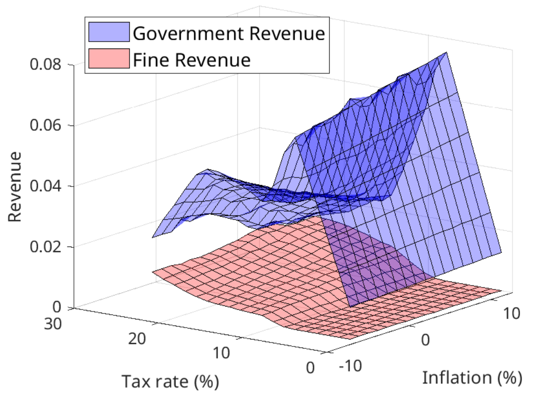
(h) Output

Figure 4: Effects of different inflation rates for $\tau = 0.05$

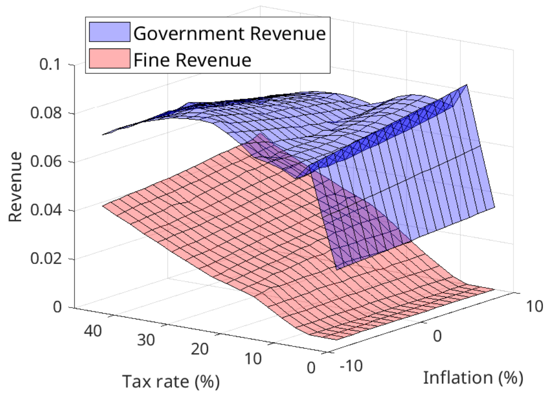
8.2.1 Government Revenue Maximization

In this section, we examine the policy mix that maximizes government revenues. For expositional clarity, we fix the penalty rate at its baseline value and focus on the optimal combination of inflation and tax rates. The results are presented in Figure 5a. Total government revenues are shown in blue, while fine revenues are shown in red. Consistent with earlier results, at intermediate tax rates government revenues are maximized under low inflation, as higher inflation encourages cash usage.

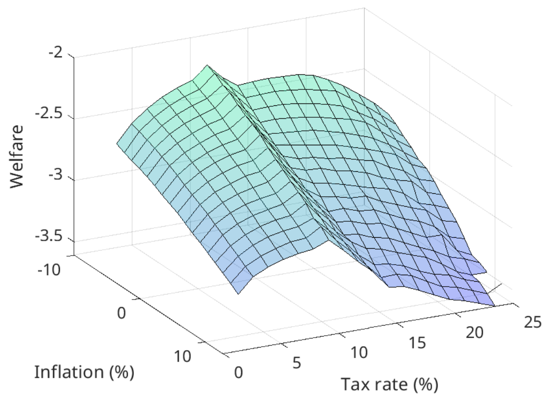
When the tax rate is sufficiently low—so that equilibrium involves only debit transactions—inflation instead raises government revenues. Overall, government revenues are maximized by a mix of a low tax rate (around $\tau = 0.09$) and inflation. In fact, the figure suggests a monotone increase in revenues at the optimal tax rate as the inflation rate increases. This aligns with the previous finding that inflation boosts tax revenues at debit-only equilibria through the "hot potato effect." In fact, for an inflation rate of 15%, revenues are 20% higher than at an inflation rate of -7%.



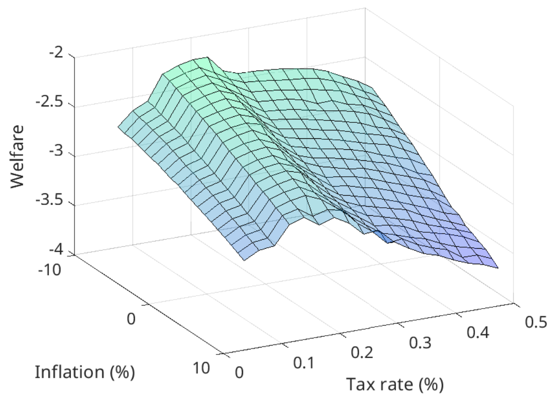
(a) Government Revenue — Baseline τ



(b) Government Revenue — Optimal τ



(c) Welfare — Baseline τ



(d) Welfare — Optimal τ

Figure 5: Optimal Monetary and Fiscal Policies

Finally, we study the revenue-maximizing fiscal–monetary policy mix under the optimal penalty rate, shown in Figure 5b. The optimal penalty is $\tau^P = 1$, implying full seizure of unreported revenues. A higher penalty rate does not materially shift the tax threshold at which the economy transitions from a debit-only to a mixed-payment equilibrium, since the average cash discount is unaffected by τ^P. As a result, the revenue-maximizing policy is unchanged relative to the baseline penalty. Instead, the higher penalty steepens the fine-revenue schedule in the tax rate, generating additional revenues from higher taxes. Under a 7% deflation rate, revenues are locally maximized at a tax rate of 30%, where fines mitigate the revenue loss associated with the transition to a mixed-payment regime.

8.2.2 Social Welfare Maximization

In this section we relax the assumption that taxation serves no purpose and assume that the government purchases goods in the day market, and redistributes them to the buyers. This means that instead of rebating the tax revenues in a lump-sum fashion, the government uses taxes to *buy goods* in the centralized market. Buyers' day-time utility function in this modified framework is given by $U(x) + u(G) - h$. We assume that the utility derived from government purchases, G, is additive and has the same functional form as the night-market utility.[31] Given stationarity and quasilinear preferences, the day-market choices are state-independent, allowing us to compute welfare as

$$W = \frac{1}{1-\beta}\Bigg[\underbrace{\int_0^1 [U(x) + u(G) - l]di}_{\text{Buyers' daytime utility}} + \underbrace{\sum_{t\in\{H,L\}} \int_0^1 [U(x^t) - l^t]dj}_{\text{Sellers' daytime utility}} + \underbrace{\sum_{t\in\{H,L\}} f(z^t) \int_0^1 u(q^t)di}_{\text{Buyers' nighttime utility}} - \underbrace{\sum_{t\in\{H,L\}} f(z^t) \int_0^1 h^t dj}_{\text{Sellers' nighttime utility}}\Bigg],$$

where we index buyers with i, and sellers with j, which are omitted from the variables due to symmetry. The results are reported in Figure 5c in utils.

Welfare is maximized at the Friedman rule, and by setting a tax rate of around $\tau = 0.09$. In our calibration, tax evasion is therefore suboptimal: it is preferable to set the highest tax rate consistent with a debit-only equilibrium, boosting government spending without generating consumption losses in the private sector relative to the

[31] This formulation avoids two complications: distorting day-market incentives and inducing spurious tax adjustments by the central planner to exploit differences between the utility of night-market consumption and government-provided goods.

mixed-payment equilibria. Thus, by facilitating tax enforcement, debit usage can improve welfare, allowing adequate public good provision while limiting theft. Deflation improves welfare by reducing the labor-supply distortion associated with holding nominal assets.

For the optimal penalty rate, Figure 5d shows that the welfare-maximizing outcome lies close to the Friedman rule and corresponds to a tax rate of approximately 16%. Thus, optimal fiscal policy occurs in the presence of a mixed-payment equilibrium and some tax evasion. Intuitively, higher fine revenues expand public good provision, while tax evasion dampens the output costs of high taxes for unaudited sellers.

At the optimum, some sellers pay relatively little in taxes due to high evasion, while others are heavily taxed through fines. Consequently, an outcome in which all sellers effectively face the same tax rate—as in a cashless economy—is suboptimal. One reason is that penalties are imposed randomly within each submarket and only after production and consumption decisions have been made. Hence, although sellers ultimately face different tax liabilities, they are ex ante symmetric in each submarket, and consumers allocate demand uniformly across them. Moreover, market segmentation prevents buyers from reallocating consumption towards sellers that end up paying lower tax rates.

9 Conclusion

Our paper presented the critical role of electronic payments in enhancing tax compliance in developing countries, using both experimental and theoretical approaches - coupled with observational evidence. The randomized controlled trial (RCT) conducted in Kenya provides robust evidence that electronic payment systems like Lipa Na M-Pesa lead to a significant increase in tax payments among small and medium-sized enterprises. This finding is consistent with the broader literature, highlighting the increased traceability and transparency of electronic payments compared to cash transactions, which facilitates better compliance with tax obligations.

The general equilibrium monetary framework we developed matches the qualitative and quantitative properties observed in the data. Our analysis reveals the conditions under which cash and electronic payments coexist, and the interaction between monetary and fiscal policies and the technology-based financial development in determining the tax compliance in the economy. The insights resulting from our analysis are crucial for policymakers aiming to increase government revenues, as it highlights the need to balance technological advancements with appropriate monetary and fiscal policies.

