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I thank Richard Carson, Roger Gordon, Mark Jacobsen, and various seminar participants for their helpful comments. All remaining errors are my own.
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Incorporating Endogenous Tax Evasion into CGE Tax Models: Implementation and an Illustration

Antung A. Liu*

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Abstract

Computable general equilibrium (CGE) tax models typically hold tax evasion constant by including only effective tax rates. We analyze the general equilibrium implications of endogenous tax evasion using the platform of Ho and Jorgenson (2007), a large CGE model estimating the impact of fuel taxes on the environment and economy of China. Our key assumption is that rates of tax evasion fall as taxes are cut, an assumption strongly supported by the recent empirical tax literature. We find that, while endogenizing tax evasion does not play a large role in aggregate outcomes, doing so can substantially affect distributional outcomes in models where two or more taxes are shifted in a revenue-neutral way. For example, endogenous tax evasion can be important when the outcomes of interest are tied to individual commodities, as in models

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1 Introduction

Computable general equilibrium (CGE) models are a staple of modern tax policy analysis. The purpose of CGE models is to transform Walrasian general equilibrium theory of balancing macroeconomic equations into a tractable simulation of a real world setting. Potential policies can be simulated, allowing the policy analyst to forecast the directions and (perhaps) magnitudes of potential changes. CGE models are now applied to many policy questions where the impact of a proposed reform cannot be analytically determined. Strains of CGE models examining the impact of taxation have become typical in the literature of trade economists, public finance economists, and environmental economists. Shoven and Whalley (1984) provide an early survey of models in the tax and trade literatures. Surveys of the recent CGE literature are comparatively rare because of the proliferation of new models; Mitra-Kahn (2008) provides a brief history of the evolution and adoption of major CGE models.

CGE models have been widely adopted by the most important policy analysts. For example, the Congressional Budget Office of the United States uses general equilibrium models to help prepare its analyses of the macroeconomic impact of reforms[1]. These reports are disseminated to policy makers and used to help shape potential policies. Other major policy analysts utilitizing CGE tax models include the Federal Reserve and the Environmental

[1]See, for example, the appendix of the CBO's analysis of the economic impact of the American Recovery and Reinvestment Act of 2009, in CBO (2010)

Protection Agency.

CGE models typically incorporate tax evasion by using effective tax rates[2]. By lumping together tax evasion and tax rates, tax evasion is implicitly fixed. However, a growing body of theoretical and empirical literature has consistently found that tax evasion may respond to the marginal tax rate[3]. Our paper studies the impact of incorporating endogenously determined tax evasion on the results obtained by CGE models where the policy being examined manipulates tax rates.

This paper offers two contributions. First, we attempt to provide an answer to the CGE practitioner attempting to answer the question of whether endogenous tax evasion will have a significant impact on his model. Tax evasion data are potentially difficult to gather by their very nature; CGE models can be difficult to solve when they are too complex. If the benefit of including extra parameters is minimal, this cost may be too high.

Second, we offer a practical template for endogenizing tax evasion, including our efforts to estimate credible tax evasion parameters in China, a setting where few published attempts to measure tax evasion have been made. To calculate the tax evasion rate between taxes, we match observed economic activity in the input-output table to reported tax collections. To calculate the tax evasion rate between sectors, we use the self-employment rate in each sector as a proxy for the sector's ability to evade taxes[4].

We use the CGE model of Ho and Jorgenson (2007) as the template for our analysis. This model is suited to our study for several reasons. First, it has been used over a significant period of time in a number of peer-reviewed publications. Second, the effect of pollution

[2]See, for example, Carraro, Galeotti, and Gallo (1996) and Sancho (2010).

[3]We review this literature in section 2. Andreoni, Erard, and Feinstein (1998) survey this literature.

[4]Self-employment has been widely tied to tax evasion. See, for example Engstrom and Holmlund (2006)

taxes in China is an important policy question and part of the ongoing debate in the double dividend literature. Third, the model simulates the impact of a new fuel tax where revenues are recycled to cut existing taxes: a "double dividend" style of reform. The endogenous response of tax evasion is most interesting in policies where several tax rates are shifted. Other topics which may find endogenous tax evasion relevant include: flat-tax reform, tax base broadening, and optimal taxation.

The key driver of our main results is the convergence in rates of evasion as taxes are cut. Taxes which are evaded heavily will have greater changes in their evasion rates when tax rates are cut, relative to taxes which are evaded lightly[5]. A revenue-neutral reform such as the double dividend shifts the tax burden from the lightly-evaded sales taxes to the heavily-evaded VAT and corporate income tax. This results in a small overall drop in prices. While aggregate outcomes do not seem to be significantly impacted by the inclusion of endogenous tax evasion, individual commodities can see substantial differences in prices and quantities relative to the case when tax evasion is static. Since some models are designed to track outcomes tied to only a few key commodities, these effects can be significant. For example, fuel taxes are 6% less effective at cutting electricity use, 23% less effective at cutting oil use, and 47% less effective at cutting transportation under our central estimates of endogenous tax evasion.

Endogenous tax evasion can also play a significant role in determining the winners and losers of policies. As the tax burden shifts from the sales tax to the VAT and business profits taxes, consumers benefit and business profits are hurt. When tax evasion is held constant during the fuel tax reform, consumer welfare drops by 5 billion yuan; when endogenous tax

[5] We expound further on this assumption in section 5.1.

evasion is included, consumer welfare **increases** by 2 billion yuan. Corporate profits see the opposite pattern.

This paper is organized as follows. Section 2 summarizes arguments for the existence of endogenous tax evasion. Section 3 briefly sketches the CGE model of Ho and Jorgenson which acts as the platform for this project. Section 4 explains our methodology for incorporating tax evasion and calculating tax evasion rates in China. Section 5 presents our results. Section 6 concludes.

2 The Endogeneity of Tax Evasion

Early theoretical models such as that of Allingham and Sandmo (1972) first noted that higher tax rates increase the returns to evading taxes. Their model divided the impact of higher rates into two offsetting components. There is an income effect, where higher rates make the taxpayer poorer and less willing to take risks. There is a substitution effect, where higher rates increase the returns to evading taxes. Many models of tax evasion have followed Allingham and Sandmo, incorporating new elements such as labor supply effects in general equilibrium, repeated games, and behavioral aspects of tax evasion. The theme of the endogenous determination of tax evasion runs throughout the literature of the theory of tax evasion[6].

Until recently, reliable empirical literature on tax evasion has been comparatively scarce. Early studies found mixed results, but suffered from serious problems of measurement error and endogeneity (Slemrod 2007). Over the past few years, there has been a burgeoning of well-published papers studying the link between tax evasion and the marginal tax rate.

[6] See Andreoni, Erard and Feinstein (1998) for a survey of this theory.

