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ABSTRACT

Income Tax Flattening: Does It Help to Reduce the Shadow Economy?

This paper examines the effect of global transition to simpler, flatter income tax systems on the size of the shadow economy. By offering a new estimation framework, the paper revives the traditional electricity consumption approach to measuring the shadow economy. It overcomes the limitations of previous literature by using a new functional form, better quality data, a larger sample of 170 countries, a longer time span of 25 years, a panel framework, and instrumental variables. Our analysis provides strong evidence of a positive relationship between income tax rates and the size of the shadow economy. The effects of structural progressivity and complexity of national tax schedules are also found to be positive and statistically significant. These positive effects are reinforced when tax changes are accompanied by improving government services and strengthening the legal system. The flat tax is estimated to reduce the shadow economy in the short run, but this effect diminishes and disappears in the long run.

JEL Classification: D73, H1, J3, J4, O1, P2

Keywords: shadow economy, tax evasion, personal income tax, corporate income tax, flat tax, structural progressivity, tax complexity, electricity approach, institutions

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1. Introduction

The last three decades witnessed a considerable change in income tax systems throughout the world. Many countries opted for notably lower rates, flatter tax schedules, and simpler filing systems. Figure 1 shows that between 1981 and 2005 for 189 countries there is a decline in the top statutory corporate income tax (CIT) rate from 39% to 28% and an even stronger decline in the top personal income tax (PIT) rate from 47% to 29%.[1] The average number of PIT brackets dropped considerably from an average of 11 tax brackets per tax system in 1981 to 4 tax brackets per tax system in 2005. The aggregate tax complexity index also fell by 20%. Flat personal income tax rates are becoming increasingly popular.[2] Even where a flat tax was not introduced, many countries chose to flatten their PIT schedules by reducing the upper rates. Clearly, taxpayers on average face significantly lower tax rates and flatter and simpler tax structures than they did twenty five years ago. But to what end? Are these new policies and tax reforms effective and do they generate changes on the real side of the economy?

While this paper does not attempt to definitely answer all of these questions, it does address the important issue of how global tax reforms affected the shadow economy. After all, one reason for reducing tax rates in the higher brackets and making tax systems simpler is to bring more potential tax payers into the official economy from the shadow economy. This justification seems intuitive and reasonable, can be rationalized by the theory, and sounds convincing in political rhetoric. Yet, there is little support for this justification in the empirical

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[1] Figure 1 is constructed on the basis of the 1981-2005 World Tax Indicators (WTI v.1) described in Peter, Buttrick, and Duncan (2007).

[2] Estonia, Lithuania, Latvia, Russia, Serbia, Slovak Republic, Ukraine, Romania, and Georgia are examples of the countries that have introduced one-rate income tax schedules in recent years. Other countries such as Croatia, Czech Republic, Greece, and Mexico are giving a flat tax schedule serious consideration. By 2005, more than 8% of the countries have one flat PIT rate, as compared to less than 1% in the early 1980s, respectively. By 2008, the number of flat tax countries is expected to increase to 21 as seven more countries (Albania, Kazakhstan, Kyrgyzstan, Mongolia, Montenegro, Poland, and Republic of Macedonia) introduced or announced introduction of the flat PIT in 2007-2008.

research. The existing estimates of the effect of taxes on the shadow economy are highly inconsistent across different studies and vary from being positive and significant in early one-country studies (Clotfelter 1983, Slemrod 1985, Schneider 1986) to being insignificant or even strongly negative in the latest cross-country literature (Johnson et al 1998a, Friedman et al 2000, Torgler and Schneider 2006). There seems to be a fundamental contradiction between the justification espoused by policy makers that lowering taxes will bring potential tax payers back in to the official economy, thus reducing the size of the shadow economy,[3] and the glaring lack of empirical evidence to support this contention.

This paper re-examines the link between the tax policy and the shadow economy by using new comprehensive panel tax data for 189 countries from 1981 to 2005. The collected data represent approximately 94% of the world population and 98.5% of the world output for the entire period. By offering a new estimation framework, the paper revives the traditional electricity consumption approach to measuring the shadow economy. It shows that under certain assumptions, a correctly specified function for the log of electricity per output can produce a consistent estimate of the effect of the tax burden on the shadow economy. This approach requires large data collection efforts, which were undertaken to gather various taxation variables, macro indicators, energy prices, weather conditions, and energy consumption statistics.

Unlike previous cross-sectional studies, this paper seeks to establish the causal effect of tax policy and therefore requires attention to identification problems. If a growing shadow economy motivates governments to increase the tax base by either reducing rates or simplifying

[3] For example, many policy makers praise the flat tax rate and believe in its power to reduce the shadow economy. Macedonia's Prime Minister, Nikola Gruevski, says "this [flat-tax] reform will decrease tax evasion and encourage people to meet their obligations to the state." Giorgios Alogoskoufis, Finance Minister of Greece, believes “a flat tax rate, by discouraging evasion and corruption and also boosting incentives for high earners, would help narrow the deficit.” Prime Minister of Bulgaria Sergei Stanishev states that "the introduction of the flat tax is expected to generate more money for the country and bring undeclared incomes ‘to light’".

the tax system, then the corresponding tax policy is endogenous, even when country fixed effects (FE) are included. To address the potential endogeneity in the relationship between the tax policy and the shadow economy, tax rates and other features of tax systems in neighboring countries are employed as instrumental variables (IV) for national tax variables. The IV estimates with country fixed effects consistently show a strong positive effect of top statutory corporate and personal income tax rates on the size of the shadow economy. Similar positive and statistically significant effects are found for actual average and marginal PIT rates at different levels of income and for the tax complexity measure.

This paper also examines the relation between the structural progressivity of PIT schedule and changes in the shadow economy. A flatter PIT schedule featuring slower growing average and marginal rates along the income distribution is estimated to have a negative impact on the shadow economy, *ceteris paribus*. This finding also holds for the case of flat income tax rate with zero structural progressivity; however, it holds only in the short run. The estimates suggest that while flat tax rates help to decrease the shadow economy in the first year after its adoption, this effect declines (in absolute terms) and fades away in 5 to 9 years afterwards.

Perhaps the most important finding of this paper is how institutions affect agents in the unofficial economy as they respond to changes in tax policy. While regressions through the mean show a positive effect of the tax burden on the size of the shadow economy, this effect is not ubiquitous. In the countries with poor institutions, simple tax cuts are not found to be effective in reducing the shadow economy. For the tax policy to have such an effect, countries should already have some governance put in place. The stronger the institutions, the stronger the impact taxation has on shadow economy activity.

The rest of the paper is organized as follows. Section 2 introduces the electricity-based measure of the shadow economy and shows its usability and main weak points. In Section 3, an attempt is made to overcome these weak points and to derive an empirical one-stage model of the shadow economy based on electricity or energy consumption. Section 4 discusses theoretical and empirical relationship between the tax policy and the shadow economy. Section 5 introduces data, variables, and sources. Section 6 provides with the FE and IV estimates of the basic specification of the shadow economy function using top statutory tax rates. In Section 7, I consider several measures of structural progressivity and complexity of the national tax schedules and estimate the effect of these measures on the size of the shadow economy. Section 8 offers an empirical analysis of the interactions between tax policy and institutions in their impact on the shadow economy, followed by Section 9 that draws conclusions.

2. The Electricity-Based Measure of the Shadow Economy

The idea behind the electricity consumption method (ECM) of measuring the shadow economy is clever and straightforward. It is based on the presumption that electricity consumption is a single best indicator of total economic activity. As a product, electricity is homogeneous and measured in consistent physical units, it has relatively low substitutability with other goods and services, and it is difficult to hide. Assuming unitary elasticity of electricity consumption with respect to total output, the difference between the growth rate of electricity consumption and the growth rate of recorded output (official GDP) can be attributed to the growth rate in the shadow economy. Thus, the whole time-series for the share of the shadow economy in GDP can be constructed using the independent estimate of the initial value of the shadow economy and its growth rates.

The paper by Kaufman and Kaliberda (1996) was the first study that applied this method to a number of transition economies. Although the authors did not write their formula for the size of the shadow economy explicitly, it can be derived based on their description:

$$S_t = S_{t-1}\left(1+\frac{1}{\mu}g_{Et} - g_{Yt}\right) = S_0\prod_{i=1}^{t}\left(1+\frac{1}{\mu}g_{Ei} - g_{Yi}\right) \quad (1)$$

where S_t is the output in the shadow economy in year t, S_0 is the output in the shadow economy in base year, g_{Et} is the annual growth rate of electricity power consumption (dE/E), g_{Yt} is the annual growth rate of recorded GDP (dY/Y), and μ is the constant output elasticity of electricity consumption $\mu=(dE/E)/(dT/T)$, where T is total output in recorded and unrecorded activities ($Y+S$). μ is assumed to be unitary or varied by the type of countries (0.9 for "energy-efficient" Central and Eastern European countries, 1 for "energy-neutral" Baltic countries, and 1.1 for "energy-inefficient" former Soviet Union (FSU) republics). Since the data on GDP and electricity power consumption are widely available, the Kaufman-Kaliberda method became very popular and has been applied literally to any country that has a plausible base-year value of S_0 from an outside data source, generating the vast dataset on the size of the shadow economy throughout the world.

The growing number of estimates of the shadow economy also made it possible to exploit the cross-country heterogeneity in examining the determinants of the size of the shadow economy, in particular the effect of taxation, regulations, and institutions. Among the most cited studies are Johnson et al. (1997) for 15 transition economies, Johnson et al. (1998) for 32-49 countries (mostly from OECD and the former Soviet block), and Friedman et al. (2000) for 69 different countries. Using cross-sectional data, these studies found a predictable positive effect of over-regulations, weak legal system, and corruption on the size of the shadow economy. At the same time, the effect of taxation was estimated to be zero and even negative in some specifications, which is explained by higher tax rates generating revenue that provides productivity enhancing public goods and a strong legal environment. However, reverse causality might be responsible for some of the above results: a larger shadow economy reduces the tax base needed to develop strong institutions and creates the demand for tax cuts. With a reverse causality of this kind, the effect of taxes will be understated, and the effect of weak institutions and over-regulation will be overstated (in absolute terms) in the shadow economy function. Unfortunately, these important relationships were not subsequently re-tested in the panel data framework. Instead, a considerable number of papers have been written to criticize the electricity-based measure of the shadow economy itself, thus demeaning the possibility of the unbiased estimates of the effect of institutions, regulations, and taxes on the size of the shadow economy.

It has been argued that the ECM measure is sensitive to the initial value of the shadow economy (S_0) that, for example, was arbitrarily set as 12% for former Soviet Union republics in 1989 (Alexeev and Pyle 2003). As equation (1) shows, changing the initial values S_0 also changes the current size of the shadow economy S_t. The method has also been criticized for its strong assumptions on the output elasticity of electricity consumption μ (Eilat and Zinnes 2002). The method does not take into account the relative price changes, changes in the output mix, changes in weather, and energy-saving technological progress that also affect μ (Eilat and Zinnes 2002, Hanousek and Palda 2006).[4] The final estimates of the shadow economy by the Kaufman-Kaliberda method are found to be implausible. For example, high estimates are obtained for Ukraine (48.9% in 1995), low estimates are for Uzbekistan (6.5%) and Romania (19.1%), and

[4] Kaufmann and Kaliberda (1996) acknowledge some of the problems themselves and speculate that on average downward-biasing factors might offset the upward-biasing factors.

the shadow economy in the Slovak Republic is twice as low as in the Czech Republic (5.8% vs. 11.3% in 1995) (Lacko 2000). Furthermore, the replication of the method (even with higher initial values) produces negative estimates of the shadow economy for a number of countries (Feige and Urban 2003).