Overall, our research contributes to the understanding of how payment methods influence tax compliance and provides a concrete foundation for policy recommendations. The results suggest that fostering the adoption of electronic payment systems in developing countries can enhance formalization and reduce tax evasion, suggesting a role for policies that lower barriers to adopting electronic payments. The combination of experimental and empirical evidence and theoretical modeling offers a comprehensive view of the dynamics between financial development, payment methods choice, and tax compliance, making it relevant for both academic literature and policy debates.

Our model is grounded in the unique institutional context and evidence from Kenya, where the coexistence of payment methods arises under tax enforcement frictions. While tailored to this setting, the framework is readily generalizable to both developing and advanced economies, offering a foundation for future research.

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Online Appendix

A Supplementary Text

A.1 Supplement to Institutional Context

A.1.1 Additional Notes on Taxation in Kenya

According to the KPMG East Africa (2017), there is a withholding tax, levied at source, with varying rates (between 5% and 30%) for different income categories — such as dividends, interest payments, royalties, commissions, and rents. These rates also differ for residents and non-residents. For the former, the amounts withheld could be credited against the final corporate tax liability. Furthermore, according to the Kenyan Revenue Authority[32], excise duties are imposed on selected classes of goods such as alcohol, bottled water, tobacco, and cosmetics. Since withholding taxes primarily affect larger corporations and the excise duties applied mostly to manufacturers, these taxes are not directly relevant to our sample of small- and medium-sized pharmacies and restaurants, though they remain important for calibration purposes. Lastly, there is PAYE ("Pay As You Earn"), one of the primary tax levies in Kenya. However, since it is essentially an individual income tax withheld at source and, therefore, cannot be evaded by misreporting revenues, we do not incorporate it in our quantitative analysis.

A.1.2 Additional Notes on Tax Enforcement in Kenya

The legal framework for investigating and punishing tax evasion in Kenya is primarily governed by the Tax Procedures Act, No. 29 of 2015 (National Council for Law Reporting, 2015) and operationalized by the Investigations and Enforcement Department (IED) of the Kenya Revenue Authority (KRA). The Tax Investigations Handbook: Taxpayers' Edition (Kenya Revenue Authority, 2019b) outlines the investigative process. Tax investigations are initiated when the Commissioner has reasonable cause to suspect tax evasion. These include preliminary inquiries, surveillance, requests for documents from the taxpayer and third parties, and interviews. Upon completion, the IED may recommend either civil enforcement or criminal prosecution. If an underpayment is confirmed, the Commissioner issues an assessment notice, which the taxpayer may settle or formally appeal. Where criminal behavior is established, the taxpayer may be prosecuted in court. Punishments for tax offenses include fines and imprisonment. Moreover, the Commissioner is empowered to use a range of administrative and judicial enforcement tools

[32]Summarized in this page.

to recover outstanding liabilities, including debt collection orders, restrictions on asset access, and administrative cancellation of compliance certifications (National Council for Law Reporting, 2015; Kenya Revenue Authority, 2019b).

A.2 Descriptive Statistics

Table OA1 reports baseline and endline descriptive statistics for the sample of Kenyan SMEs. In this table we document a substantial increase in the use of electronic payments over time: general mobile money usage rises from 51% to 60%, Lipa Na M-Pesa account ownership increases from 9% to 21%, and acceptance of Lipa Na M-Pesa payments expands sharply from 4% to 19%. Over the same period, firms experience modest declines in average sales, profits, and employment, but exhibit increases in profit, revenue, and value-added productivity per worker, suggesting a shift toward higher productivity among surviving firms. Tax compliance increases slightly over the sample period, as the tax share rose from about 0.87% to 0.96%. Finally, endline pricing data indicate sizable cash discounts relative to mobile money prices, underscoring the continued role of cash-based incentives despite the rapid diffusion of electronic payment technologies.

A.2.1 Acceptance of mobile payments and productivity (Extensive margin)

Table OA2 reports the results of logit regressions where the dependent variable is a dummy equal to one if a firm lists a price for mobile money payments (M-Pesa or LPN M-Pesa) on at least one of its three main products, and undefined if no price is reported for cash transactions. The explanatory variables include (three alternative) measures of log productivity, the business owner's education, a dummy for whether the business has a bank loan — in addition to sector, enumerator, and time fixed effects. The three productivity measures correspond to the logarithm of (i) profits, (ii) revenues, and (iii) value added per employee. Education and access to bank loans are included to account for alternative sources of correlation between productivity and the acceptance of electronic payments. Education is plausibly positively correlated with both productivity and payment technology adoption, while, as documented in Dalton et al. (2024), the use of Lipa Na M-Pesa improves credit access, which may in turn enhance productivity.

We report standard errors in parentheses. The results indicate that a 1% increase in productivity is associated with at least a 43% higher likelihood of accepting mobile payments. This finding is consistent with Beck et al. (2018), who using an alternative dataset from Kenya, show that more productive firms are more likely to accept mobile money payments.

Table OA1: Descriptive Statistics: Baseline vs Endline

	Baseline	Endline
Mobile Money Usage		
Use of mobile money for general business purposes	0.51	0.60
Use of mobile money to receive payments	0.33	0.40
Lipa Na M-Pesa Metrics		
Lipa Na M-Pesa adoption (business has an account)	0.09	0.21
Acceptance of LPN to receive payments	0.04	0.19
Barrier: Cost of opening account is too high	0.11	0.07
Barrier: Transaction fees are too high	0.16	0.07
Barrier: Owner does not have time to open account	0.12	0.05
Barrier: System is too complex to use	0.10	0.10
Barrier: Lack of trust in provider	0.02	0.00
Business Characteristics & Performance		
Monthly Sales (in thousands KSh)	225.99	197.83
Monthly Profits (in thousands KSh)	66.49	61.37
Number of Employees (permanent and temporary)	5.91	4.27
Profit Productivity (thousands KSh/Employee)	12.05	13.56
Revenue Productivity (thousands KSh/Employee)	38.41	40.74
Value Added Productivity (thousands KSh/Employee)	24.16	27.17
Tax Compliance & Informality		
Possession of a business license	0.72	0.69
Tax Share (taxes/sales)	0.0087	0.0096
Pricing		
Average cash discounts (relative to mobile money prices)	.	0.89

Table OA2: Likelihood of Kenyan Firms Accepting Mobile Payments

	(1)	(2)	(3)
Log Profit Productivity	0.476^{***}		
	(0.105)		
Log Revenue Productivity		0.583^{***}	
		(0.103)	
Log Productivity			0.429^{***}
			(0.094)
N	746	758	645

Notes: All regressions include sector, time and enumerator fixed effects.

Marginal effects; Standard errors in parentheses

(d) for discrete change of dummy variable from 0 to 1

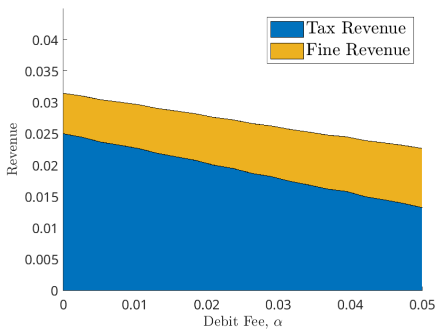
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A.3 The Effects of Debit Fee

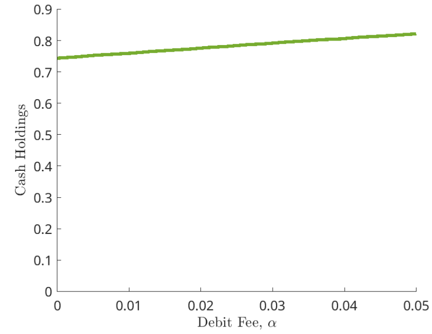
In Figure OA1, we report the comparative statics illustrating how the model's outcomes vary as debit fees increase from 0% to 5%. Higher debit fees lead to greater cash usage, resulting in higher tax evasion and lower idle debit balances. While tax revenues decline and fine revenues rise with the fee, their combined value decreases overall.

The mechanism operates through firms' pricing behavior: as debit fees rise, high-productivity sellers offer larger cash discounts to discourage debit payments, whereas low-productivity sellers reduce their cash discounts. The latter occurs because greater cash usage raises their sales volume and, consequently, the expected fine if caught evading taxes—prompting an upward adjustment in cash prices. For high-productivity sellers, higher debit fees reduce debit-based sales and production, leaving aggregate output largely unchanged.

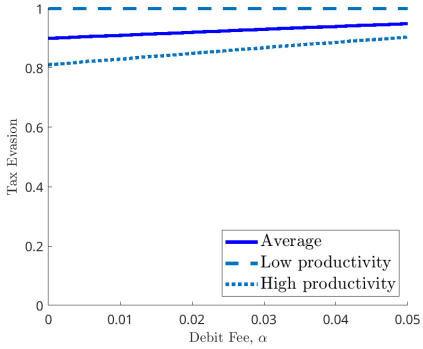
Since low-producitvity sellers do not accept debit payments, their probability of being caught is unaffected by the fee, while high-productivity ones are more likely to be audited due to the higher evasion levels. Although cash discount dispersion and leftover money respond markedly to debit fees, most other variables remain relatively stable. Overall, debit fees appear only weakly connected to tax evasion incentives, suggesting potential efficiency gains from taxing financial institutions and FinTech platforms.



