Institutions, Tax Evasion and Optimal Policy*

S. Borağan Aruoba
University of Maryland

July 27, 2018

Abstract

The mix of inflation and income taxation that governments adopt vary considerably across countries. We take a Ramsey optimal-policy approach to explain these differences, focusing on the institutions of the country, modeled as the difficulty of tax evasion, as the key variation across countries. In our model households optimally choose the extent of informal activity and a benevolent government optimally chooses policies, both taking as given the institutions of the economy. The model matches qualitatively the observed relationships between institutions and inflation, taxes and tax evasion. In a cross-country quantitative exercise with 125 countries, the model delivers a good fit: the correlation of data and model-generated values for inflation and taxes are 0.42 and 0.78, respectively.

Key Words: Ramsey problem, Friedman rule, inflation, taxation, informal sector

*The author thanks Peter Murrell for extensive discussions, Stefania Albanesi, Morris Davis, David Givens, David Lagakos, Ellen McGrattan, Guillermo Ordoñez, Guillaume Rocheteau, Richard Rogerson, Felipe Saffie, John Shea, Rob Shimer, Aleh Tsyvinski, Michael Waugh, Mark Wright, Randy Wright, participants at numerous conferences and seminars for useful comments and Henry Siu for collaborations in the earlier phases of this project. The usual disclaimer applies. This paper previously circulated under the title "Informal Sector, Government Policy and Institutions".

1 Introduction

There is considerable heterogeneity across countries regarding the sources of revenues of the government, in particular the use of income taxes versus the inflation tax. To explain this heterogeneity, we develop a macro/public finance model in the tradition of Ramsey (1927) that focuses on the effect of institutions on the optimal decisions of governments.[1] The key channel in the model through which institutions affect outcomes is tax evasion, or equivalently, informal activity.[2] Institutions in the model determine the difficulty of tax evasion and this in turn influences the optimal mix of inflation and taxation to raise a given amount of revenue.

Figure 1 shows the distribution of three key variables across 125 countries and their relationship with institutions: inflation, income taxes (measured two different ways) and the size of the informal sector.[3] The left panels show the distributions for these variables while the right panels show a simple scatter plot of them versus institutions, with the correlation between the two shown in a box and the linear regression line. First row of panels show results for inflation, for countries with an annual inflation less than 20%. The second and third row of panels contain results for effective tax rates for a smaller set of countries for which the data is available, and the tax revenue as a fraction of GDP for all 125 countries, respectively. The last row of panels show results for the size of the informal sector measured as a fraction of the formal sector. The distributions on the left column of panels demonstrate that there is substantial variation in these four variables across countries. The scatter plots on the right column of panels show fairly strong relationships between these variables and institutions. These are far from perfect relationships with correlations ranging from 0.38 (tax revenue / GDP) to -0.71 (size of the informal sector) but differences in institutions are related to meaningful differences in the variables of interest: a one standard deviation improvement in institutions relative to the mean is associated with a 2.5 percentage point

[1]By institutions we refer to the set of rules that determine how economic activity is conducted. In our empirical analysis our primary measure of institutions is Rule of Law by the World Bank.

[2]For our purposes the terms “unofficial”, “informal” or “shadow” economy refer to the same phenomenon, which is any economic activity that is done outside the reach of the government and therefore is not subject to taxation. A key characteristic of informal activity is that it is typically cash-intensive. While tax evasion is of course illegal, our concept of informal sector does not include activities that are inherently illegal.

[3]Details about data sources and transformations are provided in Section 4.1. In Figure 1 a unit of observation is a country with data averaged over a 15-year period, which is meant to capture long-run relationships. Appendix C contains more empirical results which show that the relationships shown in this figure are robust in a variety of different configurations: more controls, panel data, instrumental variables to account for the endogeneity of institutions, and different measures for institutions.

decline in inflation, 8.7 percentage point increase in effective taxes, 2.9 percentage point increase in the tax revenue / GDP ratio and a 10.8 percentage point decrease in the size of the informal sector. The goal of the paper is to explain the distributions show on the left column of panels using a model that delivers relationships as the ones on the right column panels.

In order to do so, we use a general equilibrium model that generates government policies and the extent of informal activity *endogenously,* taking as given the institutional structure of the country, as well as the size of the government and the level of labor productivity.[4] In our model there is a benevolent and optimizing government whose objective is to raise a given amount of revenue in the least distorting way. As in many similar Ramsey optimal-policy problems, the government strikes a balance between inflation, which is an implicit tax on cash-intensive activities and explicit income taxation. The additional wrinkle in this model comes from the fact that these policies also affect the tax evasion incentives for the private sector. Facing a risk of a tax audit (and a punishment if found evading taxes), and taking into account the government's income tax and inflation policies, the agents in the economy optimally choose the level of informal activity. Thus, the government may choose to use inflation as a tool to reduce informal activity and increase the tax base, in addition to the pure revenue motive in standard models.

To understand how the mechanism in our model works, let us consider the distinctly different experiences of two countries: United States (U.S.) and the Philippines. For the sake of argument, we will focus on the differences in their institutions as the starting point even though their government spending and labor productivity are also different. Institutions in the Philippines are about two standard deviations below those for the U.S. This difference in institutions makes the cost of tax evasion in the U.S. higher and everything else equal the people in the U.S. will choose to do less informal activity than those in the Philippines. (The Philippines' informal sector is 37% of its formal sector, while the one in the U.S. is only 9% of its formal sector.) Since informal activity is cash intensive, there will be less money demanded for informal activity in the U.S. Focusing on the effect of inflation only on money demand for informal activity, the marginal utility of money will be larger in the U.S., simply because there is less of it. Since the governments want to balance distortions,

[4]We are well aware that there is considerable work in the literature that consider each of these variables as *endogenous*. See for example Acemoglu, Johnson and Robinson (2005) for institutions, Hall and Jones (1999) and the vast literature on endogenous growth for labor productivity and Barro (1990) for government spending. We choose to keep the analysis simple and focused on the endogenous determination of inflation and taxation by taking the aforementioned variables as exogenous.

the U.S. government will choose to distort money demand, and thus informal activity less, and formal activity more than the government of the Philippines. As a result, inflation, which is the distortion in the informal sector, will be lower in the U.S. and taxes, which is the distortion in the formal sector, will be higher in the U.S. (The effective tax rate and inflation in the U.S. are 27% and 2%, respectively, while these in the Philippines are 20% and 5%, respectively.) In the end, then, we find that the country with better institutions has less informal activity, lower inflation and higher taxes. This shows that our model can *qualitatively* explain the relationships shown in the scatter plots in Figure 1.

In order to show that our model can also generate a meaningful distribution of government policies *quantitatively,* we conduct a cross-country exercise using the 125 countries in our dataset, maintaining the assumption that households have identical preferences across countries, and that the only differences across countries are those created by differences in the three exogenous variables. Comparing model-generated policies and private-sector behavior with those from our dataset, we conclude that our model delivers a reasonable fit. The correlation of model-generated inflation and the data is 0.42, and the correlations for the two tax rate measures we use are 0.78 and 0.61. The model's informal sector size has a correlation of 0.68 with the data measure. Among the three exogenous variables we consider, institutions emerges as the key variable that generates most of the variation in inflation and informal activity, while the level of government expenditures is equally responsible for explaining variation in tax rates. Considering the large set of countries we have in our dataset, the assumption of a benevolent and optimizing government choosing policies is clearly a stretch. In many countries factors other than the ones considered in our model, such as political-economy considerations, could be key in determining policies. We view this as a test of our theory. In fact, our results show that the link between data and model are strongest for countries that are more democratic and free, and for countries are in the upper half of the distribution for institutions.

Our work is related to a number of different strands in the literature. There has been considerable research at the intersection of macroeconomics and public finance led by Lucas and Stokey (1983) and Chari, Christiano and Kehoe (1991), among others, where ideas from public finance such as Ramsey's (1927) original exploration of how a government should distribute distortions were applied to models under general equilibrium. Most of this literature developed models that show how various tax instruments (for example consumption, labor income or capital income taxes or nominal interest rate) depend on exogenous factors like total factor productivity or government spending.[5] Despite theoretical advances, quantitative applications are rare in this literature and those that have a quantitative aspect typically focus on policies in one or a handful of countries – see Bhandari et al. (2017) for a recent example.

Perhaps not surprisingly most of previous studies that aim to understand the determinants of inflation, do so using the basic idea that informal activity uses cash and thus inflation is a way to tax it.[6] Nicolini (1998) is one of the first to show theoretically in the context of a cash-good-credit-good model that tax evasion due to informal activity (taken exogenously) is a motive for inflation under optimal policy. As a quantitative application, he uses his model to explain the inflation rates of Peru and the United States (U.S.) but this exercise does not generate the right amount of inflation for Peru, a country with a large informal sector. He concludes that the quantitative effects of tax evasion on the inflation rate, even in countries where informality is prevalent, is small. Yesin (2004, 2006) considers the optimal policy in the same model when the government faces (exogenous) tax collection costs and finds some success in explaining different policies for a small set of countries. The extent of informal activity (the set of goods that are formal versus informal) is assumed to be exogenously fixed in these papers. Koreshkova (2006) also models the trade-off that an optimizing planner faces between taxation (and evasion) and inflation in a cash-in-advance model with costly credit. The size of the informal sector in her model is directly linked to the assumed productivity differences across formal and informal production, and as such can be considered exogenous. We contribute to this literature by providing the first large-scale cross-country application of a Ramsey approach that shows a reasonable quantitative success in explaining cross-country differences in policy mixes. In Section 4.5.4 we explain in detail why our model is able to match the data in ways previous models were not able to by breaking down various mechanisms at work. Part of the success comes from considering tax evasion or informality as an *endogenous* outcome of the model, as opposed to *exogenously* given as most of the literature.[7]

[5] Canzoneri, Cumby and Diba (2010) and Schmitt-Grohe and Uribe (2010) provide reviews of the recent macro/public finance literature. The former is focused on the interaction between fiscal and monetary policy while the latter focuses on the inflation targets (that are typically around two percent per year) and if they could be obtained as a result of an optimal policy problem.

[6] Bordo and Vegh (2002) presents a model without an informal sector, where countries may differ in terms of their tax collection costs and this would determine the optimal mix of taxes and inflation.

[7] Gordon and Li (2009) consider a model where financial development of a country is exogenous and influences firms' choices of informality. They show that their model is able to explain some cross-country differences in taxes qualitatively. Although very different in model and methodology, the "tax riot" equilibrium

Our work is also related to a large literature on the macroeconomic effects of institutions. We continue the tradition of Hall and Jones (1999) and Acemoglu, Johnson and Robinson (2005) of relating the differences in institutions to differences in macroeconomic outcomes – taxation and inflation policies in our case. Our paper is one of the few papers that considers the impact of institutions in the macro/public finance literature. In this aspect our work is also related to Acemoglu et al. (2003) and Alfaro et al. (2008). The former paper makes the point that the empirical relationship between economic policies and volatility of the economy all but disappears once institutions of the country are controlled. The latter makes a similar point in that the Lucas paradox (capital does not flow from rich countries to poor countries) ceases to be a paradox when the institutions of countries are controlled. In the data, as we show in Section 4.1 there is a positive relationship between inflation and the size of the informal sector, and a negative relationship between tax rates and the size of the informal sector. Just like in the aforementioned papers, once institutions are controlled, these relationships disappear, indicating a similar omitted variable bias.[8] Thus this is another reason why using an optimal policy structure where both government policies and private decisions are endogenous and react to institutions is the more reasonable approach.

There is also a large literature on political-economy explanations of cross-country differences in government policies. Two examples include the seminal paper, by Alesina and Drazen (1991), who link political polarization of a country to higher incidence of instability (and thus high inflation) and Albanesi (2007) who associate highly unequal income distribution in a country with higher inflation.[9] The channel we focus on in this paper, how endogenously determined tax evasion shapes the inflation-taxation mix, cannot be, and according to our results indeed is not, the only possible explanation. The goal of our paper is to see how far the standard Ramsey analysis can go in explaining cross-country differences in policies. Especially for countries where various assumptions of our setup, such as the presence of a benevolent planner choosing policies, are violated, these political economy

of Bassetto and Phelan (2008), where households coordinate on underreporting their incomes, resembles the equilibrium in our model when institutions are bad and informal activity is high.

[8] It is also important to note that the signs of the relationships are the opposite of what one would expect if government policies were exogenous and the private sector reacted to them. Higher inflation or lower taxes would make informal activity less attractive, not more.

[9] Alesina, Ardagna and Trebbi (2006) test the implications of the mechanism in Alesina and Drazen (1991) and find that the delay in stabilization is shorter when the ruling executive has more control over the legislative body of the country or when the executive has more institutional constraints. Explanations for cross-country differences in policies based on the conflict between heterogenous segments of the society have also been provided by Fernandez and Rodrik (1991), Cukierman, Edwards and Tabellini (1992) and Laban and Sturzenegger (1994).

explanations will have much more to say. As such, we think our analysis complements these existing political economy explanations.

Our approach is also closely related to the idea of state capacity or tax capacity, which argues that governments are restricted in how high taxes they can enforce and thus may have to choose policy mixes where inflation has to substitute for taxation beyond a certain level. Besley and Persson (2009) provide a framework that makes this point. Separately, Kleven et al. (2016) argue that better institutions (or legal capacity) make it harder to conceal income (because, for example, most income is reported by third parties) and this increases the ability of the government to raise taxes. These and most of the other discussions of tax capacity provide a link between the institutions of the country and the tax mix that the government can sustain. As such our paper can be seen to be addressing the same issues since in our model the presence of the informal market limits the amount of taxes the government can raise and create a meaningful trade-off between taxes and inflation. Institutions, which are directly linked to tax audits in the model, influence this trade-off.

There is a vast empirical literature that focuses on the causes of informal activity. Johnson, Kaufmann and Schleifer (1997), Johnson, Kaufmann and Zoido-Lobaton (1997) and Friedman et al. (2000) provide empirical results suggesting that large informal markets are typically associated with institutional factors such as excessive regulation, poor enforcement of law and corruption. These results, which we also replicate in our empirical analysis, are especially useful in establishing the link between institutions and informal activity. To complement the empirical literature on the determinants of informal activity, there has been work on economic models to formalize these links. Ihrig and Moe (2004), Kuehn (2007), Quintin (2008) and de Paula and Scheinkman (2011) are some examples. In these models, if they exist, government policies are considered to be exogenous, and this is the main substantive difference between our model and theirs.

In terms of modelling strategy, we focus on two properties of informal activity: tax evasion and cash intensiveness. To capture these features, we use a search-based monetary model combining elements from Lagos and Wright (2005), Rocheteau and Wright (2005) and Aruoba and Chugh (2010).[10] Gomis-Porqueras et al. (2014) is a related paper where exogenous government policies are linked to informal activity in a search-based model.

The paper is organized as follows. In Section 2, we present our model and describe

[10]In this class of models, a medium of exchange is "essential" for trade in decentralized exchange. In our model the decentralized market is narrowly defined as the informal sector but these papers take a more general view of the decentralized market.

equilibrium for a given set of policies. In Section 3 we present the optimal policy problem and the Ramsey equilibrium where policies are also endogenous. In Section 4 we present our quantitative results. Section 5 concludes. The Online Appendix provides proofs of propositions, detailed derivations and supporting empirical analysis.

2 Model

The environment is based on the structure in Rocheteau and Wright (2005), who in turn build on the setup in Lagos and Wright (2005). Time is discrete and continues forever, and we abstract from any aggregate uncertainty. The economy is a closed one with no interaction with the rest of the world.[11] It is populated by infinitely-lived households with measure $\Lambda+1$, where $\Lambda > 0$. In every period a formal market meets, followed by an informal market. In the formal market (FM) all households have identical preferences, supply labor to a neoclassical firm, pay labor income taxes to the government at rate τ, adjust their portfolio of assets and consume. In the FM labor and goods markets are frictionless and everyone acts as price-takers. Transactions can be completed without a medium of exchange.

In the informal market (IM), measure 1 of households would like to purchase goods and measure Λ of households are able to produce goods. We label these households as buyers and sellers, respectively and these types are permanent. A measure $n \in (0, \Lambda)$ of the sellers choose to participate in the IM and actively look for a buyer. The buyers and participating sellers are randomly matched in the IM and it is possible for some households on either side to be unmatched in a given period. We assume that buyers in this market are anonymous and therefore contracts are not enforceable. As a result the sellers demand a *quid pro quo* and the buyers bring money into the IM to pay for their purchases. Once a buyer-seller pair successfully matches, they bargain over the terms of trade and the buyer pays d units of money in exchange for q units of the good. This transaction occurs outside the purview of the government and therefore the proceeds are not taxed. After the IM is complete, the buyers consume the goods they purchased in the two markets.

Since all buyers participate in the IM, the number of successful matches are given by the matching function $\mu(n)$ with $0 \leq \mu(n) \leq \min\{n, 1\}$. Accordingly, the probability that a

[11] This assumption is critical in two aspects. First, it rules out government revenues from foreign trade, external borrowing or foreign aid, which may make the government rely less on domestic taxes. Second, it rules out "dollarization" where, if the inflation rate becomes too high, agents in the economy can start using an alternative currency. In Appendix C we show that once institutions are controlled for, openness of a country and its interaction with institutions, have no predictive power for its policies.

buyer can find a seller is given by $\alpha_b(n) \equiv \mu(n)$ and the probability that a participating seller can find a buyer is given by $\alpha_s(n) \equiv \mu(n)/n$. These probabilities are taken as given by the agents and where obvious we drop the n argument.

The buyers participate in the IM at no cost. The sellers, on the other hand, face possible audits from the government, which is how we introduce institutions to the model. The government cannot observe whether or not a seller have participated in the IM – this is the whole point of an audit – and thus the sellers to be audited are randomly selected from the set of all sellers. Specifically, the government audits a seller with probability $\zeta(n)$. After the audit, if tax evasion is found, then a utility cost of $\mathcal{P}$ is imposed on the seller. This scheme resembles the one used in Bassetto and Phelan (2008) and is a "wasteful" punishment in that no one gains from it.[12] The sellers choose whether or not they want to enter the IM understanding the audit structure. The way the government can conclude whether or not a seller has participated in the IM is by observing their money holdings at the end of the IM. If the seller was not participating in the IM or was participating but was not successful in finding a match, he has no money and thus there is no punishment. If a participating seller that is able to find a match is audited, then he is punished. In equilibrium, due to free entry, the marginal seller will be indifferent between entering and not entering, taking into account the ex-ante cost of entering and the measure of participating sellers n. This ex-ante cost is $\alpha_s(n)\zeta(n)\mathcal{P}$.[13] We define $\zeta(n) = \varsigma\rho(n)$ where ς is a constant shift parameter, and $\rho(n)$ is an arbitrary function of n. We consider $\kappa \equiv \varsigma\mathcal{P}$ as the measure of institutions in the model – each of the two components of κ, the shift parameter of the probability of audits, ς, and the punishment for evading taxes, $\mathcal{P}$, can easily be linked to the institutions of the country. In what follows we formulate the seller's problem with $\kappa\alpha_s(n)\rho(n)$ denoting the (up-front) cost of entering the IM and drop the n argument where obvious.[14] Finally, we assume that the sellers alone conduct the illegal act of tax evasion by participating in the IM and the

[12] One can consider a number of alternative ways of punishment. One way would be to impose a cost in terms of goods, instead of utility as we do here. In this case, however, the government can in principle use the proceeds to pay for its expenditures. This would raise the possibility to use audits to raise revenue which we choose to avoid. The scheme here also resembles "paying through the nose", which, evidently, was a punishment for stealing in the middle ages.

[13] From the viewpoint of a participating seller, with probability $\alpha_s(n)$ he will have been successful in finding a match, with probability $\zeta(n)$ he will be audited and leading to a payoff of $-\mathcal{P}$ in that case and zero payoff with the remaining $1-\alpha_s(n)\zeta(n)$ probability.

