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Financial Inclusion, Technology and their Impacts on Monetary and Fiscal Policy: Theory and Evidence*

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Abstract

In economies with a low level of financial inclusion (FI), most activities are settled in cash and are thus more difficult to trace, record, and tax. I show theoretically that economies with inefficient financial technologies exhibit low levels of FI and of tax revenue and that using an inflation tax as an additional source of income improves welfare. Improvements in technology lead to a higher level of FI, increased tax revenue and lower (optimal) inflation. I test this prediction using panel data from a broad set of countries. The data show a strong and robust negative link between FI and inflation and a positive link between FI and tax revenue for developing countries.

Keywords: Financial Inclusion, Financial Technology, Monetary Policy, Fiscal Policy

JEL Classification: C12, C22, E31, E41, G21, H21

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1 Introduction

The level of financial inclusion[1] has increased considerably in the last few years, supported by new technologies as well as public and private initiatives. According to the Global Financial Inclusion Database[2], between 2011 and 2017, the global share of adults with an account at a financial institution rose from 51 to 69 percent.[3] In India, for example, the share of adults with an account more than doubled during the same time period to 80 percent. According to Demirguc-Kunt et al. (2018) an important driving factor was government-issued biometric identification cards, lowering the cost of access and boosting account ownership among unbanked adults. D'Silva et al. (2019) provide a detailed case study of how India's provision of digital financial infrastructure contributed to financial inclusion.

In this paper, I analyze how new applications of technology that reduce the cost of financial services and increase the effectiveness of tax collection affect financial inclusion, tax revenue, and optimal inflation theoretically as well as empirically. The theoretical monetary model builds on Lahcen and Pedro (2019) and allows households to decide endogenously whether to join the financial system or not, i.e., where financial inclusion is an equilibrium outcome. Inflation, taxes, interest rates on deposits, the cost of handling cash, the technology in the financial system (modeled as the utility cost of joining the financial system) and the technology for tax collection (modeled as the level of tax enforcement) are important determinants of the equilibrium. I show that it is optimal for the government to set an inflation rate above zero (which is consistent with the findings of Koreshkova (2006) and Nicolini (1998)) and that more efficient technologies help to increase the level of financial inclusion, and simultaneously lead to a decrease in the optimal level of inflation and an increase in tax revenue.

Estimating these effects empirically is challenging because technological progress in the financial system and in tax collection is difficult to observe and other policy variables such as inflation and taxes are set at the same time, together with

[1] Financial inclusion generally means that individuals and businesses have access to useful and affordable financial products and services that meet their needs—for transactions, payments, savings, credit and insurance—delivered in a responsible and sustainable way. See https://www.worldbank.org/en/topic/financialinclusion/overview

[2] https://globalfindex.worldbank.org

[3] Individuals with an account can make and receive cashless payments or store value.

financial inclusion. For the empirical analysis, I exploit the fact that recent technological innovations have swiftly improved access to financial services by offering better and cheaper services. For example, the entry of FinTech and mobile phone companies offering payment services—and increasingly saving, credit, and insurance services—has been swift in several countries and its potential to accelerate financial inclusion is well recognized (see, for example, Bech and Hancock (2020), Philippon (2020)). According to Frost et al. (2019) the success of these new payment service providers seems to rely on the use of technology to offer cheaper services, the ability to reach a wide audience through existing platforms and thereby reaping network effects, and the ability to process and analyze data to improve services and benefit customers even further.

More generally, new applications of technology to financial services and to tax collection have accelerated in the last few years with implications for how financial services are provided, accessed and used and how effectively taxes are collected. CPMI-IOSCO (2020) provides a recent account of the opportunities and risks in fintech developments for financial inclusion.[4] The report stresses that to harness this technology, the government needs to provide financial and ICT infrastructure, legal and regulatory frameworks and collaborate with the private sector. Similar approaches are advocated to increase the effectiveness of tax collection by, for example, enhancing the ability of tax authorities to detect economic activity in the informal sector (see, for example, Bird and Zolt (2008)). Countries that successfully provide the foundations for harnessing new technologies are in a good position to improve both financial inclusion and tax collection.

Despite the progress in account ownership, the share of adults with a transaction account at a financial institution in a country can vary from slightly above zero to 100 percent. Economies with low levels of financial inclusion settle most economic activities in cash, which implies that these activities are more difficult to trace, record, and tax. Accordingly, in order to finance public spending, governments often need to resort to other sources of funding. For economies that rely heavily on cash, governments use the inflation tax (or seigniorage taxation) as an additional

[4]These range from application programming interfaces, big data analytics, cloud computing, contactless technology, digital identification for distributed ledger technologies and the Internet of Things leading to new products and services.

source of income.
Figure 1, which plots the share of adults with an account at a financial institution against inflation and tax revenue (as a percent of GDP), supports this claim: the two panels show a negative correlation between financial inclusion and inflation and a positive correlation between tax income and financial inclusion.[5] What does the literature have to say about this?

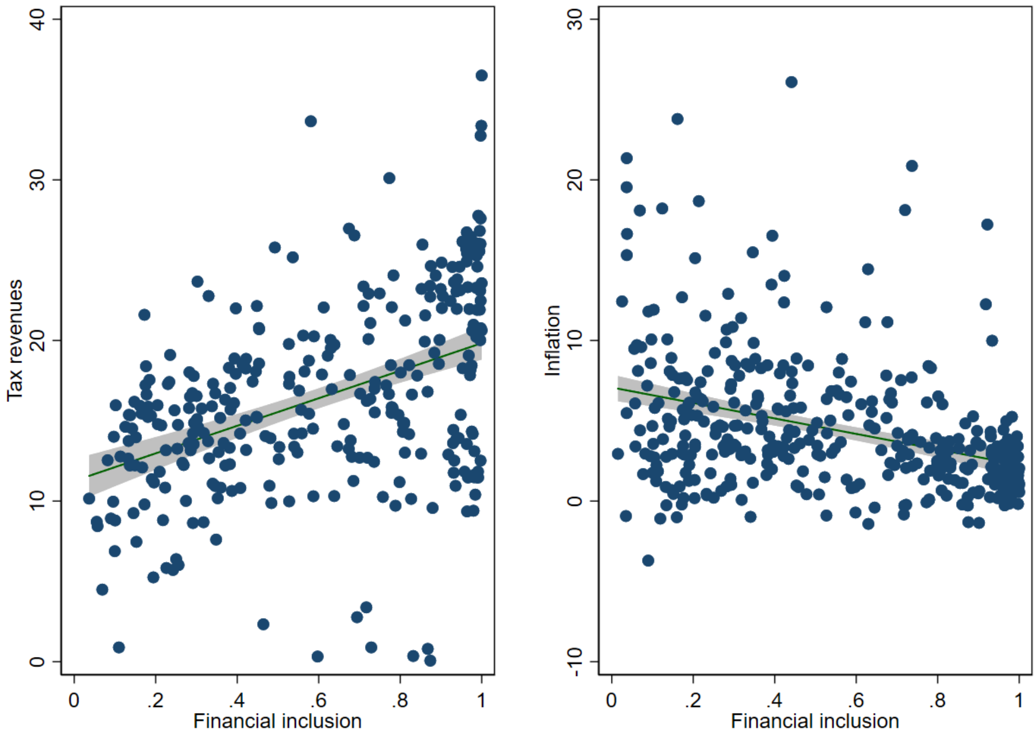


Figure 1: Financial Inclusion (share of adults with an account at a financial institution), Inflation (Consumer Price Index), and Tax Revenue (as a % of GDP), 2011, 2014, 2017

Given the amount of attention financial inclusion has received in the last decade, there are surprisingly few studies that explore, either theoretically or empirically, whether governments adjust inflation and taxation to the level of financial inclu-

[5] Of course, the figure does not reflect many other factors that affect tax revenue and inflation, e.g., differences in institutional quality. This will be controlled for in the empirical portion of the paper.

sion. Several studies consider the somewhat related impact of the shadow economy on tax revenue and inflation either from a theoretical point of view (for example, Koreshkova (2006) or Nicolini (1998)) or use estimates to predict the impact of the shadow economy on taxes and inflation (Mazhar and Meon (2017)). In addition, Roubini and Sala-i-Martin (1995) show in a theoretical model that financial repression is associated with high levels of tax evasion, low growth, and high inflation and Levine (1997) discusses more generally the relationship between financial development and economic growth. To my knowledge, only Oz-Yalaman (2019) assesses the impact of financial inclusion on tax revenue and finds a significant and positive relationship between financial inclusion and tax revenue. A theoretical and empirical approach to financial inclusion and both tax revenue and inflation is still missing.