Using new sources of data and improved empirical methods, each of these papers has found a strong positive relationship between the level of tax evasion and the tax rate.

Fisman and Wei (2004) match data from Chinese reports of imports from Hong Kong and Hong Kong reports of exports to China; they connect the rate of evasion to the tariff rate and VAT rate on each commodity. They estimate that a 1% rise in taxes raises tax evasion rises by 3%, implying an elasticity of evasion with respect to tax rates of 3. Goolsbee (2000) looks at variation in state sales taxes to estimate how much sales taxes drive online shopping, where sales tax is generally not charged. He finds that a 1% increase in sales taxes increases the probability of shopping online by 0.5%, implying an elasticity of evasion of 0.5.

Gorodnichenko, Martinez-Vazquez, and Peter (2009) perform a unique study of the macroeconomic impact of the response of tax evasion. They examine the impact on tax evasion of flat-tax reform in Russia, which lowered marginal income tax rates between 7% and 17%. Using a panel of household data, they examine the differences in growth between reported income and reported consumption around the time period of this policy. They report an elasticity of the amount of evasion with respect to tax rates of 0.376.

We regard the study of Gorodnichenko et. al as the best estimate of tax evasion elasticity for the purposes of this paper. Their study is the only paper that examines a macroeconomic response to an economy-wide shift in tax rates. Fisman and Wei (2004), Goolsbee (2000), and other works may be less reliable for our purposes because they allow close substitutes for the good being taxed, and ascribe tax evasion to mechanisms that are unsuited to an economy-wide set of taxes.

3 The Model of Ho and Jorgenson

3.1 Background of the Model

The CGE model of Ho and Jorgenson (2007) is the center of a long-running project analyzing the impact of environmental taxes on China's pollution and economy[7] The version we use is published as one chapter of Ho and Nielson (2007), a book integrating the core CGE model with models of dosage-response and the valuation of health. The goals of Ho and Nielson (2007) are to estimate the health damages caused by pollution, and to provide a simulation of the impacts of environmental taxes on the macreconomy of China and the health of its residents.

3.2 The Version of the Model We Received

We received GAMS code and data inputs directly from Mun Ho. When the model was run as we received it, we are able to reproduce the broad macroeconomic and health results reported in Ho and Jorgenson (2007). However, a few differences in the results from our version and the results reported suggest that we received a modestly different version[8].

Since we are able to reproduce many of the central results of Ho and Jorgenson (2007), and we received GAMS code directly from Dr. Ho, we believe that the baseline version of our model fairly reproduces the original work of Ho and Jorgenson (2007). Throughout the paper, we report results as obtained from our runs of the GAMS code, which differ slightly

[7]See Ho, Jorgenson, and Perkins (1998), Garbaccio, Ho, and Jorgenson (1999) for earlier versions of this model.

[8]For example, while sulfur dioxide, SO_2, and carbon dioxide, CO_2, emissions are explicitly tracked in our version, nitrous oxide, NO_X, emissions are not tracked and do not appear to factor into calculations of health damages. Also, one sector in our version, labeled "building materials", appears to substitute for the category "nonmetal mineral products" reported in Ho and Jorgenson (2007).

from the results in the tables in Ho and Jorgenson (2007)[9].

3.3 Brief Description of the Model

While a full description of the model can be obtained from Ho and Nielsen (2007), and from prior publications[10], we summarize here the essential elements of the model most relevant to our analysis of the implications of adding tax evasion to the base model.

There are two basic components of the model: an economic portion and a health portion. Our modifications to tax evasion affect only the economic portion of the model. The economic portion of the model is a general equilibrium model estimating the demand and supply of the 33 sectors in the model. General equilibrium is achieved when the prices and quantities of buyers and sellers for each commodity match. Labor and capital are also balanced in the model.

3.3.1 Actors in the Model

The primary actors in the model are: Households, firms, the government, and the rest of the world.

Households are identical. They supply labor, capital, and land to firms. Supply of each input is inelastic and households receive no utility from leisure. Population and household savings rates are exogenous; all savings are invested in capital which is then rented to firms. Households utility functions are Cobb-Douglas; they purchase goods and services from firms.

[9] We find that real GDP and consumption are marginally greater as a result of a fuel tax, where Ho and Jorgenson (2007) reported that these decreased marginally in the short run. Both models agree that these increase in the long run.

[10] Garbaccio, Ho, and Jorgenson (2000) is particularly helpful and lists almost all equations in the CGE model.

Firms buy inputs from other firms according to the 1997 input-output table of China. They also rent land and capital from households. There is one representative firm for each type of commodity. Firms generate goods to be sold to other firms and to households. Sales taxes on goods vary depending on the type of good. Firms pay several kinds of taxes to the government: the VAT, business profits taxes, and fuel taxes when they are assessed. Firm profits accrue partially to households as dividends, with the remainder invested into future capital stock.

The government receives revenue from sales taxes, the VAT, business profits taxes, household fees, tariffs, and fuel taxes when they are assessed. It provides transfers to household income at a rate determined exogenously, and buys real goods in the economy. The government uses net revenues to purchase 2 goods which directly improve household utility: social services, and health and cultural services. The government also provides administrative services, an input for some firms.

The rest of the world sells imports and buys exports. They pay tariffs. The prices of imports to China factor into the overall prices of goods.

3.3.2 Pollution

There are three kinds of pollution tracked in the model: carbon dioxide emissions CO_2, particulate emission $PM10$, and sulfur dioxide emissions SO_2. $PM10$ and SO_2 have health effects on households which are tracked but do not cycle back into the model. In other words, the ability of reduced pollution to improve the number of labor hours or the productivity of workers, as in Williams (2000), do not enter into the model.

Pollution is generated from two sources. First, it is generated from the use of polluting goods: coal, oil, and natural gas. Each input has a linear relationship with the pollutants tracked in the model. Second, pollution is generated from polluting processes, like those of the chemical industry.

3.3.3 Policy Reform

The proposed policy reform focused on in this paper is a fuel tax which matches 30% of the average marginal health damages generated by coal and by refined petroleum. The initial tax under the baseline simulation raises the price of coal by 32%, and raises the price of refined petroleum 2%. Revenues from the fuel tax are recycled to cut sales taxes, the VAT, and corporate income taxes by an equal percentage. This is a "double dividend" style of reform.

4 The Introduction of Endogenous Tax Evasion

4.1 Theoretical Model of Tax Evasion

As in Liu (2010), we model tax evasion as a fraction of the tax rate evaded. If the tax base for tax i is X_i, and the tax rate is τ_i, the revenue from this tax that should be collected are $\tau_i X_i$. However, if tax i is evaded at rate E_i, the revenue collected is only $(1 - E_i)\,\tau_i X_i$.