[14] In Rochetau and Wright (2005), the ex-ante cost of entering what we call the IM in this paper is given by a constant. This is equivalent to choosing $\rho(n) = 1/\alpha_s(n)$ using the notation in this paper. We prefer the specification in this paper because it allows for a free $\rho(n)$ function, instead of tying it closely to the matching function.

buyers are not audited by the government.[15]

Households have utility function $u(q, x)$ where x denotes the quantity of FM consumption. We make standard assumptions on the utility function: $u_q, u_x > 0$, $u_{qq}, u_{xx} < 0$, and we assume $u_{qx} < 0$, which makes q and x Edgeworth substitutes.[16] Our benchmark results will assume q and x are in fact perfect substitutes, and we will investigate the robustness of our results when their substitutability is less than perfect.[17]

The sellers operate a decreasing-returns-to-scale production function in the IM given by $q = Se^{(1/\psi)}$ with $\psi > 1$, where e denotes the seller's effort in the IM and S is labor productivity, which is common across markets and constant over time. In the FM, a neoclassical firm operates a constant-returns-to-scale production function $Y = SH$, where H is the labor they hire in a competitive market at pre-tax real wage $w = S$. There is ample evidence about informal production having a smaller scale relative to formal production, which is why we use decreasing returns to scale in the former and constant returns to scale in the latter. Households have linear disutility of effort in the FM and IM markets, with one unit of effort in each market creating a disutility of $A > 0$ and 1 units, respectively, where A is a parameter. We can thus express the total utility cost of production for a seller in the IM as $c(q) \equiv (q/S)^{\psi}$.[18]

The government's objective is to finance a constant amount of government expenditures, denoted by G, using revenues from income taxes in the FM, seigniorage and borrowing via

[15] One reasonable question to ask is whether a seller who made a sale in the IM would voluntarily report the income to the government to avoid the possible audit. Naturally, this may happen if the penalty after reporting is sufficiently low. We derive an exact expression in the Appendix A.1. We show that the maximum punishment cannot exceed the income from the tax-evading activity for the seller to voluntarily report the income. Looking at various Internal Revenue Service (IRS) documents, it is evident that voluntary reporting does not necessarily eliminate the possibility of criminal prosecution, which would have a very large cost. Under a temporary program the IRS put in place in 2009, whose details can be found at https://www.irs.gov/uac/voluntary-disclosure-questions-and-answers, even if criminal prosecution is waived, the monetary cost can be much more than the unreported income itself. Based on this, we conclude that it is not reasonable to consider voluntary reporting of IM income in our model.

[16] That $u_{qx} \neq 0$ is necessary for technical reasons. As Aruoba and Wright (2003) show for the model in Lagos and Wright (2005), which immediately applies to the model here as well, when $u_{qx} = 0$ a dichotomy would prevail where the IM and FM variables do not interact. From a more substantive point of view, assuming $u_{qx} < 0$ makes it clear that the goods sold in the two markets are similar goods.

[17] In a setup with price-taking in both good markets, a consumer would only choose to consume some of each good if the goods have the same price and otherwise would choose to consume a single good. In this model, however, because IM terms of trade is determined via bargaining (and no one takes prices as given), there will always be some consumption of both goods.

[18] The assumption that the utility function in the FM features some linearity, in our case in the disutility of labor, is key for tractability of our model. This issue is discussed in detail in Lagos and Wright (2005). Allowing the distuity of effort in the IM to be a parameter changes one of the other parameters calibrated in the model and does not change any results. As such, it can be viewed as a normalization.

a one-period nominal bond. The government conducts all its activities in the FM and its budget constraint is given by

$$M_t + B_t + \tau_t p_t w_t H_t = M_{t-1} + R_{t-1} B_{t-1} + p_t G \tag{1}$$

where M_t and B_t denote the money and bond stocks of the government at the end of period t, τ is the labor income tax rate, w is the real wage rate, H is the aggregate labor supply, p is the price level and R_t is the gross nominal return of the bond issued in period t. We assume that bonds are book entries with no tangible proof that can be carried into the IM. This assumption guarantees that money is the only possible asset that can be used as a medium of exchange in the IM.

In what follows, we first describe the optimization problems of the buyers and the sellers in the two markets, and arrive at the equilibrium where private agents take government policies τ and R as given. We turn to the Ramsey problem in order to endogenize the policies of the government in the next section.

2.1 Formal Market

We use superscripts for variables to denote the type of the agent, where B, P and N denote buyers and participating and non-participating sellers, respectively. We show in the appendix that no one except for buyers will choose to bring money in to the IM and we impose this results from the outset here. Using $W^B(.)$ to denote the value of entering the FM and $V^B(.)$ the value of entering the IM, where $\tilde{m}_t$ and $\tilde{b}_t$ denote the money and bond holdings at the beginning of the period, a buyer that enters the FM faces the problem

$$W^B(\tilde{m}_t, \tilde{b}_t) = \max_{x_t^B, h_t^B, m_t^B, b_{t+1}^B} \left\{ -A h_t^B + V^B(m_t^B, x_t^B, b_{t+1}^B) \right\}$$

subject to

$$p_t x_t^B = p_t S (1 - \tau_t) h_t^B + \tilde{m}_t - m_t^B + R_{t-1} \tilde{b}_t - b_{t+1}^B \tag{2}$$

where he chooses purchases of the FM good, his labor supply and his money and bond holdings.[19] He experiences a disutility from working h_t^B hours. He then continues to the next IM with his purchases and his money holdings. Using χ_t^B to denote the multiplier on

[19] $\tilde{m}_t$ will be different across buyers at the beginning of the period depending on the success of the buyer in finding a match in the previous IM.

(2), the first order conditions of this problem are given by

$$
\begin{aligned}
p_t \chi_t^B &= V_x^B\left(m_t^B, x_t^B, b_{t+1}^B\right) && (3) \\
p_t \chi_t^B &= \frac{A}{(1-\tau_t)\,S} && (4) \\
\chi_t^B &= V_m^B\left(m_t^B, x_t^B, b_{t+1}^B\right) && (5) \\
\chi_t^B &= V_b^B\left(m_t^B, x_t^B, b_{t+1}^B\right) && (6)
\end{aligned}
$$

As Lagos and Wright (2005) argue in detail, (5) shows that money demand of buyers does not depend on their money holdings they enter the FM with, and if $V_m^B(.)$ is strictly monotonic, then m_t^B can be uniquely determined. This is simply a result of the linearity of the disutility of labor.

The problem of a seller who enters the FM with $\tilde{m}_t$ units of money is

$$
W^S(\tilde{m}_t, \tilde{b}_t) = \max \left\{ \begin{array}{c} \max\limits_{x_t^P, h_t^P, b_{t+1}^P} u(0, x_t^P) - Ah_t^P + V^S(b_{t+1}^P), \\ \max\limits_{x_t^N, h_t^N, b_{t+1}^N} u(0, x_t^N) - Ah_t^N + \beta W^S(0, b_{t+1}^N) \end{array} \right\} \quad (7)
$$

where they choose between participating in the following IM and continuing to the FM next period.[20] Both problems in (7) are subject to

$$
p_t x_t^i = p_t S\left(1-\tau_t\right) h_t^i + \tilde{m}_t + R_{t-1}\tilde{b}_t - b_{t+1}^i \quad (8)
$$

for $i = P, N$.

We observe that the value functions of both buyers and sellers are linear in their arguments with slopes given by

$$
\begin{aligned}
W_m^i(\tilde{m}_t, \tilde{b}_t) &= \chi_t^i && (9) \\
W_b^i(\tilde{m}_t, \tilde{b}_t) &= \chi_t^i R_{t-1} && (10)
\end{aligned}
$$

for $i = P, N$.

Using χ_t^i for $i = P, N$ to denote the multipliers on the respective budget constraint, the

[20] We impose the result that a non-participating seller would not carry any money to the next FM, which simply follows from the higher returns offered by bonds.

first order conditions for sellers are

$$p_t \chi_t^i = u_x\left(0, x_t^i\right) \tag{11}$$

$$p_t \chi_t^i = \frac{A}{\left(1-\tau_t\right) S} \tag{12}$$

$$\chi_t^P = V_b^S(b_{t+1}^P) \tag{13}$$

$$\chi_t^N = \beta W_b^S(0, b_{t+1}^N) \tag{14}$$

for $i = P, N$.

We assume that there is free entry to the IM by sellers (after taking into account the cost due to audits, which is implicit in $V^S(.)$), and this implies the free-entry condition

$$u(0, x_t^P) - Ah_t^P + V^S(b_{t+1}^P) = u(0, x_t^N) - Ah_t^N + \beta W^S(0, b_{t+1}^N) \tag{15}$$

We need to obtain expressions for the IM value functions and related envelope conditions to fully characterize the optimal choices for households, which we turn to next.

2.2 Informal Market

The value function for a buyer entering the IM is given by

$$\begin{aligned} V^B(m_t^B, x_t^B, b_{t+1}^B) &= \alpha_{b,t}\left[u(q_t^B, x_t^B) + \beta W^B(m_t^B - d_t^B, b_{t+1}^B)\right] \\ &\quad + (1-\alpha_{b,t})\left[u\left(0, x_t^B\right) + \beta W^B(m_t^B, b_{t+1}^B)\right] \end{aligned}$$

where $\left(q_t^B, d_t^B\right)$ denotes the terms of trade the buyer faces. The first term shows that in the event the buyer is able to match with a seller, he purchases q_t^B units of the IM good, enjoys the utility of consuming this good together with the goods he bought in the FM and exits the market with d_t^B less money. The second term shows that if he cannot meet a seller he simply consumes his FM goods and proceeds to the next FM. Using the linearity of the FM value function from (9), this simplifies to

$$\begin{aligned} V^B(m_t^B, x_t^B, b_{t+1}^B) &= \alpha_{b,t}\left[u(q_t^B, x_t^B) - u\left(0, x_t^B\right) - \beta d_t^B \chi_{t+1}\right] \\ &\quad + u\left(0, x_t^B\right) + \beta W^B(m_t^B, b_{t+1}^B) \end{aligned} \tag{16}$$

Similarly, the value function for a participating seller entering the IM is

$$V^S(b^P_{t+1}) = \alpha_{s,t}\left[-c(q^S_t) + \beta W^S\left(d^S_t, b^P_{t+1}\right)\right] + (1-\alpha_{s,t})\,\beta W^S\left(0, b^P_{t+1}\right) - \kappa\alpha_{s,t}\rho_t$$

where $\left(q^S_t, d^S_t\right)$ denote the terms of trade the seller faces. The first term shows the payoff to the seller when he meets a buyer, in which case he incurs a utility cost to produce the goods, but acquires more money to spend in the next FM, the second term shows that he is not able to meet a buyer and he moves on to the next FM and the last term is the expected cost of a government audit. Using the linearity of the $W^S(.)$ function, we get

$$V^S(b^P_{t+1}) = \alpha_{s,t}\left[-c(q^S_t) + \beta d^S_t\chi_{t+1} - \kappa\rho_t\right] + \beta W^s\left(0, b^P_{t+1}\right) \tag{17}$$

The terms of trade in the IM are determined via proportional bargaining, where the buyer receives θ fraction of the surplus and the seller receives $1-\theta$ fraction. This bargaining protocol has a number of virtues over, say generalized Nash bargaining which are described in detail in Aruoba, Rocheteau and Waller (2007). In the context of the exercise in this paper, there are further reasons to prefer proportional bargaining over Nash bargaining.[21] The outcome of the bargaining will be $d = m^B_t$, so that the buyer spends all his money, while q_t solves

$$\frac{u(q_t, x^B_t) - u\left(0, x^B_t\right) - \beta m^B_t\chi_{t+1}}{-c(q_t) + \beta m^B_t\chi_{t+1}} = \frac{\theta}{1-\theta}$$

where the numerator on the left hand side is the surplus of the buyer as shown in (16) and the denominator is the surplus of the seller from (17). This expression simplifies to

$$\beta m^B_t\chi_{t+1} = g\left(q_t, x^B_t\right) \tag{18}$$

where $g(.)$ is a combination of some primitive utility functions

$$g\left(q_t, x^B_t\right) \equiv \theta c(q_t) + (1-\theta)\left[u(q_t, x^B_t) - u\left(0, x^B_t\right)\right].$$

[21] The key intuitive appeal of using proportional bargaining over Nash bargaining is that the former has strong monotonicity as one of its properties, which means the payoff of the buyer strictly increases as he brings more money in to the FM. In our Ramsey problem, as Aruoba and Chugh (2010) show in a related problem, with θ sufficiently away from unity, optimal policy under Nash bargaining becomes the Friedman rule since the Ramsey planner tries to fix the inefficiency caused by the non-monotonicity of the Nash solution. In contrast, with proportional bargaining, the Friedman rule is never optimal for any θ. Given that our quantitative exercises feature positive interest rates, using proportional bargaining is a better alternative.

(18) implicitly defines the amount of goods exchanged, q_t as a function of the amount of money and FM consumption the buyer brings in to the IM.

With the IM problem laid out, we are now ready to derive the relevant envelope conditions. For the buyers we get

$$V_m^B(m_t^B, x_t^b, b_{t+1}^B) = \alpha_{b,t}\left[\frac{\beta\chi_{t+1}}{g_q\left(q_t, x_t^B\right)}u_q(q_t^B, x_t^B) - \beta\chi_{t+1}\right] + \beta\chi_{t+1} \tag{19}$$

$$V_x^B(m_t^B, x_t^b, b_{t+1}^B) = \alpha_{b,t}\left[u_x(q_t^B, x_t^B) - \frac{g_x\left(q_t, x_t^B\right)}{g_q\left(q_t, x_t^B\right)}u_q(q_t^B, x_t^B)\right] + (1-\alpha_{b,t})\, u_x\left(0, x_t^B\right) \tag{20}$$

$$V_b^B(m_t^B, x_t^b, b_{t+1}^B) = \beta W_b^B(m_t^B, b_{t+1}) = \beta\chi_{t+1}R_t \tag{21}$$

where we use the implicit function theorem applied to (18) to obtain $\partial q_t/\partial m_t^B$ and $\partial q_t/\partial x_t^B$ in (19) and (20) and we use (10) in (21). For participating sellers we get

$$V_b^S(b_{t+1}^P) = \beta W_b^S(0, b_{t+1}^P) = \beta\chi_{t+1}R_t \tag{22}$$

2.3 Household Optimality

Putting together everything we obtained so far, we can summarize our results with the following proposition.

Proposition 1 *Optimality for the households entails the following:*

a. As long as $R_t > 1$, participating or nonparticipating sellers will choose not to hold any money. As long as $R_t < \bar{R}$, buyers will hold money, for some particular $\bar{R} > 1$. We denote the money holdings of buyers with m_t.

b. All households will hold the same quantity of bonds, which we denote by b_t.

c. Participating and non-participating sellers choose the same level of consumption in the FM which we denote by x_t^S.

d. Given the heterogeneity in the experiences of households in the previous IM, there will be 4 types of households in a given FM: matched/unmatched buyers and matched/unmatched sellers. These households will have different levels of money holdings as they enter the FM. This heterogeneity will be reflected only in their labor supply and in no other decisions.

e. Free-entry condition is given by

$$-c(q_t) + g\left(q_t, x_t^B\right) = \kappa\rho\left(n_t\right) \tag{23}$$

where $q_t = q\left(m_t, x_t^B\right)$ *follows from the bargaining problem.*

Proof. See Appendix A.2. ■

To understand (23), note that $S_s = \left[-c\left(q\right) + g\left(q, x\right)\right]$ is the seller's surplus when successful in finding a match and $\alpha_s S_s$ is the expected return from participating in the IM. $\alpha_s \rho\kappa$ is the expected cost of participating in the IM due to the possibility of an audit. The free-entry condition sets these two terms equal to each other.

2.4 Equilibrium

Money and bond market clearing imply $m_t = M_t$ and $\left(\Lambda + 1\right) b_t = B_t$. Combining everything obtained so far and defining $\pi_{t+1} \equiv p_{t+1}/p_t$, $\mathcal{M}_t \equiv m_t/p_t$ and $\mathcal{B}_t = \left(\Lambda + 1\right) b_{t+1}/p_t$, as the gross inflation rate, real money and bond stocks of the economy, respectively, we can define a monetary equilibrium. We do this in the Appendix A.3. Furthermore, Appendix A.4 contains a detailed discussion of existence and uniqueness of equilibria in this model and how these relate to the optimal policy problem that follows. In a nutshell we argue that while equilibrium may not be unique, we are able to numerically find the equilibrium that attains highest welfare for a given set of government policies and then our Ramsey problem optimizes over government policies to find the optimal combination of policies.

The size of the informal sector relative to the formal sector is a key variable we compute for the calibration and verification of the model. This measure, which we denote by $\mathcal{R}$, is computed as the value of output in the IM as a fraction of the output in the FM. Using model objects it is defined as

$$\mathcal{R} \equiv \frac{\mu\left(n\right)\mathcal{M}}{Y} \tag{24}$$

where $\mu\left(n\right)$ is the measure of matches in the IM, $\mathcal{M}$ is the real quantity of money spent in each of these matches in FM-good units and Y is the output in the FM.

Before we conclude this section, we turn to some of the properties of the monetary equilibrium we use. While analytical proofs are difficult to obtain due to the highly nonlinear $g\left(.\right)$ function and the existence of the free-entry condition, we compute some comparative statics numerically using the calibrated values for parameters. There are three relevant exogenous variables at this stage: tax rate, inflation rate and the level of institutions. As in all monetary models, inflation acts as a tax on money holdings and as inflation increases, buyers bring less money into the IM. This in turn reduces the amount of goods they can purchase, and by reducing the payoff to the sellers, it reduces the entry of sellers. Due to the substitution created through the utility function, FM consumption of buyers and therefore FM output increases. Turning to an increase in the tax rate, it reduces the quantity consumed by the buyers and make them hold more money in order to purchase more in the IM. Sellers' payoff in the IM increases, inducing them to enter the IM. As a result FM output falls and IM output increases. Finally an increase in κ reduces the incentives for the sellers to enter the IM by increasing the cost of entering the IM. Since the buyers are now less likely to find sellers in the IM, they reduce their money holdings and increase their consumption in FM.

3 Optimal Policy

Having defined equilibrium, which takes the policies of the government (R, τ) as given, we now turn to endogenizing these policies. We consider the problem of a benevolent planner, the Ramsey planner, who seeks to pick the least distorting policies (R, τ) in order to finance the given government expenditures G, taking as given the institutions and labor productivity of the economy, as well as the level of government expenditures. We assume that the Ramsey planner is able to commit to these policies. Mechanically, the Ramsey problem then is to find policies that maximize social welfare in the resulting equilibrium given these policies. The proposition below summarizes the Ramsey problem, which is stated in Lucas and Stokey's (1983) primal form.

Proposition 2 *The Ramsey planner's problem is to choose allocations* $\left\{x_t^B, x_t^S, q_t, n_t, H_t\right\}$ *to maximize the objective function*

$$\sum_{t=0}^{\infty} \beta^t \left\{\mu\left(n_t\right)\left[u\left(q_t, x_t^B\right) - c\left(q_t\right) - \kappa\rho\left(n_t\right)\right] + \left[1 - \mu\left(n_t\right)\right] u\left(0, x_t^B\right) + \Lambda u\left(0, x_t^S\right) - AH_t\right\} \tag{25}$$

subject to the Present-Value Implementability Constraint (PVIC)

$$\sum_{t=0}^{\infty} \beta^t \left\{u_x(0, x_t^S)\left(x_t^B + \Lambda x_t^S\right) - AH_t + \mu\left(n_t\right) g\left(q_t, x_t^B\right)\left[\frac{u_q(q_t, x_t^B)}{g_q\left(q_t, x_t^B\right)} - 1\right]\right\} = \mathcal{A}_0 \text{ (multiplier } \xi\text{)} \tag{26}$$

where $\mathcal{A}_0 \equiv u_x(0, x_0^S)\left[R_{-1}\mathcal{B}_{-1}/\pi_0 + \mathcal{M}_{-1}/\pi_0\right]$; *the resource constraint (RC)*

$$SH_t = x_t^B + \Lambda x_t^S + G \text{ (multiplier } \nu_t\text{);} \tag{27}$$

the uniform-tax condition (UT)

$$\mu(n_t)\left[u_x(q_t^B, x_t^B) - \frac{g_x\left(q_t, x_t^B\right)}{g_q\left(q_t, x_t^B\right)}u_q(q_t^B, x_t^B)\right] + \left[1-\mu(n_t)\right]u_x\left(0, x_t^B\right) = u_x\left(0, x_t^S\right) \text{ (multiplier } \lambda_t\text{);} \tag{28}$$

the free-entry condition (FE)

$$-c(q_t) + g\left(q_t, x_t^B\right) = \kappa\rho(n_t) \text{ (multiplier } \eta_t\text{);} \tag{29}$$

and the zero-lower-bound condition (ZLB)

$$\mu(n_t)\left[u_q(q_t, x_t^B) - g_q\left(q_t, x_t^B\right)\right] \geq 0 \text{ (multiplier } \iota_t\text{)} \tag{30}$$

given $\mathcal{B}_{-1}$ *and* $\mathcal{M}_{-1}$.

This problem yields allocations $\left\{x_t^B, x_t^S, q_t, n_t, H_t\right\}$ *that are associated with the optimal policies, which in turn can be obtained using*

$$\tau_t = 1 - \frac{A}{Su_x(0, x_t^S)} \tag{31}$$

$$R_t = \mu(n_t)\left[\frac{u_q(q_t, x_t^B)}{g_q\left(q_t, x_t^B\right)} - 1\right] + 1 \tag{32}$$

At the steady state, inflation rate under the Ramsey policy follows from $\pi = \beta R$ *with* R *representing the steady state value of* R_t.