In line with the prediction of the theoretical model, I find a significant and robust negative relationship between financial inclusion and inflation and a positive relationship between financial inclusion and tax revenue, even after controlling for major macroeconomic variables. The relationship between inflation and financial inclusion holds even when controlling for the independence of central banks but disappears for developed countries. The relationship between taxation and financial inclusion is more robust and holds for all specifications.

Related Literature

This paper builds on several strands of literature. First, the monetary model is based on Lagos and Wright (2005) and Rocheteau and Wright (2005), who introduce an environment where currency is essential by facilitating the exchange of goods. Many subsequent papers have expanded this core model by introducing additional features (see Lagos et al. (2017) for an overview). Most relevant to this paper, Berentsen and Waller (2007) introduced the banking sector into the standard monetary model. This paper borrows many features from Williamson (2012), who explicitly models an environment in which agents pay in currency or with interest-earning bank deposits. This feature is crucial because agents who join banks can avoid the use of cash and the affiliated costs of inflation.

Second, this paper relates to the vast literature that studies the shadow or underground economy.[6] One of the recurring findings in this literature is that shadow economy activities are found in all economies but that their size varies considerably (see Schneider and Enste (2000) for an extensive review of this literature). Some of the papers that seek to explain these variations are based on the centuries-old notion that inflation, or more generally, debasing the value of money, can be used to finance government expenditure (see, for example, Sussman (1993) for an account of France's debasement of coinage to increase revenue during the Hundred Years' War in the 15th century). For example, Gomis-Porqueras et al. (2014) use a monetary model in the tradition of Rocheteau and Wright (2005) in which agents can choose to use cash to pay for goods and avoid taxes or to use readily available credit but be charged with taxes. Since inflation increases the cost of holding cash, it provides incentives to pay with credit and thus reduces the size of the non-taxed or shadow economy; i.e., they establish that there is a negative relation between inflation and the size of the shadow economy. Nicolini (1998) and Koreshkova (2006) take the public finance perspective and argue that it might be welfare improving to use inflation to extract tax revenue when an economy is faced with a large informal sector. Nicolini (1998) takes the size of the informal economy as given in contrast to Koreshkova (2006), where the size of the formal and informal sectors is driven by the productivity gap between the two producing sectors. The financial sector in Koreshkova (2006) offers protection from inflation but does not help the government collect taxes. Thus, a more productive banking sector increases the size of the informal sector and the level of optimal inflation. Finally, Aruoba (2018) explains cross-country differences in inflation, tax revenue and the size of the informal sector through the institutional factors of a country, modeled as the difficulty of tax evasion.[7]

This paper differs from this literature in several ways. In Gomis-Porqueras et al. (2014), the financial system is fully developed and efficiently operated; thus, technological changes, unlike in the present paper, do not play a role. In Koreshkova (2006), the financial system helps agents avoid the cost of inflation, but the finan-

[6]Schneider and Enste (2000) defines the shadow economy as either all legal economic activities that avoid taxation or all illegal activities that avoid regulation or laws.

[7]Similarly, Ihrig and Moe (2004) and Prado (2011) seek to explain the differences in the size of the informal sector based on taxation and tax enforcement without considering inflation as a main driving force.

cial system does not support the government in collecting taxes. Thus, relative improvements in the efficiency of the financial system reduce tax evasion and lead to a higher level of optimal inflation. This contrasts with the role of the financial sector in this paper, in which improvements in technology (and thus efficiency) increase financial inclusion and tax revenues but decrease (optimal) inflation.

In the empirical analysis, I show that as predicted by the model, there is indeed a negative relationship between financial inclusion and inflation and a positive relationship between financial inclusion and tax revenue.

Third, I model public finance trade-offs in an environment with endogenous financial inclusion and follow the tradition of Chatterjee and Corbae (1992), Franklin Allen (1994) and others who show that endogenous decisions to join financial markets have potentially rich implications for macroeconomic behavior. Lahcen and Pedro (2019) study the effects of endogenous financial inclusion on inequality and find that in such a setting, monetary policy has distributional consequences. In this paper, I find similar rich and contrasting macroeconomic trade-offs.

2 The Model

2.1 Private Economic Agents

Following Lagos and Wright (2005) and Rocheteau and Wright (2005), at each date $t = 0, 1, ...$, agents convene sequentially in a decentralized market (DM) and a centralized market (CM). In the DM, some agents, called *sellers*, provide a good that is demanded by other agents, called *buyers*. In the CM, both buyers and sellers meet in a centralized Walrasian market and make production and consumption decisions. Let there be a continuum of sellers and buyers, each with mass one. The period utility for buyers and sellers is given by

$$\mathcal{U}(h, q) = -h + u(q) \quad \text{and} \quad \tilde{\mathcal{U}}(x, H) = x - H$$

where the pair $\langle h, x\rangle$ represents labor and consumption in the CM, and $\langle q, H\rangle$ is consumption and labor in the DM. The utility of the buyer in the DM $u(\cdot)$ is twice continuously differentiable so that some $\hat{q} > 0$ exists, such that $u(\hat{q}) - \hat{q} = 0$.

Define q^* by $u'(q^*) = 1$ and define the utility function as having constant relative risk aversion, or $-x\frac{u''(x)}{u'(x)} = 1$. The production technology available to buyers and sellers allows the production of one unit of the perishable consumption goods q and x, respectively, for each unit of labor supply, which hinders the barter between agents across the CM and DM. I also assume that agents are anonymous in the DM, which hinders unsecured credit. These two frictions (perishable goods and anonymity) generate a role for assets in the facilitation of exchange.

There are two assets that can serve in this capacity: currency, with supply M and ownership claims on a financial intermediary promising to pay q_{+1} units of currency in the next period with supply A. If the financial intermediary is a bank, then the claim is also referred to as a deposit. In this paper, I use the terms bank and deposits, which include any other financial entity, including Fintech and Big Tech companies. Given that ϕ is the CM price of money in terms of the consumption good x, then the real value of currency and deposits is $m = \phi M$ and $a = \phi A$. All agents can hold and receive currency, but to hold and receive deposits, agents need to join a bank; i.e., agents cannot hold government bonds directly.

In the CM, all sellers, buyers, and the government meet in a centralized Walrasian market, where production and consumption decisions are made and where buyers decide whether to join a bank and deposit their savings at that bank. Given that a fixed exogenous fraction $\rho \in [0, 1]$ of sellers have a bank account (accepting cash as well as deposits as payment), an endogenous fraction $\gamma \in [0, 1]$ of buyers decide to join a bank. A buyer's decision about whether to join a bank is affected by the following factors: the cost of opening a bank account ω, the cost of handling cash c, inflation μ, and tax payment τ, which will be discussed in detail in section 3.

Finally, in the DM, each buyer is matched at random with a seller. In cases where both the buyer and seller have joined a bank, a communication technology is available that permits the buyer to transfer ownership of a claim on the bank to the seller. Following Williamson (2012), I refer to these as *monitored* meetings. In all other cases, *nonmonitored* meetings occur, in which only currency issued by the government can be used to pay for the exchange of goods. Finally, let us assume that, when a buyer meets a seller, the buyer makes a take-it-or-leave-it offer of assets in exchange for goods.

2.2 Technology

In addition to the factors mentioned above, technology affects γ, the share of financially included buyers, in two ways. First, ω reflects the cost of accessing and using a bank account for making payments. Assuming that the banking sector is competitive and that the cost of providing a bank account is zero, ω can be interpreted as the utility cost to the buyer of opening and accessing a bank account to make payments. Thus, ω is agent specific and permanent. I assume that this utility cost is uniformly distributed across buyers, $\omega \sim U[0, k]$, where $k \in [0, 1]$ represents the *technology* in the financial sector: the lower k is, the more efficient the financial sector is.

Second, a buyer's transactions are easier to trace, record, and tax if he or she has joined a bank. Therefore, a buyer who has joined a bank pays the full tax τ, whereas a buyer who has not joined a bank pays only $(1-\theta)\tau$, where $(1-\theta) \in [0, 1]$ represents the likelihood of being caught. Improvements in the *technology* of the taxation system help increase the likelihood of being caught, i.e., the level of enforcement. This is similar to Ihrig and Moe (2004), who model the level of enforcement as the probability of being caught and then having to pay taxes or, alternatively, having to pay an additional penalty. They note that the level of enforcement is difficult to measure and use the inverse of seigniorage as a proxy. Unlike Ihrig and Moe (2004), who assume the relationship between seigniorage and enforcement, I aim to establish this relationship by arguing that technology plays an important role.

Finally, I assume that the two types of technology are closely intertwined and move in the same direction, which means that technological improvements reduce the cost of access to the financial system and support better tax enforcement; i.e., technological improvements lower the parameters k and θ.