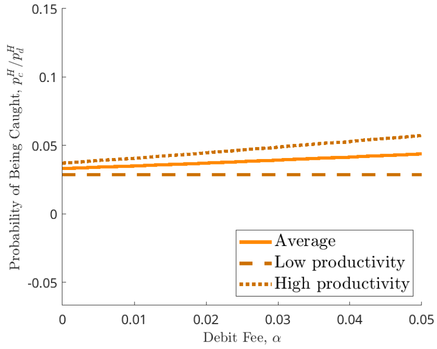
(a) Government revenues



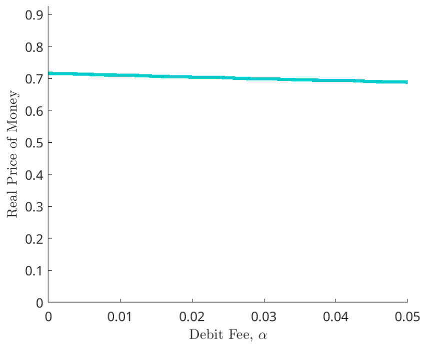
(b) Cash holdings



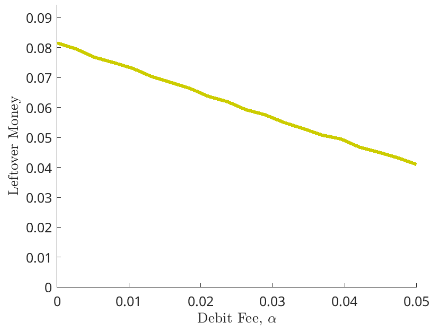
(c) Tax evasion



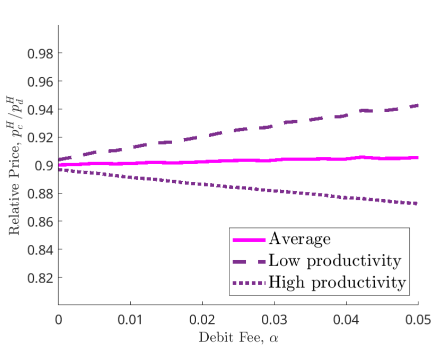
(d) Probability of being caught



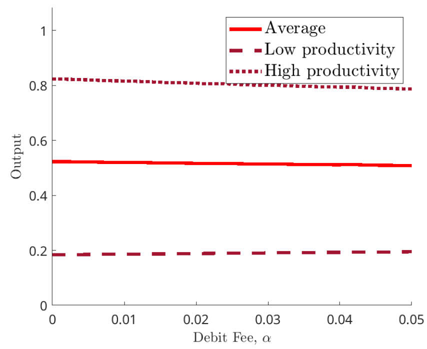
(e) Real price of money



(f) Leftover money



(g) Relative prices



(h) Output

Figure OA1: Effects of different debit fee rates

B Proofs of Propositions

B.1 Proposition 1

B.1.1 Day

The buyers' day market problem then yields the following first-order conditions

$$\begin{aligned} U'(x) &= 1, &\text{(OA1)}\\ \sum_{t\in\{H,L\}} f(z^t)V_c^B(c,d,z^t) &= \frac{\phi}{\delta}, &\text{(OA2)}\\ \sum_{t\in\{H,L\}} f(z^t)V_d^B(c,d,z^t) &= \phi, &\text{(OA3)} \end{aligned}$$

and the envelope condition

$$W_m^B(m_{-1}) = \frac{\phi}{1+\pi}. \tag{OA4}$$

Since we are interested in equilibria where both cash and debit are used, we ignore the corresponding non-negativity constraints. We note that the right-hand side of equation (OA2) represents the cost of one unit of cash for the day market, whereas the left-hand side stands for the marginal expected benefit of having an extra unit of cash in the next night market. The same intuitive interpretation holds for units of debit in equation (OA3). Moreover, (OA2) and (OA3) can be used to pin down the real price of money in the day market. The sellers' day-time problem yields the first-order condition

$$U'(x^t) = 1, \tag{OA5}$$

and the envelope condition

$$W_m^S(m_{-1}^{t-1}) = \frac{\phi}{1+\pi}. \tag{OA6}$$

B.1.2 Night

The envelope conditions here are only relevant for buyers, since sellers' choices at the day market do not matter for the night market. We adopt μ_c^t and μ_d^t to represent the shadow prices of, respectively, the cash and the debit constraints in the night. Hence, the envelope conditions for the buyers' night-time value function are:

$$\begin{aligned} V_c^B(c,d,z^t) &= \frac{\beta\phi_{+1}}{1+\pi} + \mu_c^t, &\text{(OA7)}\\ V_d^B(c,d,z^t) &= \frac{\beta\phi_{+1}}{1+\pi} + \mu_d^t. &\text{(OA8)}\\ & &\text{(OA9)} \end{aligned}$$

Utilizing (OA2) and (OA3) we obtain

$$\delta \sum_{t=\{H,L\}} f(z^t)\mu_c^t = (1-\delta)\frac{\beta\phi_{+1}}{1+\pi} + \sum_{t=\{H,L\}} f(z^t)\mu_d^t, \tag{OA10}$$

which in turn implies

$$\sum_{t=\{H,L\}} f(z^t)\mu_c^t > \sum_{t=\{H,L\}} f(z^t)\mu_d^t.$$

This means that the expected shadow price of the cash constraint is higher than the one for the debit constraint during the day.

Next, turning to the buyers' night-time problem, the first-order conditions with respect to the quantities are

$$u'(q^t) - \frac{\beta\phi_{+1}}{1+\pi}p_c^t - \mu_c^t p_c^t + \Phi_c^{B,t} = 0, \tag{OA11}$$

$$u'(q^t) - \frac{\beta\phi_{+1}}{1+\pi}p_d^t - \mu_d^t p_d^t + \Phi_d^{B,t} = 0. \tag{OA12}$$

This yields (24). The fact that buyers exhaust the cheapest payment method first implies

$$p_a^t < p_{a'}^t \quad \Rightarrow \quad \mu_a^t \geq \mu_{a'}^t, \tag{OA13}$$

where the equality holds only in the case where $\mu_a^t = \mu_{a'}^t = 0$ and $\Phi_{a'}^t > 0$. Now, consider the case where, for any $t \in \{H, L\}$, $p_c^t = p_d^t = p^t$. Then:

$$q^t = \begin{cases} 0 & \text{if } p^t > u'(0)/\beta\phi_{+1} \\ (u')^{-1}(\frac{\beta\phi_{+1}}{1+\pi}p^t) & \text{if } q^{t*} \leq (c+d)/p^t \\ (c+d)/p^t & \text{if } q^{t*} > (c+d)/p^t \end{cases} \tag{OA14}$$

Let us analyze each case in turn. In the first case, $\mu_c^t = \mu_d^t = 0$ and $\Phi_c^{B,t} = \Phi_d^{B,t} > 0$. In the second case, the composition of q^t into q_c^t and q_d^t is undefined, but $\mu_c^t = \mu_d^t = \Phi_c^{B,t} = \Phi_d^{B,t} = 0$. Lastly, we consider the third case. Naturally, then, $\Phi_c^{B,t} = \Phi_d^{B,t} = 0$, which means that $\mu_c^t = \mu_d^t > 0$ by the first-order conditions. Therefore, the condition (27) cannot be satisfied if the prices are equal across payment methods for both $t \in \{H, L\}$. In fact, (OA13) implies that (27) can only be satisfied if $p_c^t < p_d^t$ for some $t \in \{H, L\}$. Next, we analyze the sellers' night-time problem in two blocks: tax evasion and relative prices.

B.1.3 Tax evasion

Let us define a cost function $C(\cdot)$

$$C^t(p_c^t, p_d^t, q_c^t, q_d^t, e^t, \tau^P) = P^t(e^t)\tau^P e^t(p_c^t q_c^t + p_d^t q_d^t), \tag{OA15}$$

We solve for the optimum tax evasion of the firm, from (15). By the first-order conditions:

$$\frac{\beta\phi_{+1}}{1+\pi}\tau + \frac{\underline{\lambda}_c^t - \bar{\lambda}_c^t}{p_c^t q_c^t} \; = \; \kappa^t \; = \; \frac{\frac{\beta\phi_{+1}}{1+\pi} C_e^t(p_c^t, p_d^t, q_c^t, q_d^t, e^t, \tau^P) - \underline{\lambda}^t + \bar{\lambda}^t}{p_c^t q_c^t + p_d^t q_d^t} > 0, \tag{OA16}$$

where the inequality at the end comes from the fact that, as will be shown below, $\underline{\lambda}^t = 0$. We analyze possible cases as follows.