Tax evasion should respond endogenously to changes in tax rates; higher tax rates should cause more evasion. In addition, when taxes are zero, there should be no tax evasion, $E_i = 0$. In our baseline parameterization, tax evasion is modeled as a quadratic function:

$$E_i = (A_i \tau_i)^{N_i} \tag{1}$$

The elasticity of evasion with respect to the tax rate is constant: N_i. Using estimates from Gorodnichenko et. al (2009), we calculate that the elasticity of tax evasion with respect to the tax rate is 0.420[11]. We then use the baseline evasion rate and statutory tax rate, as will be calculated in section 4.2, to calibrate A_i.

Under this quadratic specification, changes in the rate of tax evasion are initially relatively slow in response to changes in the tax rate; as the tax is eliminated altogether, evasion approaches 0 more quickly. We have also tested the impact of a linear response of tax evasion with respect to the tax rate as a robustness check.

4.2 Empirical Calculation of Evasion Rates

Our goal is to derive credible parameters of the tax evasion rate for each type of tax for each commodity. Since the policy being examined varies only the statutory rates for the fuel tax, the sales tax, the VAT, and the business profit taxes, we incorporate tax evasion for only these taxes.

It is important to define what is meant by "tax evasion" for the purposes of this paper. For the purposes of CGE modeling, tax evasion is the link between observed underlying economic activity and taxes actually collected. A typical policy analyst may have information about sales, business profits, and other tax bases; he may also be able to collect data on taxes actually received. The difference between what the government would have received if statutory tax rates were applied to tax bases, and what is actually received, is all included

[11] Gorodnichenko et. al define evasion e as the amount of unreported earnings. We define evasion as a rate of evasion on the tax rate E; this implies $e = wlE$, where w is the wage and l is the labor supplied. We can easily calculate that $\epsilon_E = \epsilon_e + \epsilon_{wl}$, where ϵ_i is the elasticity of i with respect to the tax rate. Gorodnichenko et. al calculate that $\epsilon_e = 0.376$ (p. 544) and $\epsilon_{wl} = -0.044$ (p. 543), so $\epsilon_E = 0.420$.

under the wrapper of "tax evasion.[12]" Conceptually, the goal of empirically calculating evasion rates is the same as the "effective tax rate" method of the prior CGE literature: to provide a connection between sources of data on economic activity and taxes collected.

To estimate the evasion rate for each type of tax, we first compare the amount of tax that should be paid, as calculated by applying statutory tax rates to the input-output table of China, with actual taxes collected. To estimate the evasion rate of each sector, we assume that each sector's self-employment rate is a proxy for its inherent ability to evade taxes. Finally, using the baseline values of sectors as weights, we back out the evasion rate for each sector for each type of tax.

4.2.1 Calculation of Evasion Rates for Types of Taxes

Our understanding of the statutory tax law is derived from Liu (2006). Actual tax collection figures are derived from China Tax Yearbooks, annual publications of the National Statistical Bureau of China.

Sales Tax Evasion Only firms categorized as services firms pay the sales tax in China. Sales tax in China is charged as a flat percentage on sales; the rate varies with the category of service.

Using data on the production of services from the 1997 Input-Output table, we estimate the amount of sales tax that should be charged on each category of services. We estimate that 198 billion yuan were owed in sales taxes (table 1). Since the China Tax Yearbooks

[12]The public finance literature has long distinguished between avoiding by illegal means, tax evasion, and avoiding taxes through legal means, tax avoidance. Legal forms of tax avoidance might include purchasing tax-sheltered goods or working in tax-favored industries. Both of these, and all other economic phenomena which may create a gap between taxes owed and taxes collected, are "tax evasion" for the purposes of this study.

report that 135 billion yuan in sales taxes were actually collected, our estimate of the evasion of sales taxes is 32%.

VAT Evasion The VAT in China is charged on only industrial categories of output. Businesses pay either the VAT or the sales tax. Each business calculates its VAT owed by multiplying its revenues by its applicable VAT rate. It then subtracts VAT paid by its suppliers. We assume that firms receive a 100% refund when they export their sales, a simplification of the tiered system of refunds.

Using the 1997 Input-Output table, we estimate each industry's VAT payable using figures for total production and exports. We use the constant rate of 13% for the sectors of agriculture, electricty production, and refining, and a constant rate of 17% on other sectors. We can also estimate the VAT paid by each industry's suppliers to yield VAT paid. We find that 899 billion yuan were owed on VAT taxes in 1997 (table 2). The China Tax Yearbooks report that 348.1 billion yuan were collected; our estimate of the evasion rate on the VAT is 61%.

Business Income Tax Evasion Businesses owe income taxes on their profits. Income taxes are charged at a flat rate of 33% of profits.

Our best estimate of business income taxes comes from the 1997 Input-Output table, which provides the "operating surplus" for each industry. We multiply each sector's operating profits by the flat 33% rate to estimate the business income taxes owed. We estimate that that 449 billion yuan of business income taxes were owed (table 3). Since the China Tax Yearbooks report that 107.5 billion yuan were paid, our estimate of the business income tax evasion rate is 76%.

Fuel Tax Evasion Fuel taxes in the model are levied on only coal and refined petroleum. Although no fuel tax has been currently levied in China, we estimate fuel tax evasion using another tax with possibly similar properties: the resource extraction tax. Taxes are levied on crude oil, coal, and natural gas as the price for extracting natural resources. Tax rates depend on the quality of the resource extracted.

The China Statistical Yearbooks report total crude oil output, coal output, and natural gas output in 1997. We multiply these outputs by the mean of the range of prices on these resources to estimate the taxes owed. We estimate that 6.81 billion yuan were owed on resources extracted (table 3). Since 5.66 billion yuan were paid, we estimate that the resources tax was evaded at a rate of 17%. We use this estimate for fuel taxes.

Comparing Rates of Evasion Between Types of Tax We have found that the highest rates of evasion occur for the business income tax and the VAT; the sales tax and fuel tax have the lowest rates of evasion. This makes sense intuitively, since computing business profits and value added involves monitoring sales along with other elements. Klepper and Nagin (1989) showed using line-item tax return data that tax evasion was strongly related to the difficulty of establishing noncompliance.

4.2.2 Calculation of Evasion Rates of Sectors

Self-employment has widely been linked to tax evasion. We use the self-employment rate in each sector as an identifying characteristic which shows how much tax evasion will occur in that sector relative to other sectors.

We estimate self-employment using the 2001 China Labor Statistical Yearbook. The 2001 edition is used since it contains the best data on self-employment. Later editions do not report total employment by sector. Earlier editions do not contain all of the types of other employment that we would like to exclude.