These are all important and valid criticisms of the ECM measure. However, as I will show below, the general problems with the ECM measure do not necessarily create biased coefficients on institutions, regulations, and taxes if appropriate covariates are used in the panel model of the shadow economy. The following model is written in an attempt to address the above criticisms of the ECM measure and to help in drawing proper inferences on the institutional determinants of the shadow economy.

3. The Empirical Model of the Shadow Economy

The relative size of the shadow economy can be linked to the electricity/energy consumption through the following identity:

$$\ln\left(\frac{E}{Y}\right) = \ln\left(\frac{T}{Y}\right) + \ln\left(\frac{E}{T}\right), \qquad (2)$$

where T is total output in the official and shadow sectors (T=Y+S) and E could denote either electricity consumption or total primary energy consumption, which includes the consumption of petroleum, natural gas, and coal, in addition to electric power. By including additional sources of energy, we can allow for the potential substitution effect among energy sources due to relative price changes.

The first term of equation (2) captures the log deviations of recorded GDP (Y) from total output (T), and hence it approximates the relative size of the shadow economy.[5] We can model this term as a function of observable economic and institutional determinants of the shadow economy X (e.g., tax burden, government size, law and order, macroeconomic volatility, etc.) and an unobserved error term ν, that is $\ln\left(\frac{T}{Y}\right) = X\beta + \nu$, with $E(\nu)=0$, $Cov(X,\nu)=0$.[6]

The second term can be modeled in two ways. First, we can assume a relatively flexible functional form for energy consumption such as $E=AT^{\mu}$, where μ is the output elasticity of energy consumption. Note that if $\mu \to 1$ (the standard assumption of the shadow economy estimates), then $\ln(E/T) \to \ln A$, which is constant, and hence the $\ln(E/Y)$ function simplifies to the shadow economy function.

In more general case, the formula for the second term is

$$\ln\left(\frac{E}{T}\right) = \frac{1}{\mu}\ln A + \left(1-\frac{1}{\mu}\right)\ln E \,. \tag{3}$$

By substituting (3) into (2), we derive a functional form (4) that allows us to estimate β and μ. The disadvantage of this approach is that μ is neither country-specific nor time-variant.

$$\ln\frac{E}{Y} = \frac{1}{\mu}\ln A + \left(1-\frac{1}{\mu}\right)\ln E + \left(X\beta + \varepsilon\right). \tag{4}$$

The second approach is less restrictive in this regard, but it is more data demanding. The assumption of constant elasticity can be relaxed by modeling the second term of equation (2) as a linear function of variables Z that affect the log ratio of energy consumption and total output.

[5] Note that if S/Y is sufficiently small, the first term of equation (2) becomes the ratio of output in the shadow economy relative to recorded GDP, that is $\ln(T/Y) = \ln(S/Y+1) \to S/Y$.

[6] The zero covariance assumption will be relaxed and addressed in Section 6 below.

$$\ln\left(\frac{E}{T}\right) = Z\gamma + \varepsilon, \text{ with } E(\varepsilon) = 0, Cov(Z, \varepsilon) = 0 . \tag{5}$$

The *Z* vector includes observable factors that alter energy/electricity consumption without a corresponding change in total output such as energy-saving technological progress, changes in output mix and relative prices, and weather fluctuations. For instance, the share of renewable sources in total energy consumption might be a good measure of the efficient energy use. Services and agriculture tend to be less energy consuming than manufacturing, and hence changes in output mix might be another relevant *Z* factor. Lagged GDP per capita is another proxy for technological progress and overall total factor productivity. Higher energy prices relative to the prices for other goods and services generally lead to a higher degree of energy conservation in both consumption and production. Studies by Eilat and Zinnes (2002) and Hanousek and Palda (2006) indicated that colder climate is positively associated with higher electricity consumption per unit of output.

By substituting equation (5) into (2), our model becomes

$$\ln\left(\frac{E}{Y}\right) = X\beta + Z\gamma + (\nu + \varepsilon). \tag{6}$$

If *X* is uncorrelated with the error term and with *Z*, we can omit the *Z*-vector from equation (6) and still obtain consistent, although less efficient, estimates of β. Under these assumptions, it would be proper to use the two-stage estimation procedure, e.g., first obtain the size of the shadow economy by the Kaufman-Kaliberda method and then regress it on the economic and institutional characteristics *X*. It would also be appropriate under these assumptions to measure the GDP share of the shadow economy by the modified ECM (Eilat and

Zinnes 2002), and then in the second stage regress the obtained shares on the set of economic and institutional characteristics.[7]

However, common sense suggests that the correlation between *X* and *Z* is likely to exist. Changes in energy/electricity prices might be associated with price liberalization and thus be correlated with other deregulation policies and institutional changes. The energy/electricity prices are also likely to fluctuate during the periods of macroeconomic instability when informal economies tend to rise. A country's efforts on renewable energy development could be driven by stronger government institutions. Also, trade and other services tend to grow following the economic liberalization reforms. Perhaps the only variable that could be omitted without serious consequences if country fixed effects are included is cold weather.[8] Thus, to obtain the unbiased and consistent estimates of β, the Z vector has to be included in a shadow economy function (6).

The above discussion shows that not only *X* and *Z* vectors are correlated with each other but they can also overlap. For example, the output mix is an important determinant of the shadow economy as it is easier to avoid taxes in agriculture and services than in manufacturing (Torgler and Schneider 2006). Furthermore, shifts from agriculture to manufacturing and from manufacturing to a service-based economy reflect the general stages of economic development that may influence the evolution of the shadow economy. Changes in energy prices might be indicative of macroeconomic volatility as well as the possibility of rent extractions in energy-

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[7] The modified ECM constructs the shadow economy series using residuals from regressing an annual percentage change in electricity consumption against changes in electricity prices, industry share of GDP, and private sector share in GDP. The Eilat-Zinnes method improves the Kaufman-Kaliberda method by accounting for other factors that may influence the discrepancy between the electricity consumption growth and total output growth. However, if someone takes the shadow economy estimates obtained by the modified ECM and regress them against taxes and other country characteristics in a separate regression, it would produce the biased estimates unless these characteristics are uncorrelated with price changes, structural changes, and privatization, which is not a realistic assumption.

[8] Without country fixed effects, climatic conditions should not be omitted from the shadow economy function since they may affect the overall productivity (Sachs 2001) and participation in informal activities, especially in agriculture.

exporting countries, thus, affecting the shadow economy. For these factors, it would be difficult to separate the energy efficiency effect from the shadow economy effect.

Likewise, for β to be interpreted as the effect of X on the shadow economy, the corresponding X variable should not belong to the Z vector, i.e., it should not alter the technological relation between energy consumption and total output. For example, personal income taxes can be argued to be such a variable. According to the general equilibrium models of tax incidence, these taxes are borne entirely by workers and, therefore, do not affect a firm's technological decision to substitute more expensive labor for energy (Musgrave, Case and Leonard 1974).[9] Corporate income taxes, on the other hand, are generally considered to be born by capital and affect the demand for capital (Harberger 1962). As such, they could potentially affect energy use depending on the degree of its substitutability or complementarity with capital. However, a recent survey of 22 studies and 155 different estimates concludes that the cross-price elasticities between energy and capital tend to be close to zero (Koetse, de Groot, and Florax 2006), and thus an increase in CIT rates (via capital prices) is unlikely to alter the relationship between energy use and total output. Consequently, one can interpret the coefficients on both PIT and CIT rates in equation (6) as the shadow economy effects under the assumption that all potential effects of taxes on energy efficiency cancel out and, on average, become insignificant.

It is also important to control for time-invariant unobserved country heterogeneity as a first step in treating the endogeneity problem in X that will be discussed in Section 6. Country fixed effects can account for many country characteristics such as geographic location, size,

[9] In principle, higher personal income taxes may reduce the demand for residential energy via the income effect. However, the income elasticity of the demand for residential energy is generally found to be small. Furthermore, the income effect may equally affect household economic activity, thus keeping the E/T ratio unchanged. But even if there is a decline in the use of residential energy per unit of output in response to higher personal income taxes, it will produce a "good" downward bias in our estimates, implying that we are *understating* the effect of taxes on the shadow economy.

natural resource endowment, ethnic fractionalization, time-invariant social norms, legal and colonial origins, and other essential determinants of the shadow economy. In this case, the identification of causal effects relies on within-country variation over time as opposed to between-country variation.

$$\ln\left(\frac{E}{Y}\right)_{it} = \beta X_{it} + \gamma Z_{it} + \xi_t + \alpha_i + u_{it}\,, \qquad (7)$$

where α_i are country fixed effects and ξ_t are year effects.

The above empirical model is simple to estimate, and it has several important advantages over the cross-sectional regression of the standard ECM measure of the shadow economy on *X*'s. The model does not require assumptions on the initial values of the shadow economy for which the Kaufman-Kaliberda method has been criticized. There is no need to assume unitary or any constant value for the output elasticity of energy consumption. This model reduces the bias in coefficients on taxes due to including previously omitted variables *Z*. Finally, the model is estimated in one stage, and thus it avoids the two-stage estimation biases caused by the correlation between *X* and *Z*.

4. Taxes and the Shadow Economy

Now, as we established that it is possible to estimate the effect of taxes and other government interventions on the size of the shadow economy in a consistent way, we can turn to the central question of the paper about whether tax policies cause the shadow economy contract or grow.

Previous studies provide conflicting evidence on the effect of taxes. The estimates vary from being positive and significant mostly in one-country studies to being insignificant or even strongly negative in cross-country data. For example, using IRS tax returns to evaluate the 1986

U.S. Tax Reform, several studies show a positive effect of marginal tax rates on tax evasion (Clotfelter 1983, Slemrod 1985). Schneider (1986) finds that the average and marginal tax rates have a positive and significant influence on the shadow economy approximated by the demand for currency in Denmark, Norway, and Sweden. Similar results are found for Austria, Germany and other developed countries. See Schneider and Enste (2000) for a comprehensive review of these studies. Recently, Gorodnichenko et al (2008) report large and statistically significant reduction in tax evasion following the 2001 Russian flat tax reform.