2.3 Government

The government is a consolidated entity, consisting of a fiscal and a monetary authority. The government can levy lump-sum taxes on financially included buyers in the CM, with τ denoting the tax per buyer in units of goods used to finance real government spending G. In addition, the government issues M units of currency and B one-period nominal bonds held by the banks. The bonds issued by the government have a payoff of q_{+1} in the next period as measured in units of money. Letting ϕ denote the price of money in terms of goods in the CM market, the consolidated government budget constraint is

$$\phi(M + B) + \gamma\tau + (1-\theta)(1-\gamma)\tau = \phi(M_{-1} + qB_{-1}) + G \tag{1}$$

Equation (1) states that the government's outstanding liabilities at the end of the CM, plus tax revenue, must equal the government's net outstanding liabilities at the beginning of the CM, for all periods.

To limit the class of monetary policies, I follow Williamson (2012) and fix two parameters: first, the total stock of government liabilities grows at a constant rate μ, and the ratio of currency to total government debt is a constant δ, i.e., $M = \delta(M + B)$. Since I consider only cases where the government is a net debtor ($B > 0$), it follows that $\delta \in [0, 1)$.

Given this, lump sum taxes can be passively determined as

$$\tau = \frac{1}{1-\theta(1-\gamma)}\Big[- \frac{\phi M}{\delta}\frac{\mu - 1}{\mu} + \frac{\phi M}{\mu}\frac{1-\delta}{\delta}(q-1) + G\Big] \tag{2}$$

In equation (2), the first term in front of the square bracket expresses the scope of buyers covered by the tax; i.e., more buyers joining the financial system γ or improvements in the tax technology θ lower the lump sum tax. The first term in the square bracket expresses the negative of the proceeds from the increase in currency, i.e., higher proceeds decrease the lump sum taxes. The second term in the square bracket is the real value of the net interest on government liabilities, which needs to be financed by the lump sum tax. Finally, the last term represents the to-be-financed real government spending.

2.4 Banks

Banks form in the CM before buyers know whether they will meet a financially included or excluded seller in the DM, and dissolve in the CM of the subsequent period, when they are replaced by new banks.

Banks can invest deposits into government-issued bonds or into currency. Since I

assume that the banking system is competitive, the gross real interest rate paid on the deposits equals the gross real interest rate r_{+1} of the government bonds, which is defined to be $r_{+1} = q_{+1}\frac{\phi}{\phi_{-1}}$.
When a financially included buyer meets a financially included seller, then she can pay with her interest-bearing deposits. However, if she meets a financially excluded seller, she would need to withdraw cash and forego the interest on the deposit. Following Williamson (2012), banks offer a deposit contract that maximizes the expected utility of each of its depositors by offering interest rates on deposits and minimizing the amount of cash that must be put aside to pay for transactions with financially excluded sellers. Based on this optimal offer, buyers decide whether to join the bank (and make deposits in the form of goods).

3 Equilibrium

In this section I define and characterize the equilibrium.

3.1 Financially Excluded Buyers

The CM and DM value functions are denoted by $W(m_e)$ and $V(m_e)$, where m_e refers to the currency that will be used by the financially excluded buyers in real terms. The CM problem is

$$W(m_e) = \max_{\hat{m}_e, h} -h + \beta\hat{V}(\hat{m}_e), \quad \text{s.t. } h = \mu\hat{m}_e - m_e + c + (1-\theta)\tau$$

where $\hat{m}_e$ is the real value of money taken out of the CM and put into the DM in the next period, and c is the cost of handling cash, which represents the cost of theft protection, the inconvenience of handling banknotes and coins, etc. The first-order condition (FOC) is $\beta\hat{V}'(\hat{m}_e) = \mu$ and the envelope condition $W'(m_e) = 1$ demonstrates that $W(m_e)$ is linear.
Let q_e denote the exchanged good and p_e the respective payment in a nonmonitored

meeting in the DM. Then, the value function in the DM can be written as:

$$\hat{V}(\hat{m}_e) = \hat{W}(\hat{m}_e - p_e) + u(q_e), \quad \text{s.t. } p_e \leq \hat{m}_e \tag{3}$$

Since in the baseline model, we are considering take-it-or-leave-it offers, the buyer will offer the seller enough currency to cover her costs; i.e., to get q_e, the buyer offers to pay $p_e = \hat{m}_e = q_e$.

As usual, $\frac{\beta}{\mu} < 1$ implies that buyers spend all their currency when they meet a seller in the DM, i.e., that they are constrained in a meeting and that $m_e = 0$. In the case where $\frac{\beta}{\mu} = 1$, the buyer can consume the optimal amount of goods q^* and is indifferent to carrying currency into the CM or not (i.e., $m_e \geq 0$). Differentiating (3), and using the FOC from the CM, we get the Euler equation:

$$u'(\hat{m}_e) = \frac{\mu}{\beta} \tag{4}$$

Since $q_e = \hat{m}_e$, it follows that $q_e < q^*$ when $\frac{\mu}{\beta} > 1$. The discounted utility of the financially excluded buyer in the CM expressed in terms of real goods is then

$$\mathcal{V}_e = \mathcal{L}_e - c - (1-\theta)\tau, \quad \text{where } \mathcal{L}_e = -\mu q_e + \beta u(q_e) \tag{5}$$

The first term represents the net utility of the financially excluded buyer: to buy q_e goods in the DM next period, the buyer needs to acquire $\hat{m}_e = \mu q_e$ money in real terms in the CM.

3.2 Financially Included Buyers

For each buyer, the bank acquires m_n units of currency (to be spent in a nonmonitored meeting) and a units of interest-bearing assets. Since a fraction of buyers γ join a bank, all banks together acquire γm_n units of currency and γa units of interest-bearing assets.

When buyer-depositors learn their types, at the end of the CM, each depositor who will be in a nonmonitored meeting in the DM withdraws $\frac{m_n'}{1-\rho}$ units of currency. Depositors in monitored meetings each receive the right to trade away deposit claims on $\frac{(m_n - m'_n + a - a')}{\rho}$ units of the bank's original assets.[8] The CM problem for a buyer is

$$W(a) = \max_{\hat{m}_n, \hat{a}, h} -h + \beta \hat{V}(\hat{m}_n, \hat{a}), \quad \text{s.t. } aq + h = \mu(\hat{m}_n + \hat{a}) + \tau + (1-\rho)c + \omega \quad (6)$$

It is optimal for the financially included buyer to spend all currency in the DM. Therefore, the agent will only take deposit claims a into the CM. The key FOCs are $\beta \hat{V}_1(\hat{m}_n, \hat{a}) = \beta \hat{V}_2(\hat{m}_n, \hat{a}) = \mu$ and the EC is $W'(a) = q$. The DM problem can be stated as follows:

$$\hat{V}(\hat{a}, \hat{m}_n) = (1-\rho)u^n(q_n) + \rho u^m(q_m) + \hat{W}(\hat{a}') \quad (7)$$

where $q_n = \frac{\hat{m}'_n}{1-\rho}$ and $q_m = q_{+1}\frac{\hat{a}-\hat{a}'}{\rho} + \frac{\hat{m}_n - \hat{m}'_n}{\rho}$.
Naturally, q_n represents the exchanged good in a nonmonitored meeting where currency was used, and q_m is the quantity of exchanged goods in a monitored meeting against bank-deposits. Substituting (7) into (6), and expressing m and a in current real values, we can reformulate the problem of the bank as follows:

$$\max_{m_n, m'_n, a, a'} -(m_n + a) + \beta(1-\rho)u^n\left(\frac{m'_n}{\mu(1-\rho)}\right) + \beta\rho u^m\left(r_{+1}\frac{a-a'}{\rho} + \frac{m_n - m'_n}{\mu\rho}\right) + \beta r_{+1} a' \quad (8)$$

The FOCs are as follows, where $q_n = \frac{m'_n}{\mu(1-\rho)}$ and $q_m = r_{+1}\frac{a-a'}{\rho} + \frac{m_n - m'_n}{\mu\rho}$:

$$\beta u^m_{m_n} - \mu = 0 \quad (9a)$$

$$u^n_{m'_n} - u^m_{m'_n} = 0 \quad (9b)$$

$$\beta r_{+1} u^m_a - 1 = 0 \quad (9c)$$

$$u^m_{a'} - 1 = 0 \quad (9d)$$

An equilibrium in which real bonds are plentiful requires that $\beta r_{+1} = 1$, in which case, according to (9c) $u^m_a = 1$ and since $u^m_a = u^m_{a'}$, according to (9d), the bank is willing to acquire any amount of additional real bonds a' that are available in the market. Buying more bonds than necessary for the exchange (i.e., $a' > a$) does

[8] It is natural to assume that buyers spend all currency in the DM, since we look at equilibria where $\frac{\phi_{+1}}{\phi}\beta \leq 1$.