Proof. See Appendix A.5 ■

The PVIC is a compact way of summarizing the equilibrium conditions that the Ramsey planner is subject to. Typically, as in the canonical problems in Chari and Kehoe (1999), the PVIC and the RC fully summarize these conditions. In this problem we need three more conditions, all of which are equilibrium conditions. First, as is standard in any monetary version of the problem, we need to make sure that the interest rate implied by the choices of the Ramsey planner is non-negative, which is necessary for the existence of monetary equilibrium. This leads to the ZLB constraint. Second, the number of participating sellers the Ramsey planner chooses should be consistent with the free-entry condition, which is guaranteed by FE. Finally, the Ramsey planner is not allowed to condition the tax rate in the FM on the type of the agent, or his success in trading in the previous IM. Because of the nonseparability of preferences, buyers and sellers will have different marginal utilities of consumption and in principle the Ramsey planner can exploit this and transfer resources across agents. We make sure the Ramsey planner does not do this by imposing UT. In the numerical analysis below, we assume $\mathcal{A}_0 = 0$, which means the government is born with (and thus in the limit will have) zero liabilities. Appendix A.6 shows the details of the solutions of this problem. We focus on the steady state of this solution given our interest in explaining the long-run determination of policies. Appendix A.7 revisits the issue of existence and uniqueness of equilibria and how these affect the Ramsey problem.

In order to show (*qualitatively*) how our model works, we trace the effects of changing κ, holding everything else constant, in essence taking a partial derivative. We do this numerically using parameter values discussed in Section 4.3, and results are reported in Figure 2. Consider a small κ which means that the expected punishment of participating in the IM is small. Since it is "cheap" to do informal activity most sellers participate which lead to a large informal sector. This induces the buyers to carry a lot of real money balances since the probability of meeting a seller in the IM is high. Given the level of expenditures the government needs to finance, the government finds an optimal balance between taxing income in the FM and taxing money holdings, or implicitly the IM activity. As we move from the low level of κ to higher values, the sellers will have less incentives to participate in the IM due to the higher cost and n goes down. Since the buyers are now less likely to find sellers to trade with, they choose to bring less money to the IM and this reduces q, the amount traded in the IM. The declines in n and q mean that the size of the IM is now smaller. In turn, the buyers will consume more in the FM as IM and FM goods are substitutes. The sellers consume less in the FM since they receive less income in the IM and the FM output can go up or down as a result. As a result, the social marginal cost of inflation goes up (since money balances are now lower and marginal benefit of a unit of money is higher) and the social marginal cost of taxation goes down. The planner's desire to balance distortions implies that the inflation rate is now lower and the income tax rate in the FM is now higher. This argument shows how an increase in institutions can lead to a decline in inflation and size of the informal sector and an increase in taxation, all of which are consistent with the correlations we report in the Introduction.

4 Quantitative Results

We now turn to exploring the success of our model in explaining the cross-country variation in tax and inflation policies as well as the extent of informal activity. We do this numerically, by imposing discipline on the parameter values using appropriate calibration targets. To reiterate, we have three sources of exogenous variation across countries: their institutions (κ), labor productivity (S) and government spending (G). While these will vary across countries, the values we use for parameters will be fixed.

We start this section by providing some details about the data we use for the calibration and verification of the model. We also summarize the results of an empirical analysis that involves the variables of interest in our model. This will be useful to put the performance of our model in perspective. Next, we describe our functional form choices and detail our calibration exercise. This is followed by our main quantitative results, some counterfactuals to investigate the importance of various exogenous variables, and we conclude by some robustness analysis.

4.1 Data Sources and Summary of Empirical Results

Our main data set consists of measures of institutions, government policies, informal activity, and economic indicators for 125 countries, covering 1996-2015, or a subset as dictated by data restrictions. Since our interest is in understanding long-run cross-country variation in government policies, we take averages of all variables over this time period. Our model is not suited to study episodes of persistently high inflation, and accordingly we restrict attention to countries with average inflation less than 20%. In the rest of this section we provide some key information about the data we use, with more details in Appendix B.

Our main measure of institutions is Rule of Law constructed following Kaufmann, Kraay and Mastruzzi (2010) by the World Bank. According to its source, Rule of Law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. We consider three alternative measures of institutions and both our empirical results and results regarding the performance of the model are unchanged using these measures.

Turning to government policies, inflation is standard and comes from World Development Indicators (WDI) by the World Bank. It is measured as the annual percentage change in consumer prices. Measuring taxes, on the other hand, requires some care. In our model there is no distinction between tax rates and tax revenues as a fraction of national output. However, in general, computing tax rates that are conformable with the assumptions in macroeconomic models is a difficult task.[22] We use a measure of effective tax rates that is based on the work of Mendoza, Razin and Tesar (1994), which covers 34 countries. In order to test our model with a larger set of countries, we also consider tax revenues as a fraction of GDP as an alternative measure, as well as one more alternative based on the work of Vegh and Vuletin (2015).

One of the important testable implications of our model is the relationship of the size of the informal sector with institutions and government policies. As a measure of informal activity, we use the measure produced by Hassan and Schneider (2016).

We obtain a number of macroeconomic indicators from Penn World Tables 9.0 (PWT) compiled by Feenstra et al. (2015), and WDI. These include output per worker and government spending as a fraction of GDP, which captures the size of the government.

Appendix C and the associated tables in the Appendix describe the results of some empirical work conducted with our dataset. We summarize the key findings here:

- Rule of Law is the key determinant of inflation across countries, explaining 33% of the variation. There is a negative relationship between these two variables. Size of the government (measured by the ratio of government spending to GDP) has a small positive effect.

- Size of the government explains 32% of the variation of tax rates across countries or tax revenue / GDP ratio, with a positive coefficient. Rule of Law explains another 35% of tax rates and 14% of the tax revenue / GDP ratio, also with a positive coefficient.

- Rule of Law explains about 50% of the variation of the size of informal sector across countries, with a negative coefficient. Labor productivity explains a further 5% with a negative coefficient.

[22] For example most models imply that the labor income tax creates a wedge between the real wage of a worker and his marginal product. According to this definition, social security taxes that an employer pays should be included in a measure of labor income tax along with taxes paid by the worker, even though employer-paid taxes do not affect the workers take-home pay directly.

4.2 Functional Forms

A unit measure of buyers and a measure n of participating sellers in the IM are matched via a matching function given by

$$\mu(n) = \chi \frac{n}{(n^{\phi} + 1)^{\frac{1}{\phi}}} \tag{33}$$

where $\chi < 1$ is a scaling parameter. This matching function follows den Haan et al. (2000) and it satisfies constant returns to scale, it is always bounded by 0 from below and the lower of n or 1 from above (unlike the standard Cobb-Douglas function), and it is increasing in n.

The probability of an audit in the IM is defined as $\zeta(n) \equiv \varsigma\rho(n)$ where $\rho(n) = n^{\omega}$, which is a flexible functional form that allows the $\rho(.)$ function to be convex or concave.

Households have constant-relative-risk-aversion utility over a composite good Q

$$U(q,x) = \begin{cases} \dfrac{Q(q,x)^{1-\sigma} - 1}{1-\sigma} & \text{if } \sigma \neq 1 \\ \log[Q(q,x)] & \text{if } \sigma = 1 \end{cases} \tag{34}$$

where the composite good Q is given by the constant-elasticity-of-substitution function

$$Q(q,x) = \begin{cases} (\gamma q^{\varepsilon} + x^{\varepsilon})^{1/\varepsilon} & \text{if } \varepsilon \neq 0 \\ \left(\dfrac{q+b}{b}\right)^{\gamma} x & \text{if } \varepsilon = 0 \end{cases} \tag{35}$$

In this specification ε determines the elasticity of substitution, $b > 0$ is a small number to make sure $U(0,x)$ is well-defined when $\varepsilon = 0$ and γ determines the relative weights of IM and FM goods. Note that in order to preserve the Edgeworth-substitutes property of the utility function, we need $\varepsilon > 1 - \sigma$.

4.3 Calibration

The key assumption in our quantitative exercise is that every country in the world is populated by people with identical preferences. Assuming otherwise would imply that at least a part of the cross-country differences in informal activity and government policies are due to differences in preferences. We discipline our model by having it match a number of calibration targets, which include inflation and the size of the informal sector for the U.S. As we explain below, we need one more piece of information to discipline how things change as we go across countries. We pick the size of the informal sector for the Maldives, a country with the median level of institutions, for this purpose. Intuitively, matching this extra target disciplines the model's implied elasticity of the size of informal sector with respect to institutions. To be sure, government policies for all countries except for the U.S. and size of the informal sector for all countries except for the U.S. and the Maldives are not targeted in the calibration.

Including the parameters in the functional forms above, we have 11 parameters to fix. In addition to these, the values for 6 exogenous variables also need to be determined, three for each of the two countries we use in the calibration, the U.S. $\left(\kappa^{US}, S^{US}, G^{US}\right)$ and the Maldives $\left(\kappa^{M}, S^{M}, G^{M}\right)$. Some of these can be directly measured in the data, while some will be set to match some targets. We can divide parameters and exogenous variables to be calibrated in to three groups. First, we fix a subset of them to values that are either commonly used in the literature, or are otherwise reasonable. Second, we fix a subset of them directly in order to match targets in the data, including some normalizations. Finally, the remaining ones are jointly calibrated to match some calibration targets. Table 1 shows the complete list of parameters and exogenous variables, and the targets used to fix them, where relevant.

Turning to the first group, shown in panel (a) of Table 1, we fix $\sigma = 1$ and have log utility over the composite good Q, and we set $\varepsilon = 1$ to reflect perfect substitutability between IM and FM goods. The measure of sellers Λ is set to 3, which is large enough that in all our experiments $n < \Lambda$ is satisfied. We set the bargaining parameter θ to 0.5 which results in egalitarian bargaining, where the surplus of the match in the IM is split equally between buyers and sellers. We set $\chi = 0.5$ to make the IM matching function somewhat inefficient. One parameter which is not very obvious is the curvature parameter ω of the function $\rho(n)$. We pick $\omega = 0.75$ to make the function $\rho(n)$ mildly concave. This makes the probability of an audit not increase as much when the number of participating sellers increase.

We fix two parameters and two exogenous variables directly to match targets as shown in panel (b). Lemieux et al. (1994) estimates the degree of decreasing returns in the informal sector based on a survey conducted in Canada, and we set $\psi = 1/0.7 = 1.4285$ based on the mid-point of the range of estimates they report, which is 0.7. We set $\beta = 0.985$ to match a 1.5% real return, which is the average real one-year return in the U.S. over 1998-2007 as computed by Aruoba (2017). We normalize $S^{US} = 1$ and given this set $S^{M} = 0.3623$, which is labor productivity in the Maldives, relative to the U.S.

All of this leaves three parameters, A, γ and ϕ, and four exogenous variables, $\left(\kappa^{US}, G^{US}, \kappa^{M}, G^{M}\right)$

to determine. To do so, as we show in panel (c), we use seven calibration targets: for the U.S. we have $Y^{US} = 1$ (normalization), share of government spending in GDP, $G^{US}/Y^{US} = G^{US} = 0.2192$; size of the informal sector, $\mathcal{R}^{US} = 0.0920$; and inflation, $\pi^{US} = 2.2\%$; and for the Maldives we us these targets: size of the informal sector, $\mathcal{R}^{M} = 0.2264$; and the share of government spending in GDP, $G^{M}/Y^{M} = 0.2517$. These provide six targets. The last target comes from a linear mapping we use that maps the value of Rule of Law we observe in the data for the Maldives to κ^{M}.[23] Panel (d) of Table 1 shows how the calibration performs in matching the six quantitative targets from the data.

Even though these seven objects are calibrated jointly to match the seven targets, the calibration can be roughly described as follows. Given the normalization for $S^{US} = 1$, the parameter A adjusts such that $H = 1$ in the FM so that FM output $Y^{US} = 1$. Given $Y^{US} = 1$, G^{US} directly pins down the G/Y for the U.S. The parameter γ and exogenous variable κ^{US} pin down the size of the IM and optimal inflation for the U.S.. This completes the calibration of U.S. values. The linear mapping pins down the value for κ^{M} and ϕ determines how responsive the IM is to κ and is set to match $\mathcal{R}^{M}$. More specifically, as ϕ increases the matching function $\mu(n)$ shifts down and becomes flatter. Since κ directly influences n via the free-entry condition, and the measure of matched sellers $\mu(n)$ is crucial in determining $\mathcal{R}$, ϕ controls the effect of κ on $\mathcal{R}$. Finally G^{M} pins down the value for G/Y for the Maldives.

4.4 Main Results

We now turn to the main cross-country exercise where we vary the three exogenous variables across countries, keeping the parameters at the values calibrated for the U.S. To do this, we use the mapping of the solution to the Ramsey planner's problem, where the exogenous variables (κ, S, G) are mapped in to the endogenous variables $\left(q, n, x^{S}, x^{B}, H, R, \tau, \text{multipliers}\right)$ as provided in Proposition 2, along with the definition of $\mathcal{R}$ in (24).[24]

To compute the key objects of interest, government policies (π^{i}, τ^{i}) and size of the informal sector $(\mathcal{R}^{i})$, we need to set the values for three exogenous variables for each of the

[23] For a generic country i with rule of law $\mathcal{I}^{i}$, the mapping is $\kappa^{i} = a_0 + a_1\mathcal{I}^{i}$. In order to pin down a_0 and a_1, we use two restrictions: the mapping should go through $\left(\mathcal{I}^{US}, \kappa^{US}\right)$ where κ^{US} is a part of the calibration and it should also go through $\left(\mathcal{I}^{\min}, \kappa^{\min}\right)$ where $\mathcal{I}^{\min} = -1.5$ is slightly smaller than the lowest value for rule of law in our data and after some experimentation we set $\kappa^{\min} = 0.5$.

[24] This amounts to solving a system of equations using a numerical solver. To ensure stability and reliability of the solution, we complement this with a grid search for the optimal π using the insight of Proposition 4 in Appendix A.4.

125 countries: rule of law (κ^i), share of government expenditures in output (G^i) and labor productivity (S^i) where the i superscript denotes a country-specific value. Since we normalized $S^{US} = 1$, we compute S^i as the ratio of the labor productivity of the country divided by the labor productivity of the U.S. in the data. We have direct measures of G^i/Y^i from our dataset and we solve for the value of G^i that delivers this ratio. Finally, we compute κ^i using the mapping we outlined in footnote 23, which maps the value of Rule of Law for the country to the model object κ.

Figure 3 and Table 2 present our main results. Figure 3 plots four key variables obtained from the model versus their data counterparts: inflation, taxes, tax revenues of the government as a fraction of GDP and the size of the informal sector.[25] Each panel is set up as a square so that clusters below (above) the 45 degree line indicate that our model produces smaller (larger) numbers than those in the data. The red line shows the best fitting line. Panel (a) of Table 2 shows the correlations from the scatter plots depicted in Figure 3. Panels (b) and (c) compare some moments and correlations obtained from the model with those from the data.

Focusing first on the match between the data and model-generated objects, the correlation for inflation is 0.42. For the 34 countries that we have tax rate data, the correlation is 0.78 and for the full set of countries where we have data on tax revenue / GDP, the correlation is 0.61. Turning to the size of the informal sector, the correlation between the model-generated value and the data is 0.68. Panel (b) of Table 2 shows the mean and standard deviation of the model-generated objects (across countries) and compares them with their data counterparts. The distribution of model-generated inflation is quite close its empirical counterpart with a slightly smaller mean and smaller dispersion. Figure 3 shows that the model-generated values are lower than the data for roughly half of the countries. For taxes, the model generates smaller tax rates when compared to tax rates in the data, but somewhat larger ones when compared to the tax revenue / GDP ratio. Finally the average size of the informal sector in the data is about 11 percentage points larger than what the model delivers.

One way to put these results in perspective is to consider the tightness of the empirical relationships between inflation, taxes, the size of the informal sector and the variables we consider as exogenous in our model, especially institutions. These were reported in the right panels of Figure 1 and the correlations are also in panel (c) of Table 2. Panel (b) of Figure 1

[25] Since we have only 34 countries with tax data, all the subsequent results using tax rates will have a significantly smaller subsample relative to other results.

shows a fairly tight relationship between inflation and Rule of Law for countries with good institutions but a fairly loose one for others, with an overall correlation of -0.57. This figure suggests that, especially for countries at the bottom half of the institutions distribution there are other factors important for understanding inflation. The correlations for the remaining three variables, reported in panel (c) of Table 2 are between 0.4 and 0.7, indicating that there are other (unmodeled) factors that explain as large as half of the variation in these variables.[26] Further comparing the first and second columns of panel (c) of Table 2, we see that the model delivers correlations that are quite reasonable. Considering all these, and despite the mixed results regarding *levels*, we find the results reported so far as demonstrating that the model is successful in explaining a good portion of the cross-country *variation* in government policies.[27]

4.5 Discussion of Results

Having presented our main results, we now turn to understanding them better. In order to do so, we first present results from some counterfactuals, followed by results for various subsets of countries. We also discuss the relationship between institutions and welfare and conclude this section by relating our findings and the quantitative success of the model to the earlier Ramsey literature cited in the Introduction.

4.5.1 Counterfactuals

Figure 4 shows how three key variables in the model, inflation, income tax rate and size of informal sector (in columns) changes as the three exogenous variables change, one at a time (in rows), around the neighborhood of the values for the U.S. The first row replicates the results in Figure 2 and shows that as institutions improve inflation rate falls, tax rate goes up and the informal sector become smaller. The second row shows that labor productivity

[26] In a bivariate regression R^2, the fraction of the variation in the dependent variable explained by the independent variable, is the square of the correlation coefficient. The R^2 that corresponds to the largest correlation, 0.71 is 0.504, indicating that 49.6% of the variation is unaccounted for.

[27] A major reason why our model delivers too much inflation, too little taxation and too small informal sector is the assumption that inflation has no direct impact on FM activity, or more specifically our assumption that transactions in the FM do not require a medium of exchange. This is a simplifying assumption one can relax. If one were to model money demand in the FM explicitly, FM consumption would also fall as inflation increases, adding to the cost of inflation. In our model, then, the Ramsey planner does not account for the cost of inflation on welfare through the FM and as a result chooses a level of inflation that is higher than in the data. Since inflation is too high (relative to data), informal activity is discouraged too much in the model. This also means the income tax rate is too low since sufficient revenue is raised through seigniorage.

has no effect on these variables. This is a result particular to the benchmark calibration and hinges on the perfect substitutability of IM and FM goods as given by $\varepsilon = 1$. Finally, as the size of the government spending as a fraction of GDP increases, both inflation and taxes increase and the informal sector shrinks. It is useful to note that these responses, including the negligible responses to changes in labor productivity, are qualitatively in line with those obtained from data (as reported in Table A2 – panel (a), column (2) for inflation and panel (b), column (2) or (5) for taxes).

To understand how our model matches the government policies and the size of the informal sector, we conduct two counterfactual exercises. Since the middle row of Figure 4 shows that S does not affect the model's predictions regarding these variables, in the first exercise we fix G/Y and let only κ vary across countries and in the second exercise we fix κ and vary G/Y. The last two columns of Table 2 show the results under these two counterfactual exercises and Figures 5 and 6 provide a visual demonstration of the model fit under these different scenarios. In both figures the blue dots show the data and the red dots show what the model delivers in the benchmark calibration, with all sources of exogenous variation turned on. Then in Figure 5 the green crosses show what happens when only κ is allowed to vary across countries and in Figure 6 they show the results when only G/Y changes. Figure 5 shows the 4 key variables with Rule of Law (or equivalently κ) on the x axis, while Figure 6 shows the same with G/Y on the x axis. It is important to emphasize that the there are only three things in the figures targeted in the calibration of the model: inflation and size of the informal sector for the U.S. and the size of the informal sector for the Maldives; rest are obtained using the variation in the exogenous variables through the workings of the model.

It is not straightforward to judge how good the red dots track the blue dots in these figures. The correlations we report in panel (a) of Table 2 provide this information. When we compare the red dots with the green crosses, this shows us how the particular exogenous variable under consideration helps deliver the model's value for each country. Let's start with inflation. Top left panel of Figure 5 shows that the model with only κ is able to capture the relationship between institutions and inflation quite well with the green line tracing the somewhat nonlinear relationship between the two. Therefore, despite the noisy relationship between Rule of Law and inflation (the bivariate R^2 is only 0.33), the model captures the essence of the relationship between the two. Panel (a) of Table 2 shows that shutting down G/Y actually slightly improves the match of the model to the data (the correlation coefficient increases by 0.09). This is because of the relationship between G/Y and inflation, as depicted in the top-left panel of Figure 6; while the correct sign, is a bit too strong in the model and makes the model fit slightly worse as a result. Last column of Table 2 shows that when only G/Y is allowed to vary, the model delivers inflation rates that are mildly negatively correlated with the data, much smaller on average and its cross-country dispersion is less than half of the benchmark model. All of these show that in order to have a hope of matching the cross country variation in inflation, considering changes institutions (and thus having a model where institutions play a role) is crucial.