However, multiple-country studies were not able to reproduce this result. Applying the MIMIC (Multiple Indicators Multiple Causes) method to a cross-section of 14 Latin American countries, Loyaza (1997) reports insignificant (though positive) effect of top marginal corporate income tax rates on the value-added tax evasion and the percent of non-agricultural labor force not contributing to social security. Results in Johnson et al. (1998a, b) are mixed and include strong negative effect of top marginal tax rates (both personal and corporate) on the size of the shadow economy but positive effect of the subjective tax burden index from the 1997 Global Competitiveness Survey. Friedman et al. (2000) also show either negative or zero influence of marginal taxes on the shadow economy for the cross-section of 69 countries. Using the 3-year pooled OLS model with four regional fixed effects, Torgler and Schneider (2006) find that an increase in top marginal tax rates reduces the size of the shadow economy; however, this effect vanishes after controlling for tax morale and labor market regulations. Dreher and Schneider (2006) estimate a statistically significant negative coefficient on the Heritage Foundation Index of Tax Burden but statistically insignificant coefficients on all other tax variables, including top marginal personal income tax rates and taxes on international trade.

The common explanation for the observed weak relationship between taxes and the size of the shadow economy is that it is not high tax rates that cause the shadow economy to grow but onerous bureaucracy, the corrupt system of tax administration, and over-regulation by the government that matter. Someone may argue, however, that the importance of institutional factors does not really explain why tax rates should not be relevant as well. It has yet to be established if this statistically weak result is driven by empirical limitations (e.g., small sample size, unaccounted endogeneity of tax rates, measurement error, etc.) or a more fundamental, intrinsic relationship between the tax rates and the shadow economy.

In principle, it can be shown that the non-linear relationship between taxes and government services might be responsible for the conflicting results in the linear shadow economy functions. To illustrate this point, let's look at the existing model of resource diversion (Friedman et al. 2000). In this model, the entrepreneur maximizes utility derived from the reported official output (*Y-D*) and the output diverted to the shadow economy (*D*). The official output is taxed at rate τ, and it is subject to bureaucracy cost *r* per unit of output. The unofficial output is also costly, with a convex cost structure and a penalty *k* that serves as a proxy for the strength of legal institutions or "law and order".

$$Max\ U(D,\tau,r,k,g) = (1-\tau-r)(Y-D)R(g) + D - \frac{k(g)D^2}{2} \qquad (8)$$

Since the official sector has a better access to productivity-enhancing public services, it is assumed to be more productive, with the relative efficiency $R>1$. The efficiency of the official sector as well as "law and order" could be improved via better government services *g* such that $R_g>0$ and $k_g>0$. From the first order conditions, the optimal amount of diversion to the shadow economy is derived as

$$D^*(\tau, r, k, g) = \frac{1-(1-\tau-r)R(g)}{k(g)} \tag{9}$$

If government services are exogenous (i.e., independent of τ), the comparative statics with respect to all parameters is straightforward: high bureaucracy cost r, low penalty rate k, poor government services g, and high tax rate τ all increase the size of the shadow economy. However, if government services enter the model as a function of taxes $g(\tau)$, the sign of the partial derivative of D^* with respect to τ becomes ambiguous.

$$\frac{\partial D^*}{\partial \tau} = \frac{1}{k^2}\left[Rk-(1-\tau-r)R_g g_\tau - \left[1-(1-\tau-r)R\right]k_g g_\tau\right] \gtreqless 0 \tag{10}$$

It is important to note here that for a country that optimally chooses its tax rates to maximize government services (g_τ=0), the effect of tax rates on the size of the shadow economy is unambiguously positive (R/k). Yet, for a country that does not maximize its revenues (e.g., due to different objectives, uncertainty, corruption of officials, etc.), the sign is ambiguous. For example, if government services are not productivity-enhancing (R_g<0), ineffective in improving "law and order" (k_g<0), and decreasing with higher tax burden (g_τ<0), the effect of taxes on the size of the shadow economy might be zero or even negative.

Theoretically, it is plausible that in the cross-section, on average, the positive effect of taxes on the shadow economy cancels out its negative effect, and the resulting estimate becomes insignificant in the linear specification. This suggests that in empirical work it might be necessary to include an interaction term between taxes and institutions in the shadow economy function. Countries with stronger institutions are more likely to choose their tax rates optimally and display the positive effect of taxes on the size of shadow economy. In countries with poor governance, the responsiveness of the shadow economy to changes in tax rates is going to be attenuated by corruption, weak legal institutions, and ineffective government services.

In addition to the problems with the functional form, there could be other reasons why previously estimated effects of taxes are insignificant. Small sample sizes (sometimes as low as 14-15 countries), an attenuation bias due to measurement error,[10] a downward bias of cross-sectional analysis, omitted variables – these are just a few explanations that could bring the coefficients on taxes down to zero. Next, we will see if better quality data, a larger sample, a longer time span of 25 years, a panel framework, and accounting for previously omitted variables can produce a different result.

5. Variables and Sources

In comparison with many conventional economic functions (e.g., earnings, production, economic growth, etc.), the shadow economy function is not very well defined. The economic theory of the shadow economy is still in its early years while the empirical literature is experimenting with different variables for which available data exist. Nevertheless, the four factors that theoretical and empirical literature seems to agree on and consistently include in the shadow economy function are the official tax burden, the degree of administrative controls of the economy (or regulations broadly defined), the extent of macroeconomic volatility, and some measure of the overall socio-economic development. As a starting point, the X vector in our base specification of equation (7) includes the variables that represent each of the above factors, maximize the sample size subject to specification constraints, and are publicly available for easy replication.

[10] The commonly used data sources on tax rates such as the World Tax Database (WTD), Heritage Foundation, and World Development Indicators are not free from entry errors and inaccuracies. For example, the Russian personal tax rate is coded as 90% in the 1990 WTD while this rate was applied only to the inheritors of book writers for honorariums received. We had to change this rate to the second highest rate of 60% charged on incomes from individual economic activity that was often performed underground. The top marginal PIT rate for Denmark rises from 22% to 68% in the 1988 WTD while in fact it drops from 73% to 68%. The reason for such a discrepancy is omitted surcharges and regional taxes prior to 1988 in WTD. We made every effort to create consistent series for each country across time.

The tax burden in the base specification is approximated by the top statutory PIT rate and the top statutory CIT rate.[11] The top rates are of particular interest since entrepreneurs deciding to divert resources to the underground economy are likely to face the maximum rates. These statutory rates are strictly preferable to the effective rates or to any other derivative measure of actual tax revenues since low tax collection (and hence effective rates) is a direct outcome of the shadow economy, making the effective tax rates endogenous.[12] The statutory tax rates are drawn from more than 100 distinct reference books and datasets, including the University of Michigan Office of Tax Policy Research, *World Tax Database*; *OECD Tax Database*; PricewaterhouseCoopers, *Individual and Corporate Taxes: Worldwide Summaries*; Coopers and Lybrand, *International Tax Summaries*; Economist Intelligence Unit, *Country Commerce*; International Monetary Fund, *Staff Country Reports*; etc. The accompanied working paper documents all of the data sources and describes the process of consistency checks and data reconciliation efforts (Peter, Buttrick, and Duncan 2007). The final tax dataset contains 3613 top PIT rates and 3587 top CIT rates from 1981 to 2005, averaging to 145 countries per year.

A government may influence the shadow economy not only via taxes but also through other forms of government regulations and administrative controls. Licenses, permits, subsidies to selected businesses, price and wage controls, inspections, and other forms of government interventions increase the costs of operating officially, and hence create greater incentives for escaping to the underground. The degree of government regulations is difficult to quantify, and

[11] The top rate is a legally determined marginal tax rate applicable to the top bracket of the income tax schedule. It applies to resident individuals or corporations. Generally, the rate should be effective on January 1 to be considered as the tax rate for the year.

[12] For the same reason, some of the widely used indices of tax burden should also be avoided in the shadow economy function. For example, the Heritage Foundation Index of Fiscal Freedom is calculated as a weighted average of the top marginal income tax rates (personal and corporate) and the tax revenue as a portion of GDP. The tax revenue component is clearly endogenous as it is directly affected by the size of the shadow economy.

it is often approximated by the size of the government measured via general government final consumption expenditures as percent of GDP.[13]

The shadow economy is thriving under macroeconomic instability. In particular, depreciation of the national currency and high inflation induce an escape to foreign currency, stimulate non-taxable barter transactions, devalue previously accumulated tax debt and incurred penalties, and provide an easy escape from tax authorities. Both measures of macroeconomic volatility (the rate of currency depreciation and the inflation rate) exist for most of the countries from 1980 to 2005. They are primarily drawn from the IMF International Finance Statistics and supplemented by other data sources (see Appendix 1 for sources and calculations formula).

Based on our earlier discussion, the *Z* vector in equation (7) includes the share of renewable energy resources in total net electricity consumption, the share of industry in GDP, the share of services in GDP, lagged log GDP per capita in PPP-adjusted international dollars, cold weather, and changes in energy prices.[14] The first four variables are straightforward, available for most of the countries (140+ from 1980 to 2005), and obtained directly from the sources identified in Appendix 1. The cold weather is approximated by the mean daily temperature in January or June depending on the hemisphere. The daily temperature data come from the global surface database published by the U.S. National Climatic Data Center. Missing values are replaced by the observed temperature in a country's closest neighbor. Energy price changes are calculated on the basis of the consumer price indices for electricity, gas and other fuels obtained from the International Labor Organization Laborsta Database.[15]

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[13] Instead of government expenditures, I also used the share of public administration employment in total employment. While the results are qualitatively similar, the sample size is significantly smaller for this variable.

[14] The *X* and *Z* may overlap as some of the variables in the *Z* vector (e.g., GDP per capita, output mix, and energy prices) can have an independent effect of the size of the shadow economy.

[15] Energy price indices are missing for almost 30% of the sample. Instead of deleting missing observations and creating the sample selection problem, all estimates include a dummy variable for missing energy price indices.

To construct dependent variables, I use primary energy consumption and net electricity consumption. Both measures are obtained from the U.S. Department of Energy *International Energy Annual* (2005) that publishes original data from individual country sources. Net electricity consumption is calculated as the net electricity generation of hydroelectric, nuclear, and other electric power, plus electricity imports, minus electricity exports, and minus electricity distribution losses. The net generation excludes the energy used by the generating units. The consumption of primary energy includes net electricity consumption as well as the consumption of petroleum, natural gas, and coal.

Finally, the denominator of the dependent variable has the log of recorded GDP in national currency at constant 1990 market prices.[16] The GDP series is taken primarily from the United Nations Common Database and supplemented by individual country sources in a few missing cases. GDP is estimated using the old 1968 System of National Accounts (SNA) methodology to avoid the potential bias due to including a portion of the shadow economy in the 1993 SNA methodology.

Thus, the final estimation sample, after deleting all missing values, consists of 3113 country-year observations, or an average of 125 countries per year from 1981 to 2005. The further description of all variables and data sources is provided in Appendix 1, while the summary statistics for the estimation sample is shown in Table 1.

6. The Shadow Economy Function

Having specified all variables, we are now in the position to estimate equation (7). Because data on cold weather begins only from 1987, it limits the time span for the OLS estimates. However, the model with country fixed effects is not sensitive to the inclusion of a

[16] I experimented with other units of measurement of GDP such as constant U.S. dollars and PPP-adjusted international dollars. The estimates hardly change if currency depreciation and inflation are controlled for.

weather variable, which could be safely dropped, thus providing us with a longer panel from 1981 to 2005.[17]

Table 2 presents the FE estimates of the base specification of the shadow economy function. When country fixed effects are included, the coefficients on taxes are *positive* and statistically significant for two energy measures and for both personal and corporate top income tax rates. On a side note, the coefficient on tax rates in the simple OLS (mis)specification is negative, which is in line with previous cross-sectional studies (see Appendix Table A2).