Since the numbers of self-employed in each sector are not directly reported, we estimate the self-employed by exclusion. Starting from the total number of employed reported in each sector, we subtract the number reported employed by each other form of employment. If an individual is employed by a state-owned enterprise or by a TVE, they cannot be self-employed. Other types of employers which directly report employment by sector are: state-owned enterprises, urban collective-owned units, other ownership units, employment by urban private enterprises, employment by rural private enterprises, and employment by township-village enterprises (TVEs). With data of the number of people whose employer can be accounted for and the total number of employees in each sector, we can estimate the percentage of the self-employed.

The 2001 CLSY also reports the number of people who are individually-employed in each sector. The number of individually-employed is only 8% of total employment, much lower than outside estimates of self-employment. For each sector, we take:

$$max\left(1 - \%\, Accounted\, For, Individually\, Employed\right)$$

to represent the percentage of people that are self-employed in each sector.

To check the accuracy of our method, we note first that our estimate of total self-employment is 61%, between the CLSY 2006's reported self-employment figure of 66.1% and the OECD's 2005 online statistical abstracts database figure of 48.2%. To assure ourselves that the general trend of self-employment is correct between sectors, we plot the level of self-employment in each sector using our method in China against the level of self-employment reported by the BEA's NIPA for the United States. We see in this figure that low self-employment sectors in China generally correspond to low self-employment sectors in the U.S.; higher self-employment also matches. The sectors that do not fit these trends make intuitive sense; wholesale trade and retail trade employ a relatively higher number of self-employed in China, while finance and insurance employ higher numbers of self-employed in the U.S.

4.2.3 Evasion Rates by Sector and Type of Tax

Combining the estimates above, we can estimate the tax evasion rates for each sector for each form of tax. We assume that the tax payment rate in each sector is proportionate to the number of self-employed in each sector, with the self-employed paying taxes at half the rate of those employed by others[13]. We weight each sector's tax evasion rate for each tax by the value of that sector in the baseline simulation with static tax evasion. Results are reported in table 6.

4.2.4 Statutory Tax Rates

For the business income tax and the value added tax, we used actual statutory tax rates for each sector, documented in Liu (2006). The fuel tax is decided internally in the model; it is set to 30% of the marginal damage caused by the fuel.

For the sales tax, Ho and Jorgenson used rates much higher than the 3-5% for the sales tax; moreover, taxes are charged on all commodities, not just services. We are unclear what is rolled up in the effective sales tax measure, but it accounts for the about half of government

[13] Slemrod (2007) records that the self-employed evade the self-employment tax at an rate of 52%, while the employed evade the equivalent tax at a rate of 2%.

revenue in the baseline simulation. Since the GAMS model does not balance without the substantial revenues of the sales tax, we chose to treat the parameters of the initial model of Ho and Jorgenson as effective sales tax rates. Combined with our estimates of the evasion rate for each sector for the sales tax, we back out the initial statutory rates for each sector for this tax.

Although we have substantially altered the baseline tax system of Ho and Jorgenson, we are able to qualitatively match the results reported in their simulations.

5 Results of Including Endogenous Tax Evasion

Before discussing the results of simulations, it is important to address what the proper counterfactual is for the purposes of analyzing the role of endogenous tax evasion. In the original model, a fuel tax is imposed equivalent to 0.3 of the marginal health damages of that fuel. The revenues from that fuel tax are used to cut the sales tax, the VAT, and the business income tax proportionately, with real government spending held constant. Tax evasion is static. The set of changes that results from this "double dividend" style of tax reform is the counterfactual for our analysis.

In our analysis, tax evasion is endogenous. Falling tax rates on the sales tax, VAT, and business income tax decrease the incentives to evade taxes; taxes are evaded less as a result. The set of changes resulting from this reform is compared to the set of changes from the counterfactual.

For the primary set of results, we set the elasticity of tax evasion with respect to tax rates at 0.42, the central result of Gorodnichenko et. al. (2007). To show how our results change as the elasticity of tax evasion is varied, we also show results with the elasticity set to 0.2 and 0.65 in each table

5.1 The Key Assumption: Convergence in Tax Evasion

The primary driver of results is a convergence in tax evasion rates between types of taxes as taxes are cut. Evasion rates on taxes that are paid dishonestly change more rapidly than those for taxes that are paid honestly. We believe that this assumption is credible for two reasons. First, under the framework where tax evaders make rational evasion decisions based on marginal costs and benefits, taxes that are evaded more must have lower marginal costs of evasion. Under the reasonable assumption of convex marginal costs, decreases in the tax rate will change evasion rates for highly-evaded taxes more than less-evaded taxes. See figure 2 for a pictorial representation. Second, if we think that all taxpayers will not evade taxes when rates near zero, the assumption of converging rates of evasion must be mathematically true.

One way of seeing this assumption in practice is illustrated in table 7, which shows the initial rate of evasion and the shifts in the rates of evasion under a variety of elasticity parameters. Since the elasticity of tax evasion is set the same for each tax, a uniform cut in tax rates decreases evasion rates by the same percentage across each simulation. Since the sales tax is evaded relatively less, a fixed percentage change affects evasion of the sales tax less in absolute terms than the effect on evasion of the corporate income tax. This effectively causes a convergence in the rates of tax evasion.

Under a revenue-neutral tax reform, this convergence causes in a shift in the composition of the tax base, illustrated in figure 3. Cuts in the sales tax rate have a substantial effect in the amount of revenue collected. Cuts in the VAT and business income tax rates are partially blunted by the behavioral response in tax evasion; taxpayers decrease their rates of evasion in response to decreased statutory rates.

5.2 Macroeconomic Outcomes

The original Ho and Jorgenson (2007) paper found relatively minor macroeconomic consequences from imposing a new fuel tax, a result they attributed to their assumptions about the high elasticity of substitution between energy and other inputs in their production functions. Macroeconomic variables from our simulations setting the elasticity of tax evasion constant are presented in tables 8 and 9, representing years 1 and 20 of the simulation. On the whole, the macroeconomic changes are relatively minor and result primarily from mechanical changes in general equilibrium.

The biggest macroeconomic impact in these tables is the prediction that endogenous tax evasion leads to lower levels of market investment. While the simulation with static evasion predicts a slight rise in GDP, the simulations with endogenous evasion predict a slight fall. The main contributors to this fall in GDP are government spending and lower investment.

The fall in investment can be explained from the shift in tax burden explained above. Under a revenue-neutral reform, the business profits tax takes a relatively higher share of the tax burden when tax evasion is endogenous. In this model, the business profits tax decreases corporate cash flow. Since all after-tax profits are re-invested into the capital stock for the next period, higher business profits taxes result in lower market investment. This fall in investment results in a moderate predicted decline in the capital stock relative to the counterfactual, as can be evidenced in the last row of table 9.

The fall in government spending also traces back mechanically to the shift in tax burden. While the tax burden on the corporate income tax increases, the tax burden of the sales tax decreases, resulting in a a small fall in prices (see figure 4). The model holds real government spending constant. With price levels dropped, the government has to spend less money to buy the same level of real goods. This salutary effect decreases government spending.