Turning to taxes, top-right and bottom-left panels of Figure 6 show that the model delivers a very strong relationship between G/Y and the optimal tax rate. Comparing the red dots and green crosses, we see that most of the model's performance in terms of taxes is indeed due to variations in G/Y. As the same panels in Figure 6 show there is a weakly positive relationship between κ and taxes in the model and since countries with low G/Y tend to have low κ, the red dots in in Figure 6 are somewhat below the green crosses. Comparing the last column of Table 2 with the first reveals that the model with only G/Y performs very close to the benchmark model in matching taxes in the data. Comparing these with the second to last column where G/Y is kept constant and κ varies, the fit to the data worsens and the cross-country dispersion shrinks to a fifth of the level in the benchmark model. This suggests that G/Y is crucial in getting the distribution of taxes across countries look like the data, though institutions also play an independent role in slightly improving the fit. Finally, the conclusions regarding the size of the informal sector follow very closely those we reached for inflation: there is a very mild negative relationship in the model between G/Y and the size of the informal sector but its main driver is κ.

4.5.2 Subsamples of Countries

In Table 3 we report the correlation between the model-based measures and the data for six subsamples of countries and compare them to the benchmark results from panel (a) of Table 2, repeated in the first row of Table 3. The goal is to see how the success of the model in matching the data changes in these subsamples.

The first panel of results, shown in rows two through four, focuses on countries with low output (less than 15% of the U.S.), low institutions (lowest quintile of the Rule of Law distribution) and those that are in neither of these two groups. The correlation of inflation generated by the model and the one in the data falls to about 0.20 in the first two groups, from 0.42 in the full sample. In contrast, in the third group the correlation is around 0.60. For taxes, for countries with low output the correlation for tax revenues / GDP is actually higher than the full sample correlation, but for low institutions it is lower. Size of the informal sector shows similar results as inflation, with the first two groups having a correlation of about 0.20, down from 0.68.

The decline in the fit of our model for countries with low level of institutions may be due to the fact that tax evasion is "cheaper" than implied by our model. Similarly, for low output countries, our implicit assumption of perfect credit markets in the FM may be violated and this may create a divergence between our model and the data.

In the remaining panels of Table 3 we slice countries along the "freedom" margin where we use the 2008 ratings by Freedom House. For the 19 countries labeled as "Not Free", our model essentially fails to deliver government policies close to what is in the data. The match is better for the "Partially Free" countries and it is the same or somewhat better than the full sample of countries for the 66 "Free" countries. These results are likely due to the failure of the assumption of a benevolent optimizing government choosing policies for countries that are labeled as "Not Free" and "Partially Free". There is no clear relationship between freedom of the country and the match of the model for the informal sector.

All in all, we find that our model is most successful for countries that have sufficiently good institutions, are not very poor and are not governed by repressive or authoritarian governments (as inferred by the "not free" ranking in the Freedom House rankings). We consider it a success that our model is able to generate results in line with the data for these countries, while it generates less strong results for countries outside this group, for which many other considerations, including the political-economy ones we summarized in the Introduction, may be much more important.

4.5.3 Welfare

Astute readers may notice that one of the implications of the model is that welfare, as measured in (25) goes *down* as κ increases. In fact, if the social planner could choose κ, he would set it to zero to maximize entry in to the IM and thus make its size large. Within the context of the model it is easy to justify this result: the IM consumption good, q, is a *good*, i.e. agents in the economy like it. An increase in κ directly reduces n via the free-entry condition (15) and makes the IM less attractive for buyers since their matching probability falls with n. As a result they choose to hold less money to bring in to the IM and when matched this means they get less q in return. At the end, both q and n fall, reducing the utility from the IM. FM output increases due to the substitutability of the two goods but this does not make up for the welfare loss. This conclusion, which is a *ceterus paribus* result, does not mean, however, that citizens of a country are worse off relative to citizens of a country with worse institutions.

To understand this, note that Hall and Jones (1999) and others have shown that there is a very tight relationship between a country's institutions and its labor productivity. In fact a simple regression shows that a one standard deviation increase in rule of law would increase a country's labor productivity relative to the U.S. by 25 percentage points. Therefore the thought experiment above where we held everything else constant when we increased κ is not a reasonable one – in order to evaluate how institutions affect welfare, we need to consider also the variations in labor productivity. Figure 7 shows the welfare of each country in our dataset calculated in our cross-country exercise using (25). It is plotted versus institutions but all three exogenous variables are allowed to change across countries. Thus, even though it is not modeled explicitly, as κ increases as does S. This figure clearly demonstrates that welfare is an increasing function of institutions once the effect of institutions on labor productivity is accounted for. When we look deeper into the results, we find, not surprisingly, that labor productivity is the main driving force of welfare in our model, significantly counteracting the welfare-reducing direct effect of κ.

4.5.4 Understanding the Mechanism

In this section we go back to the macro-public finance literature we referred to in the Introduction and explain what forces are behind the model's ability to match the patterns in the data.

We start with Chari et al. (1991) and the review by Chari and Kehoe (1999). In a cash-good-credit-good model, they show that as long as the utility function is homothetic, optimal policy includes $R = 1$, which is the Friedman rule. In their setup the tax system is complete in the sense that there is at least one policy instrument for each wedge that the Ramsey planner wants to create in a margin.

Nicolini (1998) extends the model in Chari et al. (1991) to include an informal sector where money is used and income cannot be taxed. This is a model with four consumption goods (cash and credit good each for the formal and the informal sectors) and thus with four margins. Since there are only two tools (labor income tax and nominal interest rate) and interest rate is the only tool that can influence informal activity, the optimal policy includes

$R > 1$. This result would hold even if the utility function is homothetic.

Aruoba and Chugh (2010) consider optimal policy in the Lagos and Wright (2005) model, which is similar to the model in our paper. The main difference between the two models is the entry choice of sellers in ours versus the fixed measures of buyers and sellers in their paper. They show that the optimal policy in their model includes $R > 1$ despite the tax system being complete. They show that this result is due to the implied or "reduced-form" utility function in their model displaying non-homotheticity.

In our model, there are four margins: x^b vs. leisure, x^s vs. leisure, q (buyers' perspective) vs. q (sellers' perspective) and the entry margin. These can be seen from the solution to the social planner's problem, which can be obtained using the conditions in Appendix A.6 by setting all Ramsey problem multipliers equal to zero. The Ramsey planner has two policy instruments at his disposal to influence these four margins, which means that we have an incomplete tax system. Moreover, the same non-homotheticity of reduced-form preferences pointed out by Aruoba and Chugh (2010) also applies here. Finally, the measure of sellers that enter the IM is endogenous and is typically inefficiently high. All three of these features, incomplete tax system, non-homotheticity and inefficient entry, collectively cause the optimal policy to include $R > 1$. Note that the quality of institutions, introduced to the model by κ, also directly influences the degree of entry in to the IM and this creates the link between institutions and optimal interest rate.

4.6 Robustness

In this section we recalibrate our model changing the value of three of the parameters which were fixed in the calibration. These are ε, which influences the elasticity of substitution between IM and FM goods, θ, the buyer's share of the surplus in the IM bargaining, and ω, the curvature parameter in the audit probability function $\rho(n)$. In our benchmark calibration we chose ε to reflect perfect substitutability between IM and FM goods. Here we consider $\varepsilon = 0.5$, which yields an elasticity of substitution of 2. Our benchmark calibration had $\theta = 0.5$ which lead to the somewhat natural outcome of buyer and seller splitting the surplus equally – the so-called egalitarian bargaining. One way to calibrate θ, as Aruoba, Waller and Wright (2009) and other papers that use the Lagos and Wright (2005) model do, would be to use a measure of markup in the IM. Given the lack of data on this (unlike markups in the formal economy), we chose to be agnostic and try two alternative values, $\theta = 0.4$ and 0.6. Finally, we chose ω as 0.7 which was a value that made the $\rho(n)$ function mildly concave.

We consider two alternative values, 0.5 and 0.9, which still keep the function concave but change the strength of the curvature.

This yields five different ways of fixing these parameters. For each, we recalibrate the model, matching the same targets and recompute everything. As a summary, Table 4 reports the correlations of model-based objects and the data. The first row shows the results in the benchmark calibration and the remaining five row show the robustness results. While one can go through each row carefully, the overall conclusion is that our results are very robust to any of these changes: the correlations are quite similar to the benchmark results.

5 Conclusion

Existing literature shows that a country's institutions are key in determining its labor productivity, output and ultimately the welfare of its citizens. In this paper we show that they are also key in determining the mix of policy choices its government chooses to finance its expenditures. By using a Ramsey optimal-policy approach we show that a model that explicitly contains a tax evasion choice is successful in explaining the cross-country distributions of inflation, taxes and informality. It is also able to capture the relationship of these variables with the country's institutions.

The policy takeaway from our exercise is that reforming institutions of a country, specifically reducing incentives for tax evasion (or equivalently increasing the punishment for it), is key for increasing its output and welfare. This in itself is not a novel result in the context of the bigger literature on institutions. But what our analysis adds is to show that as the country fights (successfully) tax evasion, inflation will fall, taxes will increase, the informal sector of the economy will shrink and more of the economic activity will be registered in the formal sector.

Our goal in this paper was to explain the cross-country variation in informal activity and policies in the long run. A next step would be to consider a dynamic framework where these variables, as well as institutions, vary over time. Our model also abstracted from capital accumulation and assumed simple (identical) linear production functions in the two sectors. A common modeling choice among related papers is the difference in productivity and/or factor intensities between formal and informal sectors. Extending our model to capture this fact would be an interesting exercise. Finally, a number of "stylized facts" related to inflation such as its volatility or cyclicality differ across developed and developing countries, which is a challenge for our standard models. We can address this in a dynamic and stochastic version of our model.

References

[1] Acemoglu, Daron, Simon Johnson and James A. Robinson (2005), "Institutions as the Fundamental Cause of Long-Run Growth," *Handbook of Economic Growth,* Philippe Aghion and Stephen Durlauf (eds), Elsevier, North Holland.

[2] Acemoglu, Daron, Simon Johnson, James Robinson, and Yunyong Thaicharoen (2003), "Institutional causes, macroeconomic symptoms: volatility, crises and growth," *Journal of Monetary Economics,* 50(1), 49-123.

[3] Albanesi, Stefania (2007), "Inflation and Inequality," *Journal of Monetary Economics,* 54(4), 1088-1114.

[4] Alesina, Alberto, Silvia Ardagna and Francesco Trebbi (2006), "Who Adjusts and When? The Political Economy of Reforms," *IMF Staff Papers*, 53, 1-29

[5] Alesina, Alberto and Allan Drazen (1991), "Why are stabilizations delayed?," *American Economic Review,* 81 (5), 1170–1188.

[6] Alfaro, Laura, Sebnem Kalemli-Ozcan, and Vadym Volosovych (2008), "Why doesn't capital flow from rich to poor countries? An empirical investigation," *The Review of Economics and Statistics,* 90(2), 347-368.

[7] Aruoba, S. Boragan (2017), "Term Structures of Inflation Expectations and Real Interest Rates,", *mimeo.*

[8] Aruoba, S. Boragan, Sanjay K. Chugh (2010), "Optimal Fiscal and Monetary Policy when Money is Essential," *Journal of Economic Theory*, 145(5), 1618–1647.

[9] Aruoba, S. Boragan, Guillaume Rocheteau, Christopher Waller (2007), "Bargaining and the value of money," *Journal of Monetary Economics,* 54, 2636–2655.

[10] Aruoba, S. Boragan and Randall Wright (2003), "Search, Money and Capital: A Neoclassical Dichotomy", *Journal of Money, Credit and Banking*, 35, 1086-1105.

[11] Barro, Robert J (1990), "Government spending in a simple model of endogeneous growth," *Journal of Political Economy*, 98(5) Part 2, S103-S125.

[12] Bassetto, Marco and Christopher Phelan (2008), "Tax Riots," *Review of Economic Studies*, 75, 649-669.

[13] Besley, Timothy, and Torsten Persson (2009), "The Origins of State Capacity: Property Rights, Taxation, and Politics," *American Economic Review* 99(4), 1218-44.

[14] Bhandari, Anmon, David Evans, Mikhail Golosov and Thomas J. Sargent (2017), "Inequality, Business Cycles and Fiscal-Monetary Policy," *mimeo,* University of Chicago.

[15] Bordo, Michael D., and Carlos A. Vegh (2002), "What if Alexander Hamilton had been Argentinean? A Comparison of the Early Monetary Experiences of Argentina and the United States," *Journal of Monetary Economics,* 49(3), 459-494.

[16] Bureau of Economic Analysis (2001), "Hidden and Informal Economic Activities in the U.S. National Income and Product Accounts", *mimeo*.

[17] Canzoneri, Matthew, Robert Cumby, and Behzad Diba (2010), "The Interaction Between Monetary and Fiscal Policy," In *Handbook of Monetary Economics*, vol. 3, 935-999. Elsevier.

[18] Carey, David and Harry Tchilinguirian (2000), "Average Effective Tax Rates on Capital, Labour and Consumption," *OECD Economics Department Working Papers,* No. 258.

[19] Chari, Varadarajan V., and Patrick J. Kehoe (199) "Optimal Fiscal and Monetary Policy," *Handbook of Macroeconomics 1*, 1671-1745.

[20] Chari, V.V., Lawrence Christiano and Patrick Kehoe (1991), "Optimal Fiscal and Monetary Policy: Some Recent Results," *Journal of Money Credit and Banking*, 23(3), 519-539.

[21] Cukierman, Alex, Sebastian Edwards and Guido Tabellini (1992), "Seignorage and Political Instability," *American Economic Review,* 82(3), 537-555.

[22] De Paula, Aureo, and José A. Scheinkman (2011), "The Informal Sector: An Equilibrium Model and Some Empirical Evidence from Brazil," *Review of Income and Wealth,* 57, S8-S26.

[23] Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table," *American Economic Review,* 105(10), 3150-82.

[24] Fernandez, Raquel and Dani Rodrik, (1991), "Resistance to Reform: Status Quo Bias in the Presence of Individual- Specific Uncertainty," *American Economic Review*, 81(5), 1146-1155.

[25] Frankel, J. and D. Romer (1999), "Does Trade Cause Growth?," *American Economic Review*, 89(3), pp. 379-399.

[26] Friedman, Eric, Simon Johnson, Daniel Kaufmann, Pablo Zoido-Lobaton (2000), "Dodging the Grabbing Hand: The Determinants of Unofficial Activity in 69 Countries," *Journal of Public Economics*, 76, 459–493.

[27] Gomis-Porqueras, Pedro, Adrian Peralta-Alva, and Christopher Waller (2014), "The Shadow Economy as an Equilibrium Outcome," *Journal of Economic Dynamics and Control,* 41, 1-19.

[28] Gordon, Roger, and Wei Li (2009), "Tax Structures in Developing Countries: Many Puzzles and a Possible Explanation," *Journal of Public Economics,* 93(7-8), 855-866.

[29] Hall, Robert E. and Charles I. Jones, (1999), "Why Do Some Countries Produce So Much More Output Per Worker Than Others?", *Quarterly Journal of Economics*, 114(1), pp. 83-116.

[30] Hassan, Mai, and Friedrich Schneider (2016), "Size and Development of the Shadow Economies of 157 Countries Worldwide: Updated and New Measures from 1999 to 2013,", *mimeo.*

[31] Ihrig, Jane and Karine S. Moe (2004), "Lurking in the Shadows: The Informal Sector and Government Policy," *Journal of Development Economics,* 73, 541-557.

[32] Johnson, Simon, Daniel Kaufmann, Andrei Shleifer (1997), "The Unofficial Economy in Transition," *Brookings Papers on Economic Activity*, 1997(2), 159-239.

[33] Johnson, Simon, Daniel Kaufmann, Pablo Zoido-Lobatón (1997), "Regulatory Discretion and the Unofficial Economy," *American Economic Review Papers and Proceedings*, 88(2), 387-392.

[34] Kaufmann, Daniel, Aart Kraay, and Massimo Mastruzzi (2010), "The Worldwide Governance Indicators: Methodology and Analytical Issues," *World Bank Policy Research Working Paper,* No. 5430.

[35] Kleven, Henrik Jacobsen, Claus Thustrup Kreiner, and Emmanuel Saez (2016), "Why Can Modern Governments Tax So Much? An Agency Model of Firms as Fiscal Intermediaries," *Economica,* 83(330), 219-246.

[36] Koreshkova, Tatyana A. (2006), "A quantitative analysis of inflation as a tax on the underground economy," *Journal of Monetary Economics,* 53, 773–796.

[37] Kuehn, Zoe (2007), "Tax Rates, Governance, and the Informal Economy in High-Income Countries", *mimeo*, Universidad Carlos III de Madrid.

[38] Laban, Raul and Federico Sturzenegger (1994), "Distributional Conflict, Financial Adaptation and Delayed Stabilizations," Economics and Politics, 6(3), 257-276.

[39] Lagos, Ricardo and Randall Wright (2005), "A Unified Framework for Monetary Theory and Policy Evaluation", *Journal of Political Economy,* 113, 463-484.

[40] Lemieux, Thomas, Bernard Fortin, and Pierre Frechette (1994), "The Effect of Taxes on Labor Supply in the Underground Economy," *The American Economic Review*, 231-254.

[41] Lucas, Robert E. Jr and Nancy Stokey (1983), "Optimal Fiscal and Monetary Policy in an Economy Without Capital," *Journal of Monetary Economics*, 12, 55-93.

[42] Mendoza, Enrique G., Assaf Razin, Linda L. Tesar (1994), "Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption," *Journal of Monetary Economics,* 34, 297-323.

[43] Nicolini, Juan Pablo (1998), "Tax Evasion and the Optimal Inflation Tax," *Journal of Development Economics*, 55, 215-232.

[44] Quintin, Erwan (2008), "Contract Enforcement and the Size of the Informal Economy," *Economic Theory*, 37, 395-416.

[45] Ramsey, Frank P. (1927), "A Contribution to the Theory of Taxation," *Economic Journal*, 37(145), 47-61.

[46] Rocheteau, Guillaume and Randall Wright (2005), "Money in Search Equilibrium, in Competitive Equilibrium and in Competitive Search Equilibrium", *Econometrica,* 73, 75-202.

[47] Schmitt-Grohé, Stephanie, and Martin Uribe, (2010) "The Optimal Rate of Inflation," In *Handbook of Monetary Economics*, vol. 3, 653-722. Elsevier.

[48] Schneider, Friedrich, (2004), "The Size of the Shadow Economies of 145 Countries all over the World: First Results over the Period 1999 to 2003," *IZA Discussion Paper*, No. 1431.

[49] Vegh, Carlos A., and Guillermo Vuletin (2105), "How is Tax Policy Conducted over the Business Cycle?," *American Economic Journal: Economic Policy,* 7(3), 327-70.

[50] Yesin, Pinar (2004), "Financing Government Expenditures Optimally," *mimeo*, Study Center Gerzensee.

[51] Yesin, Pinar (2006), "Tax Collection Costs, Tax Evasion and Optimal Interest Rates," *mimeo*, Study Center Gerzensee.