I also note that the Wooldridge test for autocorrelation in panel data (*xtserial* in Stata 10) indicates no autocorrelation in the energy consumption specification (p-value is 0.204) but the presence of autocorrelation in the electricity consumption specification (p-value is 0.025). To account for possible serial correlation, all tables in this paper report bootstrap standard errors after 100 replications based on country clusters.[18]

The FE estimates in Table 2 show a predictable negative effect of the lagged log of GDP per capita and an expected positive effect of the government size, inflation and energy prices[19] on the log of electricity consumption per recorded output. The estimated coefficient on currency depreciation is also positive and large in magnitude (compared to inflation), but it has a large standard error. The effect of output mix is not statistically significant, which is not that surprising given the discussion of this factor in Section 3. Although services may require less energy per unit of output, they provide more opportunities for informal activities, and hence the

[17] Appendix Table A1 reports the OLS and FE estimates of the shadow economy function with and without the weather variable for the 1987-2005 period. As the Hausman test suggests, the OLS estimates are highly sensitive to omitting the weather variable (χ^2=324.8 and χ^2=368.67), while the FE estimates are not affected by excluding this variable (χ^2=0.01 and χ^2=0.34).
[18] I chose to bootstrap because there is no simple way to calculate the Newey-West standard errors in the models with fixed effects and instrumental variables.
[19] Whereas higher energy prices are likely to reduce the demand for energy, they also reflect macroeconomic volatility (simple correlation with inflation is 0.7305) as well as the possibility of rent extractions in energy-producing countries, which tend to spread the shadow economy.

resulting effect might be nil. The share of renewable energy sources has an anticipated negative sign as it reduces energy consumption per unit of output.

Thus, a larger sample and panel framework produce a significant positive effect of statutory tax rates on the size of the shadow economy.

We still have to be concerned about the potential endogeneity of tax rates. Having country fixed effects and statutory rates on the right hand side of the equation help in alleviating this problem, but only partially. In contrast to the effective, revenue-derived tax rates, which are simultaneously determined with the size of the shadow economy and hence adjust instantly, the statutory rates tend to be sluggish due to political delays and time lags needed to introduce new rates. However, the statutory rates might also be endogenous if, for example, a country revises its legal tax rates in response to changes in the size of the informal sector.[20]

While it is often problematic to find an appropriate instrumental variable within a country, the statutory tax rates in neighboring countries might be a good solution for IV. The rates from bordering countries are unlikely to be correlated with the unobservable within-country component of the shadow economy after controlling for country fixed effects and, therefore, accounting for everything that is time-invariant and pertinent to the group of neighboring countries. For an instrument to be valid, it should also be correlated with the endogenous tax variable. The large body of tax competition literature suggests that such correlation is likely to be found as revisions in the tax schedule in a given country can be influenced by the existing tax rates in other countries. With respect to the statutory CIT rates, there is some evidence of corporate tax competition among neighboring countries (and neighboring regions within a

[20] As evidenced in footnote 3, some policy makers may favor lower rates in attempt to combat the shadow economy. This kind of endogeneity works in our favor as it produces a downward bias in the estimated effect of taxes, implying that the true effect should be bigger than the estimated effect. However, if policy makers, in response to a rising informal sector, decide to increase rates on a smaller formal sector, then the OLS estimates would be biased upward.

country) in attracting direct investment (Devereux et al 2004 for OECD countries, Brett and Pinske 2000 for Canadian provinces, Rork 2003 for U.S. states, etc.). But even PIT rates are likely to exhibit the neighborhood effect since they are an important determinant of labor costs and thus may influence the international flows of capital and labor. As with any instruments, it is important to make sure that they pass the relevance test for statistical significance in the first stage as well as the over-identification test in case of multiple instruments.

For each tax variable, I use two instrumental variables based on geographic contiguity: the average top tax rate of bordering countries;[21] and a weighted average of top tax rates, in which the bordering countries that are closer to the country's capital and have larger populations are given a higher weight. The contiguity indicator and distance-population weights are taken from the CEPII Country Distance Data. The IV estimates are performed using XTIVREG2 Stata module (Schaffer 2007) and reported in Table 3. The two instrumental variables display a strong positive neighborhood effect for both CIT and PIT rates in the first stage of estimation. It is interesting that the neighborhood effect is significantly larger for CIT rates than for PIT rates, which could be explained by higher mobility and more competition in capital markets than in bordering labor markets. As predicted, the IV estimates of coefficients on tax rates are considerably higher than the FE estimates and suggest that a one percentage point increase in top PIT and CIT rates is associated with a 0.018-0.052 percentage point increase in the size of the shadow economy, *ceteris paribus*.

Thus, regardless of specifications and estimation methods, there is strong evidence supporting the positive effect of the top statutory tax rates on the size of the shadow economy. The next section examines if this result remains robust to several alternative measures of individual tax burden.

[21] For country-islands, the top tax rate of the closest neighbor is used.

7. Progressivity and Complexity of the Income Tax System

While top statutory rates are useful in capturing the maximum marginal rate facing wealthiest taxpayers, it is also important to examine the effect of actual tax rates at other points of the income distribution. In addition, the overall progressivity and complexity of the national tax systems are likely to influence the size of the shadow economy. The progressive tax systems increase the benefits of tax evasion at the top of income distribution whereas the complex systems with multiple rates and schedules, large number of tax brackets, complicated tax formulas, and numerous rules are likely to increase the costs of tax compliance and hence induce the escape of individuals and firms to the shadow economy, *ceteris paribus*.

The analysis of these important features of the national tax systems became possible due to the new consolidated PIT dataset that I have created together with Steve Buttrick and Denvil Duncan. This dataset contains a detailed country-level information on the personal income tax schedule that includes all statutory rates and thresholds, basic allowances and deductions, tax credits, local taxes, surtaxes, multiple tax schedules, tax and allowance formulas, and other information needed to generate several important variables covering the 1981-2005 period.[22] We use this information to calculate actual marginal and average PIT rates for a single employed resident at 100 different levels of pre-tax income that are evenly spread in the range from 0.04 to 4 times a country's GDP per capita (y). Figure 1 and Table 4 show a downward trend in actual marginal and average PIT rates at y, $2{\cdot}y$, $3{\cdot}y$, and $4{\cdot}y$, with a relatively bigger decline in tax rates at the higher levels of income.

This top-skewed decline in actual rates is consistent with a downward trend in structural PIT progressivity described in Duncan and Peter (2008). As in the cited paper, I also estimate

[22] Even in the case of highly data-demanding variables such as tax progressivity measures which require the complete tax schedule, the dataset has non-missing values for 175 countries, or an average of 123 countries per year.

two measures of structural progressivity – marginal rate progression (MRP) and average rate progression (ARP), which are obtained as a slope coefficient from regressing marginal (or average) rates on the log of gross income using 100 data points that are formed around a country's GDP per capita in a given year. The tax structure is interpreted as progressive, proportional, or regressive if the slope is positive, zero, or negative, respectively. Table 4 shows a noticeable decline in both progressivity measures over the sample period. What we see here is a strong transition from progressive toward less progressive tax structures. Along with this global trend of income tax flattening, we also observe an apparent tendency toward simpler tax systems, which is depicted in Figure 1 and Table 4 by the steep drop in the average number of PIT brackets and by the considerable decline in the composite PIT complexity index.[23]

Thus, governments throughout the world are moving away from complex, progressive tax systems featuring multiple tax brackets and escalating stair step tax rates to simpler, flatter tax schedules distinguished by fewer tax brackets and lower rates. Now we can turn back to the shadow economy determinants and ask if this global trend toward less progressive and simpler tax structures had any impact on the size of the shadow economy. As a first step, we can replace top statutory marginal rates in the base specification of the shadow economy function by actual marginal and average rates at different points of income distribution. The estimation results with country fixed effects and instrumental variables are reported in Table 5. The one-stage FE estimates for the electricity-based measure of the shadow economy are not statistically different from zero for most of the tax rates. However, the two-stage estimates with FE and IV are positive and statistically significant across all tax rates and all specifications. Again, as in

[23] The PIT complexity index is computed on a zero to ten scale (with zero being less complex) using certain characteristics of the personal income tax structure that contribute to tax complexity. The highest value of the complexity index denote the PIT system that includes non-standard allowances, numerous tax credits, multiple tax schedules (e.g., different tax scales by marital status, occupation, and industry), special tax formulas, local taxes, national surtaxes, and 6 or more tax brackets (Peter, Buttrick, and Duncan 2007).

Section 6, I use the weighted and unweighted average of the corresponding tax rate in bordering countries as an instrumental variable.[24] While there are no apparent differences in the impact of average rates at different points of the income distribution, the marginal rate at the lower level of income (equivalent to GDP per capita) has a significantly smaller effect on the shadow economy than the marginal rate at the higher levels of income above the double GDP per capita. Conceivably, the reduction in marginal tax rates in upper brackets could have a stronger impact on the size of the shadow economy.

The results for the measures of PIT progressivity and complexity are qualitatively similar (Table 5). Whereas the one-stage FE method produces somewhat contradictory, mostly insignificant estimates, the two-stage FE-IV estimation shows the positive and statistically significant effect of PIT progression slopes and the complexity index on the shadow economy at the conventional levels of significance.[25,26]

As a robustness check, I also included these new tax measures into the demand function for local currency, which is occasionally used as an indicator of the shadow economy (Tanzi 1983). The dependent variable in this function is the share of local currency outside the banking system in M1. The function is estimated with country fixed effects and contiguity-based

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[24] I also experimented with multiple IVs and reported some of the results in Appendix Table A2. For example, I used lower rates and progressivity slopes in neighboring countries as multiple IVs for actual upper rates in a given country. The second stage results are similar to the estimates reported in Table 5. The overidentification test (*J*-statistics) does not reject the null that the instruments are uncorrelated with the error term in 5 out of 6 specifications.

[25] For all actual PIT rates and both progressivity measures, I use the corresponding average (weighted or unweighted) value of the same variable in bordering countries. The first stage results strongly indicate the presence of the own neighborhood effect in these variables. However, the neighborhood effect in tax complexity is not found to be statistically significant; and therefore, the PIT complexity in bordering countries cannot be considered as a valid IV. Instead I use the top statutory PIT rate in bordering countries as IV as it has a positive and statistically significant effect on the complexity of the national tax schedule in the first stage.