5.2.1 Environmental Outcomes

Since many environmental models are interested in tracking outcomes such as pollution, we turn next to the impact of including endogenous tax evasion on individual commodities. While shifts in aggregate outcomes are more minor, significant shifts in prices and quantities demanded of individual goods are created by the presence of endogenous tax evasion.

The environmental portion of our results are set up by table 10, which illustrates how producer prices have changed in each sector when tax evasion is static and when it is endogenous. Table 8 has shown that higher elasticities of endogenous evasion create allow higher cuts in taxes with recycled revenue.

The secondary industry, a relatively sector with relatively low evasion opportunities heavily targeted by the pollution tax, has a much lower overall rise in prices when tax evasion is endogenous. The primary industry, which evades the most, sees almost no cuts in prices, even under simulations with bigger tax cuts.

These shifts in pricing are also reflected in purchases: the secondary industry, which sees the biggest changes in quantities resulting from the new fuel tax, sees the biggest relative decreases when endogeous tax evasion is included. While both the primary and tertiary industries see quantities demanded grow, the changes are not as great as those in the secondary industry.

Incorporating Static Tax Evasion The main environmental variables examined in the model appear in table 11. The first and second columns of this table contrast the current approach of the existing literature with an approach which includes tax evasion in the newly introduced fuel tax.

By combining tax evasion and statutory rates into effective tax rates, previous papers miss the substantial impacts caused by tax evasion in the newly-introduced tax. We find that the pollution-cutting strength of these taxes is diminished by 10-15% when static tax evasion in the environmental tax is incorporated.

Incorporating Endogenous Tax Evasion The introduction of endogenous evasion has a smaller impact on the primary targets of the tax such as overall energy use, coal use, and overall carbon dioxide emissions. It has a larger impact on secondary targets of the fuel tax, including oil use, electricity production, and the transportation sector.

Major price shifts such as the introduction of the fuel tax on the coal industry are preserved, even when faced with the decline in overall price levels illustrated in table 10. Minor price shifts and secondary targets of the pollution tax are predicted to have more minor price changes under the counterfactual; the subtle shifts caused by endogenous tax evasion then have a major impact on the magnitude of these changes and even their direction.

For example, a revenue-neutral fuel tax raises coal prices and is predicted to cut electricity production by 4.2% if tax evasion rates are constant. Our central tax evasion simulation shows that electricity use will be cut only 4.0%, a 5.6% decrease in effectiveness. Oil use is directly targeted by the fuel tax and is predicted to decline 1.0% under static tax evasion rates. Endogenous tax evasion simulations show that oil production will decline 0.8%, a 22.6% decrease in effectiveness. The transportation sector is targeted by higher fuel taxes. While it declines 0.4% in the static tax evasion simulation, it declines only 0.2% in the endogenous tax evasion simulations, a 46.8% decrease in effectiveness.

5.2.2 The Impact on the Distribution of Welfare

Consumers and firms bear the burden of taxes differently. While consumers bear the burden of sales taxes (including fuel taxes) more closely, firms bear more of the burden of business income taxes and the VAT. As tax rates are cut, tax evasion rates for business taxes and the VAT decrease more rapidly than those for sales taxes. As a result, the tax burden shifts more to business taxes and the VAT, illustrated by figure 3.

The impact of the tax shift on consumers can be illustrated using figure 4, a plot of the changes in consumer prices under the policies examined. Under endogenous tax evasion, almost all consumer prices are lower.

Changes in consumer welfare are typically using **equivalent variation**, the amount households would be willing to pay under the status quo to be equally well-off with a proposed policy. We measure the equivalent variation associated purely from goods consumed, separately from pollution or from health outcomes. The utility of households and the price of utility were calculated using the consumer's utility function, assumed to be Cobb-Douglas with respect to goods consumed. Changes in corporate welfare are measured using **net profits.**

We plot changes in corporate net profits and equivalent variation as a result of the policy in figure 5. Under the counterfactual of static tax evasion, households suffer from price distortions (Goulder 1995) and are made worse-off by the fuel tax. They would be willing to pay 5.2 billion yuan to avoid the policy. Under the simulation using the central parameter for tax evasion elasticity, the diminished tax burden operating through consumer prices has a large enough impact to offset the fuel tax policy and make households better off. They would have to receive 2.2 billion yuan under the baseline to be as well off as they are when the policy is enacted.

These gains to households are offset by losses in profits to corporations. Under the counterfactual of static tax evasion, corporations initially have higher net profits of 8.3 billion yuan as a result of the fuel tax policy; they benefit from cuts in their business income taxes and VAT rates. Under the simulation using the central parameter for tax evasion elasticity, corporate profits decrease by 1.5 billion yuan. Increased tax burdens on the corporate profits tax and the VAT have decreased corporate profits.

6 When is Endogenous Tax Evasion Important to Include in Tax CGE Models?

We have presented in this paper an illustration of the impact of including endogenous tax evasion in tax CGE models. Endogenous tax evasion may be important when evaluating policies that involve shifting tax rates, such as flat-tax reform, tax base-broadening reform, and the determination of optimal tax rates.

In some ways, this study has helped highlight the importance of reliable estimates of tax evasion elasticity parameters. We used the same tax evasion elasticity for each tax, necessitated in part by a lack of good macroeconomic evidence. Further empirical work could look at how tax evasion of the VAT responds to statutory rates, or how corporate income taxes respond.

We found that endogenous tax evasion had small aggregate macroeconomic effects. Since the tax burden shifted from taxes on consumer prices to taxes on corporate profits, endogenous tax evasion caused a small decline in real investment and in government spending. We also found that secondary targets of pollution such as electricity and transportation saw big effects. Endogenous tax evasion seems to be particularly important when the proposed analysis examines results tied to individual commodities. The most significant impact to occur in the distribution of outcomes between actors in the model. Variation in evasion between different kinds of taxes can play a potentially pivotal role for welfare gains and losses for households and corporations.

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Table 1: Estimates of Sales Taxes Owed in 1997.

	Construction	Transport-ation	Commerce and Catering	Public Utilities	Banking and Insurance	Other Services	Total
Output	266,271	1,039,198	1,226,222	502,050	1,256,329	129,291	4,419,361
Tax Rate	3%	3%	3%	3%	8%	5%	
Taxes Owed	7,988	31,176	36,787	15,061	100,506	6,465	197,983

Notes: All figures are in millions of RMB. Output data are obtained from the 1997 Input-Output table of China.

Table 2: Estimates of VAT Owed in 1997.