Figure 1: Government Policies, Informal Sector and Institutions

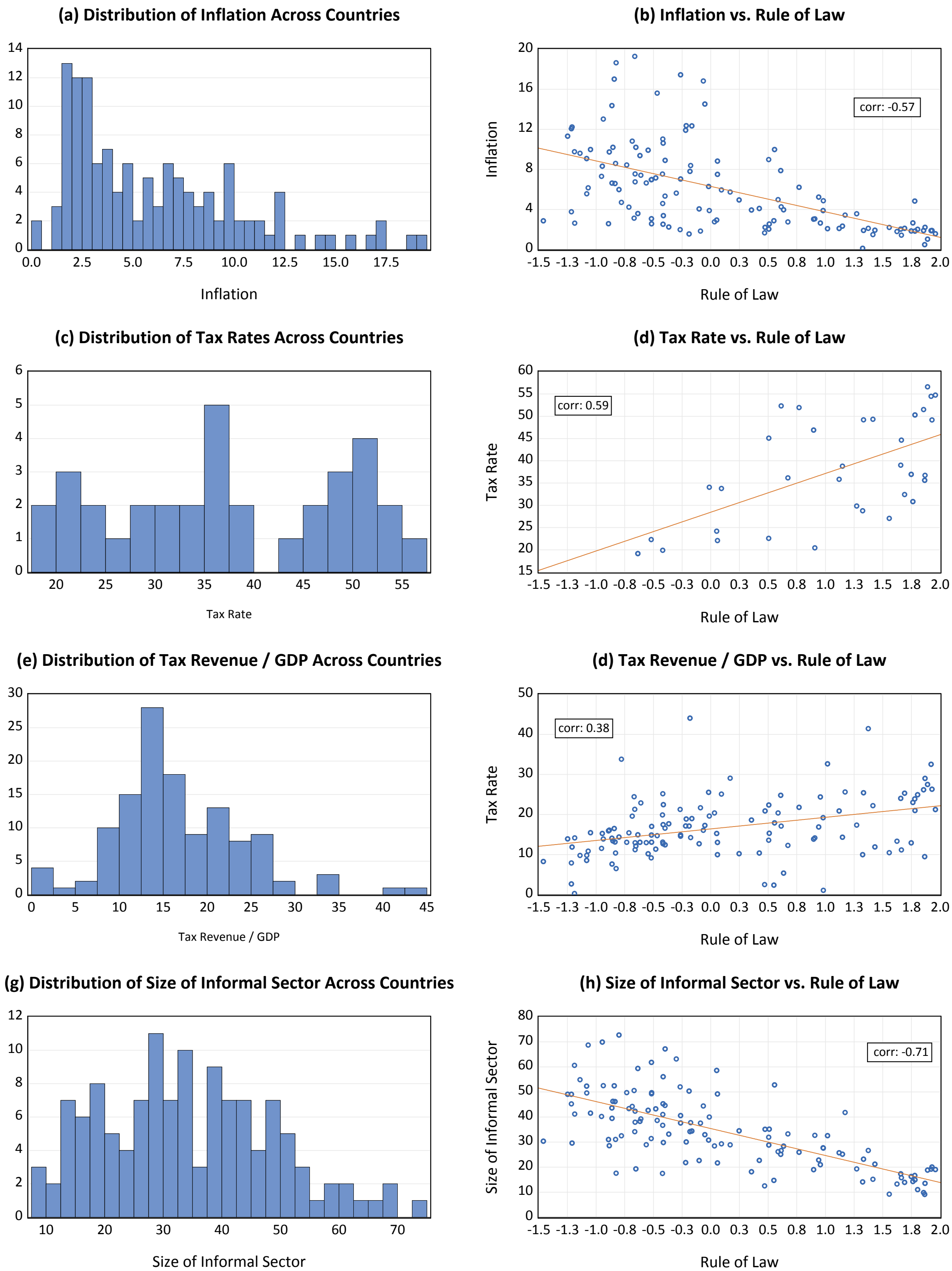
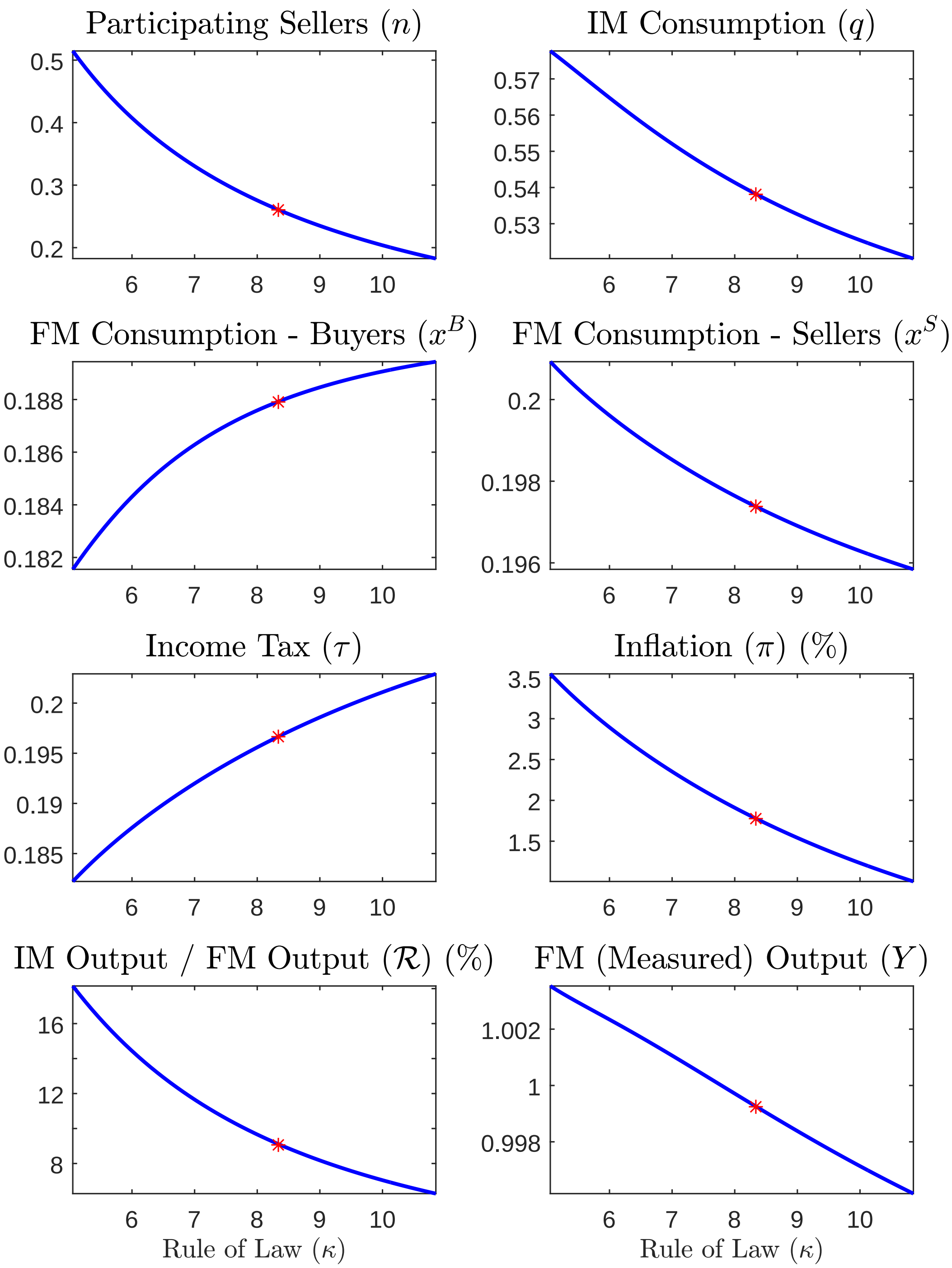
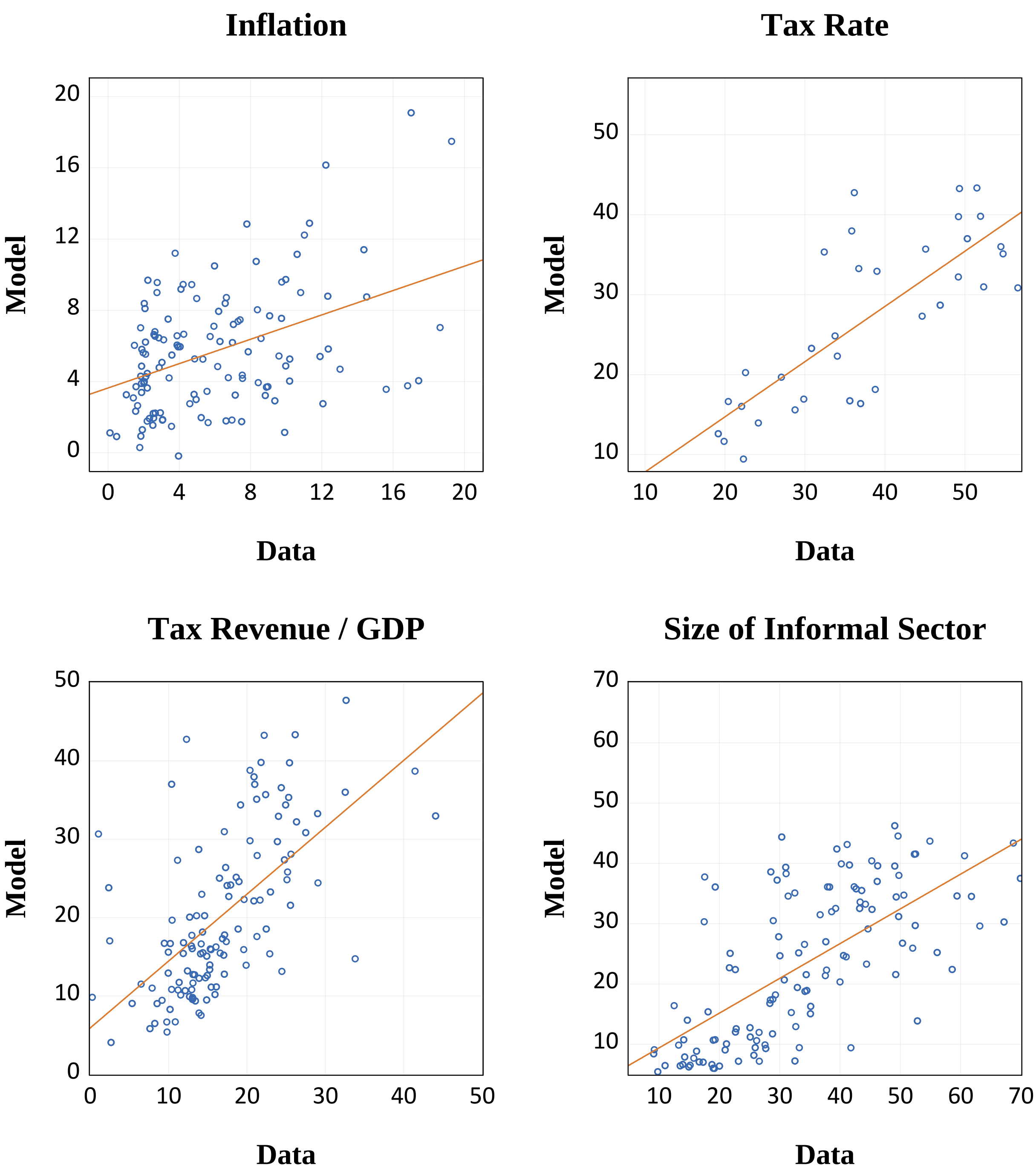


Figure 3: Comparative Statics when Institutions Change



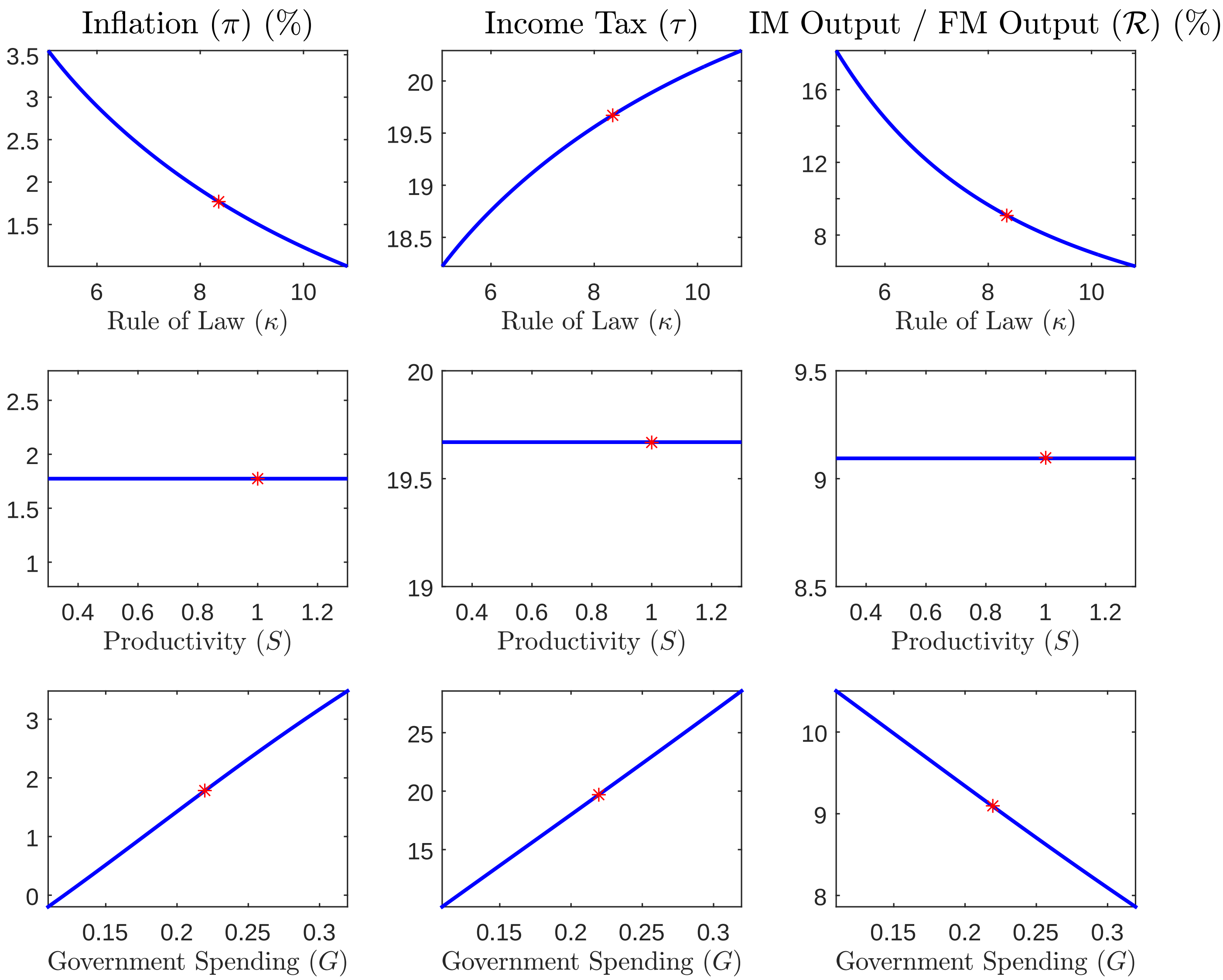
Notes: The red stars in each panel correspond to the calibrated value for the United States.

Figure 3: Cross Country Exercise - Key Variables, Data vs. Model



Notes: In each panel the x-axis shows the data and the y-axis reports the results from the model. Each figure is a square so that values above (below) the 45-degree line show the model predicts higher (lower) values relative to the data.

Figure 4: Partial Derivatives with Respect to Exogenous Variables



Notes: Each figure shows how a particular endogenous variable (π, τ or $\mathcal{R}$) changes as each of the exogenous variables (κ, S and G) are changed in a range around the values for the U.S., one at a time, holding others constant at U.S. values. The red stars in each panel correspond to the calibrated value for the United States. In the bottom panel, $Y = 1$ holds throughout and thus a change in G is equivalent to a change in G/Y.

Figure 5: Data vs. Model (Only κ)

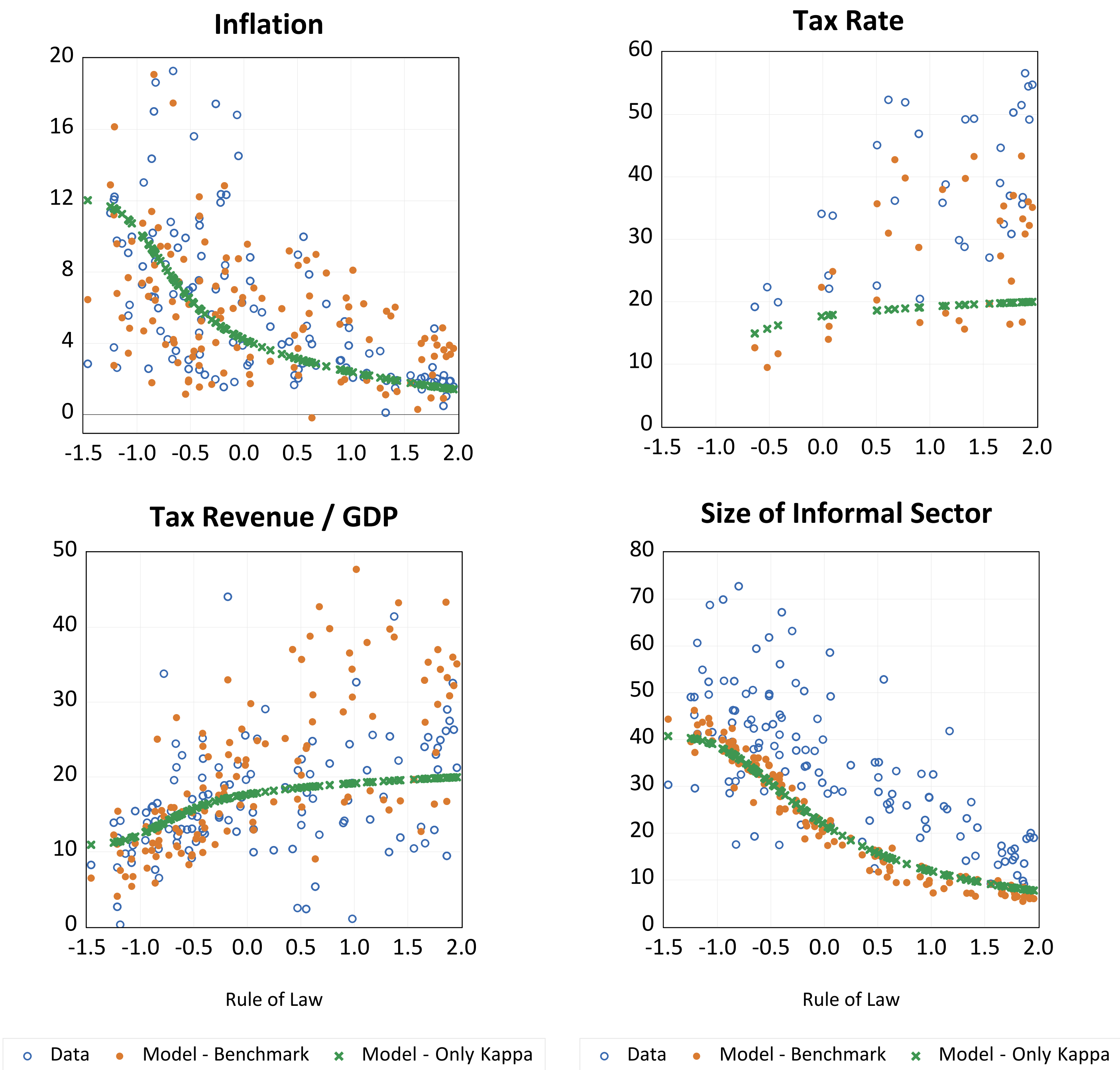
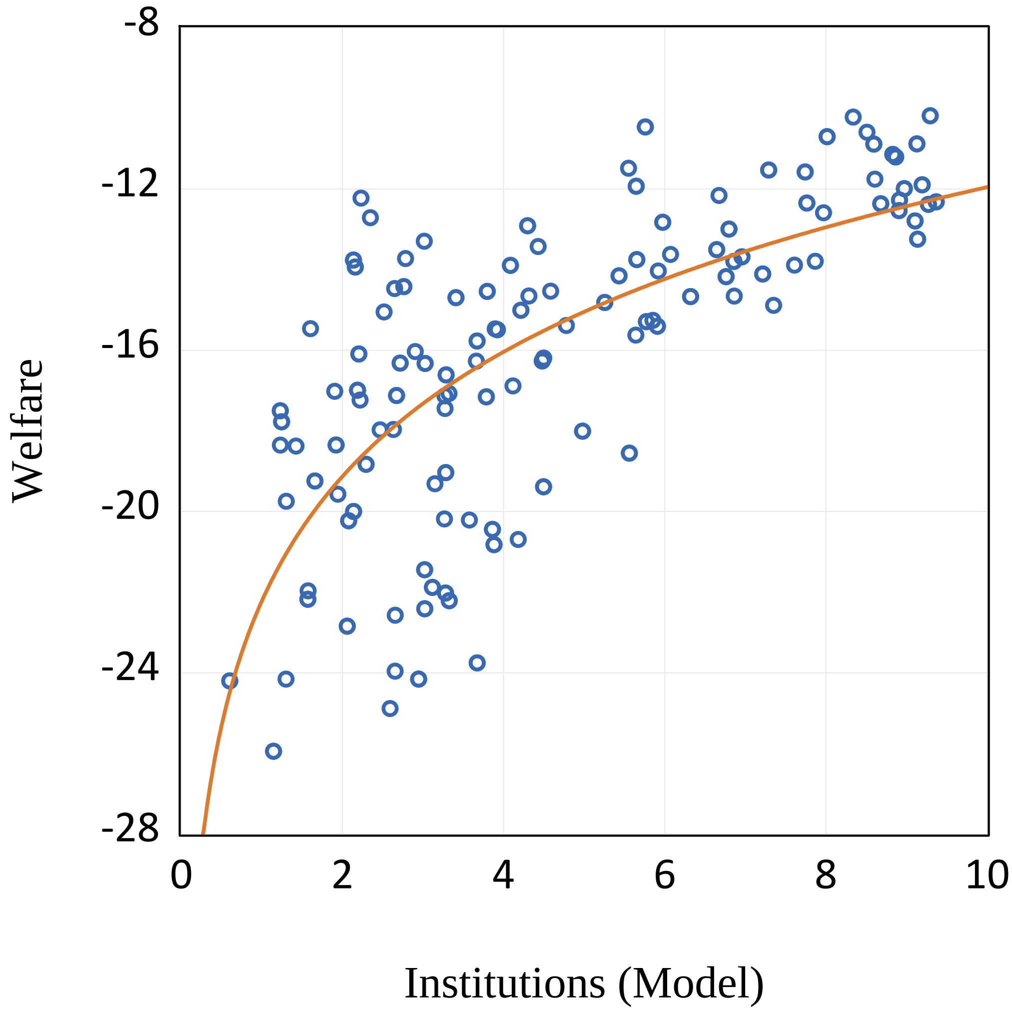


Figure 6: Data vs. Model (Only G/Y)

Figure 7: Model-Implied Welfare Across Countries



Notes: Figure shows welfare for each country in the cross-country exercise versus the measure of institutions, which in turn is a linear transformation of Rule of Law. Welfare is calculated as defined in (25) and it is in arbitrary units. The orange line is a log-linear regression line.