<u>No tax evasion</u>

By (OA16), and using (OA15) to simplify it further, we get:

$$C_e^t(p_c^t, p_d^t, q_c^t, q_d^t, 0, \tau^P) > \tau(p_c^t q_c^t + p_d^t q_d^t) \qquad \therefore \qquad 0 = P^t(0)\tau^P > \tau,$$

which is not possible, since $\tau > 0$. Thus, there will always be some degree of tax evasion.

<u>Internal solution</u>

For the internal solution, which is the unconstrained level of tax evasion, we obtain:

$$C_e^t(p_c^t, p_d^t, q_c^t, q_d^t, e^{t*}, \tau^P) = \tau(p_c^t q_c^t + p_d^t q_d^t) \qquad \therefore \qquad P_e^t(e^{t*})e^{t*} + P^t(e^{t*}) = \tau/\tau^P. \tag{OA17}$$

This equation pins down e^{t*}, the optimal level of tax evasion, by equating its marginal cost and marginal benefit.

<u>Binding evasion: $\bar{\lambda}_c^t > 0$, $\bar{\lambda}^t \geq 0$</u>

For the case of a constrained level of tax evasion, we characterize:

$$C_e^t(p_c^t, p_d^t, q_c^t, q_d^t, e^t, \tau^P) < \tau(p_c^t q_c^t + p_d^t q_d^t) \qquad \therefore \qquad P_e^t(e^t)e^t + P^t(e^t) < \tau/\tau^P,$$

We would like to note that, in this case, $e_c^t = 1$ and $e^t \leq 1$, which holds with equality only if no transactions are conducted in debit. This is the case whenever the optimal level of tax evasion $e^{t*} > c/(c + p_d^t q_d^t)$. Let $\mathcal{E}^t := \{e \mid P_e^t(e)e + P^t(e) < \tau/\tau^P\}$ be the set of tax evasion levels for which the tax evasion constraint $e_c^t \leq 1$ binds, that is, the firm would like to be able to increase the level of tax evasion but is constrained by the amount of cash transactions. Since $P_e^H(e) > P_e^L(e)$ and $P^H(e) > P^L(e)$, then $\mathcal{E}^H \subset \mathcal{E}^L$, implying that the constraint is more likely to bind for low productivity sellers.

B.1.4 Relative prices

Next we solve for the optimal quantities from (15). The FOCs yield:

$$\frac{p_c^t}{p_d^t} = \frac{\frac{\beta\phi_{+1}}{1+\pi}(1 - \alpha - \tau - C_d^t(p_c^t, p_d^t, q_c^t, q_d^t, e^t, \tau^P)) + \kappa^t e^t + \frac{\Phi_d^t}{p_d^t}}{\frac{\beta\phi_{+1}}{1+\pi}(1 - \tau + e_c^t\tau - C_c^t(p_c^t, p_d^t, q_c^t, q_d^t, e^t, \tau^P)) - \kappa^t(e_c^t - e^t) + \frac{\Phi_c^t}{p_c^t}}, \tag{OA18}$$

where Φ_d^t and Φ_c^t correspond to the non-negativity constraints $q_d^t, q_c^t \geq 0$ from the perspective of the seller. This means that, although cash transactions allow the seller to evade taxes (which gives a benefit $e_c^t\tau$), it has two costs: 1) it increases total revenues and, hence, the size of the fine given a certain e^t, and 2) given e_c^t, an increase in cash transactions increases e^t, which produces a cost proportional to $C_e^t(e^t)$. Debit transactions also increase the size of the fine, but they allow for a lower e^t and $C_e^t(e^t)$, given a certain e_c^t. Let us analyze the implications of this property for each of the possible tax evasion cases.

Internal solution

In order to further investigate the implications of equilibrium prices at (OA18), we impose an interior solution for the choice of tax evasion — as well as the cost function specified at (OA15). Since the property $p_c^t/p_d^t < 1$ is also valid here, we omit Φ_c^t from the equations below and obtain

$$\frac{p_c^t}{p_d^t} = \frac{1-\alpha-\tau+\tau e^{t*} - P^t(e^{t*})e^{t*}\tau^P + \frac{1+\pi}{\beta\phi_{+1}}\frac{\Phi_d^t}{p_d^t}}{1-\tau+\tau e^t - P^t(e^{t*})e^{t*}\tau^P} \tag{OA19}$$
$$= 1 - \frac{\alpha - \frac{1+\pi}{\beta\phi_{+1}}\frac{\Phi_d^t}{p_d^t}}{1-\tau+\tau e^{t*} - P^t(e^{t*})e^{t*}\tau^P}.$$

This equation implies that the good is sold with a discount on cash. At the optimal tax evasion level, the seller is indifferent between cash and debit from a tax evasion perspective. This happens because the cash-specific benefit of evading taxes $\beta\phi_{+1}e^*t_c\tau p_c^t q_c^t/(1+\pi)$ cancels out with the cash-specific increase in the cost of evading taxes given a certain e_c^{t*}.

Binding evasion

Finally we study the equilibrium prices under the case of constrained binding tax evasion with

$$\frac{p_c^t}{p_d^t} = \frac{1-\alpha-\tau+\tau e^t - P^t(e^t)e^t\tau^P - \frac{1+\pi}{\beta\phi_{+1}}\left(\frac{\bar\lambda_c^t}{p_c^t q_c^t} - \frac{\Phi_d^t}{p_d^t}\right)}{1-\tau+\tau e^t - P^t(e^t)e^t\tau^P + (1-e^t)\frac{1+\pi}{\beta\phi_{+1}}\frac{\bar\lambda_c^t}{p_c^t q_c^t}} \tag{OA20}$$
$$< 1 - \frac{\alpha - \frac{1+\pi}{\beta\phi_{+1}}\frac{\Phi_d^t}{p_d^t}}{1-\tau+\tau e^t - P^t(e^t)e^t\tau^P} < 1 - \frac{\alpha - \frac{1+\pi}{\beta\phi_{+1}}\frac{\Phi_d^t}{p_d^t}}{1-\tau+\tau e^{t*} - P^t(e^{t*})e^{t*}\tau^P},$$

where the last inequality follows from the fact that

$$\frac{\partial\left[e\tau - P^t(e)e\tau^P\right]}{\partial e} = \tau - P_e^t(e)e\tau^P - P^t(e)\tau^P \geq 0,$$

holding with equality at e^{t*}. Thus, as $e^t \uparrow e^{t*}$, then we must have $e^t\tau - P^t(e^t)e^t\tau^P \uparrow e^{t*}\tau - P^t(e^{t*})e^{t*}\tau^P$, which gives us the inequality above.

B.2 Proposition 2

We begin by focusing on equilibria with both cash and debit usage, and subsequently characterize the conditions under which such equilibria emerge. First we note that (OA10) can be written as

$$\mu_c > \delta\mu_c = (1-\delta)\frac{\beta\phi_{+1}}{1+\pi} + \mu_d > \mu_d \geq 0. \tag{OA21}$$

By the definition of mixed-payment equilibrium, $q_d > 0$ and, thus, $\Phi_d^B = 0$. Then, notice that (OA11) and (OA12) yield

$$\mu_c \frac{p_c}{p_d} = \left(1 - \frac{p_c}{p_d}\right)\frac{\beta\phi_{+1}}{1+\pi} + \mu_d.$$

Plugging (OA21) gives

$$\mu_c\left(\delta - \frac{p_c}{p_d}\right) = -\frac{\beta\phi_{+1}}{1+\pi}\left(\delta - \frac{p_c}{p_d}\right),$$

which can only hold when

$$\frac{p_c}{p_d} = \delta.$$

As a result, in general, $q = q^*$, if and only if the following condition holds

$$u'\left(\frac{m}{p_d}\right) \leq \frac{\beta\phi_{+1}}{1+\pi}p_d, \tag{OA22}$$

in which case $\mu_d = 0$ and $\mu_c = \left(\frac{1-\delta}{\delta}\right)\frac{\beta\phi_{+1}}{1+\pi}$. If $u'\left(\frac{m}{p_d}\right) > \frac{\beta\phi_{+1}}{1+\pi}p_d$, then $q < q^*$, and the debit constraint binds.

Now, consider the case $\frac{p_c}{p_d} > \delta$. Whenever the buyer enters the night market with $c > 0$, it is optimal to spend cash first due to the cash discount. However, we note that

$$\frac{c}{p_c} = \frac{\delta(m-d)}{p_c} < \frac{m-d}{p_d}$$

implying the buyer can afford less by using cash due to theft than by carrying the entirety of m as units of debit to the night market. As a result, $c = 0$ and $d = m$ when $\frac{p_c}{p_d} > \delta$. A similar argument can be made to show that, $c = \min\{m/\delta, q_c^*\}$ and $d = 0$ when $\frac{p_c}{p_d} < \delta$. Whenever only one asset is being used, we obtain:

$$p_c = \frac{1+\pi}{z\beta\phi_{+1}\left[1-\tau+e^*\tau-P(e^*)e^*\tau^P\right]} \qquad \text{if } d=0$$

$$p_d = \frac{1+\pi}{z\beta\phi_{+1}\left[1-\alpha-\tau\right]} \qquad \text{if } c=0$$

Next, we go back to the equilibrium with $c, d > 0$ and note that (28) implies buyer's indifference between payment methods. This renders the equilibrium indeterminate, since any $c \in [0, \frac{m}{\delta}]$ is optimal for buyers in this case. We will now derive the upper and lower bounds for the value of α described in the proposition.