[26] Since tax variables are highly collinear, they are examined one by one. However, I also experimented with so called "kitchen sink" specifications when several or all tax variables are included to see which one survives. Generally, the CIT rate maintains its statistical significance; average PIT rates for upper income levels also survive but marginal PIT rates and progressivity measures lose their statistical significance; and the ARP estimated coefficient switches its sign when the average PIT rates are included.

instrumental variables. Like the energy/electricity consumption approach, the currency demand approach yields the positive and statistically significant coefficients on various PIT measures (Table A3).[27] Thus, these two relatively distant approaches produce a similar result in that the size of the shadow economy is increasing in response to higher rates and more progressive national tax schedules.[28]

Next, let's consider the special case of zero (or close to zero) structural progressivity under the one flat rate of personal income tax.[29] An increasing number of governments are embracing the flat PIT schedules in anticipation of an increase in tax revenues from bringing the economy out from the shadows. Yet, the empirical evidence of the link between the flat PIT rate and the size of the shadow economy is mostly at the micro level. For example, Ivanova *et al* (2005) and Gorodnichenko *et al* (2008) find a large and significant reduction in tax evasion following Russia's 2001 flat tax reform based on household-level data.

Our sample includes 14 countries with the flat PIT rate in 2005 as compared to 2 countries in 1982 and 5 in 1989-1992. Thus, for the first time there is a unique opportunity to examine the time-varying cross-country effect of the flat PIT rate on the size of the shadow economy. The flat tax rate model is an extended version of equation (7), in which a dummy variable for the flat tax schedule enters independently. To examine the long-term effect of the flat tax rate, I also include the interaction of the flat tax rate dummy with the time passed since the adoption of the flat tax rate.

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[27] The only exception is the PIT complexity index. Possibly because of the smaller sample size, all potential IV candidates for the complexity index (such as PIT rates and complexity measures in bordering countries) are not found to have a statistically significant effect in the first stage and thus did not pass the first test of the IV validity.

[28] While these results are reassuring, the currency demand function is not fully specified and will be developed further in a separate paper. In this paper, the currency demand estimates are considered only as an additional consistency check and reported in Appendix.

[29] It should be noted that the flat PIT rate is not a pure flat consumption tax as outlined in Hall and Rabushka (1985). Different rates may still apply to capital gains and business income. The presence of deductions in some countries means that the flat PIT rate may not be proportional.

$$\ln\left(\frac{E}{Y}\right)_{it} = \beta_1\tau_{it} + \beta_2 F_{it} + \beta_3 F_{it} T_{it} + \alpha \tilde{X}_{it} + \gamma Z_{it} + u_t + u_i + u_{it}, \quad (11)$$

where τ is the top statutory PIT rate, F is a dummy variable indicating if a country has a non-zero flat tax rate,[30] T is number of years since the flat tax rate has been introduced (=0 in the first year), and $\tilde{X}$ is sub-vector of X that does not include tax rates. All remaining terms are specified in equation (7).

The estimates of equation (11), which are reported in Table 6, show that there is an immediate adverse effect of the flat tax on the shadow economy during the first year following the tax reform. However, this effect diminishes over time and almost disappears 5-9 years after the reform takes place. In other words, the flat tax appears to reduce the shadow economy in the short run while its effect slowly fades away in the long run.[31]

8. Taxes and Institutions

The results so far indicate that the shadow economy is responsive to certain characteristics of the national tax system, and that governments possess an important tool of influencing the size of the shadow economy. While this result appears to be robust, on average, it may not be universally applicable to every country category. The model presented in Section 4 suggests that the responsiveness of the shadow economy to the changes in tax rates is not likely to be uniform. A positive response is expected in countries where governments optimally design their tax policy to maximize government services. However, a negative response is also possible

[30] The dataset also has 15 to 17 countries with no personal income tax in each given year. Among these countries, British Virgin Islands is the only country that changes its PIT rate from non-zero to zero tax in 2005. This prevents us from including the interaction term between the dummy for zero tax and the tax duration variable.

[31] The estimates of equation (11) should be interpreted cautiously as the timing of introduction of flat tax rates is endogenous to the size of the shadow economy, possibly even more so than changes in other tax variables. As footnote 3 indicates, combating shadow economy is in fact one of the main justification for the adoption of flat tax rates in former centrally-planned economies. Unfortunately, it is difficult to find appropriate instruments for the timing of flat rate adoption, which is a serious limitation of these estimates.

when, for example, higher taxes result in less revenue whilst government services fail to improve the productivity and law enforcement. In other words, under weak institutions, simple tax cut may not bring a desired reduction in the shadow economy as the benefits of the formal sector remain low, and the cost of tax evasion are hardly affected.

To capture the institutional variation in the shadow economy response to tax changes, the model in equation (7) can be further extended by including an interaction term between the tax variable and the institutional quality. For the institutional measure, I use the rating of civil liberties provided by the Freedom House and two indices for corruption and “law and order” published by the International Country Risk Guide (ICRG). The first series is available for all years and almost all countries in our sample. The other two series are slightly shorter (begin in 1984) but more suitable for our purpose as they assess the strength of the legal system, law enforcement, and the level of government corruption. Both ICRG indices are on the scale from 0 to 6, with 0 representing the worst corruption and law and order. The model is estimated with country-year fixed effects and the alternative tax measures introduced earlier - top CIT and PIT rates, actual average and marginal PIT rates, progressivity slopes, and the PIT complexity index.

The results in Table 7 suggest that the effect of tax rates and progressivity on the size of the shadow economy is increasing with more economic freedom, a stronger legal system, and less corruption. Thus, taxes and institutions are found to be complementary in their impact on the shadow economy. In poorly governed societies, a simple cut of upper tax rates may not necessarily reduce the size of the shadow economy. The positive interaction term is consistent with the fact that most of the decline in actual PIT rates and progressivity of national tax schedules occurred in high income and upper middle income countries (Peter, Buttrick, and Duncan 2007). These are the countries that benefit the most from these policies.

9. Conclusions

The income tax systems throughout the world are going through a remarkable transformation from complex, escalating stair step tax schedules to simpler, flatter tax schedules characterized by fewer tax brackets, lower rates, and simpler filing procedures. More and more governments are introducing these changes with the expectation that simpler, flatter tax systems will discourage tax evasion and bring in more tax revenues. But are these expectations warranted? Will simply lowering taxes and making tax systems simpler discourage unofficial economic activity? These are the questions this study attempts to address using an improved econometric methodology.

Previous cross-country studies provided ambiguous, mostly insignificant estimates of the tax effect due to small sample sizes, unaccounted endogeneity of tax rates, measurement errors, cross-sectional data and other empirical limitations. This empirical study overcomes the limitations of previous literature by using better quality data, a larger sample, a longer time span of 25 years, a panel framework, instrumental variables, and including previously omitted variables.

Unlike previous studies, our analysis provides strong evidence of a positive relationship between income tax rates and the size of the shadow economy. The effects of structural progressivity and complexity of national tax schedules are also found to be positive and statistically significant. Consequently, the global transition to simpler, flatter income tax systems appears to reduce the size of the shadow economy. These positive effects are reinforced when tax changes are accompanied by improving government services and strengthening legal system. On the other hand, corruption, weak legal institutions, and ineffective government services tend to attenuate the responsiveness of the shadow economy to changes in tax rates.

A second issue this study addresses is the effect of the flat tax rates on the size of the shadow economy. This analysis is particularly important in the light of the rapidly growing number of countries introducing the one-rate flat personal income tax in recent years. At the writing of this paper, twenty one countries adopted a flat PIT schedule, and more countries are expected to join the "flat tax club" in the near future. Our estimates suggest that while the flat tax rate helps to decrease the shadow economy in the short run, this effect diminishes and disappears in the long run.

The fact that higher progressivity and higher complexity are associated with a larger share of the shadow economy does not imply that it is socially optimal to have a flatter tax system. There are implications of these tax changes for income inequality and economic justice that need to be addressed in the future. The question is whether an increase in the tax base is sufficient to compensate for lower taxes and generate higher tax revenues that could be subsequently re-distributed.

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Table 1: Summary Statistics of Key Variables by Period

	1981-1985	**1986-1990**	**1991-1995**	**1996-2000**	**2001-2005**	**All**
Log (Energy/GDP)	-4.305	-4.274	-4.076	-4.095	-4.122	-4.160
	(0.578)	(0.639)	(0.862)	(0.926)	(0.887)	(0.819)
Log (Electricity/GDP)	-1.104	-0.982	-0.750	-0.742	-0.748	-0.840
	(0.603)	(0.605)	(0.842)	(0.955)	(0.951)	(0.846)
Top PIT rate, %	51.414	43.432	35.720	33.578	31.203	37.765
	(20.278)	(19.610)	(16.184)	(14.480)	(13.733)	(17.985)
Top CIT rate, %	41.393	39.257	34.040	31.703	28.867	34.179
	(11.509)	(12.477)	(10.531)	(9.368)	(8.330)	(11.231)
Log (GDP per capita)	8.160	8.391	8.535	8.567	8.704	8.503
	(1.040)	(1.051)	(1.039)	(1.132)	(1.167)	(1.110)
Gov't expenditures, % GDP	16.745	16.299	16.788	15.702	15.710	16.177
	(6.010)	(6.466)	(7.135)	(5.875)	(5.866)	(6.275)
Currency depreciation, %	12.830	7.402	12.171	9.474	0.837	8.049
	(19.815)	(21.642)	(23.610)	(14.999)	(13.719)	(19.170)
Inflation, %	25.428	32.575	83.899	16.678	8.380	31.947
	(83.122)	(119.964)	(233.202)	(66.294)	(25.763)	(127.109)
Energy prices change, %	22.719	19.593	48.103	17.099	8.346	22.902
	(68.433)	(97.349)	(166.395)	(59.008)	(16.328)	(95.860)
Energy prices missing	0.313	0.287	0.291	0.305	0.384	0.320
(dummy)	(0.464)	(0.453)	(0.454)	(0.461)	(0.487)	(0.467)
Service, % GDP	51.336	52.909	53.567	54.443	54.858	53.644
	(10.693)	(11.380)	(13.392)	(13.921)	(15.075)	(13.329)
Industry, % GDP	33.322	32.197	31.548	30.026	30.758	31.370
	(12.179)	(10.297)	(10.070)	(11.154)	(12.812)	(11.461)
Renewable energy, %	1.411	1.389	1.388	1.399	1.819	1.501
	(4.978)	(3.920)	(3.987)	(3.860)	(4.630)	(4.279)
Cold weather, C^0	…	14.770	13.173	12.974	13.033	13.329
		(10.544)	(11.097)	(11.681)	(11.512)	(11.323)
N	476	512	619	737	769	3113

Notes: Standard deviations are in parentheses. N counts country-year observations with non-missing values on all variables (N=3113), except for energy prices (N=2116). The description of variables and sources is provided in Appendix 1. GDP per capita is measured in PPP international dollars.