not affect the utility of the agent.
With regard to the currency acquired by the bank, which is based on (9a) $u^m_{m_n} < u^m_a$ as long as $\mu > \beta$, and so $m_n = m'_n$. In this case, (9b) can be simply expressed as $u^n_{m'_n} = \frac{\mu}{\beta}$. If $\mu = \beta$, the bank acquires any currency that is issued by the government without affecting the utility of the agent.
Finally, the expected utility of a financially included buyer in each period is then

$$\mathcal{V}_i(\omega) = (1-\rho)\mathcal{L}_n + \rho\mathcal{L}_m - (\omega + (1-\rho)c + \tau) \tag{10}$$

where $\mathcal{L}_n = -\mu q_n + \beta u^n(q_n)$ and $\mathcal{L}_m = -\frac{1}{r+1}q_m + \beta u^m(q_m)$. The first and second parts sum up the net utility in the case of a nonmonitored and a monitored meeting, respectively. The third part contains the expected costs after joining a bank $\omega + (1-\rho)c$ and the tax payment τ.
A buyer will join the financial system if $\mathcal{V}_i(\omega) \geq \mathcal{V}_e$. The share of buyers joining the financial system can be defined as $\gamma = \frac{\tilde{\omega}}{k}$ where $\mathcal{V}_i(\tilde{\omega}) = \mathcal{V}_e$.

3.3 Characterization

I confine attention to stationary monetary equilibria where real quantities are constant over time, i.e., $m = \phi M = \phi_{-1}M_{-1}$ and $b = \phi B = \phi_{-1}B_{-1}$. This implies that $\mu = \frac{\phi_{-1}}{\phi}$ and the nominal gross interest rate can be expressed as $q = \mu r$. Further, I assume that the supply of government bonds is plentiful so that, as will be shown later, the gross real interest rate is $r = \frac{1}{\beta}$.

Definition 1 *Given monetary policy μ, δ and share ρ of sellers joining banks, an equilibrium consists of real quantities of currency $m = \gamma m_n + (1-\gamma)m_e$ and plentiful amount of real bonds $b \geq \gamma a$ (to be defined below) with a gross real interest rate $r = \frac{1}{\beta}$, such that (i) m_n and a solve (8) and m_e solve (4), (ii) the tax rate is defined (based on equation (2)) as*

$$\tau = \frac{\gamma m_n + (1-\gamma)m_e}{\gamma + (1-\theta)(1-\gamma)}\Big(\frac{r - \delta r - 1}{\delta} + \frac{1}{\mu}\Big) + \frac{G}{\gamma + (1-\theta)(1-\gamma)} \tag{11}$$

and (iii) the share γ of buyers joining a bank is defined as $\gamma = \frac{\tilde{\omega}}{k}$ where $\mathcal{V}_i(\tilde{\omega}) = \mathcal{V}_e$.

As discussed in Williamson (2012), there are four possible equilibria: i) liquidity trap, ii) plentiful interest-bearing assets, iii) scarce interest-bearing assets, and iv) the Friedman rule. Equilibria i) and iii) require that interest-bearing assets are scarce, equilibrium ii) requires that their supply is plentiful, and equilibrium vi) is possible in a scarce or plentiful environment. Since I define the interest-bearing assets to be plentiful, I reduce the possible solutions to equilibria ii) and iv), which are characterized and discussed in the following.

3.3.1 Plentiful Interest-Bearing Assets Case

In this equilibrium, $\frac{1}{\mu} < r = \frac{1}{\beta}$, which means that the nominal interest rate on interest bearing assets is positive and that currency is comparably scarce. Therefore, based on the first-order condition for problem (8), we have $m_n' = m_n$, $a \in [\beta\rho q^*, \infty]$, and $a' \geq 0$, and m_n solves

$$\frac{\beta}{\mu} u'\Big(\underbrace{\frac{1}{\mu}\frac{m_n}{1-\rho}}_{q_n}\Big) = 1 \tag{12}$$

which allows us to make two observations. First, in nonmonitored meetings, exchange is not efficient and leads to the same size of goods exchanges as in the case of the financially excluded buyer, i.e., $q_n = q_e = q$, which implies that $m_n = (1-\rho)m_e$. Second, the assumption that $-x\frac{u''(x)}{u'(x)} = 1$ implies that the demand for currency m_b is independent of μ.

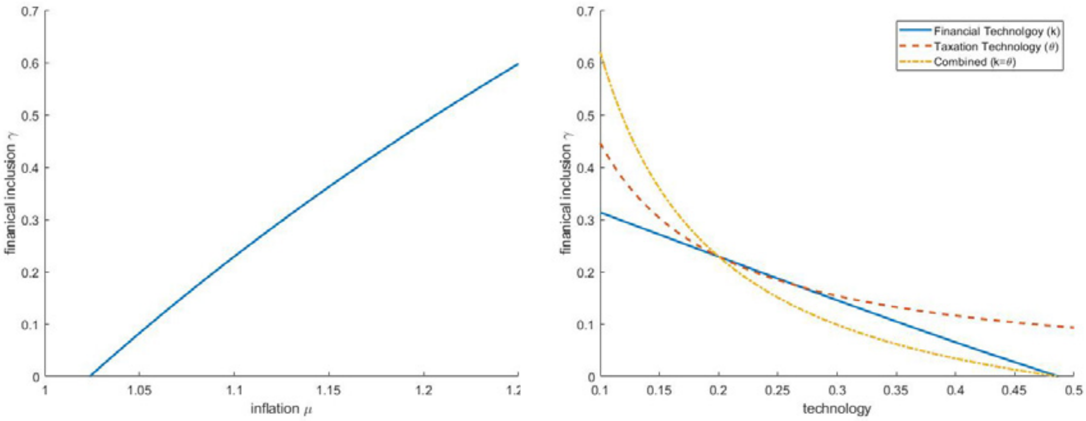
Since the rate of return on interest-bearing assets is equal to the rate of time preference, exchange is efficient in monitored meetings (all buyers receive q^* in the DM), and the bank is willing to acquire an unlimited quantity of interest-bearing assets. For the interest-bearing assets to be plentiful, we require that the supply of real bonds b is above the threshold $\underline{b} \geq \beta\gamma\rho q^*$.

The share of buyers joining a bank can be expressed as[9]

$$\gamma = \frac{\rho}{k}(\mathcal{L}^* - \mathcal{L} + c) - \frac{\theta}{k}\tau \tag{13}$$

[9]For certain parameters the implicit function, (13) has two possible solutions for $\gamma_{1,2} \in (0, 1)$. I consider only the solution leading to a higher level of financial inclusion, since the lower solution has no meaningful economic interpretation. For example, better technology would lead to a lower level of financial inclusion.

Figure 2: Drivers of Financial Inclusion



(a) Inflation and financial inclusion (b) Technology and financial inclusion

The utility $u(x) = \log(x)$ and parameters displayed in table (1) are used. In addition, for the right-hand figure, an inflation rate of $\mu = 1.1$ is applied, and for the left-hand figure, the technology parameters $k = \theta = 0.2$ are applied.

where $\mathcal{L}^* = -\beta q^* + \beta u(q^*)$, $\mathcal{L} = -\mu q + \beta u(q)$ and τ based on (11) can be rewritten as follows:

$$\tau = m_e \frac{1-\gamma\rho}{1-\theta(1-\gamma)}\Big(\frac{r-\delta r-1}{\delta} + \frac{1}{\mu}\Big) + \frac{G}{\gamma + (1-\theta)(1-\gamma)} \tag{14}$$

Clearly, joining the financial system is more attractive when the share of sellers in the financial system ρ and the cost of handling cash c are high.

The effects of inflation μ and technology k as well as of θ are not straightforward because they also affect the level of taxes τ. Generally, an increase in μ boosts the level of financially included buyers γ. Similarly, a reduction in k and θ, e.g. through a cost-cutting technology allowing cheaper access to banks and better collection of taxes from the financially excluded, increases financial inclusion, as displayed in Figure (2). With growing financial inclusion, the threshold $\underline{b}$ at which interest-bearing assets are plentiful also increases.

3.3.2 Friedman Rule Case

If $\frac{1}{\mu} = r = \frac{1}{\beta}$, then $m_n > (1-\rho)q^*$, $m_n' = (1-\rho)q^*$, $a' = a + m_n - q^*$, and $a + m_b \geq q^*$.

In this case, all rates of return are equal to the rate of time preference, $\mu = \beta$, and the equilibrium exists for any number of real bonds b. Only buyers who have a cost of handling cash high enough to offset the higher tax burden join the financial system, i.e.,

$$\gamma = \frac{\rho}{k}c - \frac{\theta}{k}\tau$$

Note that the financially included would need to finance not only government spending but also the reduction in the money base. Therefore, for a certain set of parameters, there is no solution; i.e., no one joins the financial system.