Bounds

We analyze, in turn, 1) the situation where the optimal level of tax evasion is achievable, and 2) the situation in which it is not.

<u>Internal solution</u>
By (OA19), when the optimal level of tax evasion is achievable, we have

$$\frac{1-\alpha-\tau+\tau e^*-P(e^*)e^*\tau^P}{1-\tau+\tau e^*-P(e^*)e^*\tau^P}=\delta,$$

which implies

$$\alpha=(1-\delta)\left[1-\tau+e^*\tau-P(e^*)e^*\tau^P\right] =: \overline{\alpha} \tag{OA23}$$

Since e^* depends only on $P(\cdot)$, τ and τ^P, this is a knife-edge condition. This means that the situation where there is no shortage of cash (relative to the tax evasion incentives of the seller) is unlikely to happen. We would like to note that, if the left-hand side of (OA23) is larger than the right-hand side, then $\frac{p_c}{p_d}<\delta$, in which case, as argued above, $c=\min\{\frac{m}{\delta},q_c^*\}$ in all equilibria. These equilibria are definite, because, under this condition, it is impossible for prices to arise that would make consumers indifferent between using cash or debit.

<u>Binding evasion</u>
Analogously, by (OA20), when the constraint on evasion binds, we have

$$\alpha=(1-\delta)\left[1-\tau+e\tau-P(e)e\tau^P\right]-(1+\delta(1-e))\frac{\overline{\lambda}_c}{c}\frac{1+\pi}{\beta\phi_{+1}}, \tag{OA24}$$

where $e=c/(c+p_dq_d)$. We note that this implies

$$\alpha<(1-\delta)\left[1-\tau+e\tau-P(e)e\tau^P\right]<(1-\delta)\left[1-\tau+e^*\tau-P(e^*)e^*\tau^P\right]=\overline{\alpha},$$

where we have used the prior result that $e\tau-P(e)e\tau^P$ is increasing in e.

We now need to find an expression for the lower bound for α. For that purpose, we return to (OA18) and note $\Phi_d=0$ around the lower bound, since debit is being used. We impose $\frac{p_c}{p_d}>\delta$ and plug (OA16) into (OA18). Since we are interested in the case where evasion is not possible due to $c=0$, we impose $e=0$ and $e_c=1$, which yields

$$\delta<\frac{1-\alpha-\tau}{1+\frac{\underline{\lambda}}{p_dq_d}\frac{1+\pi}{\beta\phi_{+1}}+\Phi_c\frac{1+\pi}{\beta\phi_{+1}}},$$

and in turn

$$\alpha<1-\tau-\delta-\delta\left[\frac{\underline{\lambda}}{p_dq_d}\frac{1+\pi}{\beta\phi_{+1}}+\Phi_c\frac{1+\pi}{\beta\phi_{+1}}\right]\leq 1-\tau-\delta=:\underline{\alpha}. \tag{OA25}$$

Therefore, if $\alpha < \underline{\alpha}$, a relative price of $\frac{p_c}{p_d} = \delta$ cannot be sustained even when $\underline{\lambda} = \Phi_c = 0$, that is, when the seller prefers to avoid cash payments because the required cash discount is too large. Naturally, just like single-payment equilibria with $q_d = 0$, if $c = 0$, the equilibrium must also be determinate. Lastly, we need to show that, $\alpha = \underline{\alpha}$ is compatible with a mixed payment equilibrium. In order to observe this, we only need to plug the value for $\underline{\alpha}$ into (OA24), which holds for:

$$\bar{\lambda}_c = \frac{\delta\beta\phi_{+1}\tau c + \beta\phi_{+1}(1-\delta)\left[e\tau - P(e)e\tau^P\right]c}{(1+\pi)[1+\delta(1-e)]} > 0,$$

which is well-defined for $c, e > 0$. □

B.3 Lemma 1

Since we have $q_d^t > 0$, then $e^t < 1$ and, thus, $\bar{\lambda}^t = 0$. Moreover, we have $p_c^t q_c^t = c$ for $t \in \{H, L\}$. We ca note that, by (OA16) and (OA15), we obtain:

$$\bar{\lambda}_c^t = \frac{\beta\phi_{+1}}{1+\pi}\left[\tau - \left(P_e^t(e^t)e^t + P^t(e^t)\right)\tau^P\right]c, \tag{OA26}$$

and, hence, the partial derivative of $\bar{\lambda}_c^t$ with respect to e^t is given by:

$$\frac{\partial\bar{\lambda}_c^t}{\partial e^t} = -\frac{\beta\phi_{+1}}{1+\pi}\left(P_{ee}^t(e^t)e^t + 2P_e^t(e^t)\right)\tau^P c < 0,$$

under the assumption of a convex probability of being caught. Now, taking the partial derivative of the relative price with respect to the tax evasion level, e^t, yields:

$$\frac{\partial\frac{p_c^t}{p_d^t}}{\partial e^t} = \frac{\left[1 - \left(P_e^t(e^t)e^t(1-e^t) + P^t(e^t)\right)\tau^P\right]\bar{\lambda}_c^t - \left(\frac{\partial\bar{\lambda}_c^t}{\partial e^t}\right)\left[(2-e^t)(1-\tau+\tau e^t - P^t(e^t)e^t\tau^P) - \alpha(1-e^t)\right]}{\frac{\beta\phi_{+1}}{1+\pi}c\left[1-\tau+\tau e^t - P^t(e^t)e^t\tau^P + (1-e^t)\frac{1+\pi}{\beta\phi_{+1}}\frac{\bar{\lambda}_c^t}{c}\right]^2},$$

which is unambiguously positive. Lastly, let us define:

$$\mathcal{E}_{<\delta}^t \coloneqq \left\{ e \in [0,1] \,\middle|\, \frac{p_c^t}{p_d^t} < \delta \text{ and } \bar{\lambda}_c^t > 0 \right\}$$

Next, we note that:

$$\frac{1+\pi}{\beta\phi_{+1}}\frac{\bar{\lambda}_c^t}{c} + P^t(e)e\tau^P = \tau - P_e^t(e)e\tau^P - (1-e)P^t(e)\tau^P.$$

This means for any arbitrary $e \in (0,1)$, we have:

$$\frac{1+\pi}{\beta\phi_{+1}}\frac{\bar{\lambda}_c^L(e)}{c} + P^L(e) > \frac{1+\pi}{\beta\phi_{+1}}\frac{\bar{\lambda}_c^H(e)}{c} + P^H(e),$$

where $\bar{\lambda}_c^t(e)$ is the shadow price of the tax evasion constraint corresponding to the type $t \in \{H, L\}$ at the arbitrary tax evasion level, e. Moreover, as can be easily seen from (OA26), $\bar{\lambda}_c^L(e) > \bar{\lambda}_c^H(e)$. By (OA20), this means that $\mathcal{E}_{<\delta}^H \subset \mathcal{E}_{<\delta}^L$ or, in other words, the low-productivity type is more likely to have a relative price below δ for any $e \in [0,1]$. □

B.4 Proposition 3

From (OA11) and (OA12), we obtain:

$$\mu_d^t = \left(\frac{p_c^t}{p_d^t} - 1\right)\frac{\beta\phi_{+1}}{1+\pi} + \mu_c^t\frac{p_c^t}{p_d^t} + \frac{\Phi_d^{B,t}}{p_d^t} \geq 0$$

where we have used the fact that $\Phi_c^{B,t} = 0$. Given condition (OA10), we have:

$$\sum_{t\in\{H,L\}} f(z^t)\mu_c^t\left(\delta - \frac{p_c^t}{p_d^t}\right) = \beta\phi_{+1}\sum_{t\in\{H,L\}} f(z^t)\left(\frac{p_c^t}{p_d^t} - \delta\right) + \sum_{t\in\{H,L\}} f(z^t)\frac{\Phi_d^{B,t}}{p_d^t}. \quad \text{(OA27)}$$

The remaining part of the proof will be organized by cases and subcases. We first consider the case where $\Phi_d^{B,t} = 0$ in both submarkets. Next, we consider the case where $\Phi_d^{B,t} > 0$ for some $t \in \{H, L\}$, but not for the other. Naturally, the situation where $\Phi_d^{B,t} > 0$ in both submarkets is not a mixed-payment equilibrium. For most of the proof, it suffices to show that, in a given robust mixed-payment equilibrium, there is one submarket $t \in \{H, L\}$ in which $\frac{p_c^t}{p_d^t} > \delta$, whereas $\frac{p_c^s}{p_d^s} < \delta$ for $s \in \{H, L\}$ and $s \neq t$ for as long as $\mu_c^t, \mu_c^s > 0$. The reason is that, if the cash constraint binds, given cash prices, the buyer would like to increase consumption. In submarket s, consumption can be increased by increasing cash holdings.[33] In submarket t, the opposite holds: consumption can be increased by bringing more debit.