Table 2: Shadow Economy Function 1981-2005: Base specification, FE

	Log (Energy Consumption/GDP)			Log (Electricity Consumption/GDP)		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Top PIT rate	0.002***	…	0.001**	0.002***	…	0.001*
	(0.001)		(0.001)	(0.000)		(0.001)
Top CIT rate	…	0.003***	0.003***	…	0.004***	0.004***
		(0.001)	(0.001)		(0.001)	(0.001)
Log (GDP per capita)$_{t-1}$	-0.268***	-0.257***	-0.278***	-0.239***	-0.209***	-0.227***
	(0.033)	(0.033)	(0.035)	(0.027)	(0.031)	(0.027)
Gov't expenditures	0.008***	0.008***	0.008***	0.008***	0.007***	0.009***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Currency depreciation	0.040	0.038	0.041	0.034	0.027	0.032
	(0.025)	(0.024)	(0.028)	(0.023)	(0.027)	(0.024)
Inflation	0.011**	0.010**	0.013***	0.015***	0.017***	0.015***
	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
Energy prices change	0.014***	0.016***	0.014***	0.013**	0.013***	0.013***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)
Energy prices missing	0.005	-0.002	-0.004	0.037***	0.029**	0.030**
(dummy)	(0.012)	(0.012)	(0.011)	(0.013)	(0.012)	(0.012)
Service, % GDP	-0.002	-0.001	-0.001	-0.001	0.001	-0.000
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Industry, % GDP	0.001	0.001	0.002	0.002	0.003**	0.002
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)
Renewable energy	-0.004**	-0.002	-0.003*	-0.006***	-0.004***	-0.004***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
R^2 (within)	0.116	0.105	0.125	0.280	0.256	0.275
N (observations)	3113	3156	3015	3113	3156	3015
N (countries)	171	172	170	171	172	170

Notes: To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. The model is estimated with country fixed effects. Year dummies are included but not shown here. The overall trend is positive.

Table 3: Shadow Economy Function 1981-2005: Instrumental Variables, FE

	Log (Energy Consumption/GDP)				Log (Electricity Consumption/GDP)			
	IV-Unweighted		IV-Weighted		IV-Unweighted		IV-Weighted	
Top PIT rate	0.018**	…	0.031*	…	0.037***	…	0.052*	…
	(0.008)		(0.016)		(0.013)		(0.027)	
Top CIT rate	…	0.020***	…	0.023***	…	0.024***	…	0.026***
		(0.005)		(0.005)		(0.005)		(0.006)
Log (GDP per capita)$_{t-1}$	-0.252***	-0.269***	-0.225***	-0.268***	-0.198***	-0.235***	-0.166**	-0.235***
	(0.038)	(0.035)	(0.053)	(0.036)	(0.053)	(0.027)	(0.084)	(0.027)
Gov't expenditures	0.007***	0.006***	0.007**	0.005***	0.006***	0.005***	0.006	0.004***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.001)	(0.004)	(0.001)
Currency depreciation	-0.044	0.003	-0.111	-0.003	-0.147*	-0.018	-0.229	-0.021
	(0.059)	(0.032)	(0.102)	(0.034)	(0.088)	(0.034)	(0.160)	(0.036)
Inflation	0.011**	0.014**	0.011	0.014**	0.014	0.022***	0.013	0.022***
	(0.005)	(0.005)	(0.008)	(0.006)	(0.009)	(0.005)	(0.013)	(0.005)
Energy prices change	0.011	0.019***	0.009	0.020***	0.007	0.017***	0.004	0.017***
	(0.008)	(0.005)	(0.012)	(0.006)	(0.012)	(0.006)	(0.019)	(0.006)
Energy prices missing	0.003	-0.015	0.003	-0.017	0.034	0.011	0.035	0.010
(dummy)	(0.018)	(0.017)	(0.025)	(0.019)	(0.025)	(0.019)	(0.037)	(0.020)
Service, % GDP	0.002	0.003	0.004	0.004*	0.006*	0.005***	0.009	0.006***
	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)	(0.002)	(0.007)	(0.002)
Industry, % GDP	0.005**	0.004**	0.009*	0.004**	0.011**	0.006***	0.015*	0.007***
	(0.003)	(0.002)	(0.005)	(0.002)	(0.004)	(0.002)	(0.008)	(0.002)
Renewable energy	-0.005**	0.002	-0.006**	0.002	-0.008***	0.001	-0.009**	0.001
	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.004)	(0.002)
N (observations)	3051	3096	3051	3096	3051	3096	3051	3096
	First-stage results for excluded instruments							
IV	0.085***	0.181***	0.063**	0.152***	0.085***	0.181***	0.063**	0.152***
	(0.023)	(0.024)	(0.022)	(0.022)	(0.023)	(0.024)	(0.022)	(0.022)
F-test of excluded IV	13.42***	56.89***	8.12***	46.14***	13.42***	56.89***	8.12***	46.14***

Notes: To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. The model is estimated with country fixed effects. N (countries) = 169. N excludes singletons or countries with one data point. Year dummies are included but not shown here. The model is just identified. IV is the corresponding average top PIT or CIT rate in bordering countries, and it is either unweighted or weighted by distance-population. The p-values for the overall F-test in the second stage are less than 0.01.

Table 4: Summary Statistics of Income Tax Variables by Period

	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	N
Top PIT rate	46.768	40.397	34.263	32.493	30.109	3613
	(23.300)	(21.199)	(17.478)	(15.795)	(14.735)	
Top CIT rate	38.936	37.267	33.693	31.623	28.476	3587
	(13.872)	(14.194)	(11.539)	(10.146)	(9.012)	
Number of tax brackets	10.305	8.026	5.527	5.037	4.565	3143
	(9.122)	(7.105)	(4.498)	(3.635)	(3.128)	
MR at $1 \cdot y$	14.149	13.062	11.353	10.886	10.680	3082
	(18.525)	(15.649)	(13.633)	(12.851)	(12.250)	
$2 \cdot y$	20.743	19.551	16.754	16.750	16.363	3082
	(22.297)	(19.126)	(16.080)	(15.176)	(14.517)	
$3 \cdot y$	24.519	23.167	19.962	19.914	19.388	3082
	(23.645)	(20.443)	(16.968)	(16.062)	(15.349)	
$4 \cdot y$	27.465	25.823	22.335	22.085	21.266	3082
	(23.968)	(21.050)	(17.187)	(16.143)	(15.240)	
AR at $1 \cdot y$	8.839	7.694	6.746	6.582	6.411	3082
	(12.561)	(10.630)	(9.303)	(8.537)	(8.247)	
$2 \cdot y$	13.263	12.348	10.695	10.442	10.201	3082
	(16.412)	(13.908)	(11.885)	(11.047)	(10.489)	
$3 \cdot y$	16.441	15.439	13.333	13.136	12.814	3082
	(18.352)	(15.658)	(13.209)	(12.327)	(11.717)	
$4 \cdot y$	18.876	17.675	15.328	15.133	14.720	3082
	(19.507)	(16.735)	(13.990)	(13.072)	(12.400)	
MR progression	0.078	0.075	0.065	0.066	0.063	3082
	(0.070)	(0.064)	(0.052)	(0.050)	(0.050)	
AR progression	0.071	0.072	0.061	0.061	0.060	3082
	(0.070)	(0.066)	(0.056)	(0.053)	(0.054)	
Complexity index	4.666	4.479	4.025	3.941	3.788	3132
	(2.373)	(2.344)	(2.167)	(2.040)	(1.964)	

Notes: Standard deviations are in parentheses. MR=marginal PIT rate, AR=average PIT rate, y is gross annual income equivalent to a country's GDP per capita.

Table 5: The Effect of Income Tax Burden on the Shadow Economy, FE

	Log (Energy Consumption/GDP)			Log (Electricity Consumption/GDP)		
	FE	**FE-IV1**	**FE-IV2**	**FE**	**FE-IV1**	**FE-IV2**
MR at 1·*y*	0.001**	0.010***	0.012***	0.001	0.009***	0.010***
	(0.001)	(0.004)	(0.004)	(0.001)	(0.003)	(0.004)
2·*y*	0.001**	0.020***	0.023***	-0.000	0.017***	0.020***
	(0.001)	(0.004)	(0.005)	(0.001)	(0.004)	(0.004)
3·*y*	0.001**	0.019***	0.021***	-0.000	0.016***	0.018***
	(0.000)	(0.005)	(0.005)	(0.001)	(0.005)	(0.005)
4·*y*	0.001**	0.019***	0.021***	-0.001	0.015***	0.017***
	(0.000)	(0.005)	(0.005)	(0.001)	(0.004)	(0.004)
AR at 1·*y*	0.004***	0.021***	0.023***	0.004***	0.020***	0.019***
	(0.001)	(0.005)	(0.005)	(0.001)	(0.005)	(0.005)
2·*y*	0.002***	0.019***	0.022***	0.001	0.016***	0.017***
	(0.001)	(0.004)	(0.005)	(0.001)	(0.004)	(0.004)
3·*y*	0.002***	0.020***	0.023***	0.001	0.017***	0.019***
	(0.001)	(0.005)	(0.005)	(0.001)	(0.004)	(0.004)
4·*y*	0.002***	0.021***	0.024***	0.000	0.017***	0.019***
	(0.001)	(0.005)	(0.005)	(0.001)	(0.004)	(0.004)
MR progression	0.052	5.035**	5.850***	-0.486***	3.585**	4.890***
	(0.133)	(2.023)	(2.073)	(0.151)	(1.569)	(1.746)
AR progression	0.274	5.280***	6.008***	-0.348	4.618***	5.723***
	(0.216)	(1.620)	(1.638)	(0.267)	(1.429)	(1.506)
	[2701]	[2612]	[2612]	[2701]	[2612]	[2612]
Complexity index	-0.009*	0.155*	0.175*	-0.007	0.310*	0.285**
	(0.005)	(0.091)	(0.094)	(0.005)	(0.188)	(0.126)
	[2721]	[2670]	[2670]	[2721]	[2670]	[2670]

Notes: To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. Number of observations (in brackets) excludes singletons or countries with one data point. The model is estimated with country fixed effects. Each cell shows the estimated coefficient of the corresponding PIT measure in the shadow economy function. Except for the tax measure, the specification includes the same set of covariates as in Table 2. IV is the corresponding average top PIT or CIT rate in bordering countries, and it is either unweighted (IV1) or weighted by distance-population (IV2). The p-values for the overall F-test in the second stage and p-values for the F-test for excluded IV in the first stage are less than 0.01 in all specifications. MR=marginal PIT rate, AR=average PIT rate, *y* is gross annual income equivalent to a country's GDP per capita.