Table 1: Calibration

(a) Fixed

Parameter	Value	Justification
σ	1	Log utility
ϵ	1	IM and FM goods perfect substitutes
Λ	3	Large to ensure $n < \Lambda$
θ	0.5	Egalitarian bargaining
χ	0.5	Matching function inefficient
ω	0.75	Probability of audit slightly concave in n

(b) Directly Calibrated

Parameter / Exogenous Variable	Value	Target	Source
ψ	1.4285	Degree of DRS in IM 0.7	Lemieux et al. (1994)
β	0.985	Real return of 1.5% over 1998-2007	Aruoba (2017)
S^{US}	1	-	Normalization
S^{M}	0.3623	S in the Maldives relative to the U.S.	Data

(c) Jointly Calibrated

Parameter / Exogenous Variable	Value	Target	Source
A	4.0708	$Y^{US} = 1$	Normalization
γ	230.1368	$R^{US} = 0.0920$	Data
ϕ	2.7691	$R^{M} = 0.2264$	Data
κ^{US}	8.3386	$\pi^{US} = 2.2\%$	Data
G^{US}	0.2192	$G^{US}/Y^{US} = 0.2192$	Data
κ^{M}	4.0853	Linear mapping	See text
G^{M}	0.0930	$G^{M}/Y^{M} = 0.2517$	Data

(d) Data vs. Model

Target	Data	Model	Target	Data	Model
Y^{US}	1	0.9991	π^{US}	2.20%	1.78%
R^{US}	0.0920	0.0910	G^{US}/Y^{US}	0.2192	0.2194
R^{M}	0.2264	0.2237	G^{M}/Y^{M}	0.2517	0.2517

Table 2: Main Results

	Data	Benchmark	Only κ	Only G/Y
(a) Correlation of Model-Based Measures and Data				
Inflation	-	0.42	0.51	-0.21
Tax Rate	-	0.78	0.60	0.75
Tax Rev / GDP	-	0.61	0.40	0.62
$\mathcal{R}$	-	0.68	0.69	0.43
(b) Moments - Data and Model-Implied				
$mean(\pi)$	6.02	5.70	5.35	2.24
$mean(\tau)$ [Taxes]	37.73	26.96	18.94	27.61
$mean(\tau)$ [Rev]	16.72	20.19	16.66	22.70
$mean(\mathcal{R})$	34.22	23.35	23.63	8.74
$std(\pi)$	4.28	3.46	3.14	1.72
$std(\tau)$ [Taxes]	11.69	10.40	1.27	10.10
$std(\tau)$ [Rev]	7.36	10.24	2.70	9.45
$std(\mathcal{R})$	14.70	12.45	11.05	1.27
(c) Correlations - Data and Model-Implied				
$corr(\kappa, \pi)$	-0.57	-0.43	-0.93	0.57
$corr(\kappa, \tau)$ [Taxes]	0.59	0.49	0.94	0.41
$corr(\kappa, \tau)$ [Rev]	0.38	0.70	0.92	0.56
$corr(\kappa, \mathcal{R})$	-0.71	-0.95	-0.98	-0.57

Notes: The table reports various statistics from the benchmark version where all the exogenous variables κ, S and G/Y are allowed to vary across countries and two counterfactual where only κ or only G/Y are allowed to vary. $\mathcal{R}$ denotes the ratio of informal activity to formal activity, π denotes inflation and τ denotes taxes. Throughout the table, results with tax rates uses 34 countries.

Table 3: Results for Subsamples of Countries

		Correlation of Model-Based Measures and Data			
	Count	Inflation	Tax Rate	Tax Rev / GDP	Informal
Benchmark	125	0.42	0.78	0.61	0.68
Low Output	52	0.18	-	0.80	0.23
Low Institutions	17	0.20	-	0.43	0.20
Others	73	0.60	0.75	0.54	0.66
Not Free	19	0.12	-	0.09	0.59
Partially Free	39	0.24	0.54	0.63	0.41
Free	66	0.54	0.73	0.54	0.71

Notes: The table reports correlation of model-based measures and data for different subsets of countries. The first column reports the number of countries in the particular sample. 'Low Output' refers to countries that have less than 15% of the output of the U.S., 'Low Institutions' refers to countries with Rule of Law in the lowest quintile and 'Other countries' are those that satisfy neither of these two criteria. 'Free', 'Partially Free' and 'Not Free' designations follow the 2008 issue of 'Freedom in the World' by Freedom House. '-' indicate subsamples where no tax rate data was available for the countries.

Table 4: Robustness

				Correlation of Model-Based Measures and Data			
	ϵ	θ	ω	Inflation	Tax Rate	Tax Rev / GDP	Informal
Benchmark	1	0.5	0.7	0.42	0.78	0.61	0.68
(1)	0.5	-	-	0.45	0.77	0.61	0.70
(2)	-	0.4	-	0.51	0.77	0.57	0.68
(3)	-	0.6	-	0.43	0.77	0.60	0.70
(4)	-	-	0.5	0.46	0.78	0.61	0.66
(5)	-	-	0.9	0.41	0.77	0.61	0.68

Notes: The table reports correlation of model-based measures and data for different calibrations. Each of the alternatives change one of the fixed parameters as reported in columns two through four ('-' means unchanged from the benchmark calibration).

Online Appendix

A Proofs of Propositions and Detailed Analysis of the Model

A.1 Would a Successful Seller Report IM Income

Using (16), a seller with a match in the IM receives

$$-c(q_t^S) + \beta d_t^S \chi_{t+1} - \kappa \rho_t \tag{A-1}$$

if he does not report his income to the government, where the last term denotes the expected cost of punishment through an audit. If he reports his income to the government, then he gets

$$-c(q_t^S) + \beta \left(d_t^S - p_{t+1}\eta \right) \chi_{t+1} \tag{A-2}$$

where η is the penalty he needs to pay in real terms.

Thus, a successful seller would choose to report if the following relationship holds

$$\kappa \rho_t > \eta \beta p_{t+1} \chi_{t+1} \tag{A-3}$$

Using equilibrium relationships, the solution to the bargaining problem, and dropping time subscripts, we get

$$\frac{\eta}{\mathcal{M}} < \frac{\kappa \rho}{\pi g\left(q, x^B\right)} \tag{A-4}$$

where the LHS is the penalty relative to the income the seller receives since $d = m$. Moreover, $\kappa\rho$ via the FE condition is $g - c$, which yields

$$\frac{\eta}{\mathcal{M}} < \frac{g\left(q, x^B\right) - c\left(q\right)}{\pi g\left(q, x^B\right)} \tag{A-5}$$

and it is easy to show that this implies $\eta/\mathcal{M} < 1$ must hold. This shows that for the seller to report, the punishment cannot exceed the actual benefit from evading taxes.

A.2 Proof of Proposition 1

For the derivations here, we explicitly impose the constraint $m_t^i \geq 0$ for $i = B, P, N$. Combining (3)-(6) with (19)-(21) we get the following optimality conditions for buyers

$$\frac{A}{S(1-\tau_t)} = \alpha_b \left[u_x(q_t^B, x_t^B) - \frac{g_x(q_t, x_t^B)}{g_q(q_t, x_t^B)} u_q(q_t^B, x_t^B) \right] + (1-\alpha_b) u_x(0, x_t^B) \quad \text{(A-6)}$$

$$\chi_t \geq \beta \chi_{t+1} \left[\alpha_b \left(\frac{u_q(q_t^B, x_t^B)}{g_q(q_t^B, x_t^B)} - 1 \right) + 1 \right], \text{ with} = \text{if } m_t^B > 0 \quad \text{(A-7)}$$

$$\chi_t = \beta \chi_{t+1} R_t \quad \text{(A-8)}$$

Combining (11)-(13) with (22) and calculating the appropriate optimality condition for m_t^P, we get the following optimality conditions for participating sellers

$$u_x(0, x_t^P) = \frac{A}{S(1-\tau_t)} \quad \text{(A-9)}$$

$$\chi_t \geq \beta \chi_{t+1}, \text{ with} = \text{if } m_t^P > 0 \quad \text{(A-10)}$$

$$\chi_t = \beta \chi_{t+1} R_t \quad \text{(A-11)}$$

Similarly, using (10), (11), (12) and (14) we get the optimality conditions for nonparticipating sellers

$$u_x(0, x_t^N) = \frac{A}{S(1-\tau_t)} \quad \text{(A-12)}$$

$$\chi_t \geq \beta \chi_{t+1}, \text{ with} = \text{if } m_t^N > 0 \quad \text{(A-13)}$$

$$\chi_t = \beta \chi_{t+1} R_t \quad \text{(A-14)}$$

Proof of (a): Comparing (A-10)-(A-11) and (A-13)-(A-14), we can conclude that $m_t^P = m_t^N = 0$ since money cannot provide the same return to the sellers (participating or non-participating) as the bond, as long as $R > 1$. In (A-7) the sign of the term in the square brackets, which is the return on holding money in the period t IM, depends implicitly on m_t^B. Given both (A-7) and (A-8), the buyers choose a level of m_t^B such that this term exactly equals R_t, which can be guaranteed to be strictly positive as long as R_t is not too large. Intuitively, since there is no uncertainty, the return on holding money and bonds need to be identical. If, however, R_t is larger than a threshold $\bar{R}$, then no value of m_t^B can deliver the same return and the buyer will choose $m_t^B = 0$ and monetary equilibrium ceases to exist.

In simpler models one can show analytically, and in this model we show numerically that q_t falls as R increases. As such there will be a value for R that we call $\bar{R}$ where $q_t = 0$ so that any increase beyond $\bar{R}$ will not change the outcome.

Proof of (b): Since (A-8), (A-11) and (A-14) are identical, all three types of agents choose the same level of bond holdings.

Proof of (c): Since (A-9) and (A-12) are identical, $x_t^P = x_t^N$.

Proof of (d): Given the structure of the environment and the properties of equilibrium we found so far, there are four types of agents at the start of period t. They differ according to how much money they enter period t with and how much money they exit the FM in period t.

The table below summarizes the properties and actions of these four types of agents, showing their money holdings at the beginning and the end of the FM and their measure.

Type	Matched in $t-1$	Type in t	Start FM	End FM	Measure
MB	Yes	B	0	M_t	$\mu(n_{t-1})$
UB	No	B	M_{t-1}	M_t	$[1-\mu(n_{t-1})]$
MS	Yes	P or N	M_{t-1}	0	$\mu(n_{t-1})$
US	No	P or N	0	0	$[\Lambda-\mu(n_{t-1})]$

- The MB agents are buyers who were matched in period $t-1$. In equilibrium they will have no money at the beginning of period t since they will have spent all of it in the previous IM and will exit the FM with $m_t^B = m_t = M_t$ units of money.

- The UB agents are buyers who were unmatched in period $t-1$ and they have kept their money from period $t-1$ since they could not find a match.

- The MS agents are sellers who participated and found a match in the previous IM. They acquired $m_{t-1}^B = M_{t-1}$ units of money from the buyer they met and as soon as they can, in the period t FM, they spend it and exit the FM with no money.

- The US agents either chose not to participate in the period $t-1$ IM, or they participated and were not matched. It is important to note that the choices of participation of MS and US agents in period t does not affect any of this.

Denoting h_t^i, $i = MB, UB, MS$ or US the labor supply choices of each type, using (2) and (8) their FM budget constraints can be written as

$$
\begin{aligned}
x_t^B &= \Omega_t + S(1-\tau_t)\,h_t^{MB} + \left(\frac{0-M_t}{p_t}\right) \\
x_t^B &= \Omega_t + S(1-\tau_t)\,h_t^{UB} + \left(\frac{M_{t-1}-M_t}{p_t}\right) \\
x_t^S &= \Omega_t + S(1-\tau_t)\,h_t^{MS} + \frac{M_{t-1}}{p_t} \\
x_t^S &= \Omega_t + S(1-\tau_t)\,h_t^{US}
\end{aligned}
$$

where we use $\Omega_t \equiv (R_{t-1}B_t - B_{t+1})/p_t$. Solving each of these equations for h yields

$$
h_t^i = \begin{cases}
\frac{1}{S(1-\tau_t)}\left(x_t^B - \Omega_t + \frac{M_t}{p_t}\right) & i = MB \\
\frac{1}{S(1-\tau_t)}\left(x_t^B - \Omega_t + \frac{M_t - M_{t-1}}{p_t}\right) & i = UB \\
\frac{1}{S(1-\tau_t)}\left(x_t^S - \Omega_t - \frac{M_{t-1}}{p_t}\right) & i = MS \\
\frac{1}{S(1-\tau_t)}\left(x_t^S - \Omega_t\right) & i = US
\end{cases}
$$

This shows the well-known result of the Lagos-Wright model where the agents' choices are heterogenous in the variable which enters utility linearly.

Proof of (e): Turning to the free-entry condition, the expression in (15) simplifies to

$$
-Ah_t^P + V^S(b_{t+1}) = -Ah_t^N + \beta W^S(0, b_{t+1})
$$

since $b_t^P = b_t^N = b_t$ and $x_t^P = x_t^N$ from (a)-(c) above. From (d), we see that $h_t^P = h_t^N$, conditional on the match status of the agent in $t-1$. Using (17) and the equilibrium outcome $d_t^S = m_t^B = M_t$, the free-entry condition simplifies to

$$
-c(q_t^S) + \beta M_t \chi_{t+1} = \kappa \rho(n_t)
$$

Using the result in (18), we obtain the expression in the proposition.

A.3 Definition of Equilibrium

We can define a monetary equilibrium as follows:

Definition 3 *Given* $1 \leq R_t < \bar{R}$ *and* τ_t, *and exogenous variables* (κ, S, G), *a monetary equilibrium is a list of sequences* $\left\{x_t^B, x_t^S, H_t, \mathcal{B}_t, \mathcal{M}_t, n_t, q_t, \pi_t\right\}$ *that satisfy*

$$u_x(0, x_t^S) = \frac{A}{S\left(1-\tau_t\right)} \tag{A-15}$$

$$\mu\left(n_t\right)\left[u_x(q_t^B, x_t^B) - \frac{g_x\left(q_t, x_t^B\right)}{g_q\left(q_t, x_t^B\right)} u_q(q_t^B, x_t^B)\right] + \left[1-\mu\left(n_t\right)\right] u_x\left(0, x_t^B\right) = \frac{A}{S\left(1-\tau_t\right)} \tag{A-16}$$

$$u_x(0, x_t^S) = \frac{\beta R_t}{\pi_{t+1}} u_x(0, x_{t+1}^S) \tag{A-17}$$

$$u_x(0, x_t^S) = \frac{\beta}{\pi_{t+1}}\left\{\mu\left(n_t\right)\left[\frac{u_q(q_t, x_t^B)}{g_q\left(q_t, x_t^B\right)} - 1\right] + 1\right\} u_x(0, x_{t+1}^S) \tag{A-18}$$

$$\frac{A\beta\mathcal{M}_t}{S\left(1-\tau_{t+1}\right)\pi_{t+1}} = g\left(q_t, x_t^B\right) \tag{A-19}$$

$$-c(q_t) + g\left(q_t, x_t^B\right) = \kappa\rho\left(n_t\right) \tag{A-20}$$

$$\mathcal{M}_t + \mathcal{B}_t + \tau_t S H_t = \frac{\mathcal{M}_{t-1} + R_{t-1}\mathcal{B}_{t-1}}{\pi_t} + G \tag{A-21}$$

$$SH_t = x_t^B + \Lambda x_t^S + G \tag{A-22}$$

Most of the equilibrium conditions directly follow from the derivations in the previous section. In particular, (A-15) follows from (A-9) and (A-12); (A-16) follows from (A-6); (A-17) follows from (4) along with (A-15) and (A-8), (A-11) and (A-14); (A-18) follows from (A-7) with equality, (4) and (A-15), since we are characterizing a monetary equilibrium; (A-19) follows from (4) along with the outcome of the bargaining problem (18); (A-20) is the free-entry condition in (23) and (A-21) is the budget constraint of the government in (1). In order to obtain the resource constraint in (A-22) we need to define the aggregate labor supply H_t by summing up the expressions of h_t^i for each type $i = MB$, UB, MS and US using their appropriate weights. We obtain

$$\begin{aligned} H_t &= \mu\left(n_{t-1}\right) h_t^{MB} + \left[1-\mu\left(n_{t-1}\right)\right] h_t^{UB} + \mu\left(n_{t-1}\right) h_t^{MS} + \left[\Lambda - \mu\left(n_{t-1}\right)\right] h_t^{US} \\ &= \frac{1}{S\left(1-\tau_t\right)}\left[x_t^B + \Lambda x_t^S + \frac{B_{t+1} - R_{t-1}B_t}{p_t} + \frac{M_t - M_{t-1}}{p_t}\right] \end{aligned} \tag{A-23}$$

which can also be viewed as the aggregate budget constraint of the households. Combining this with the government's budget constraint, we get (A-22).

A.4 Existence and Uniqueness of Equilibrium

Rocheteau and Wright (2005) prove that there are two monetary equilibria in their model as long as $\beta < \pi \leq \bar{\pi}$, where $\bar{\pi}$ is a threshold level of inflation beyond which there is no monetary equilibria, corresponding to the nominal interest rate $\bar{R}$ in Definition 3. In one of these equilibria, both q and n are small and in the other one they are both large. For the purposes of this discussion, let's call the equilibria the low and high equilibrium, respectively. Finally they also show that when $\pi = \beta$ there is a unique monetary equilibrium. All of these results also hold in our model.[28]

Non-uniqueness of competitive equilibrium is in principle a major problem for a Ramsey problem. At its heart, the Ramsey problem seeks to find the set of policies that lead to the highest welfare. If the same set of policies lead to two different sets of allocations and hence welfare, it is conceptually impossible to find the best policy. One may characterize all equilibria given policies and find the policy that leads to the best one, but given that policy there is no guarantee that the desired equilibrium will be selected.

There are two reasons why the non-uniqueness of monetary equilibrium is not a major concern in our analysis. First, we calibrate the solution to the Ramsey problem to match some realistic informal sector sizes, which requires *both* q and n to be sufficiently large. The low equilibrium cannot achieve the necessary levels. To understand the second reason, first two results: the equilibrium when $\pi = \beta$ is unique; the q and n in the high equilibrium converge to those in this unique equilibrium as $\pi \to \beta$. Given the solution of the high equilibrium as described in 3, we can prove the following result.

Proposition 4 *The steady state of the monetary equilibrium which originally is a function of policies* (R, τ) *and exogenous variables* (κ, S, G) *can be written as a function of a single policy* R *and the exogenous variables with the additional assumption of* $R\mathcal{B} + \mathcal{M} = 0$.