Case 1: $\Phi_d^{B,t} = 0\ \forall t \in \{H, L\}$

Begin by noticing that, by (OA11), $\mu_c^t = \frac{u'(q^t)}{p_c^t} - \frac{\beta\phi_{+1}}{1+\pi}$ and, thus:

$$\frac{\partial \mu_c^t}{\partial q^t} = \frac{u''(q^t)}{p_c^t} < 0. \quad \text{(OA28)}$$

Since $p_a^H < p_a^L$ for $a \in \{c, d\}$, $q^H > q^L$, implying that $\mu_c^H < \mu_c^L$. Now, we will consider three subcases regarding the expected relative price, namely, 1) when it is above δ, 2) when it is lower than δ, and 3) when it equals δ.

Subcase 1: $\sum_{t\in\{H,L\}} f(z^t)\frac{p_c^t}{p_d^t} > \delta$

Assume, by contradiction, that $\frac{p_c^t}{p_d^t} \geq \delta\ \forall t \in \{H, L\}$ with $\frac{p_c^s}{p_d^s} > \delta$ for some $s \in \{H, L\}$. Then, the right-hand-side of (OA27) is positive, while the left-hand-side is non-positive, since $\mu_c^t > 0$ for some $t \in \{H, L\}$. This proves that $\frac{p_c^s}{p_d^s} < \delta < \frac{p_c^t}{p_d^t}$ for $s, t \in \{H, L\}$ and $s \neq t$.

[33] Even if $\mu_d^s = 0$, it is preferable to have more cash in submarket s, since the buyer can achieve the optimal consumption level in that submarket while sparing more debit for the next day.

Subcase 2: $\sum_{t\in\{H,L\}} f(z^t)\frac{p_c^t}{p_d^t} < \delta$

A similar argument as the one made for subcase 1 establishes that $\frac{p_c^s}{p_d^s} < \delta < \frac{p_c^t}{p_d^t}$ for $s, t \in \{H, L\}$ and $s \neq t$.

Subcase 3: $\sum_{t\in\{H,L\}} f(z^t)\frac{p_c^t}{p_d^t} = \delta$

By (OA27), this can only occur if $\frac{p_c^t}{p_d^t} = \delta$ for $t \in \{H, L\}$ since $\mu_c^H < \mu_c^L$. Naturally, this means that cash and debit are perfect substitutes in both markets, so buyers can choose any $c \in [0, \min\{m/\delta, q_c^{H*}, q_c^{L*}\}]$, rendering this equilibrium indeterminate and not self-reinforcing, given that nothing ensures that the conditions that make $\frac{p_c^t}{p_d^t} = \delta$ for $t \in \{H, L\}$ would be met.

Case 2: $\Phi_d^{B,t} > 0$ for one $t \in \{H, L\}$

Plugging (OA11) into (OA27) yields, for $s \in \{H, L\}$ such that $\Phi_d^{B,s} > 0$ and $r \in \{H, L\}$ such that $\Phi_d^{B,r} = 0$ and $r \neq s$:

$$\begin{aligned}
\sum_{t\in\{H,L\}} f(z^t)\frac{u'(q^t)}{p_c^t}\left(\delta - \frac{p_c^t}{p_d^t}\right) &= \sum_{t\in\{H,L\}} f(z^t)\frac{\Phi_d^{B,t}}{p_d^t} \\
(1 - f(z^s))\frac{u'(q^r)}{p_c^r}\left(\delta - \frac{p_c^r}{p_d^r}\right) &= f(z^s)\left[\frac{\beta\phi_{+1}}{1+\pi} - \delta\frac{u'(q^s)}{p_c^s}\right] \\
&> f(z^s)\left[\frac{\beta\phi_{+1}}{1+\pi} - \frac{u'(q^s)}{p_c^s}\right] = -f(z^s)\mu_c^s
\end{aligned} \tag{OA29}$$

where the second line follows from (OA12), $\Phi_d^{B,r} = 0$ and $q_d^s = 0$. The remainder of the analysis will consider two cases: $\mu_c^s = 0$ and $\mu_c^s > 0$.

1) $\underline{\mu_c^s = 0}$: Note that, if $\mu_c^s = 0$, we must have a positive left-hand-side to (OA29), which means that $\frac{p_c^r}{p_d^r} < \delta$. As a result, the buyer could be better off in the r submarket by having an additional unit of cash in the pocket. On the other hand, the situation of the buyer improves in the s market by having more debit. In order to observe this, note that $m^{B,t} = d + c - p_c^s q_c^{s*} = m - c\left(\frac{1}{\delta} - 1\right) - p_c^s q_c^{s*}$, which can be maximized, while keeping $p_c^s q_c^{s*}$ fixed but decreasing c.

2) $\underline{\mu_c^s > 0}$: Alternatively, we can rewrite (OA29) as:

$$\begin{aligned}
(1 - f(z^s))\frac{u'(q^r)}{p_c^r}\left(\delta - \frac{p_c^r}{p_d^r}\right) &= f(z^s)\left[\frac{\beta\phi_{+1}}{1+\pi} - \frac{u'(q^s)}{p_c^s}\right] + f(z^s)(1-\delta)\frac{u'(q^s)}{p_c^s} \\
&= -f(z^s)\mu_c^s + f(z^s)(1-\delta)\frac{u'(q^s)}{p_c^s}
\end{aligned}$$

If $\frac{p_c^r}{p_d^r} = \delta$, we must have $(1-\delta)\frac{u'(q^s)}{p_c^s} = \mu_c^s$, which, using (OA11), implies that $p_c^s = \frac{\delta(1+\pi)}{\beta\phi_{+1}}u'\left(\frac{c}{p_c^s}\right)$, which pins down p_c^s as a function of c. Plugging this in the zero profit condition of the seller in the s submarket:

$$\frac{1}{z} = \min\left[1 - \tau + e^{s*}\tau - P(e^{s*})e^{s*}\tau^P \, , \, 1 - P(1)\tau^P\right]\delta u'\left(\frac{c}{p_c^s}\right),$$

where the minimum operator comes from the fact that e^{s*} can be above 1. This is a "knife-edge" condition. Since $\frac{p_c^r}{p_d^r} = \delta$ is also a "knife-edge" condition, and both need to be satisfied independently, any deviation from either makes (OA29) not hold, bringing the economy out of a mixed-payment equilibrium. As a result, there is no robust mixed-payment equilibrium with $q_d^s = 0$, $\mu_c^s > 0$ and $\frac{p_c^r}{p_d^r} = \delta$.

Finally, we consider the case where $\frac{p_c^r}{p_d^r} > \delta$. If this occurs, the buyer can increase consumption or savings in the r submarket by bringing more debit, since the discount on cash is low. In the s submarket, on the other hand, the buyer would be better off by bringing more cash, since the cash constraint binds and $q_d^s = 0$. Lastly, consider the case where $\frac{p_c^r}{p_d^r} < \delta$. This means that the buyer can consume more in both markets bringing more cash, which means that this cannot be an equilibrium outcome. □

B.5 Proposition 4

We first note that equilibria where $q_d^L = q_d^H = 0$ are not defined as mixed-payment even if $d > 0$. By our assumption that $p_d^L > p_d^H$, then $q_d^H > q_d^L \geq 0$ by the buyers' demand schedule. Therefore, there can only be full evasion by one type of seller in equilibrium if $q_d^L = 0$. Moreover, $e^{L*} \geq 1$ is needed in order to ensure that $e^L = 1$. By (OA20), we have:

$$\frac{p_c^L}{p_d^L} = 1 - \frac{\alpha}{1 - P^L(1)\tau^P} - \frac{1+\pi}{\beta\phi_{+1}}\left(\frac{1}{1 - P^L(1)\tau^P}\right)\left(\frac{\bar{\lambda}_c^L}{p_c^L q_c^L} - \frac{\Phi_d^L}{p_d^L}\right). \tag{OA30}$$

Next, plugging (29) into (OA30) yields:

$$\frac{p_c^L}{p_d^L} > \delta + \frac{1+\pi}{\beta\phi_{+1}}\left(\frac{1}{1 - P^L(1)\tau^P}\right)\frac{\Phi_d^L}{p_d^L} > \delta.$$

By case 2 in the proof of Proposition 3, we note that $\mu_c^L = 0$. To see this, note that, on the one hand, for $\mu_c^L > 0$, if $\frac{p_c^H}{p_d^H} \leq \delta$, the equilibrium is not robust mixed-payment. On the other hand, if $\frac{p_c^H}{p_d^H} > \delta$, then the buyer can improve her consumption by bringing only debit to the night market, since $\frac{p_c^t}{p_d^t} > \delta \ \forall t \in \{H, L\}$. Thus, we conclude that $\mu_c^L = 0$, which implies that $\frac{p_c^L}{p_d^L} > \delta > \frac{p_c^H}{p_d^H}$ also by case 2 in the proof of Proposition 3, which proves our result.