Table 6: The Effect of Flat Tax Rate and Its Duration on the Shadow Economy, FE

	Log (Energy Consumption/GDP)	Log (Electricity Consumption/GDP)
Top PIT rate	0.002**	0.002**
	(0.001)	(0.001)
Zero tax	-0.179**	-0.220*
	(0.091)	(0.115)
Flat tax	-0.131***	-0.138***
	(0.024)	(0.037)
Flat tax * Duration	0.015***	0.028***
	(0.003)	(0.005)
Log (GDP per capita)$_{t-1}$	-0.266***	-0.237***
	(0.033)	(0.028)
R^2 (within)	0.123	0.294
N (observations)	3113	3113
N (countries)	171	171

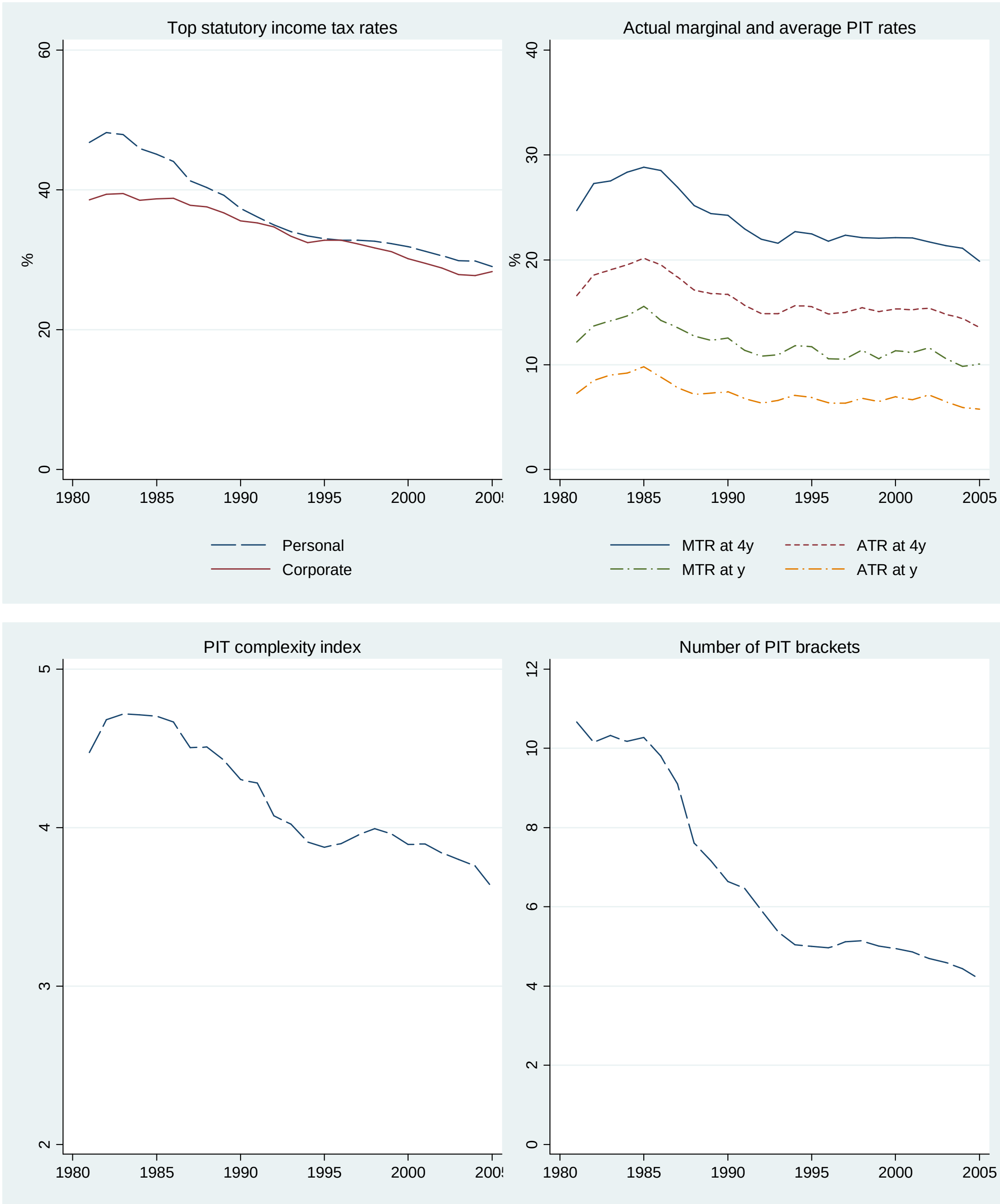
Notes: To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. Table 6 includes the same set of variables as in Table 2. Duration is number of years since the adoption of flat tax rate (=0 in the first year). The model is estimated with country fixed effects. The coefficient on zero tax shows changes in the log of energy consumption per GDP after the 2005 introduction of zero tax in British Virgin Islands, the only country in the sample with-time-varying zero PIT.

Table 7: Taxes and Institutions

Tax:	Top PIT	Top CIT	MR at *y*	MR at 4·*y*	AR at *y*	AR at 4·*y*	MRP	ARP	Complex
Tax	-0.002*	-0.001	-0.013***	-0.008***	-0.016***	-0.013***	-2.151***	-4.382***	-0.035***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.317)	(0.478)	(0.012)
Corruption (reverse)	-0.019*	-0.025**	-0.021***	-0.044***	-0.013**	-0.040***	-0.026***	-0.035***	-0.031**
	(0.011)	(0.011)	(0.007)	(0.009)	(0.007)	(0.008)	(0.008)	(0.008)	(0.014)
Tax * Corruption	0.109***	0.119***	0.323***	0.242***	0.430***	0.345***	56.691***	111.124***	1.066***
	(0.022)	(0.030)	(0.030)	(0.021)	(0.038)	(0.026)	(6.959)	(9.879)	(0.256)
N (observations)	2381	2402	2131	2131	2131	2131	2131	2131	2145
Tax	-0.001	-0.002	-0.010***	-0.006***	-0.011***	-0.010***	-1.479***	-3.061***	-0.006
	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.289)	(0.490)	(0.010)
Law and order	-0.004	-0.029***	-0.003	-0.024***	0.001	-0.020***	-0.005	-0.011	0.012
	(0.010)	(0.011)	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)	(0.007)	(0.011)
Tax * Law and order	0.070***	0.135***	0.233***	0.183***	0.332***	0.265***	34.009***	73.715***	0.146
	(0.020)	(0.025)	(0.036)	(0.021)	(0.047)	(0.029)	(6.540)	(10.244)	(0.213)
N (observations)	2381	2402	2131	2131	2131	2131	2131	2131	2145
Tax	0.000	-0.002	-0.006***	-0.005***	-0.009***	-0.008***	-1.238***	-2.323***	-0.000
	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.315)	(0.537)	(0.015)
Civil Liberties	-0.016*	-0.053***	-0.014**	-0.025***	-0.014**	-0.026***	-0.012*	-0.017**	0.002
	(0.010)	(0.010)	(0.006)	(0.008)	(0.006)	(0.007)	(0.007)	(0.007)	(0.014)
Tax * Civil liberties	0.041**	0.139***	0.118***	0.108***	0.217***	0.169***	17.502***	41.029***	-0.088
	(0.019)	(0.024)	(0.027)	(0.020)	(0.039)	(0.027)	(5.875)	(9.270)	(0.269)
N (observations)	3032	3078	2622	2622	2622	2622	2622	2622	2642

Notes: To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. All specifications include the same set of variables and country fixed effects as in Table 2. The dependent variable is the log of electricity consumption per GDP. The results for energy consumption are qualitatively similar and not reported to preserve the space. Indices for corruption, law and order, and civil liberties are scaled, with highest values representing best institutional practices.

Figure 1: Trends in Income Tax Indicators, 1981-2005



Notes: PIT is personal income tax; *y* denotes the level of gross annual income equivalent to a country's GDP per capita.

Appendix 1: Data Description[32]

A. National Accounts

Real GDP (national currency)[33]

Gross domestic product is estimated in national currency at constant 1990 market prices using SNA68 methodology.
Source: United Nations Common Database (UNCD) (2007), series code = 19480.

Real GDP (US$)

Gross domestic product is estimated in U.S. dollars at constant 1990 market prices using SNA68 methodology. National currency data are converted to U.S. dollars using the average market rates as published by the International Monetary Fund in International Financial Statistics. Official exchange rates are used when the market rate is not available. For non-members of the Fund, the conversion rates are the annual average of United Nations operational rates of exchange.
Source: UNCD (2007), series code = 19470.

PPP GDP per capita (current international dollars)

PPP GDP is gross domestic product converted to international dollars using purchasing power parity (PPP) rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States. The lagged value is used.
Sources: IMF WEO (2006); UNCD (2007), series code = 29922 (based on World Bank estimates).

General government final consumption expenditure (% of GDP)

General government final consumption expenditure includes all government current expenditures for purchases of goods and services, including compensation of employees. It also includes most of expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation.
Selected sources: IMF IFS (2006), WB WDI (2007), EIU (2005), publications of national statistical offices, and IMF country reports (all sources are documented).

Industry, value added (% of GDP)

Industry corresponds to ISIC/Rev.3 divisions 10-45 and includes mining, manufacturing, construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.
Selected sources: WB WDI (2007) supplemented by EIU (2005), UNECE (2007), ECLAC (2005) and publications of national statistical offices (all sources are documented).

Services, value added (% of GDP)

Services correspond to ISIC/Rev.3 divisions 50–99 and include wholesale and retail trade and restaurants and hotels; transport, storage and communication; financing, insurance, real estate and business services; public administration and defense; community, social and personal services. This sector is derived as a residual (from GDP less agriculture and industry).

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[32] All variables are available for all years from 1981 to 2005 unless indicated otherwise.
[33] All GDP and population data for Taiwan are from the IMF World Economic Outlook Database (2006). Real GDP for USSR in 1990-1991 are calculated using real GDP growth estimates from the IMF World Economic Outlook Report (1993).

Selected sources: WB WDI (2007) supplemented by EIU (2005), UNECE (2007), ECLAC (2005) and publications of national statistical offices (all sources are documented).

B. Energy and Weather

Energy consumption (Quadrillion 10^15 Btu)

Primary energy consumption includes the consumption of petroleum (crude oil and natural gas plant liquids), dry natural gas, coal, and net consumption of hydroelectric, nuclear, and geothermal, solar, wind, and wood and waste electric power. Primary energy consumption for each country also includes net electricity imports (electricity imports minus electricity exports). *Does it include net energy imports?*
Source: U.S. Department of Energy (2005) *International Energy Annual*.

Net electricity consumption (Billion Kilowatt-hours)

Net electricity consumption = net electricity generation of hydroelectric, nuclear, and geothermal, solar, wind, and wood and waste electric power + electricity imports - electricity exports - electricity distribution losses. Net generation excludes the energy consumed by the generating units.
Source: U.S. Department of Energy (2005) *International Energy Annual*.

Renewable energy resources (% of net electricity consumption)

This variable measures the percentage share of net electric power consumption from renewable energy sources in total net electricity consumption. Renewable energy resources are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include biomass and combustible waste, geothermal, solar, wind, ocean thermal, wave action, and tidal action.
Source: U.S. Department of Energy (2005) *International Energy Annual*.

Cold weather (C), 1987-2005

Cold weather is approximated by the mean daily temperature in January or June, depending on the hemisphere. The temperature is averaged across country stations. Missing values are replaced by the observed temperature in a country's closest neighbor.
Source: Monthly Global Surface Data, National Climatic Data Center, U.S. Department of Commerce (http://www.ncdc.noaa.gov/oa/ncdc.html); CEPII Country Distance Data (http://www.cepii.fr/anglaisgraph/bdd/distances.htm#).

C. Taxes

Top statutory personal income tax (PIT)

This is a legally determined marginal tax rate applicable to the top bracket of the personal income tax schedule.

Top statutory corporate income tax (CIT)

The top corporate tax rate is the maximum legal statutory tax rate that applies to resident non-financial corporations. It does not include local taxes, surtaxes, or special taxes. It applies only to retained earnings, not distributed earnings.

Actual marginal PIT rate at *y*

This is the marginal tax rate facing individuals earning an income equivalent to a country's GDP per capita (*y*), after accounting for standard deductions and tax credits, employee/wage allowances, local taxes, major national surtaxes, and multiple tax schedules. It is calculated as the ratio of the change in tax liability to change in gross income at level *y*.