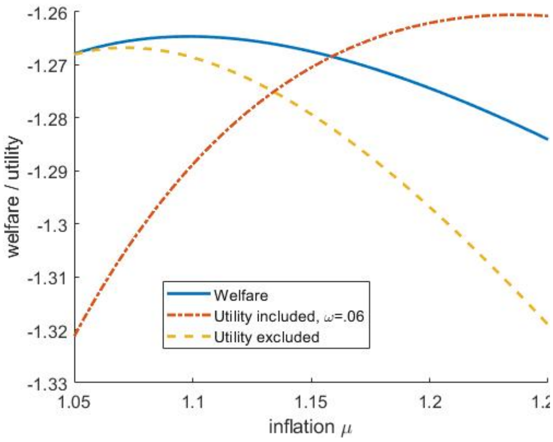
3.4 Welfare Analysis

I weight the utilities of buyers and sellers equally. In this case, the sellers drop out (zero net benefit), and welfare can be measured as the sum of the utility of financially included and excluded buyers:

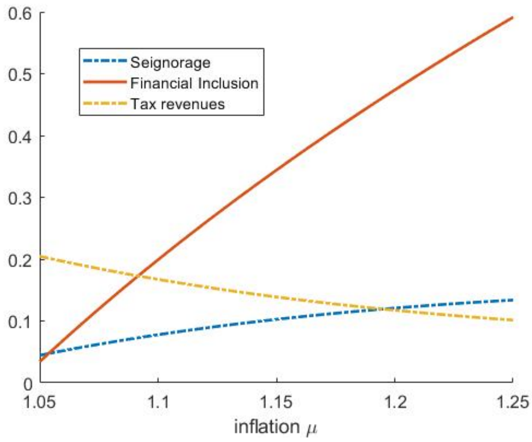
$$W = \int_0^{\omega=k\gamma} \mathcal{V}_i(x)\frac{1}{k}dx + (1-\gamma)\mathcal{V}_e$$

When comparing the plentiful interest-bearing equilibrium with the Friedman rule equilibrium, the trade-off between the level of consumption and the cost of handling cash must be considered. While the Friedman rule allows all agents to consume the same (optimal) level of goods in the DM, it is associated with a low level of financial inclusion, leading to high costs for handling cash and higher taxes for those who join the financial system. The plentiful interest-bearing equilibrium leads to a sub-optimal level of consumption among the financially excluded (and the nonmonitored meetings of the included) and thus to higher levels of inequality, but it induces higher levels of financial inclusion and thus lower costs for handling cash. This raises the question of whether welfare can be improved by introducing a wedge between the rate of inflation and real interest rates, inducing more buyers to join the banking system.

Figure 3: Welfare, seignorage and taxes



(a) Welfare and Utility



(b) Seignorage and taxes

The utility $u(x) = \log(x)$ and parameters displayed in table (1) are used. In addition, the technology parameters $k = \theta = 0.2$ are applied. Seignorage is defined as the government income gained from increasing the money base, which must equal spending net of tax income, i.e., $\phi(M - M_{-1}) = G + \phi(B - qB_{-1}) - (1 - \theta(1 - \gamma))\tau$.

Before analyzing the optimal welfare-maximizing inflation rate, it is worth discussing the externalities surrounding the decision of an agent to join the financial system. When a buyer decides whether to join the financial system, she does not consider the consequences this has on the tax rate that the other buyers need to pay. For example, if at a certain tax level, a buyer decides not to join, this might increase the tax rate and induce more buyers to not join the financial system. In an extreme case, the "official" tax rate becomes very high so that no agent joins the financial system, and all suffer the costs of holding cash but pay only a share of the official tax rate. In this case, the government can raise inflation, thus making joining the financial system more attractive through three avenues: 1) the cost of staying out of the financial system increases, 2) the official tax rate decreases because the tax base widens, and 3) a lower share of government revenue is financed through taxation, reducing the tax base further. This has implications for the utility of the financially included and excluded and for aggregate welfare, as shown in Figure (3).

I show in the following that it is optimal to have positive inflation. In the case of the plentiful asset-bearing equilibrium, inserting the utilities $\mathcal{V}_i(x)$ and $\mathcal{V}_e$, welfare can be written as follows:

$$W = \int_0^{k\gamma} \Big((1-\rho)\mathcal{L} + \rho\mathcal{L}^* - (x + (1-\rho)c + \tau)\Big)\frac{1}{k}dx + (1-\gamma)(\mathcal{L} - c - (1-\theta)\tau)$$
$$= \gamma\Big((1-\rho)(\mathcal{L} - c) + \rho\mathcal{L}^* - \tau\Big) - \frac{1}{2}k\gamma^2 + (1-\gamma)(\mathcal{L} - c - (1-\theta)\tau)$$

The first-order condition w.r.t. μ can be written as follows:

$$\frac{\partial W}{\partial \mu} = \gamma\Big((1-\rho)\frac{\partial \mathcal{L}}{\partial \mu} - \frac{\partial \tau}{\partial \mu}\Big) + (1-\gamma)\Big(\frac{\partial \mathcal{L}}{\partial \mu} - (1-\theta)\frac{\partial \tau}{\partial \mu}\Big) = 0 \tag{15}$$

The economic interpretation of equation (15) is that the first term represents the net welfare gain among the financially included, for whom welfare increases due to higher inflation (since $\frac{\partial \tau}{\partial \mu} < 0$), but the welfare from non-monitored meetings is lower. Note that the net benefit increases with ρ for the financially included.
The second term represents the welfare change for the financially excluded. On the one hand, welfare is lower because the financially excluded carry less cash in real terms and buy less in a DM meeting (since $\frac{\partial \mathcal{L}}{\partial \mu} < 0$); on the other hand, they profit from the reduction in taxes as well (as long as $\theta < 1$). The net benefit decreases with θ for the financially excluded.
It can be shown (see appendix for the proof) that[10]

$$\frac{\partial W}{\partial \mu}\Big|_{\mu=1} > 0$$

i.e., that it is optimal to have money growth that is higher than 1 and thus positive inflation.
Since it is not possible to find an analytic solution to the first-order condition (15), I provide a numerical analysis in the following section.

[10]The FOC can be alternatively written (noting that $\frac{\partial \gamma}{\partial \mu} = \frac{q}{k} - \frac{\theta}{k}\frac{\partial \tau}{\partial \mu}$) as:

$$\frac{\partial W}{\partial \mu} = -\frac{q}{\theta} + \frac{\partial \gamma}{\partial \mu}\frac{k}{\theta}(\gamma + (1-\gamma)(1-\theta)) = 0$$

4 Optimal Fiscal and Monetary Policy and Financial Inclusion

In this section, I discuss the optimal monetary and fiscal policies and the optimal level of financial inclusion under different technology parameters $\langle k, \theta \rangle$ which reflect the inefficiency in banking and tax collection. To do so, I consider specific functional forms and parameter values. The utility of the buyer in the DM is given by $u(q) = ln(q)$. The parameter values are summarized in table (1). The value for the discount rate β is set to the literature standard and G, the share of government spending in the goods consumed is set equal to the average value for central governments taken from the World Bank. The cost of using cash c is difficult to estimate. The value 2 percent of income is based on Malte and Seitz (2014), who provide an overview of these issues. The probability of meeting a financially included seller ρ is set to be approximately equal to the average financial inclusion of sellers and represents that of middle income countries. Finally, the ratio of currency to government liability δ can vary considerably. The value chosen ensures that the supply of bonds is abundant for all the relevant parameters k and θ.