We observe that since the right-hand side of (29) is positive, if $e^{L*} = 1$, then $\bar{\lambda}_c^L = 0$ and the condition is satisfied. Lastly, we note that

$$\bar{\lambda}_c^L + \bar{\lambda}^L = \frac{\beta\phi_{+1}}{1+\pi}\left[\tau - P_e^L(1)\tau^P - P^L(1)\tau^P\right]p_c^L q_c^L \tag{OA31}$$

is a continuous function, and since $\bar{\lambda}_c^L$ and $\bar{\lambda}^L$ are either both positive or both zero in mixed-payment equilibria, then $\bar{\lambda}_c^L$ is also continuous, meaning that, for a low enough $e^{L*} > 1$, (29) can also be satisfied. $\square$

C Additional Figures and Tables

C.1 Timing

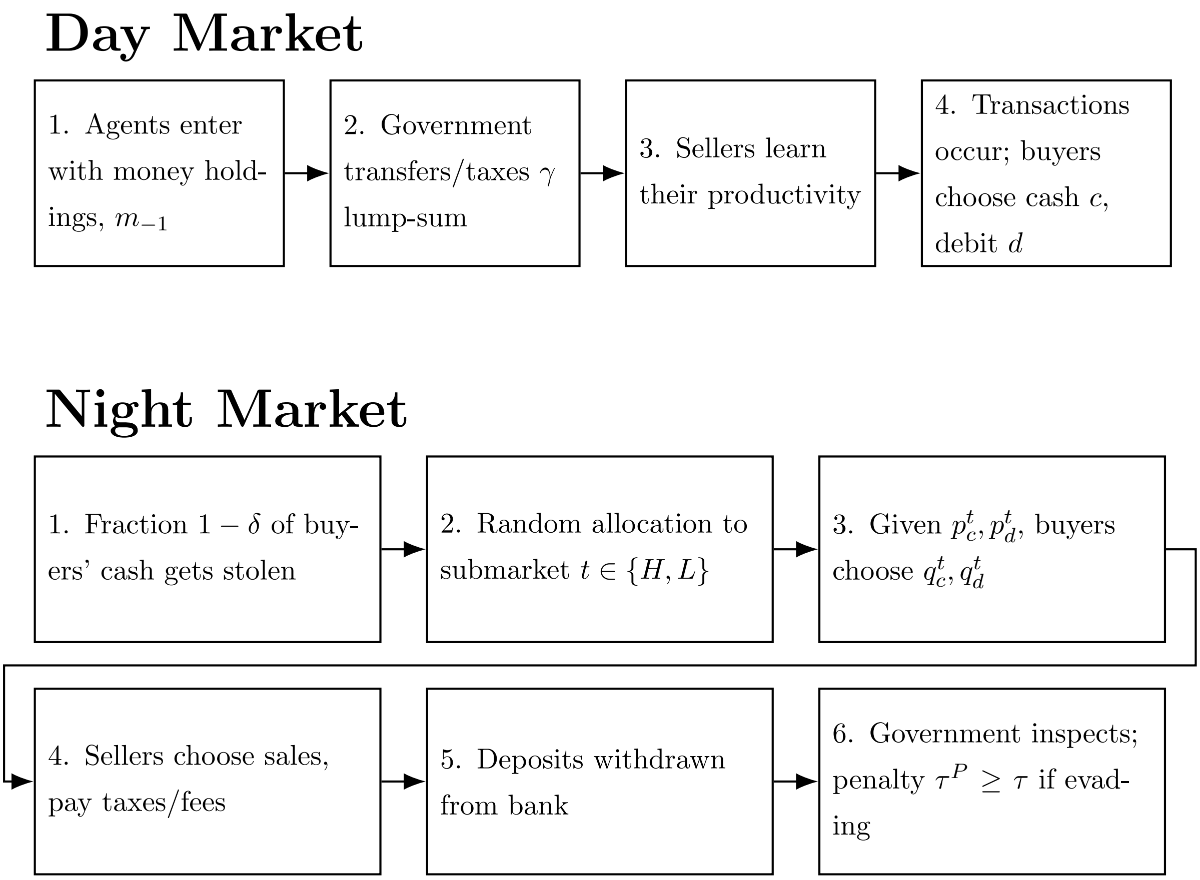


Figure OA2: Timing of events in the Day and Night markets.

C.2 Sample balance tables

Table OA3: Businesses Characteristics and Balance Tests

	Full Sample				Restricted Sample				Non-Lipa Users			
	All	Control	Treatment	Diff.	All	Control	Treatment	Diff.	All	Control	Treatment	Diff.
Standard mobile money use												
Use mobile money for business purposes	0.509	0.487	0.530	-0.044	0.512	0.480	0.544	-0.063**	0.499	0.460	0.538	-0.078**
Use mobile money to receive payments	0.328	0.301	0.356	-0.055**	0.339	0.294	0.384	-0.090***	0.334	0.287	0.380	-0.093***
Use mobile money to store money	0.177	0.182	0.171	0.011	0.154	0.164	0.145	0.018	0.149	0.155	0.143	0.013
Use mobile money to pay bills	0.317	0.319	0.315	0.005	0.338	0.319	0.357	-0.038	0.322	0.295	0.348	-0.052*
Use mobile money to pay salaries	0.055	0.046	0.064	-0.019	0.056	0.039	0.073	-0.033**	0.052	0.033	0.071	-0.038***
Use mobile money to pay inputs	0.373	0.370	0.377	-0.008	0.384	0.375	0.394	-0.019	0.372	0.354	0.389	-0.034
Awareness of Lipa Na M-Pesa												
The business is aware of Lipa Na M-Pesa	0.953	0.951	0.956	-0.004	0.961	0.963	0.959	0.004	0.959	0.961	0.957	0.004
The business has Lipa Na M-Pesa	0.087	0.073	0.100	-0.027*	0.099	0.089	0.110	-0.021	0.057	0.037	0.076	-0.038**
The business does not see the benefits of Lipa Na M-Pesa	0.261	0.269	0.254	0.015	0.246	0.252	0.240	0.012	0.246	0.252	0.240	0.012
The cost of opening a Lipa Na M-Pesa account is too high	0.106	0.105	0.107	-0.001	0.126	0.130	0.122	0.007	0.126	0.130	0.122	0.007
The transaction fees via Lipa Na M-Pesa are too high	0.162	0.162	0.163	-0.001	0.183	0.186	0.180	0.006	0.183	0.186	0.180	0.006
The business owner does not have time to open an account	0.117	0.123	0.111	0.013	0.124	0.134	0.113	0.021	0.124	0.134	0.113	0.021
Lipa Na M-Pesa would not increase sales	0.077	0.070	0.083	-0.013	0.085	0.075	0.095	-0.020	0.085	0.075	0.095	-0.020
The business owner does not trust the mobile money provider	0.023	0.021	0.025	-0.004	0.026	0.027	0.025	0.002	0.026	0.027	0.025	0.002
Lipa Na M-Pesa is too complex to use	0.095	0.086	0.105	-0.019	0.092	0.080	0.104	-0.024	0.092	0.080	0.104	-0.024
Business size												
Monthly Sales in 1,000 KSh	226	217	235	-17.7	240	228	251	-23.7	223	207	239	-31.5**
Monthly Profits in 1,000 KSh	66.490	63.686	69.326	-5.639	71.268	67.801	74.742	-6.941	68.556	65.391	71.679	-6.288
Number of Employees	5.912	5.883	5.942	-0.060	6.024	5.952	6.095	-0.143	5.720	5.659	5.780	-0.121
Investment and access to finance												
Investment in the past 6 months	0.292	0.299	0.284	0.015	0.291	0.301	0.281	0.020	0.277	0.284	0.270	0.014
Bank Loan in the past 12 months	0.093	0.083	0.102	-0.019	0.083	0.072	0.093	-0.021	0.082	0.074	0.089	-0.014
Informal Loan in the past 12 months	0.035	0.034	0.037	-0.003	0.032	0.033	0.031	0.002	0.030	0.030	0.030	0.000
Mobile Loan in the past 12 months	0.100	0.098	0.102	-0.004	0.089	0.083	0.095	-0.013	0.091	0.088	0.095	-0.008
Informality												
The business has a business license	0.721	0.721	0.720	0.001	0.902	0.911	0.892	0.019	0.898	0.906	0.890	0.016