Proof. We start with the equilibrium characterization of (A-15)-(A-22), given (R, τ, κ, S, G). The goal is to determine τ as a function of the remaining objects. First, notice that at the steady state given R (A-17) determines π. Then given (π, τ, κ, S), (A-15), (A-16), (A-18) and (A-20) determine $\left(q, x^B, x^S, n\right)$. Given these, (A-19) show how $\mathcal{M}$ is determined. Given the restriction in the theorem, $\mathcal{B} = \mathcal{M}/R$ is obtained. Finally, given G and everything

[28] We do not have a proof for this claim since our model is substantially more complex than their model. However, much of the sources of these complexions, the key of which is the nonseparability of utility, should not affect the conclusion. In numerical examples, we are able to obtain two monetary equilibria for a given set of exogenous variables.

that is determined so far, (A-21) pins down τ. Thus, in order to solve for equilibrium given only (R, κ, S, G), we remove $\mathcal{B}$ from the list of endogenous objects to solve for (and impose $\mathcal{B} = \mathcal{M}/R$ in (A-21)), and solve for τ along with other endogenous objects to satisfy the equilibrium conditions. ■

Note that Proposition 4 provides a simple way of finding the Ramsey optimal policy: one can simply do a search over various values of R and pick the value that yields the highest welfare. The assumption $R\mathcal{B} + \mathcal{M} = 0$, which we also impose in the Ramsey problem below, simply requires the government to have zero net debt at the beginning of time and in the limit. Combining the three results (that equilibrium is unique when $\pi = \beta$, or $R = 1$, the high equilibrium converges to this unique equilibrium as $\pi \to \beta$ and the proposition above), to ensure that we pick the high equilibrium, we start the search for the Ramsey-optimal inflation rate with $\pi = \beta$ and gradually increase π. As a result, we always find a Ramsey equilibrium with a monetary equilibrium corresponding to the high equilibrium.

In addition to the monetary equilibrium we discussed so far, this model also has an equilibrium where money is not valued, the nonmonetary equilibrium. This equilibrium is also an option for the Ramsey planner.

Definition 5 *Given τ_t and exogenous variables (κ, S, G), a nonmonetary equilibrium is a list of sequences $\{x_t^B, x_t^S, H_t\}$ that satisfy $x_t^B = x_t^S = x_t$ such that*

$$u_x(0, x_t) = \frac{A}{S(1 - \tau_t)} \tag{A-24}$$

$$SH_t = (\Lambda + 1)\, x_t + G \tag{A-25}$$

To obtain this, we set $q_t = n_t = \mathcal{M}_t = 0$, and remove the nominal bond, its return R and inflation π from the list of endogenous variables. Also note that since there is no borrowing, in this model the government budget constraint $\tau_t S H_t = G$ needs to hold every period.

A.5 Proof of Proposition 2

Social welfare function in a period can be defined as the sum of the utility functions for the four type of agents as they enter the period. First we define the ex-ante utilities for specific type of agents excluding their disutility from labor supply in the FM. For a buyer this is

$$U_t^B = \alpha_{b,t} u\left(q_t, x_t^B\right) + [1 - \alpha_{b,t}]\, u\left(0, x_t^B\right) \tag{A-26}$$

Similarly, we define the ex-ante utility of a generic seller in period t that excludes the disutility of labor, separately for a seller who is choosing to participate in the IM in period t and one that is not. For the former group, the utility of a representative seller is

$$U_t^{PS} = \alpha_{s,t}\left[-c\left(q_t\right) - \varsigma \mathcal{P} \rho\left(n_t\right)\right] + u\left(0, x_t^S\right) \tag{A-27}$$

where with probability $\alpha_{s,t}$ the seller finds a match, with probability $\varsigma\rho\left(n_t\right)$ he is audited and since he guilty of tax evasion, he gets the punishment $\mathcal{P}$. For the nonparticipating seller, we have

$$U_t^{NS} = u\left(0, x_t^s\right) \tag{A-28}$$

We are now ready to assemble the pieces. Using the table in Appendix A.2 to get the measures of each type of agent, we have

$$\begin{aligned}\mathcal{U}_t = {} & \mu\left(n_{t-1}\right)\left[U_t^B - Ah_t^{MB}\right] + \left[1-\mu\left(n_{t-1}\right)\right]\left[U_t^B - Ah_t^{UB}\right] \\ & +\mu\left(n_{t-1}\right)\left[\frac{n_t}{\Lambda}U_t^{PS} + \left(1-\frac{n_t}{\Lambda}\right)U_t^{NS} - Ah_t^{MS}\right] \\ & +\left[\Lambda - \mu\left(n_{t-1}\right)\right]\left[\frac{n_t}{\Lambda}U_t^{PS} + \left(1-\frac{n_t}{\Lambda}\right)U_t^{NS} - Ah_t^{US}\right]\end{aligned} \tag{A-29}$$

Collecting terms we get

$$\begin{aligned}\mathcal{U}_t = {} & U_t^B + \Lambda\left[\frac{n_t}{\Lambda}U_t^{PS} + \left(1-\frac{n_t}{\Lambda}\right)U_t^{NS}\right] \\ & -A\left\{\mu\left(n_{t-1}\right)h_t^{MB} + \left[1-\mu\left(n_{t-1}\right)\right]h_t^{UB} + \mu\left(n_{t-1}\right)h_t^{MS} + \left[\Lambda-\mu\left(n_{t-1}\right)\right]h_t^{US}\right\}\end{aligned} \tag{A-30}$$

which simplifies to

$$\mathcal{U}_t = U_t^B + \Lambda\left[\frac{n_t}{\Lambda}U_t^{PS} + \left(1-\frac{n_t}{\Lambda}\right)U_t^{NS}\right] - AH_t \tag{A-31}$$

given the definition of H_t in (A-23). Writing all the term explicitly, we get

$$\begin{aligned}\mathcal{U}_t = {} & \mu\left(n_t\right)u\left(q_t, x_t^B\right) + \left[1-\mu\left(n_t\right)\right]u\left(0, x_t^B\right) \\ & +\mu\left(n_t\right)\left[-c\left(q_t\right) - \kappa\rho\left(n_t\right)\right] + n_t u\left(0, x_t^S\right) \\ & +\left(\Lambda - n_t\right)u\left(0, x_t^s\right) - AH_t\end{aligned} \tag{A-32}$$

and finally

$$\mathcal{U}_t = \mu(n_t)\left[u\left(q_t, x_t^B\right) - c(q_t) - \kappa\rho(n_t)\right] + [1-\mu(n_t)]\,u\left(0, x_t^B\right) + \Lambda u\left(0, x_t^S\right) - AH_t \quad \text{(A-33)}$$

Before we turn to the derivation of the PVIC, it is useful to derive the expressions for the interest rate and real money balances. Combining (A-17) and (A-18) we get and expression for the nominal interest rate

$$R_t = \mu(n_t)\left[\frac{u_q(q_t, x_t^B)}{g_q(q_t, x_t^B)} - 1\right] + 1 \quad \text{(A-34)}$$

Also, combining (A-15), (A-17) and (A-19), we get

$$\mathcal{M}_t = \frac{R_t g\left(q_t, x_t^B\right) S(1-\tau_t)}{A} \quad \text{(A-35)}$$

which defines the money demand equation.

In order to construct the PVIC we take the budget constraint of each of the four types of agents and sum over time, discounting by the multiplier of the budget constraint for the period. We then aggregate these expressions using the measures for each type. Since the multipliers for all four types are identical, this amounts to starting with the aggregate budget constraint of households (A-23) which we derived in Appendix A.3, multiplying with the multiplier $A/p_t S(1-\tau_t)$ in every period and summing over time. Doing this yields

$$\sum_{t=0}^{\infty}\beta^t\left[\frac{A}{S(1-\tau_t)}X_t - AH_t + \frac{A}{S(1-\tau_t)}\mathcal{B}_t - \frac{A}{S(1-\tau_t)}\frac{R_{t-1}\mathcal{B}_{t-1}}{\pi_t}\right.$$
$$\left. + \frac{A}{S(1-\tau_t)}\mathcal{M}_t - \frac{A}{S(1-\tau_t)}\frac{\mathcal{M}_{t-1}}{\pi_t}\right] = 0$$

where we define $X_t \equiv x_t^B + \Lambda x_t^S$.

Using (A-15), we can write

$$\sum_{t=0}^{\infty}\beta^t\left[u_x(0, x_t^S)X_t - AH_t\right] + \sum_{t=0}^{\infty}\beta^t u_x(0, x_t^S)\mathcal{B}_t + \sum_{t=0}^{\infty}\beta^t u_x(0, x_t^S)\mathcal{M}_t \quad \text{(A-36)}$$
$$= \sum_{t=0}^{\infty}\beta^t u_x(0, x_t^S)\frac{\mathcal{M}_{t-1}}{\pi_t} + \sum_{t=0}^{\infty}\beta^t u_x(0, x_t^S)\frac{R_{t-1}\mathcal{B}_{t-1}}{\pi_t}$$

Substitute into the second summation on the left-hand-side in (A-36) the equilibrium condition (A-17) to yield

$$\sum_{t=0}^{\infty}\beta^t u_x(0,x_t^S)\mathcal{B}_t = \sum_{t=0}^{\infty}\beta^{t+1}R_t u_x(0,x_{t+1}^S)\frac{\mathcal{B}_t}{\pi_{t+1}}$$

and this will cancel with the second term on the right-hand-side to yield

$$\begin{aligned}&\sum_{t=0}^{\infty}\beta^t u_x(0,x_t^S)\frac{R_{t-1}\mathcal{B}_{t-1}}{\pi_t} - \sum_{t=0}^{\infty}\beta^{t+1}u_x(0,x_{t+1}^S)\frac{R_t\mathcal{B}_t}{\pi_{t+1}}\\ = \;& u_x(0,x_0^S)\frac{R_{-1}\mathcal{B}_{-1}}{\pi_0}\end{aligned}$$

on the right hand side.

Next, substitute into the third summation on the left-hand-side in (A-36) the equilibrium condition (A-17) to yield

$$\sum_{t=0}^{\infty}\beta^t u_x(0,x_t^S)\mathcal{M}_t = \sum_{t=0}^{\infty}\beta^{t+1}\frac{R_t u_x(0,x_{t+1}^S)\mathcal{M}_t}{\pi_{t+1}}$$

and using (A-34) we get

$$\begin{aligned}&\sum_{t=0}^{\infty}\beta^{t+1}\frac{u_x(0,x_{t+1}^S)\mathcal{M}_t}{\pi_{t+1}}\left\{\mu\left(n_t\right)\left[\frac{u_q(q_t,x_t^B)}{g_q\left(q_t,x_t^B\right)}-1\right]+1\right\}\\ = \;& \sum_{t=0}^{\infty}\beta^{t+1}\frac{u_x(0,x_{t+1}^S)\mathcal{M}_t}{\pi_{t+1}}\mu\left(n_t\right)\left[\frac{u_q(q_t,x_t^B)}{g_q\left(q_t,x_t^B\right)}-1\right]+\sum_{t=0}^{\infty}\beta^{t+1}\frac{u_x(0,x_{t+1}^S)\mathcal{M}_t}{\pi_{t+1}} \quad \text{(A-37)}\end{aligned}$$

Now, the second summation in (A-37) cancels with the first summation on the right-hand-side of (A-36) to yield

$$\begin{aligned}&\sum_{t=0}^{\infty}\beta^t u_x(0,x_t^S)\frac{\mathcal{M}_{t-1}}{\pi_t} - \sum_{t=0}^{\infty}\beta^{t+1}\frac{u_x(0,x_{t+1}^S)\mathcal{M}_t}{\pi_{t+1}}\\ = \;& u_x(0,x_0^S)\frac{\mathcal{M}_{-1}}{\pi_0}\end{aligned}$$

on the right-hand-side. Using (A-15) and (A-19) on the first summation in (A-37) we get

$$\begin{aligned}
&\sum_{t=0}^{\infty} \beta^t \frac{\beta u_x(0, x_{t+1}^S)\mathcal{M}_t}{\pi_{t+1}} \mu\left(n_t\right) \left[\frac{u_q(q_t, x_t^B)}{g_q\left(q_t, x_t^B\right)} - 1\right] \\
= \quad &\sum_{t=0}^{\infty} \beta^t g\left(q_t, x_t^B\right) \mu\left(n_t\right) \left[\frac{u_q(q_t, x_t^B)}{g_q\left(q_t, x_t^B\right)} - 1\right]
\end{aligned}$$

on the left-hand-side.

To summarize we simplified (A-36) to

$$\begin{aligned}
&\sum_{t=0}^{\infty} \beta^t \left\{u_x(0, x_t^S)X_t - AH_t + \mu\left(n_t\right) g\left(q_t, x_t^B\right) \left[\frac{u_q(q_t, x_t^B)}{g_q\left(q_t, x_t^B\right)} - 1\right]\right\} \\
&= u_x(0, x_0^S) \left[\frac{R_{-1}\mathcal{B}_{-1} + \mathcal{M}_{-1}}{\pi_0}\right]
\end{aligned} \tag{A-38}$$

using equilibrium conditions (A-15), (A-17), (A-18) and (A-19). This leaves equilibrium conditions (A-16), (A-20), (A-21) and (A-22). Out of these, (A-21) is redundant as long as (A-22) is included since we used the households' budget constraint to derive the PVIC. The rest of the remaining equations will have to be additional constraints on the Ramsey planner.

Given the allocations that are found from this problem, R_t will follow from (A-34) and the tax rate will follow from (A-15).

A.6 Solution to the Ramsey Problem

In solving this problem, we assume that $R_{-1}\mathcal{B}_{-1} + \mathcal{M}_{-1} = 0$, which means that the government does not have any net liabilities at time -1. This directly implies $\mathcal{A}_0 = 0$ in the PVIC. In what follows we use the following shorthands:

$$u^M \equiv u\left(q, x^B\right), \; u^N \equiv u\left(0, x^B\right), \; u^S \equiv u\left(0, x^S\right) \tag{A-39}$$

We also drop all arguments of remaining functions and after solving the Ramsey problem we impose steady state.

We also do a few simplifications. First, the Ramsey planner in this model does not have any intertemporal margins to manipulate as its clear from the fact that all variables are of period t. Since it will not create any confusion, we drop all time subscripts. Second, the

FOC of this problem with respect to H simply yields

$$-A-\xi A+S\nu=0 \tag{A-40}$$

which can be solved for

$$\nu=\frac{(1+\xi)A}{S} \tag{A-41}$$

and we use this directly in all the equations below.

The solution to the Ramsey problem that characterizes the optimal allocations and policies $\left(q,x^S,x^B,n,H,\xi,\iota,\eta,\lambda,\tau,R\right)$ is given by

$$\begin{aligned}&\mu u_x^M+(1-\mu)u_x^N+\xi\left\{u_x^S+\mu\left[g_x\left(\frac{u_q^M}{g_q}-1\right)+\frac{g}{g_q^2}\left(u_{qx}^M g_q-u_q^M g_{qx}\right)\right]\right\}-\frac{(1+\xi)A}{S}\\&+\lambda\left\{\mu\left[u_{xx}^M-\frac{u_q^M}{g_q^2}\left(g_{xx}g_q-g_xg_{qx}\right)-\frac{g_x}{g_q}u_{qx}^M\right]+(1-\mu)u_{xx}^N\right\}+\eta g_x+\iota\mu\left(u_{qx}^M-g_{qx}\right)=0\end{aligned} \tag{A-42}$$

$$(1+\xi)\left(u_x^S-\frac{A}{S}\right)+u_{xx}^S\left[\xi\left(\frac{x^B}{\Lambda}+x^S\right)-\frac{\lambda}{\Lambda}\right]=0 \tag{A-43}$$

$$\begin{aligned}&(1+\xi)u_q^M-\left(1+\frac{\eta}{\mu}\right)c_q+\left(\frac{\eta}{\mu}-\xi\right)g_q+\xi\frac{g}{g_q^2}\left(u_{qq}^M g_q-u_q^M g_{qq}\right)\\&+\lambda\left[u_{xq}^M-\frac{u_q^M}{g_q^2}\left(g_{qx}g_q-g_xg_{qq}\right)-\frac{g_x}{g_q}u_{qq}^M\right]+\iota\left(u_{qq}^M-g_{qq}\right)=0\end{aligned} \tag{A-44}$$

$$\begin{aligned}&u^M-u^N-c+\xi g\left(\frac{u_q^M}{g_q}-1\right)+\lambda\left(u_x^M-\frac{g_x}{g_q}u_q^M-u_x^N\right)\\&+\iota\left(u_q^M-g_q\right)-\frac{\kappa}{\mu'}\left(\rho\mu'+\rho'\mu+\rho'\eta\right)=0\end{aligned} \tag{A-45}$$

$$u_x^S\left(x^B+\Lambda x^S\right)-AH+\mu g\left(\frac{u_q^M}{g_q}-1\right)=0 \tag{A-46}$$

$$SH=x^B+\Lambda x^S+G \tag{A-47}$$

$$\mu\left(u_x^M-\frac{g_x}{g_q}u_q^M\right)+(1-\mu)u_x^N=u_x^S \tag{A-48}$$

$$g - c = \kappa\rho \tag{A-49}$$

$$\iota\mu\left(u_q^M - g_q\right) = 0 \tag{A-50}$$

along with (31) and (32).

Here (A-42), (A-43), (A-44) and (A-45) follow from the first-order conditions of the problem with respect to x^B, x^S, q and n respectively. (A-46) is the PVIC with steady state imposed and (A-47) is the resource constraint. Finally, (A-48) and (A-49) are the UT and FE conditions, which are equality constraints and (A-50) is the complementary slackness condition that arises from the ZLB.

A.7 Uniqueness of Equilibrium and the Ramsey Problem

We continue the discussion of equilibrium selection as a part of the Ramsey problem, given the issue of multiplicity of equilibria we explained in the previous section. First, the description of the problem in Proposition 2 assumes that the Ramsey planner picks a monetary equilibrium. This is consistent with the goal of the paper where we try to explain how inflation, an object that only makes sense in a monetary equilibrium, is determined. However, one may wonder if by focusing on monetary equilibria we are forcing the Ramsey planner to settle on suboptimal allocation, given that he can also choose to implement a nonmonetary equilibrium where inflation and interest rate are not defined and the IM is shut down. Paralleling Definition 5, here is the Ramsey problem when a nonmonetary equilibrium is selected.

Definition 6 *The nonmonetary version of Ramsey planner's problem is to choose allocations* $\left\{x_t^B, x_t^S, H_t\right\}$ *with* $x_t^B = x_t^S = x_t$ *to maximize the objective function*

$$\sum_{t=0}^{\infty} \beta^t \left(1+\Lambda\right) u\left(0, x_t\right) - AH_t \tag{A-51}$$

subject to the Present-Value Implementability Constraint (PVIC)

$$\sum_{t=0}^{\infty} \beta^t \left[\left(1+\Lambda\right) u_x(0, x_t) x_t - AH_t\right] = 0 \text{ (multiplier } \xi) \tag{A-52}$$

and the resource constraint (RC)

$$SH_t = (1 + \Lambda)\, x_t + G \;\; \textit{(multiplier } \nu\textit{)} \tag{A-53}$$

The solution to this problem is given by (x, H, τ, ξ) that satisfy

$$u_x + \xi\,(u_{xx}x + u_x) = \frac{A\,(1+\xi)}{S} \tag{A-54}$$

$$u_x x\,(1+\Lambda) = AH \tag{A-55}$$

$$(1+\Lambda)\, x + G = SH \tag{A-56}$$

$$\tau = 1 - \frac{A}{Su_x} \tag{A-57}$$

What matters for the rest of the analysis is that in solving for the optimal policy, we also solve for the optimal policy under the nonmonetary equilibrium and compare welfares of the monetary and nonmonetary solutions. In every single case, the monetary equilibrium clearly dominates the nonmonetary equilibrium and hence our focus on it is justified.

B Data

Our dataset consists of 125 countries, covering the period 1996-2015. We report some results for using the panel structure of the dataset. Most of our results are obtained using a cross-section where we take the average of each variable across years. Our analysis is restricted to countries with less than 20% annual inflation. A list of the countries along with the values for the five key variables used in the analysis are provided on Table A1. Below are detailed information for each of the variables used in this paper.[29]

Institutions

- **Rule of Law** (Main measure): From the World Bank, following Kaufmann et al. (2010). Calculated from 24 primary sources, that include a total of 74 different concepts. Sample concepts: losses and costs of crime, enforceability of government contracts, kidnapping of foreigners, organized crime, quality of police, money laundering, property rights, independence of judiciary, fairness of the court system. According

[29] The acronyms used are: PWT (Penn World Tables version 9.0) and WDI (World Development Indicators). Expressions in parantheses following data sources are the data mnemonics from the original source, where available. In the case of missing data for a given country, averaging is done over the available sample.

to the source, Rule of Law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.

- **Property Rights** : From WEF as a part of its Global Competitiveness Index. Answer to question 1.01: "In your country to what extent are property rights, including financial assets, protected? (1 = not at all, 7 = to a great extent)." Available for 2007-2013.

- **Government Integrity :** From Heritage Foundation Index of Economic Freedom. The score for this component is derived primarily from Transparency International's Corruption Perceptions Index, which measures the level of corruption in 180 countries. Available for 1998-2013.