Actual average PIT rate at *y*

This is the average tax rate facing individuals earning an income equivalent to a country's GDP per capita (*y*), after accounting for standard deductions and tax credits, employee/wage allowances, local taxes, major national surtaxes, and multiple tax schedules. It is calculated as the ratio of total tax liability to gross income at level *y*.

Marginal rate progression (MRP)

MRP characterizes the structural progressivity of national tax schedules with respect to the changes in marginal rates along the income distribution. It is the slope coefficient from regressing actual marginal tax rates on the log of gross income for the income distribution up to $4 \cdot y$ income.

Average rate progression (ARP)

ARP characterizes the structural progressivity of national tax schedules with respect to the changes in average rates along the income distribution. It is the slope coefficient from regressing actual average tax rates on the log of gross income for the income distribution up to $4 \cdot y$ income.

PIT complexity index

This index is computed on a zero to ten scale (with zero being less complex) using certain characteristics of the personal income tax structure that contribute to tax complexity such as allowances, tax credits, multiple tax schedules, special tax formulas, local taxes, national surtaxes, and the number of tax brackets.

Flat tax (dummy)

=1 if country has one-rate flat personal income tax; 0 otherwise.

The source for all tax variables is World Tax Indicators v.1 (Peter, Buttrick, and Duncan 2007).

D. Prices

Inflation (% annual change in general CPI)

Source: 92% of data points are drawn from IMF IFS (2006), 7% from IMF WEO (2006), and the remaining 1% from ILO Laborsta (2006), EIU (2005), and IMF WEO annual reports (all sources are documented). To reduce the influence of outliers, a few rare cases of hyperinflation above 1000% per year are top-coded at 1000%.

Exchange rate (national currency per US dollar)

Two series are used: end-of-period national currency units per U.S. dollar and period-average national currency units per U.S. dollar. For the countries with fixed exchange rate that are not in the IFS database, the exchange rate is taken for the currency which the national currency is pegged to. For the Euro zone (including currencies pegged to Euros), the before and after series are linked by using the exchange rate at which the currency entered the Euro. Missing observations for

the former Soviet Republics in the early 1990s are replaced by the exchange rate of the Russian ruble.
Source: IMF IFS (2006).

Depreciation rate (%)

The depreciation rate is calculated as $(EX_t/EX_{t-1}-1)*100$ if $EX_t/EX_{t-1}<1$ and $-(EX_{t-1}/EX_t-1)*100$ if $EX_t/EX_{t-1}>1$, where EX_t is national currency per U.S. dollar in year *t*. This formula treats depreciation and appreciation of currency symmetrically, which is especially relevant for the countries experiencing rapid changes in the value of national currency. For example, a decrease in exchange rate from 100 to 10 is equivalent to the 90% depreciation rate whereas an increase in exchange rate from 10 to 100 is equivalent to the 90% appreciation rate, in contrast to the 900% rate using the simple annual percentage formula. The reported results are based on the end-of-period exchange rates because of fewer missing observations; however the alternative series of period averages has also been applied and the results are available upon request. For any centrally-planned economy, for which the actual exchange rate is unknown but it is known that country used official fixed exchange rate, the depreciation rate is assumed to be zero (in late 1980s).
Source: author's calculations.

Energy prices (% annual change in energy CPI)

Energy price changes are calculated on the basis of consumer price indices for electricity, gas and other fuels. To reduce the influence of outliers, a few rare cases of energy price hyperinflation exceeding 1000% per year are top-coded at 1000%. A dummy variable for missing observations is constructed.
Source: International Labor Organization (2006) *Laborsta.*

E. Institutions

Corruption index, 1984-2005

The corruption index shows an assessment of corruption within a political system. The index is on the scale from 0 to 6, in which 0 indicates a very corrupt government.
Source: International Country Risk Guide (ICRG).

Law and order index, 1984-2005

The law and order index is an assessment of the strength and impartiality of the legal system as well as an assessment of popular observance of the law. The index is on the scale from 0 to 6, with 0 representing the worst law and order.
Source: International Country Risk Guide (ICRG).

Civil liberties country rating

The Freedom House 7-point rating of civil liberties is reversed, with one representing the lowest degree of freedom and seven the highest.
Source: Freedom House.

Table A1: Sensitivity of the Base Specification to the Inclusion of Weather, 1987-2005, OLS vs. FE

	Energy - OLS		**Electricity - OLS**		**Energy - FE**		**Electricity – FE**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Cold weather, C^0	-0.126***		-0.133***		0.000		-0.001	
	(0.004)		(0.005)		(0.002)		(0.002)	
Top PIT	-0.026***	-0.015***	-0.022***	-0.010***	0.002***	0.002***	0.001**	0.001**
	(0.002)	(0.003)	(0.002)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
Log (GDP per capita)$_{t-1}$	-0.569***	0.129	-0.528***	0.210**	-0.183***	-0.183***	-0.170***	-0.169***
	(0.096)	(0.087)	(0.099)	(0.090)	(0.046)	(0.046)	(0.032)	(0.032)
Gov't expenditures	0.094***	0.138***	0.099***	0.145***	0.008***	0.008***	0.008***	0.008***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.002)	(0.002)	(0.001)	(0.001)
Currency depreciation	3.970***	4.279***	4.102***	4.430***	0.039*	0.039*	0.009	0.009
	(0.855)	(0.869)	(0.866)	(0.883)	(0.023)	(0.023)	(0.029)	(0.029)
Inflation	1.137***	1.192***	1.150***	1.208***	0.009**	0.009**	0.016***	0.016***
	(0.133)	(0.129)	(0.136)	(0.132)	(0.004)	(0.004)	(0.005)	(0.005)
Energy prices change	-0.394**	-0.221	-0.415**	-0.232	0.016**	0.016**	0.012*	0.012*
	(0.191)	(0.189)	(0.196)	(0.194)	(0.006)	(0.006)	(0.006)	(0.006)
Energy prices missing	0.107	-0.408***	0.035	-0.510***	0.030**	0.030**	0.037***	0.036***
(dummy)	(0.120)	(0.126)	(0.124)	(0.131)	(0.013)	(0.013)	(0.014)	(0.014)
Service, % GDP	0.040***	0.015	0.044***	0.017*	-0.006***	-0.006***	-0.005***	-0.005***
	(0.010)	(0.009)	(0.010)	(0.010)	(0.001)	(0.001)	(0.002)	(0.002)
Industry, % GDP	0.053***	0.029***	0.046***	0.021**	-0.002*	-0.002*	-0.002	-0.002
	(0.008)	(0.008)	(0.009)	(0.009)	(0.001)	(0.001)	(0.002)	(0.002)
Renewable energy	-0.007	-0.029***	0.000	-0.023***	-0.001	-0.001	-0.006***	-0.006***
	(0.008)	(0.008)	(0.008)	(0.007)	(0.002)	(0.002)	(0.002)	(0.002)
R^2	0.329	0.261	0.335	0.261	0.120	0.120	0.157	0.157
Hausman test	$\chi^2(28)=324.80$		$\chi^2(28)=368.67$		$\chi^2(28)=0.01$		$\chi^2(28)=0.34$	

Notes: N=2471, number of countries is 169. To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. The dependent variable is the log of energy/electricity consumption per GDP. Year dummies are included but not reported here. FE denotes country fixed effects.

Table A2: The Effect of Actual PIT Rates on the Shadow Economy, FE with Alternative Instrumental Variables

	Marginal PIT Rate			Average PIT Rate		
	at 2·*y*	**at 3·*y***	**at 4·*y***	**at 2·*y***	**at 3·*y***	**at 4·*y***
	Second stage results for actual PIT rates					
Actual MR/AR at upper	0.011***	0.014***	0.012***	0.017***	0.016***	0.016***
income levels	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Hansen *J* statistic	2.800	0.676	0.719	0.201	0.046	0.011
Hansen *p*-value	0.094	0.411	0.397	0.654	0.831	0.9168
R^2-within second stage	0.163	0.076	0.095	0.198	0.169	0.147
	First-stage results for excluded instruments					
MR/AR progression	21.811***	29.085***	32.597***	36.998***	41.823***	44.435***
in bordering countries	(6.099)	(6.749)	(7.159)	(6.699)	(7.518)	(8.114)
Actual MR/AR at *y*	0.154***	0.115***	0.130***	0.184***	0.177***	0.174***
in bordering countries	(0.026)	(0.029)	(0.030)	(0.031)	(0.033)	(0.035)
F-test of excluded IV	34.87***	25.07***	29.25***	41.49***	41.30***	40.18***
R^2 first stage	0.203	0.201	0.202	0.262	0.263	0.259

Notes: N=2612. To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. All specifications in Table A2 include the same set of covariates and country fixed effects as in Table 2. The dependent variable is the log of electricity consumption per GDP. The results for energy consumption are similar and not reported. All instrumental variables are weighted by the distance and population of neighboring countries. MR=marginal PIT rate, AR=average PIT rate, *y* denotes the level of gross income equivalent to a country's GDP per capita.

Table A3: The Effect of Income Tax Burden on Currency Demand, FE

	FE	FE-IV1	FE-IV2
MR at 1·*y*	0.001**	0.011***	0.011***
	(0.000)	(0.002)	(0.002)
2·*y*	0.001**	0.010***	0.009***
	(0.000)	(0.002)	(0.002)
3·*y*	0.001**	0.010***	0.009***
	(0.000)	(0.002)	(0.002)
4·*y*	0.001***	0.008***	0.007***
	(0.000)	(0.002)	(0.002)
AR at 1·*y*	0.002***	0.014***	0.013***
	(0.001)	(0.002)	(0.002)
2·*y*	0.001***	0.012***	0.012***
	(0.000)	(0.002)	(0.002)
3·*y*	0.001***	0.012***	0.011***
	(0.000)	(0.002)	(0.002)
4·*y*	0.001***	0.011***	0.010***
	(0.000)	(0.002)	(0.002)
MR progression	0.043	2.004**	1.970**
	(0.060)	(0.859)	(0.860)
AR progression	0.189*	3.558***	3.496***
	(0.103)	(0.821)	(0.801)
N (observations)	2095	2030	2030

Notes: To account for arbitrary serial correlation, standard errors (in parentheses) are bootstrapped with 100 replications based on country clusters; * significant at 10%; ** significant at 5%; *** significant at 1%. Number of observations is in brackets. The model is estimated with country fixed effects. Each cell shows the estimated coefficient of the corresponding PIT measure in the shadow economy function. In addition to the tax measure, the specification includes lagged log of GDP per capita, annual deposit rate, interest rate spread (lending rate minus deposit rate), government expenditures, inflation rate, currency depreciation rate, and year dummies. The dependent variable is the share of local currency in circulation outside the banking system in money supply M1. IV is the corresponding average tax measure in bordering countries, and it is either unweighted (IV1) or weighted by distance-population (IV2). The p-values for the overall F-test in the second stage and p-values for the F-test for excluded IV in the first stage are less than 0.01 in all specifications. MR=marginal PIT rate, AR=average PIT rate, *y* is gross annual income equivalent to a country's GDP per capita.