Table 1: Parameter Values

Parameter	Description	Value
β	Discount factor	.95
G	Government spending (share of GDP)	0.2
c	Cost of using cash (share of income)	0.02
ρ	Prob. of meeting a financially included seller	0.5
δ	Ratio of currency to gov. liability	0.5
$F(\omega)$	Distribution of costs to access a bank	$U \sim [0, k]$, $k \in (0, 1)$
θ	Inefficiency in tax collection	$\theta \in (0, 1)$

The optimal inflation, tax revenue, and financial inclusion for different levels of

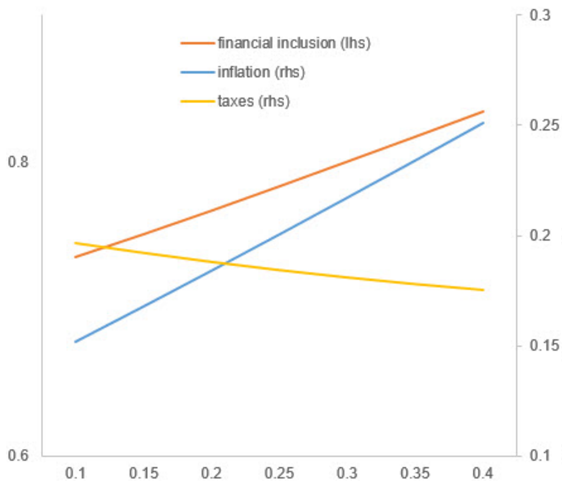
taxation and financial technology are displayed in figure (4). An improvement in taxation technology θ (leaving financial technology k fixed) leads to higher levels of financial inclusion, lower optimal inflation and higher tax revenue (see subfigure (4a)). Improving the taxation technology raises the tax revenue obtained from the financially excluded, which at the same time raises the attractiveness of joining the financial system and reduces the optimal inflation tax.
An improvement in the financial technology k (leaving taxation technology θ fixed) leads to a sharp increase in financial inclusion and tax revenue. Optimal inflation, however, increases slightly too (see subfigure (4b)); i.e., in such a case, financial inclusion and inflation are positively correlated. The reason is that with growing financial inclusion, the tax base increases, as does the optimal individual tax τ; thus the financially excluded also profit from a decrease in taxation. Therefore it is optimal to increase the inflation tax slightly.
Finally, if the financial and taxation technologies move jointly, then their improvement leads to a rapid increase in financial inclusion and in tax revenue. Optimal inflation also decreases sharply (see subfigure 4c).
Overall, in all three scenarios, technological improvements lead to higher financial inclusion and higher tax revenue; thus, both variables are always positively correlated. The correlation between inflation and financial inclusion is negative, whether taxation and financial technology move together or whether only taxation improves. In the case of an improvement in financial technology only, the correlation between financial inclusion and inflation is either positive or inconclusive. To test the model, I empirically analyze the relationship between these variables in the following sections.

5 Strategy for Empirical Analysis and Data

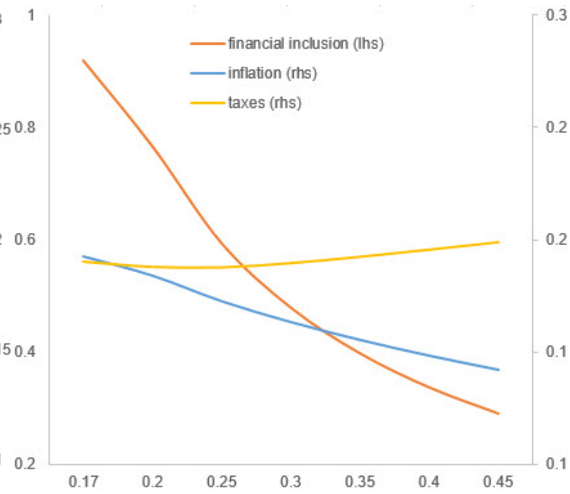
5.1 Model

In section 4, I have argued that tax revenue increases with financial inclusion and that depending on the technological progress, inflation decreases with financial inclusion. Therefore, regressing tax revenue and inflation on financial inclusion is the natural choice. However, the empirical analysis is made more difficult through

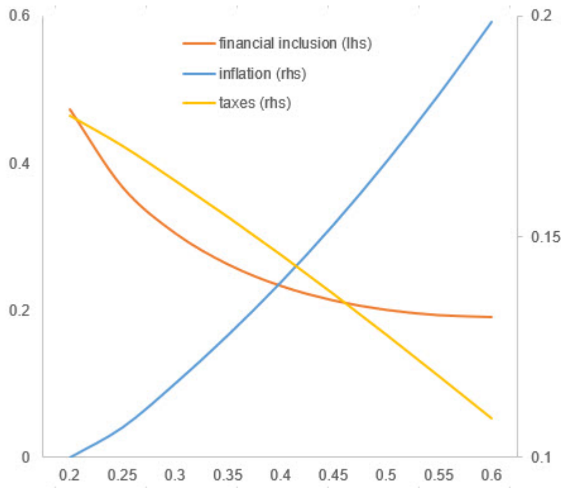
Figure 4: Taxes, inflation, and financial inclusion



(a) Taxation technology θ ($k = 0.2$ fixed)



(b) Financial technology k ($\theta = 0.2$ fixed)



(c) Technology $\theta = k$

two issues. First, the observable variables inflation, taxes, and financial inclusion $\langle \mu, \tau, \theta \rangle$ depend on the unobservable variables financial and taxation technology $\langle k, \omega \rangle$ and are set at the same time, blurring cause and effect. Second, while $\langle \mu, \tau \rangle$ can be observed for many countries over a long period, good quality data on γ for a broad range of countries are only available for the years 2011, 2014, and 2017, limiting the availability of data.

The strategy for the empirical analysis is to control for a broad set of macroeconomic variables that are known in the literature to affect inflation and tax revenue and to control for time and country-specific effects as well. More formally, I estimate the following model

$$\Gamma_{it} = \alpha\gamma_{it} + AX'_{it} + c_i + \lambda_t + \zeta_{it} \tag{16}$$

where the dependent variable Γ_{it} represents either inflation π_{it} or aggregate tax revenue T_{it}. γ_{it} measures financial inclusion (in terms of account ownership or in terms of transaction value or volume), and X'_{it} is a set of control variables that contains openness to international trade, government debt, the level of corruption, GDP growth, and unemployment. α and A represent the marginal impact of a change in financial inclusion or in the control variables on the dependent variables. c_i and λ_t represent country and year fixed effects, respectively. Finally, ζ_{it} is an error term.

5.2 The Datasets

I draw from two sources for the data on financial inclusion: the World Bank's Global Financial Inclusion survey, which looks at financial inclusion from the demand side, and the IMF's Financial Access survey, which covers the supply side. I describe each source in turn.

Since 2011, the Global Financial Inclusion Database has published a comprehensive data set on how adults save, borrow, make payments, and manage risks globally every three years.[11] The survey in 2017 covered 144 economies representing more than 97% of the world's population.[12] I have removed economies without at least two consecutive observations as well as all 19 economies that are part of the European Economic and Monetary Union because the responsibility for monetary policy was transferred from their national central banks to the ECB. For the years 2011, 2014, and 2017, the cleaned database contains 345 observations for 119 economies. Thus, the panel data are not balanced due to missing observations for some economies.

In this paper, I focus on the payment aspects of financial inclusion and use the

[11] https://globalfindex.worldbank.org/

[12] For more details on the survey methodology, see Demirguc-Kunt et al. (2018), p. 111 ff.

variable FI, which measures the share of ownership of transaction accounts at a financial institution, as the main measure of financial inclusion (see table (2) for a set of descriptive statistics).[13] I check the robustness of this approach by using two different definitions of account ownership in the robustness section: FI+, which contains account ownership at financial institutions and mobile money institutes, and FI-, which measures usage of mobile money accounts only. The latter variable is available only for the years 2014 and 2017.

The Financial Access Survey[14] has been collecting data on the use of and access to basic financial services worldwide since 2004 and has covered account ownership and the usage of mobile money since 2007 in several countries (see IMF (2019) for the latest report). Due to the way the data are collected, the account ownership statistics are of limited value to this study because they include substantial double-counting of account owners. However, the statistics on the value of mobile money transactions (variable MTV), the number of mobile money transactions (variable MTN), the and number of active mobile money accounts (variable MAU) are very useful as a complement to my analysis (see table (3) for descriptive statistics).

5.3 Descriptive Statistics and Control Variables

Descriptive statistics of all dependent variables and control variables used in this paper are displayed in tables (2) and (3). The dependent variables tax revenue (Tax) and consumer price index (CPI) contain a fair share of variation across time (see within variation), but most of the variation occurs between countries. This statement also holds for most of the control variables.

Openness is defined as the ratio of imports and exports to GDP. There is no consensus in the literature on the impact of openness to trade on inflation and taxes. Romer (1993) argues that because openness increases the cost of inflation for economies, central banks have an incentive to reduce inflation with openness and provides empirical evidence in support of this claim. However, ample theoretical

[13] Financial institution accounts include those owned by respondents who report having an account at a bank or at another type of financial institution, such as a credit union, a microfinance institution, a cooperative, or the post office (if applicable), or having a debit card in their own name.