- **Difficulty of Tax Evasion** : An index computed for this paper using underlying data of World Bank's Governance Matters project for the year 2005. Examples of questions / concepts: Corruption among public officials, quality of bureaucracy, institutional effectiveness, speediness of judicial process, accountability of public officials, competence of public personnel, tax effectiveness. Aimed to capture how well tax laws enforced.

Policy Variables

- **Inflation** : Annual change in CPI. From WDI (FP.CPI.TOTL.ZG).

- **Tax Rate** (Main Measure) : Effective average tax rate on labor income calculated as $\left(\tau^c + \tau^h\right) / (1 + \tau^c)$ where τ^c and τ^h are consumption and labor-income taxes, respectively, following the methodology of Mendoza et al (1994). Available for 34 countries. For Chile, Costa Rica, Mexico, Peru, Philippines, South Africa, Sri Lanka, Thailand and Tunisia, tax rate data comes from IMF World Economic Outlook (2003) covering unspecified periods (possibly as large as 1990-2002) for each country. For the remaining 25 countries, tax rate data come from Carey and Tchilinguirian (2000), averaged over 1991-1997.

- **Tax Revenue** : Tax Revenues (as percentage of GDP) from WDI. (GC.TAX.TOTL.GD.ZS)

- **Vegh-Vuletin Wedge :** Using highest marginal personal income tax rate and standard value-added tax calculated in Vegh and Vuletin (2015), we calculate the wedge

$\left(\tau^c + \tau^h\right) / (1 + \tau^c)$ where τ^c is the value-added tax rate and τ^h is the highest marginal personal income tax rate.

Macroeconomic Variables

- **Output** : Output per capita from PWT (rgdpo / pop).[30]
- **Output per worker** : Real GDP per worker from PWT (rgdpo / emp).
- **Government Spending** : Government Expenses (as share of GDP) from WDI. (GC.XPN.TOTL.GD.ZS)

Informal Activity

- **Size of Informal Sector** : From Hassan and Schneider (2016), computed using the DYMIMIC (dynamic multiple indicators multiple causes) method, as a fraction of formal (measured) GDP. See Schneider (2004) for more details. Available from 1999-2013.[31]

Instruments for Institutions

See Hall and Jones (1999) for detailed description of these variables.

- Distance from the Equator
- Log predicted trade share based on a gravity model of international trade that uses only the country's population and geographical factors, constructed by Frankel and Romer (1999).

[30] One issue that needs to be addressed is whether or not official estimates of GDP include any activity that could be labeled informal. Some statistical agencies (e.g. Bureau of Economic Analysis, see Bureau of Economic Analysis, 2001) adjust their estimates to reflect informal activity. We suspect many do not or the success of their adjustments vary. In our empirical analysis, we make the assumption that the macroeconomic data that we observe reflect only formal activity and do not include any information, either as explicit measurements or as adjustments, about the informal sector.

[31] There are a number of alternative estimates of the size of the informal sector that differ in terms of their methodology such as the currency demand approach or the physical input method. Schneider (2004) uses the DYMIMIC method, in which a set of equations provide causal relationships between two sets of variables and the size of the informal sector: those identified as causes of informal activity and those identified as being affected by informal activity. For example, these equations assume that burden of taxation and burden of regulation are among the causes, while various monetary and labor market variables are among those affected by informal activity. Since the DYMIMIC method provides only a relative measure across countries, Schneider (2004) combines his relative measures with absolute measures from the currency demand approach for some selected countries to compute absolute measures for all countries.

- Fraction of the population that speaks English
- Fraction of the population that speaks a European language

Freedom : From Freedom House, Freedom in the World 2008. Ranks countries according to subcategories: electoral process, political pluralism and participation, functioning of government, freedom of expression and belief, associational and organizational rights, rule of law, personal autonomy and individual rights and groups them in categories: free, partly free and not free.

C Empirical Results

In this section we present results of three sets of regressions we estimate using our data. Table A2 shows the results where we show how our three exogenous variables, rule of law, labor productivity and government expenditures / GDP ratio helps explain inflation and taxes. Table A3 shows how the size of the informal sector is related these exogenous variables, as well as inflation and taxes.

For these results we use two datasets. First is the cross-sectional data set where we take averages across time for each country. Second is the panel data set where we have country $\times$ year observations. In both datasets, we focus on countries where inflation in a year (in the panel data set) or average inflation (in the cross-sectional data set) is less than 20%. In the cross-sectional analysis, robust standard errors are used. In the panel analysis we cluster robust standard errors at the country level and we also include time fixed effects to capture a possible global factor. In all regressions a constant is included but it is not reported. For taxes, we use two measures. One is the marginal tax rate measure that is only available for 34 countries and the other is the tax revenue / GDP ratio, which is available for 124 countries. In Table A2, column (4) of panel (a) and column (3) of panel (b) show Instrumental Variables (IV) results where Rule of Law is instrumented by the Hall and Jones (1999) instruments we defined in Appendix B. In both cases (sample sizes are different) the first stage has an F-statistic that clears all Stock-Yogo thresholds for weak instruments and the J-statistic of overidentification restrictions is small not to lead to a rejection.

Panel (a) of Table A2 shows how inflation is related to the three exogenous variables. Focusing on columns (1) and (2), the exogenous variables explain about a third of the cross-country variation with Rule of Law explaining a very large part – the inclusion of the other two variables increase R^2 by only 0.02 and neither of them are significant at 5% significance. In terms of magnitude, given that Rule of Law is roughly between -1.5 and 2, these equations predict almost a 9% difference in inflation between the country with the worst and best institutions. The same conclusion holds in the panel version, albeit with a somewhat smaller coefficient. It's important to note that the panel regression does not include a country fixed effect and this coefficient is identified from the cross-country variation in Rule of Law, just like the cross-sectional regression, except here it is relative to whatever is captured by the time fixed effects. Column (4) shows that instrumenting Rule of Law does not change the key conclusion that it is an important predictor of cross-country differences in inflation.

Turning to panel (b), there are two key determinants of taxes: Rule of Law and the share of government spending in GDP. Comparing R^2 of columns (1) and (2), each variable roughly contribute equally in explaining two thirds of the variation in tax rates in our small sample of 34 countries. The contribution of Rule of Law (about a third) does not change much when we use IV results. When we use government revenues' share in GDP as the dependent variable the total explained variation falls to 44%, of which only 14% comes from Rule of Law, while government spending still accounts for about third. Finally, using the Vegh-Vuletin tax wedge measure, which covers 61 countries for which we also have other data, Rule of Law is very important with over 42% variation explained and the importance of government spending share is much reduced at 7%.

Table A3 shows the determinants of the size of the informal sector across countries. When the exogenous variables, especially Rule of Law is not controlled for, columns (1), (2), and (6) shows that inflation is positively and taxes are negatively related to size of the informal sector. We explain in the Introduction why these conclusions are counterintuitive if we take these equations as one where inflation and taxes are exogenous determinants of the size of the informal sector. Once the exogenous variables are controlled for, as in columns (3), (4), (5) and (7), both inflation and taxes become insignificant and Rule of Law and Labor Productivity explain over two thirds (over half in the panel) of the variation in informality.

Table A4 shows that our results are robust to changing the institutions measure to any of the three alternatives listed in Appendix B. To make the exposition simple, we report simple correlations in this table. First column shows that the three alternatives are highly correlated with Rule of Law, with correlations ranging from 0.89 to 0.97. The remaining columns show

how each of the four institutions measures are correlated with three key variables of our analysis: inflation, tax rates and size of the informal market. As should be expected given the high correlations in the first column, the strength of the relationships in these columns are very similar to those obtained by using Rule of Law.

Before we conclude, there are two assumptions we make in the model that we can at least partially back by some empirical evidence. First, our model is one of the long-run where we focus on explaining government policy in the long run by using the country's level of institutions. To justify this approach, as opposed to a more dynamic approach with shocks, we claimed that institutions move slowly. Using our panel data with 176 countries and 13 years we regress Rule of Law on its own lag, controlling for year fixed effects. The estimated coefficient is 0.99, indicating very high persistence and confirming our claim. Second, our model features a closed economy with no interaction with the outside world. To show that this is not unreasonable, for the narrow purpose of understanding inflation and taxation policies across countries, we extend columns (2) in both panels in Table A2 to include Openness and Openness $\times$ Rule of Law where openness is defined as standard (sum of exports and imports expressed as a fraction of GDP). In both of these new regressions the added coefficients are insignificant with the highest p-value at 0.22, while the rest of the equations looking similar to their counterparts in Table A2.

Table A1: Countries and Key Variables

Country	Rule of Law	Inflation	Tax Rate	Tax Revenue	Size
Albania	-0.71	4.22	-	15.43	43.34
Algeria	-0.78	4.70	-	33.80	32.50
Armenia	-0.40	5.32	-	16.59	44.65
Australia	1.76	2.65	30.83	23.00	14.26
Austria	1.86	1.89	51.50	26.16	9.80
Azerbaijan	-0.84	6.58	-	13.12	46.17
Bahrain	0.47	1.66	-	2.50	12.49
Bangladesh	-0.86	6.62	-	7.62	39.48
Barbados	1.17	3.43	-	25.61	41.81
Belgium	1.33	1.90	49.20	25.42	23.17
Belize	-0.27	1.98	-	21.27	52.05
Benin	-0.52	3.07	-	14.86	61.80
Bhutan	0.25	4.94	-	10.22	34.50
Bolivia	-0.80	5.98	-	14.37	72.75
Botswana	0.61	7.87	-	24.78	25.08
Brazil	-0.26	7.04	-	14.59	40.58
Bulgaria	-0.17	12.33	-	18.99	34.40
Burkina Faso	-0.52	2.56	-	13.08	49.31
Burundi	-1.25	11.31	-	13.89	49.08
Cabo Verde	0.47	2.21	-	20.89	35.10
Cambodia	-1.08	5.56	-	9.81	49.62
Canada	1.75	1.84	36.96	12.91	16.22
Central African Republic	-1.46	2.85	-	8.24	30.33
Chile	1.27	3.56	29.85	17.36	19.29
Colombia	-0.56	6.64	-	12.98	28.94
Congo, Rep.	-1.22	3.77	-	7.91	45.26
Costa Rica	0.50	8.98	22.57	13.57	31.92
Cote d'Ivoire	-1.19	2.63	-	14.15	41.18
Croatia	0.03	2.76	-	20.38	28.46
Cyprus	1.02	2.07	-	32.64	32.53
Czech Republic	0.90	3.03	46.90	13.85	18.99
Denmark	1.92	1.88	54.49	32.53	19.18
Dominican Republic	-0.62	9.37	-	13.06	38.26
Egypt, Arab Rep.	-0.18	8.38	-	14.24	37.77
El Salvador	-0.67	3.12	-	24.45	50.58
Estonia	0.98	4.87	-	1.06	27.57
Fiji	-0.41	3.38	-	22.45	29.84
Finland	1.96	1.57	54.77	21.24	19.00
France	1.41	1.49	49.32	22.20	15.15

Table A1: Countries and Key Variables

Country	Rule of Law	Inflation	Tax Rate	Tax Revenue	Size
Gambia, The	-0.30	5.62	-		63.19
Georgia	-0.51	6.98	-	17.03	49.72
Germany	1.66	1.42	44.65	11.14	15.76
Ghana	-0.06	16.82	-	16.05	44.40
Greece	0.67	2.75	36.17	12.29	33.25
Guatemala	-1.07	6.16	-	10.86	68.75
Honduras	-0.95	8.32	-	15.24	69.92
Hong Kong SAR, China	1.43	1.93	-	11.90	21.19
Hungary	0.77	6.21	51.95	21.79	25.94
Iceland	1.78	4.83	-	23.88	16.66
India	0.06	7.50	-	9.95	21.67
Indonesia	-0.65	10.19	-	12.11	19.30
Iran, Islamic Rep.	-0.83	18.64	-	6.50	17.57
Ireland	1.66	2.03	39.01	24.01	17.30
Israel	0.96	2.64	-	24.37	20.96
Italy	0.51	2.04	45.09	22.38	28.81
Jamaica	-0.42	11.02	-	25.18	41.02
Japan	1.32	0.11	28.77	9.97	14.09
Jordan	0.35	3.94	-	18.62	18.13
Kazakhstan	-0.85	10.20	-	13.41	46.25
Kenya	-0.89	9.74	-	16.09	28.53
Korea, Rep.	0.91	3.06	20.43	14.16	32.66
Kyrgyz Republic	-1.05	9.98	-	15.44	41.56
Lao PDR	-0.94	13.02	-	13.89	52.54
Latvia	0.59	4.98	-	20.38	26.18
Lesotho	-0.18	7.79	-	44.07	34.20
Liberia	-1.19	9.76	-	0.26	60.65
Lithuania	0.63	3.96	-	5.35	28.37
Luxembourg	1.80	2.02	-	24.93	11.00
Macedonia, FYR	-0.37	2.24	-	17.69	33.16
Madagascar	-0.55	9.91	-	10.18	42.67
Malawi	-0.26	17.44	-	14.87	37.64
Malaysia	0.51	2.54	-	15.32	35.15
Maldives	-0.10	4.05	-	12.70	22.64
Mali	-0.42	2.52	-	12.68	45.31
Malta	1.37	2.11	-	41.43	26.63
Mauritius	0.94	5.23	-	16.88	22.80
Mexico	-0.52	6.96	22.31	9.17	31.41
Moldova	-0.41	10.61	-	17.47	56.11
Mongolia	-0.22	11.90	-	17.14	21.78

Table A1: Countries and Key Variables

Country	Rule of Law	Inflation	Tax Rate	Tax Revenue	Size
Morocco	-0.09	1.83	-	21.67	37.57
Mozambique	-0.68	10.81	-	19.58	44.22
Namibia	0.17	5.74	-	29.06	28.88
Nepal	-0.66	7.55	-	11.22	42.35
Netherlands	1.78	1.84	50.29	20.99	14.93
New Zealand	1.87	2.21	36.73	29.00	13.51
Nicaragua	-0.73	8.43	-	13.04	49.76
Nigeria	-1.22	12.06	-	2.67	49.09
Norway	1.93	1.89	49.17	26.31	20.02
Oman	0.55	2.87	-	2.36	14.70
Pakistan	-0.83	8.59	-	10.39	31.07
Paraguay	-0.95	7.30	-	11.54	40.23
Peru	-0.64	3.58	19.16	14.93	59.41
Philippines	-0.42	4.59	19.89	13.11	36.71
Poland	0.61	4.25	52.34	17.11	26.58
Portugal	1.12	2.10	35.85	20.89	25.72
Romania	-0.05	14.52	-	17.27	32.93
Russian Federation	-0.86	14.36	-	14.08	43.60
Rwanda	-0.66	6.75	-	12.95	37.94
Senegal	-0.19	1.55	-	17.12	50.37
Serbia	-0.66	19.28	-	21.30	34.12
Sierra Leone	-1.08	9.07	-	8.54	52.34
Singapore	1.62	1.79	-	13.33	13.24
Slovak Republic	0.42	4.09	-	10.39	22.67
Slovenia	0.98	3.88	-	19.18	27.69
South Africa	0.09	5.95	33.77	25.10	29.29
Spain	1.15	2.33	38.79	14.33	25.13
Sri Lanka	0.06	8.83	22.08	13.02	49.23
Suriname	-0.21	12.36	-	18.87	30.04
Swaziland	-0.61	7.41	-	22.90	39.27
Sweden	1.89	1.03	56.61	27.50	18.78
Switzerland	1.87	0.48	35.61	9.47	9.11
Tajikistan	-1.14	9.60	-	9.77	54.90
Tanzania	-0.40	8.90	-	12.42	67.19
Thailand	0.05	2.94	24.18	15.25	58.59
Togo	-0.89	2.58	-	15.92	31.01
Trinidad and Tobago	-0.02	6.28	-	25.54	30.77
Tunisia	-0.01	3.88	34.06	19.62	39.99
Uganda	-0.48	7.14	-	11.35	43.26
Ukraine	-0.84	17.01	-	16.50	52.48

Table A1: Countries and Key Variables

Country	Rule of Law	Inflation	Tax Rate	Tax Revenue	Size
United Kingdom	1.69	2.12	32.42	25.31	13.92
United States	1.56	2.20	27.05	10.45	9.20
Uruguay	0.56	9.98	-	17.91	52.84
Vietnam	-0.42	7.54	-	19.90	17.48
Yemen, Rep.	-1.21	12.23	-	11.87	29.58
Zambia	-0.47	15.61	-	14.70	38.62
Average	**0.11**	**6.02**	**37.73**	**16.72**	**33.76**
Minimum	**-1.46**	**0.11**	**19.16**	**1.00**	**8.60**
Maximum	**1.96**	**19.28**	**56.61**	**30.69**	**67.83**

Table A2: Determinants of Government Policies

(a) Inflation

	(1)	(2)	(3)	(4)
Rule of Law	-2.54(***) (0.26)	-2.42(***) (0.82)	-1.72(***) (0.35)	-
Rule of Law (instrumented)	-	-	-	-2.07(***) (0.42)
Labor Productivity	-	-0.02 (0.02)	-0.01 (0.01)	-
Government Expenditure / GDP	-	0.07(*) (0.03)	0.01 (0.02)	-
R^2	0.33	0.35	0.24	0.31
Dataset	CS	CS	Panel	CS
Countries	125	125	144	95
Years	-	-	16	-

(b) Taxes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rule of Law	8.71(***) (1.58)	4.38(*) (2.37)	-	2.89(***) (0.63)	2.23(*) (1.31)	6.71(***) (1.09)	2.47 (2.00)
Rule of Law (inst.)	-	-	11.78(***) (1.78)	-	-	-	-
Labor Productivity	-	0.02 (0.07)	-	-	-0.09(*) (0.05)	-	0.12(*) (0.07)
Gov Exp / GDP	-	0.67(***) (0.13)	-	-	0.47(***) (0.07)	-	0.24(**) (0.11)
R^2	0.35	0.67	0.31	0.14	0.44	0.42	0.49
Dependent Variable	Tax	Tax	Tax	Rev	Rev	V-V	V-V
Countries	34	34	34	124	124	61	61

Notes: All regressions contain a constant that is not reported. Numbers in parantheses are robust standard errors. (***), (**) and (*) denote statistical significance at 1%, 5% and 10% levels, respectively. In panel (a) For dataset "CS" refers to the cross-section obtained by averaging observations over time for each country and "Panel" refers to the panel that contains all country × year observations where annual inflation is less than 20%. In the panel regression time fixed effects are included and standard errors are clustered at the country level. In panel (b) all regressions use the cross-section data set. The dependent variables in panel (b) are the average marginal tax rate (Tax), government revenue to GDP ratio (Rev) and the Vegh-Vuletin tax wedge (V-V).

Table A3: Determinants of Size of Informal Sector

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Inflation	1.24(***)	-	-0.29	-	-0.25	0.86(***)	-0.24
	(0.31)		(0.26)		(0.27)	(0.22)	(0.17)
Tax Rate	-	-0.56(***)	-	-0.03	-	-	-
		(0.17)		(0.13)			
Rev / GDP	-	-	-	-	0.11	-0.22(*)	0.13
					(0.12)	(0.12)	(0.10)
Rule of Law	-	-	-5.71(***)	-11.28(***)	-6.20(***)	-	-6.70(***)
			(1.92)	(2.89)	(1.89)		(1.32)
Labor Prod	-	-	-0.22(***)	-0.08	-0.20(***)	-	-0.18(***)
			(0.06)	(0.09)	(0.06)		(0.03)
Gov Exp / GDP	-	-	-0.00	0 .04	-0.04	-	-0.01
			(0.08)	(0.13)	(0.10)		(0.08)
R^2	0.13	0.26	0.55	0.72	0.56	0.09	0.52
Dataset	CS	CS	CS	CS	CS	Panel	Panel
Countries	125	34	125	34	124	136	130
Years	-	-	-	-	-	15	13

Notes: All regressions contain a constant that is not reported. Numbers in parantheses are robust standard errors. (***), (**) and (*) denote statistical significance at 1%, 5% and 10% levels, respectively. For dataset "CS" refers to the cross-section obtained by averaging observations over time for each country and "Panel" refers to the panel that contains all country × year observations where annual inflation is less than 20%. In the panel regression time fixed effects are included and standard errors are clustered at the country level.

Table A4: Robustness of Results to Different Institutions Measures

	Rule of Law	Inflation	Tax Rate	Informal Size
Rule of Law	-	-0.57	0.59	-0.71
Property Rights	0.89	-0.60	0.47	-0.68
Government Integrity	0.95	-0.57	0.53	-0.68
Difficulty of Tax Evasion	0.97	-0.59	0.62	-0.69

Notes: The table report simple correlations of the three key variables with the benchmark institutions measure (first row) and same correlations with three alternative measures (remaining rows) as well as the correlation of these three measures with the benchmark measure (first column).