	Agriculture	Mining and Quarrying	Food	Textiles	Other Manufac-turing	Supply of Electricity
VAT Payable	164,345	257,405	134,640	165,108	131,619	42,748
VAT Paid	128,389	40,565	128,396	157,458	88,868	28,102
VAT Owed	35,955	216,840	6,244	7,651	42,751	14,646
	Refining	Chemicals	Building Materials	Metal Products	Machinery, Equipment	Total
VAT Payable	33,216	260,262	115,693	289,829	569,694	2,164,560
VAT Paid	37,042	159,241	81,354	142,427	273,681	1,265,523
VAT Owed	-3,826	101,022	34,339	147,402	296,013	899,037

Notes: All figures are in millions of RMB. VAT payable figures are derived by multiplying an industry's output, less exports, with its VAT rate. VAT paid figures are derived by subtracting the VAT owed of each industry's inputs. All data obtained from the 1997 Input-Output table of China.

Table 3: Estimates of business profits taxes owed in 1997.

	Agriculture	Mining	Foodstuff	Textiles	Other Manufacturing	Supply of Electricity
Operating Surplus	74,514	82,652	93,971	100,523	129,060	43,598
Taxes Owed	24,590	27,275	31,011	33,172	42,590	14,387
	Refining	**Chemicals**	**Building Materials**	**Metal Products**	**Machinery, Equipment**	**Construction**
Operating Surplus	14,316	96,990	55,208	34,998	207,339	84,534
Taxes Owed	4,724	32,007	18,219	11,549	68,422	27,896
	Transportation	**Commerce, Catering**	**Public Utilities**	**Banking, Insurance**	**Other Services**	**Total**
Operating Surplus	91,692	121,738	53,193	53,550	22,785	1,360,659
Taxes Owed	30,258	40,174	17,554	17,671	7,519	449,018

Notes: All figures are in millions of yuan. The business income tax rate on all sectors is 33%. Operating surplus data are obtained from the 1997 Input-Output table of China.

Table 4: Estimates of resource taxes owed in 1997.

	Crude Oil	Coal	Natural Gas	Total
Output	160.7 mtons	1,372.8 mtons	27.8 mtons SCE	
Applicable Rate	Y19 m / mtons	Y2.65 m / mtons	Y4.14 m/ mtons SCE	
Taxes Owed	Y3.05 b	Y3.64 b	Y0.12 b	Y6.81 b

Notes: "mtons" refers to "millions of tons." "m" and "b" refer to "million" and "billion," respectively. The applicable rate is the mean of the high and low extraction cost rates for each type of resource. Output data are obtained from the 1997 Input-Output table of China.

Table 5: Estimates of employment and self-employment.

	Agriculture	Mining and Quarrying	Manufacturing	Production of Electricity	Construction	Geological, Water Conservancy
SOE	4,962	4,513	14,321	2,341	3,917	1,080
Urban Collectives	139	351	5,317	94	2,725	19
Other Ownership	64	988	13,369	404	1,159	3
TVE	2,220	0	74,667	0	15,811	0
Private Enterprise	560	415	11,278	0	1,115	0
Actual Employment	333,550	5,970	118,952	2840	35,520	1,100
Percent Accounted For	2%	105%	148%	100%	70%	100%
Individually Employed	1%	5%	10%	0%	1%	0%
Best Guess SE Rate	98%	5%	10%	0%	30%	0%
	Transportation, Communications	Wholesale and Retail Trade	Finance	Real Estate	Social Services	Health Care, Social Welfare
SOE	5,665	5,440	2,234	633	3,267	4,273
Urban Collectives	584	2,925	704	68	642	594
Other Ownership	556	1,730	330	303	926	14
TVE	8,985	19,890	0	0	4,320	0
Private Enterprise	316	7,795	0	0	1,792	0
Actual Employment	20,290	46,860	3,270	1,000	9,210	4,880
Percent Accounted For	79%	81%	100%	100%	119%	100%
Individually Employed	20%	61%	0%	0%	65%	0%
Best Guess SE Rate	21%	61%	0%	0%	65%	0%
	Education	Scientific Research	Government and Party Agencies	Others	Total	
SOE	15,084	1,512	10,989	787	81,018	
Urban Collectives	533	79	49	170	14,993	
Other Ownership	41	153	0	74	20,114	
TVE	0	0	0	2,303	128,196	
Private Enterprise	0	0	0	794	48,130	
Actual Employment	15,650	1,740	11,040	56,430	629,780	
Percent Accounted For	100%	100%	100%	7%	43%	
Individually Employed	0%	0%	0%	1%	8%	
Best Guess SE Rate	0%	0%	0%	93%	61%	

Notes: The figures in the lines "SOE", "Urban Collectives", "Other Ownership", "TVE", and "Private Enterprise" refer to the number of people, in 10,000s, that are reported employed by organizations with that form of ownership. The "Actual Employment" refers to the total number of people, in 10,000s, which are reported employed in that sector. The "Percent Accounted For" refers to the sum of other forms of employment, divided by the figure for actual employment within a sector. The "Individually Employed" refers to the number of people reported as "Urban Individual" employment or "Rural Individual" employment. The "Best Guess SE Rate" is our estimate of the self-employment rate: $max\,(1 - \%\ Accounted\ For,\ Individually\ Employed)$. All data are obtained from the 2001 China Labor Statistical Yearbook of China.

Table 6: Calculated Rates of Tax Evasion by Sector and Type of Tax

	Self-employment Rate	Sales Tax	VAT	Corporate Income Tax	Fuel Tax
Primary	0.98	0.60	0.77	0.86	
Secondary	0.08	0.24	0.57	0.73	0.83
Tertiary	0.22	0.30	0.60	0.75	
Overall	0.61	0.27	0.58	0.74	

Notes: We assume that a sector's self-employment rate reflects its ability to evade taxes, with the self-employed pay taxes at half the rate as those employed by others. Evasion rates by sector are weighted by individual sector value when calculated, but the numbers presented here are unweighted means. Source: Calculations of author.

Table 7: Evasion Rates by Type of Tax

	Baseline Evasion Rate	% Change in Sims with Static Evasion	% Change in Sims with Endogenous Evasion		
Elasticity of Tax Evasion		0	0.20	0.42	0.65
Sales Tax	26.7%	0.0%	-1.2%	-3.6%	-8.5%
VAT	57.9%	0.0%	-1.2%	-3.6%	-8.5%
Corporate Income Tax	74.3%	0.0%	-1.2%	-3.6%	-8.5%

Note: The "Baseline Rate" is the unweighted mean of tax evasion rates in the baseline simulations, as calibrated in section 4. The "Static Evasion" is change in these rates when tax evasion is held constant. The "Endogenous Evasion" is the change in these rates under a "double dividend" simulation, combining a fuel tax with a proportionate cut in each of these rates.

Table 8: Comparison of macroeconomic results between the baseline simulation, the fuel tax simulation with static tax evasion, and the fuel tax simulation with endogenous evasion. Year 1 of simulation.