[14] https://data.imf.org/FAS

Table 2: Descriptive Statistics: World Bank Group Financial Inclusion Dataset

Variable	Definition	Panel	Mean	Sd	Min	Max	Obs.
Tax [a]	Tax revenue	Overall	15.40	5.99	0.07	36.50	N = 238
	(% of GDP)	Between		6.08	0.25	34.21	n = 90
		Within		1.03	11.46	19.41	T = 2.64
CPI [a,e]	Consumer prices	Overall	5.01	4.65	-3.70	29.51	N = 328
	(annual %)	Between		4.28	-1.01	26.09	n = 116
		Within		2.64	-2.02	17.97	T = 2.83
FI [b]	Acc. ownership at fin. institutions (% age 15+)	Overall	0.48	0.30	0.02	1.00	N = 328
		Between		0.29	0.05	1.00	n = 116
		Within		0.07	0.27	0.72	T = 2.832
FI+ [b]	Fin. institutions and mobile money (% age 15+)	Overall	0.49	0.29	0.02	1.00	N = 328
		Between		0.28	0.05	1.00	n = 116
		Within		0.08	0.26	0.73	T = 2.83
FI- [b]	Mobile money	Overall	0.10	0.13	0.00	0.73	N = 139
	(% age 15+)	Between		0.11	0.00	0.66	n = 76
		Within		0.06	-0.08	0.29	T = 1.83
Openness [a]	Trade	Overall	84.19	52.84	23.93	425.98	N = 326
	(% of GDP)	Between		51.37	24.25	408.07	n = 115
		Within		8.43	48.71	123.63	T = 2.83
Debt [a]	Central government	Overall	46.17	30.61	0.06	236.07	N = 319
	debt (% of GDP)	Between		29.37	0.23	231.05	n = 113
		Within		7.93	12.66	95.70	T = 2.82
COR [c]	Corrpution	Overall	41.92	18.18	8.00	92.00	N = 314
	Perception Index	Between		18.38	11.67	90.00	n = 111
		Within		2.03	32.58	48.42	T = 2.83
Δ GDP [a]	Yearly growth	Overall	16.72	17.73	0.68	96.55	N = 328
	GDP per capita	Between		17.72	0.76	86.40	n = 116
		Within		2.01	6.36	26.88	T = 2.83
UNP [d]	Unemployment	Overall	7.40	5.78	0.32	31.38	N = 325
	(% of labor force)	Between		5.70	0.44	27.26	n = 115
		Within		1.15	2.32	11.81	T = 2.83

Source: [a] World Bank; [b] Global Findex Database, World Bank; [c] Transparency International; [d] International Labour Organization.[e] Countries with CPI $\geq$ 30% were removed from the sample

Table 3: Descriptive Statistics: IMF Financial Access Survey

Variable	Definition	Panel	Mean	Sd	Min	Max	Obs.
MTV	Value of mobile	Overall	7.93	17.20	0	142.39	N = 394
	money transactions	Between		10.01	0	41.03	n = 68
	(% of GDP)	Within		12.76	- 33.1	119.84	T = 5.79
MTN	Number of mobile	Overall	7.25	15.99	0	195.97	N = 395
	money transactions	Between		8.45	0	39.06	n = 67
	(per person)	Within		12.78	- 31.8	164.17	T =5.90
MAU	Number of active	Overall	0 .15	0.20	0	0.94	N = 268
	mobile money accounts	Between		0.16	0	0.65	n = 50
	(per person)	Within		0.13	- 0.27	0.85	T =5.36

Source: IMF Financial Access Survey

and empirical papers have either supported or contradicted the negative relation between openness and inflation (see Ghosh (2014) for a discussion). Gnangnon and Brun (2019) noted that economies that have successfully reformed their tax regimes generate higher tax revenues.
Central government debt (as a % of GDP), corruption, growth of GDP, and unemployment (as a % of the workforce) are the other major macroeconomic and institutional variables I control for.

6 Empirical Findings

Rapid and diverse changes in the level of financial inclusion in a relatively short period of time allow for an estimation of equation (16) with a fixed effects model.[15] The advantage of this approach is that the model controls for unobserved time-invariant heterogeneity between countries and that the estimators (mainly financial inclusion) can be endogenous with regard to the time-invariant heterogeneity without affecting the validity of the results. The fixed-effects model has the advantage

[15]The Hausman test clearly rejects the null hypothesis that the random effects model is the correct specification.

of controlling for such slow-moving institutional arrangements.

Table (4) presents all regression results. Columns 1 and 3 show a fixed-effects model with financial inclusion FI as the sole regressor. The log-transformed variable FI takes into account the fact that a 10 percentage point increase in financial inclusion in a country with a low level of basic inclusion is weighted higher than the same increase in a country with a high level. The coefficient on financial inclusion is positive (1.221) for tax revenues, negative (-4.057) for CPI and statistically significant in both cases, consistent with my model. The interpretation is that a doubling of the share of financially included adults in a country is associated with an increase in tax revenue of roughly 1.2 percentage points relative to GDP and a decrease in inflation of 4 percentage points.

Columns 2 and 4 show the same model with all control variables and country as well as year fixed effects. The FI coefficient w.r.t. taxes in Column 2 does not change much, while the coefficient in Column 4 decreases in magnitude (-2.291) but remains statistically significant. Openness and GDP growth are statistically significant for taxes (both positive) and government debt is significant in the CPI regression. The coefficients on corruption and unemployment are not statistically significant in either regression.

7 Robustness Checks

All results discussed in this section are summarized in tables (5) to (7).

7.1 Central Bank Independence

The theoretical model is based on implicit or explicit coordination between the fiscal and monetary policies. With an independent central bank, this coordination might break down. More precisely, the marginal effect of financial inclusion on inflation should be of lower magnitude (or not statistically significant) when accounting for central bank independence.

I use the central bank independence index from Garriga (2016) and divide the economies into two groups: independent central banks, which are at or above the median index value, and non-independent central banks, which are below the me-

Table 4: Estimation Results

Variables	(1) Tax	(2) Tax	(3) CPI	(4) CPI
FI (log)	1.221**	1.269**	-4.057***	-2.291***
	(0.477)	(0.490)	(0.666)	(0.860)
Openness		0.0370***		0.0349
		(0.0127)		(0.0248)
Debt		-0.0190		0.0604*
		(0.0188)		(0.0358)
COR		-0.0404		-0.0912
		(0.0347)		(0.0920)
Δ GDP		9.617**		-3.680
		(3.833)		(7.936)
UNP		-0.0252		0.101
		(0.0723)		(0.174)
Constant	16.36***	15.69***	0.848	1.575
	(0.406)	(2.107)	(0.671)	(6.350)
Observations	247	236	327	308
# of economies	92	88	116	109
Adj. R^2	0.054	0.173	0.175	0.257
Country FE	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes
F-test	6.561	5.174	37.12	12.77

Standard errors (clustered at the country level) shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

dian.

Column 1 of table (5) reports the result for countries with independent central banks and column 2 for countries with non-independent central banks. The financial inclusion coefficient is statistically significant for independent central banks but not for that of the other group, although the magnitudes are similar. A possible interpretation of these results is that central bank independence does not play a significant role after all in the relationships observed.

Table 5: Estimation Results: Robustness Checks

	(1)	(2)	(3)	(4)	(5)	(6)
	Indep	Dep	Developing		Developed	
Variables	CPI	CPI	Tax	CPI	Tax	CPI
FI (log)	-2.666**	-2.143	1.152*	-2.686**	-1.495	0.745
	(1.173)	(1.458)	(0.603)	(1.118)	(1.083)	(1.155)
Openness	0.0317	0.0276	0.0579***	0.0444	0.0240	0.0317
	(0.0317)	(0.0409)	(0.0160)	(0.0534)	(0.0162)	(0.0224)
Debt	0.0733	0.0821*	-0.0608**	0.186***	0.00263	-0.0496
	(0.0572)	(0.0474)	(0.0239)	(0.0437)	(0.0274)	(0.0397)
COR	-0.232	0.0716	-0.0716	-0.000308	-0.0322	-0.191*
	(0.145)	(0.112)	(0.0640)	(0.112)	(0.0437)	(0.111)
Δ GDP	-4.896	-1.083	4.310	-5.152	6.324	0.466
	(14.54)	(9.350)	(9.192)	(17.71)	(4.567)	(7.372)
UNP	0.178	0.121		0.420	-0.104	0.0449
	(0.213)	(0.337)		(0.378)	(0.0761)	(0.163)
Constant	4.685	-5.459	13.89***	-9.264	15.61***	14.12*
	(7.979)	(9.250)	(3.055)	(8.214)	(2.440)	(8.173)
Observations	144	164	95	142	141	166
# of economies	50	59	37	51	51	58
Adj.R^2,Wald χ^2	0.389	0.163	0.428	0.371	0.112	0.259
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
F-test	9.171	7.610	6.234	11.13	1.934	7.302

Standard errors (clustered at the country level) shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

7.2 Developing vs. Developed Countries

I group low-income and low-middle-income countries into "Developing" countries and high-middle-income and high-income countries into "Developed" countries. For developing countries the coefficients on financial inclusion are significant and comparable in size to those from the basic regression for both tax and inflation (CPI). For developed countries the coefficient is not significant for either dependent variable.