Notes: This table presents summary statistics for the baseline survey data. Columns represent different samples: Full Sample, Restricted Sample, and Non-Lipa Users. Within each sample, All, Control, Treatment, and Difference columns are presented. All binary variables were originally defined as (yes = 1, no = 0). *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table OA4: Pharmacies Characteristics and Balance Tests

	Full Sample				Restricted Sample				Non-Lipa Users			
	All	Control	Treatment	Diff.	All	Control	Treatment	Diff.	All	Control	Treatment	Diff.
Standard mobile money use												
Use mobile money for business purposes	0.406	0.388	0.424	-0.036	0.409	0.385	0.434	-0.049	0.408	0.385	0.433	-0.048
Use mobile money to receive payments	0.241	0.203	0.279	-0.076**	0.244	0.200	0.289	-0.089**	0.245	0.200	0.291	-0.091**
Use mobile money to store money	0.092	0.091	0.094	-0.004	0.092	0.091	0.094	-0.003	0.092	0.091	0.094	-0.004
Use mobile money to pay bills	0.261	0.254	0.268	-0.014	0.265	0.249	0.281	-0.032	0.266	0.249	0.283	-0.034
Use mobile money to pay salaries	0.040	0.022	0.058	-0.036**	0.040	0.019	0.062	-0.044**	0.040	0.019	0.063	-0.044**
Use mobile money to pay inputs	0.304	0.319	0.290	0.029	0.309	0.313	0.305	0.009	0.310	0.313	0.307	0.006
Awareness of Lipa Na M-Pesa												
The business is aware of Lipa Na M-Pesa	0.944	0.953	0.935	0.018	0.942	0.951	0.934	0.017	0.942	0.951	0.933	0.018
The business has Lipa Na M-Pesa	0.043	0.011	0.076	-0.065***	0.042	0.011	0.074	-0.063***	0.040	0.011	0.071	-0.060***
The business does not see the benefits of Lipa Na M-Pesa	0.272	0.271	0.272	-0.001	0.258	0.260	0.256	0.003	0.258	0.260	0.256	0.003
The cost of opening a Lipa Na M-Pesa account is too high	0.174	0.183	0.163	0.020	0.170	0.183	0.155	0.028	0.170	0.183	0.155	0.028
The transaction fees via Lipa Na M-Pesa are too high	0.245	0.249	0.241	0.008	0.248	0.252	0.244	0.008	0.248	0.252	0.244	0.008
The business owner does not have time to open an account	0.091	0.110	0.070	0.040	0.084	0.107	0.059	0.048*	0.084	0.107	0.059	0.048*
Lipa Na M-Pesa would not increase sales	0.092	0.081	0.105	-0.024	0.096	0.080	0.113	-0.033	0.096	0.080	0.113	-0.033
The business owner does not trust the mobile money provider	0.032	0.026	0.039	-0.013	0.032	0.027	0.038	-0.011	0.032	0.027	0.038	-0.011
Lipa Na M-Pesa is too complex to use	0.079	0.077	0.082	-0.005	0.078	0.076	0.080	-0.003	0.078	0.076	0.080	-0.003
Business size												
Monthly Sales in 1,000 KSh	133	121	145	-24.3***	134	123	146	-22.8**	133	123	144	-21.4**
Monthly Profits in 1,000 KSh	54.215	49.973	58.457	-8.484**	54.847	51.081	58.746	-7.665**	54.596	51.081	58.264	-7.183*
Number of Employees	4.380	4.308	4.453	-0.145	4.397	4.321	4.477	-0.156	4.383	4.321	4.449	-0.128
Investment and access to finance												
Investment in the past 6 months	0.193	0.186	0.200	-0.014	0.193	0.186	0.200	-0.014	0.191	0.186	0.197	-0.011
Bank Loan in the past 12 months	0.062	0.065	0.058	0.007	0.063	0.064	0.062	0.002	0.064	0.064	0.063	0.001
Informal Loan in the past 12 months	0.025	0.027	0.024	0.004	0.027	0.028	0.025	0.003	0.027	0.028	0.025	0.003
Mobile Loan in the past 12 months	0.076	0.069	0.083	-0.014	0.081	0.072	0.090	-0.018	0.081	0.072	0.091	-0.019
Informality												
The business has a business license	0.917	0.927	0.907	0.020	0.954	0.958	0.949	0.009	0.954	0.958	0.949	0.010

Notes: This table presents summary statistics for the baseline survey data for **pharmacies**. Columns represent different samples: Full Sample, Restricted Sample, and Non-Lipa Users. Within each sample, All, Control, Treatment, and Difference columns are presented. All binary variables were originally defined as (yes = 1, no = 0). *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table OA5: Restaurants Characteristics and Balance Tests

	Full Sample				Restricted Sample				Non-Lipa Users			
	All	Control	Treatment	Diff.	All	Control	Treatment	Diff.	All	Control	Treatment	Diff.
Standard mobile money use												
Use mobile money for business purposes	0.593	0.568	0.619	-0.051	0.633	0.596	0.668	-0.072	0.616	0.562	0.665	-0.103**
Use mobile money to receive payments	0.401	0.382	0.420	-0.038	0.450	0.408	0.491	-0.083*	0.449	0.406	0.488	-0.082
Use mobile money to store money	0.247	0.257	0.236	0.022	0.227	0.252	0.204	0.049	0.222	0.245	0.201	0.044
Use mobile money to pay bills	0.363	0.373	0.353	0.019	0.423	0.404	0.442	-0.039	0.394	0.359	0.426	-0.066
Use mobile money to pay salaries	0.067	0.065	0.069	-0.004	0.074	0.064	0.084	-0.020	0.067	0.052	0.081	-0.029
Use mobile money to pay inputs	0.430	0.411	0.450	-0.039	0.473	0.450	0.496	-0.046	0.451	0.411	0.488	-0.077
Awareness of Lipa Na M-Pesa												
The business is aware of Lipa Na M-Pesa	0.961	0.950	0.973	-0.023	0.982	0.977	0.987	-0.010	0.980	0.974	0.986	-0.012
The business has Lipa Na M-Pesa	0.123	0.124	0.121	0.003	0.167	0.183	0.150	0.033	0.077	0.073	0.081	-0.008
The business does not see the benefits of Lipa Na M-Pesa	0.252	0.267	0.237	0.030	0.231	0.242	0.221	0.021	0.231	0.242	0.221	0.021
The cost of opening a Lipa Na M-Pesa account is too high	0.046	0.034	0.058	-0.024	0.067	0.051	0.082	-0.031	0.067	0.051	0.082	-0.031
The transaction fees via Lipa Na M-Pesa are too high	0.088	0.081	0.095	-0.014	0.097	0.090	0.103	-0.013	0.097	0.090	0.103	-0.013
The business owner does not have time to open an account	0.140	0.135	0.146	-0.011	0.177	0.174	0.179	-0.005	0.177	0.174	0.179	-0.005
Lipa Na M-Pesa would not increase sales	0.063	0.061	0.064	-0.004	0.070	0.067	0.072	-0.004	0.070	0.067	0.072	-0.004
The business owner does not trust the mobile money provider	0.015	0.017	0.014	0.003	0.019	0.028	0.010	0.018	0.019	0.028	0.010	0.018
Lipa Na M-Pesa is too complex to use	0.110	0.095	0.125	-0.031	0.110	0.084	0.133	-0.049	0.110	0.084	0.133	-0.049
Business size												
Monthly Sales in 1,000 KSh	303	296	310	-13.9	363	355	371	-16	340	324	354	-29.8
Monthly Profits in 1,000 KSh	76.618	74.883	78.389	-3.505	90.536	88.126	92.861	-4.735	86.623	85.143	87.983	-2.841
Number of Employees	7.176	7.169	7.184	-0.016	7.932	7.936	7.929	0.007	7.449	7.505	7.397	0.108
Investment and access to finance												
Investment in the past 6 months	0.368	0.386	0.349	0.037	0.400	0.433	0.367	0.066	0.382	0.413	0.354	0.060
Bank Loan in the past 12 months	0.118	0.098	0.139	-0.041*	0.106	0.083	0.128	-0.046	0.105	0.089	0.120	-0.031
Informal Loan in the past 12 months	0.043	0.040	0.047	-0.007	0.038	0.038	0.037	0.001	0.034	0.033	0.035	-0.002
Mobile Loan in the past 12 months	0.120	0.121	0.118	0.003	0.099	0.096	0.102	-0.005	0.105	0.109	0.100	0.009
Informality												
The business has a business license	0.561	0.554	0.568	-0.015	0.840	0.853	0.827	0.026	0.825	0.833	0.818	0.015

Notes: This table presents summary statistics for the baseline survey data for **restaurants**. Columns represent different samples: Full Sample, Restricted Sample, and Non-Lipa Users. Within each sample, All, Control, Treatment, and Difference columns are presented. All binary variables were originally defined as (yes = 1, no = 0). *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.