	Base Case with Static Evasion	% Change from Fuel Tax, Static Evasion	% Change from Fuel Tax, Endogenous Evasion		
Elasticity of Tax Evasion			0.20	0.42	0.65
Real GDP	7,935.7	0.3%	0.2%	0.1%	-0.2%
Consumption	3,793.2	0.1%	0.1%	0.1%	0.1%
Investment	3,002.3	0.5%	0.3%	0.0%	-0.6%
Plan Investment	736.5	0.5%	0.4%	0.3%	0.0%
Market Investment	2,265.8	0.5%	0.3%	-0.1%	-0.8%
Gov't Revenues	1,284.2	0.5%	0.4%	0.2%	-0.1%
Gov't Spending	1,540.5	0.4%	0.3%	0.2%	-0.1%
Total Exports	1,726.3	0.0%	0.0%	0.0%	0.0%
Total Imports	1,312.8	0.0%	0.0%	0.0%	-0.1%
Change in Tax Rates	15,968.3	5%	6%	8%	13%
Pollution tax / Revenue	0%	5%	5%	5%	5%

Notes: The numbers in the first column represent the levels from the baseline simulation. Each dollar in the simulation represents roughly 1 billion yuan. The numbers in the second through 5th columns represent the percentage change in that variable after running a simulation running a policy combining a new fuel tax and a revenue-neutral cut in other taxes.

Table 9: Comparison of macroeconomic results between the baseline simulation, the fuel tax simulation with static tax evasion, and the fuel tax simulation with endogenous evasion. Year 20 of simulation.

Elasticity of Tax Evasion	Base Case with Static Evasion	% Change from Fuel Tax, Static Evasion	% Change from Fuel Tax, Endogenous Evasion 0.20	0.42	0.65
Real GDP	23,258.2	0.4%	0.3%	0.1%	-0.4%
Consumption	6,092.3	0.0%	0.0%	0.0%	0.1%
Investment	4,527.9	0.4%	0.3%	0.0%	-0.9%
Plan Investment	280.9	0.1%	0.1%	0.1%	-0.1%
Market Investment	4,247.0	0.4%	0.3%	0.0%	-1.0%
Gov't Revenues	1,749.4	0.3%	0.2%	0.1%	-0.4%
Gov't Spending	1,760.5	0.3%	0.2%	0.1%	-0.4%
Total Exports	2,805.0	0.0%	-0.1%	-0.1%	-0.3%
Total Imports	2,678.7	0.0%	-0.1%	-0.1%	-0.3%
Capital Stock	98,184.2	0.2%	0.1%	-0.1%	-0.7%

Notes: The numbers in the first column represent the levels from the baselilne simulation. Each dollar in the simulation represents roughly 1 billion yuan. The numbers in the second through 5th columns represent the percentage change in that variable after running a simulation running a policy combining a new fuel tax and a revenue-neutral cut in other taxes.

Table 10: Changes in Prices and Quantities as a Result of Tax Evasion, by Sector

Change in Prices	% Change from Fuel Tax, Static Evasion	% Change from Fuel Tax, Endogenous Evasion		
		0.20	0.42	0.65
Primary	0.1%	0.1%	0.1%	0.1%
Secondary	1.0%	0.9%	0.7%	0.4%
Tertiary	0.3%	0.2%	0.0%	-0.3%
Overall	0.6%	0.6%	0.4%	0.2%
Change in Quantities				
Primary	0.2%	0.2%	0.3%	0.5%
Secondary	-0.9%	-0.8%	-0.7%	-0.4%
Tertiary	0.0%	0.0%	0.1%	0.2%
Overall	-0.5%	-0.5%	-0.3%	-0.1%

Notes: Each column of figures here represents the result of two simulations, although the baseline for each column is the same. The first column is the change in prices resulting from a fuel tax when tax evasion is static. Other columns represent the change in prices resulting from a fuel tax when tax evasion is endogenous. The rows of the column represent the aggregated primary, secondary, and tertiary sectors in the simulation.

Table 11: Comparison of energy and pollution results between simulations adding a new fuel tax when tax evasion is static and when evasion is endogenous.

Change in Prices	% Change from Fuel Tax, No Evasion	% Change from Fuel Tax, Static Evasion	% Change from Fuel Tax, Endogenous Evasion		
			0.2	0.42	0.65
Energy Use	-17.3%	-15.2%	-15.1%	-15.0%	-14.8%
Coal use	-22.6%	-19.9%	-19.8%	-19.7%	-19.5%
Oil use	-1.1%	-1.0%	-0.9%	-0.8%	-0.5%
Natural Gas use	-0.3%	-0.3%	0.0%	0.0%	0.3%
Electricity Production	-4.8%	-4.2%	-4.1%	-4.0%	-3.7%
Transportation Sector	-0.5%	-0.4%	-0.3%	-0.2%	0.0%
CO_2 emissions	-18.6%	-16.3%	-16.3%	-16.2%	-16.0%
Primary Particulate Emissions	-10.4%	-9.1%	-9.1%	-9.0%	-8.9%
SO_2 Emissions	-16.6%	-14.5%	-14.5%	-14.3%	-14.1%
Energy-GDP Ratio	-17.5%	-15.4%	-15.3%	-15.1%	-14.6%
Health Damages	-14.6%	-14.7%	-14.6%	-14.4%	-14.4%

Notes: Each column of figures here represents the result of two simulations, although the baseline for each column is the same. The first column is the change in quantities resulting from a fuel tax when no fuel tax evasion is considered. The second column introduces static tax evasion of the fuel tax. Other columns represent the change in prices resulting from a fuel tax when tax evasion is endogenous. All simulations are intended to capture the year 1997.

Figure 1: Plot of self-employment rates obtained by the authors for China against self-employment rates reported by the BEA for the U.S.