Given that developed countries have a more developed taxation system, increasing financial inclusion does not affect tax revenue or inflation.

Table 6: Estimation Results: Different Measures of Financial Inclusion (World Bank)

Variables	(1) Tax	(2) CPI	(3) Tax	(4) CPI	(5) Tax	(6) CPI
FI (log)	1.269**	-2.291***				
	(0.490)	(0.860)				
FI+ (log)			1.192***	-1.796**		
			(0.380)	(0.742)		
FI- (log)					-0.290	-0.0412
					(0.255)	(0.490)
Constant	15.69***	1.575	15.56***	2.258	13.36***	1.768
	(2.107)	(6.350)	(2.090)	(6.429)	(4.162)	(8.300)
Observations	236	308	236	308	93	129
# of economies	88	109	88	109	54	71
Adj. R^2	0.173	0.257	0.182	0.250	0.111	0.011
F-test	5.174	12.77	5.436	13.18	1.455	1.991

Standard errors (clustered at the country level) shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Coefficients of all CV are suppressed, Country FE and Year FE: YES;

7.3 Other Measures of Financial Inclusion

Tables 6 and 7 estimate the impact on tax revenue and inflation using different measures of financial inclusion from the World Bank and the IMF dataset, respectively. The coefficients on the control variables are suppressed.

In table 6, I inserted Columns 2 and 4 from table (4) for comparison. Compared to these earlier estimates, the coefficients for FI+ in columns 3 and 4 are similar in size and statistically significant. However, the coefficients for FI- in columns 5 and 6 are not statistically significant. One possible reason for this surprising result is that FI-, which measures access to mobile money only, has been collected only in the years 2014 and 2017.

The estimation results presented in Table 7 use the measures of financial inclusion from the IMF dataset. In column 1, the coefficient on the value of mobile transactions (MTV) with regard to tax revenue is positive (0.0525) and statistically significant. The interpretation of the MTV coefficient is that an increase in the value of mobile phone transactions of 100 percentage points relative to GDP

Table 7: Estimation Results: Different Measures of Financial Inclusion (IMF)

Variables	(1) Tax	(2) CPI	(3) Tax	(4) CPI	(5) Tax	(6) CPI
MTV	0.0525**	-0.0146				
	(0.0245)	(0.0127)				
MTN			0.00958	-0.0526***		
			(0.0230)	(0.0150)		
MAU (log)					-0.123	-0.321*
					(0.110)	(0.176)
Constant	11.16*	-0.543	9.377	-3.110	7.935***	-2.968
	(5.692)	(3.349)	(5.702)	(2.524)	(2.322)	(3.363)
Observations	154	243	155	339	161	237
# of economies	44	60	44	61	38	46
Adj. R^2	0.175	0.132	0.124	0.196	0.175	0.122
F-test	2.706	3.474	2.031	6.606	3.344	3.323

Standard errors (clustered at the country level) shown in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Coefficients of all CV are suppressed, Country FE and Year FE: YES;

increases tax revenue by 5.25 percentage points. In column 2, the MTV coefficient is not statistically significant.

In column 4, the coefficient on the number of mobile transactions (MTN) with regard to inflation (CPI) is negative (-0.0526) and statistically significant. Accordingly, an increase of 100 mobile phone transactions per person reduces inflation by 5.26 percentage points. However, the coefficient in column 3 is not statistically significant (though it has the expected positive sign).

The last two columns, 5 and 6, show the results from regressing the number of active mobile money accounts per person on tax revenues and inflation (CPI). In this case, only column 6 has a statistically significant coefficient.

8 Concluding Remarks

This paper joins the discussion on the causes and the impact of financial inclusion by analyzing the link to technology and to monetary as well as fiscal policy.

I show that inefficient technologies, which lead to high costs of access to financial institutions, and an inefficient taxation system can lead to low levels of financial inclusion, low tax revenue and high (optimal) levels of inflation. Lowering the cost of access and improving taxation has the potential to not only raise financial inclusion (which in itself brings significant benefits for households and the economy as a whole) but also to increase the ability of governments to tax directly and lessens the pressure to do so through higher inflation.

The paper presents empirical evidence that this is already happening. One possible cause of the sudden and fast improvements in financial inclusion is arguably the rise of mobile payment services, cheaper identification, cheaper as well as faster payment infrastructure, and the appropriate regulation of these new payment providers.

The current empirical analysis does not provide a final and definitive answer on causality. The question of endogeneity and a suitable instrumental variable that correlates with financial inclusion but is not correlated with inflation and taxation deserves further attention in future research.

Proof: Welfare Analysis

First Derivative

Consider the welfare function, which, after taking the integral, can be written as

$$W = \gamma\Big((1-\rho)\mathcal{L} + \rho\mathcal{L}^* - \tau\Big) - \frac{1}{2}k\gamma^2 + (1-\gamma)(\mathcal{L} - c - (1-\theta)\tau)$$

Taking the derivative w.r.t. μ, I obtain:

$$\frac{\partial W}{\partial \mu} = \frac{\partial \gamma}{\partial \mu}(1-\rho)(\mathcal{L}-c) + \gamma(1-\rho)\frac{\partial \mathcal{L}}{\partial \mu} + \frac{\partial \gamma}{\partial \mu}(\rho\mathcal{L}^* - \tau) - \gamma\frac{\partial \tau}{\partial \mu} - k\gamma\frac{\partial \gamma}{\partial \mu} - \frac{\partial \gamma}{\partial \mu}(\mathcal{L} - c - (1-\theta)\tau)$$
$$+(1-\gamma)(\frac{\partial \mathcal{L}}{\partial \mu} - (1-\theta)\frac{\partial \tau}{\partial \mu}) = 0$$

Rearranging, I obtain:

$$\frac{\partial W}{\partial \mu} = \frac{\partial \gamma}{\partial \mu}\underbrace{(\rho(\mathcal{L}^* - \mathcal{L} + c) - \theta\tau)}_{k\gamma} - \frac{\partial \gamma}{\partial \mu}k\gamma + \gamma((1-\rho)\frac{\partial \mathcal{L}}{\partial \mu} - \frac{\partial \tau}{\partial \mu}) + (1-\gamma)(\frac{\partial \mathcal{L}}{\partial \mu} - (1-\theta)\frac{\partial \tau}{\partial \mu}) = 0$$

Since the first two terms cancel each other out, I am left with equation (15).

First Derivative: Positive for $\mu = 1$

Based on equation (14), the derivative of τ w.r.t. μ can be expressed as:

$$\frac{\partial \tau}{\partial \mu} = -\frac{\partial \gamma}{\partial \mu}\Big(\frac{m_e\rho}{1-\theta+\theta\gamma} + \frac{m_e\theta(1-\gamma\rho)}{(1-\theta+\theta\gamma)^2}\Big)\Big(\frac{r-\delta r-1}{\delta} + \frac{1}{\mu}\Big) - \frac{m_e(1-\gamma\rho)}{1-\theta+\theta\gamma}\frac{1}{\mu^2} - \frac{\partial \gamma}{\partial \mu}\frac{\theta G}{(1-\theta+\theta\gamma)^2}$$

Re-arranging equation (15) to $\frac{\partial W}{\partial \mu} = \frac{\partial \mathcal{L}}{\partial \mu}(1-\gamma\rho) - \frac{\partial \tau}{\partial \mu}(1-\theta+\theta\gamma) = 0$ and inserting the above result as well as noting that $\frac{\partial \mathcal{L}}{\partial \mu} = -q = -\frac{m_e}{\mu}$, I obtain the following expression:

$$\frac{\partial W}{\partial \mu} = -(1-\rho\gamma)\frac{m_e}{\mu} + \frac{\partial \gamma}{\partial \mu}\Big(m_e\rho + \frac{m_e\theta(1-\gamma\rho)}{1-\theta+\theta\gamma}\Big)\Big(\frac{r-\delta r-1}{\delta} + \frac{1}{\mu}\Big) + (1-\gamma\rho)\frac{m_e}{\mu^2} + \frac{\partial \gamma}{\partial \mu}\frac{\theta G}{1-\theta+\theta\gamma}$$

Therefore, it follows that:

$$\frac{\partial W}{\partial \mu}\Big|_{\mu=1} = \frac{\partial \gamma}{\partial \mu}\theta\frac{G}{1-\theta(1-\gamma)} + \frac{\partial \gamma}{\partial \mu}\Big(m_e\rho + \frac{m_e\theta(1-\gamma\rho)}{1-\theta+\theta\gamma}\Big)\Big(\frac{r-\delta r-1}{\delta} + \frac{1}{\mu}\Big) > 0$$

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