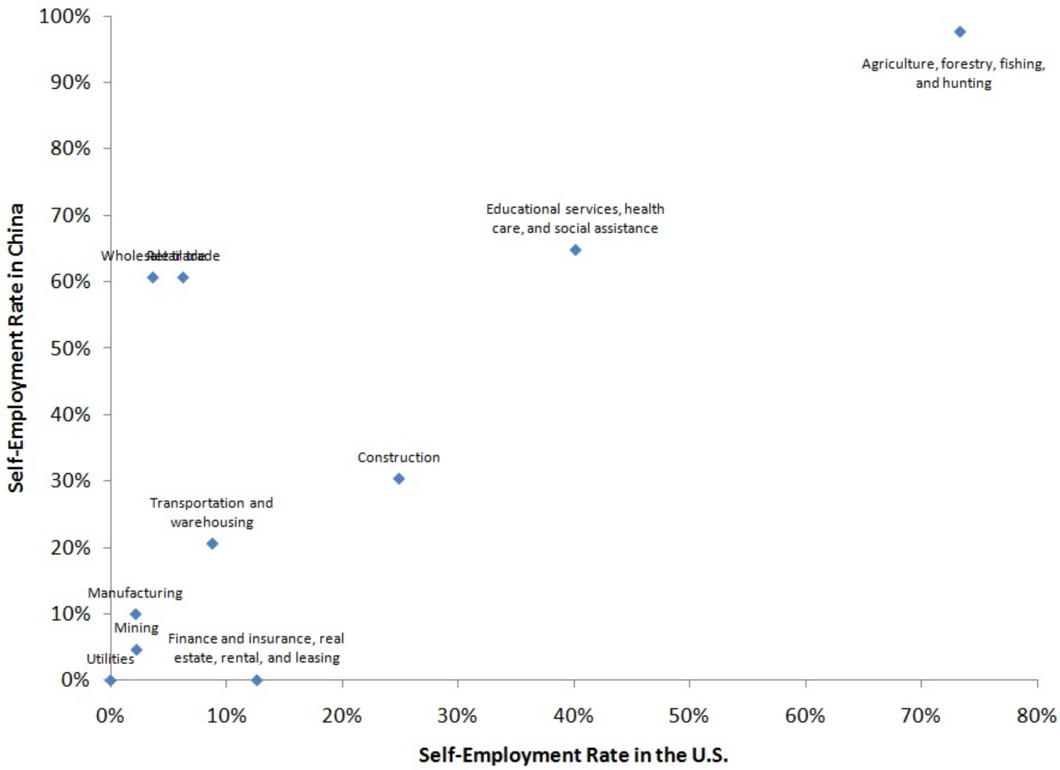


Figure 2: The Marginal Cost and Marginal Benefit of Tax Evasion

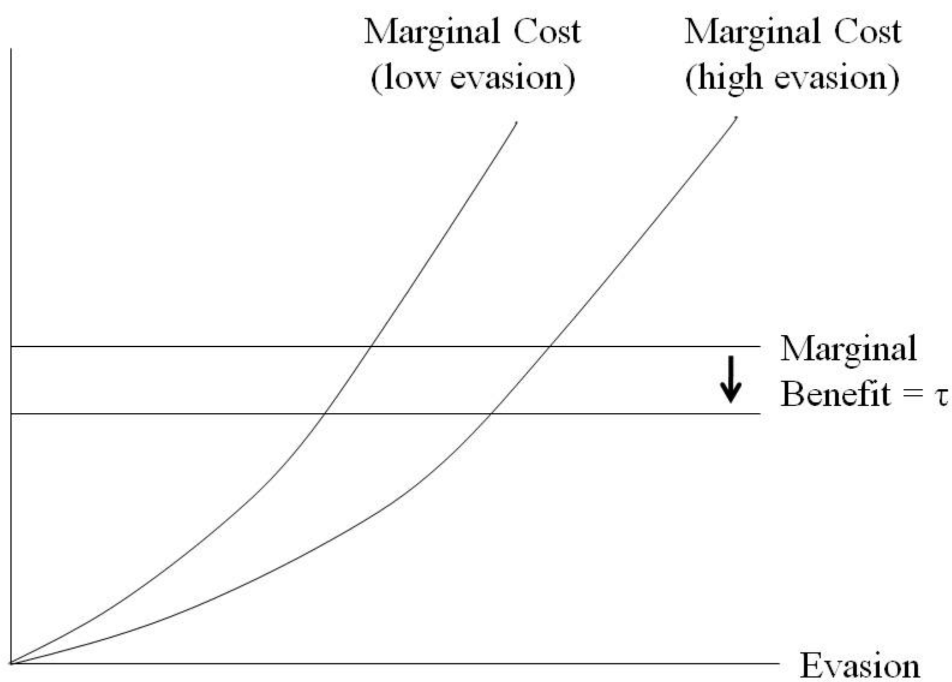
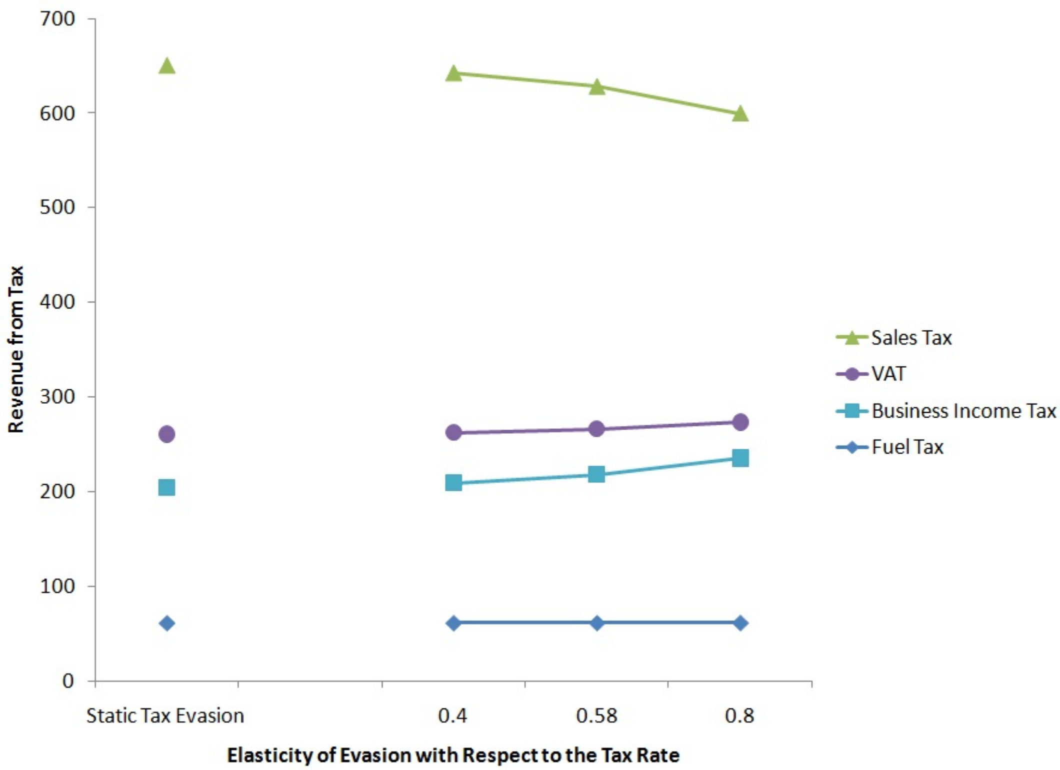


Figure 3: The Shift in Composition of the Tax Base



Notes: Each column of this graph represents the result of one simulation. The simulation combines a new fuel tax with an equal tax cut on the sales tax, VAT, and business income tax.

Figure 4: Plots of Initial Price and Change in Price after a fuel tax.

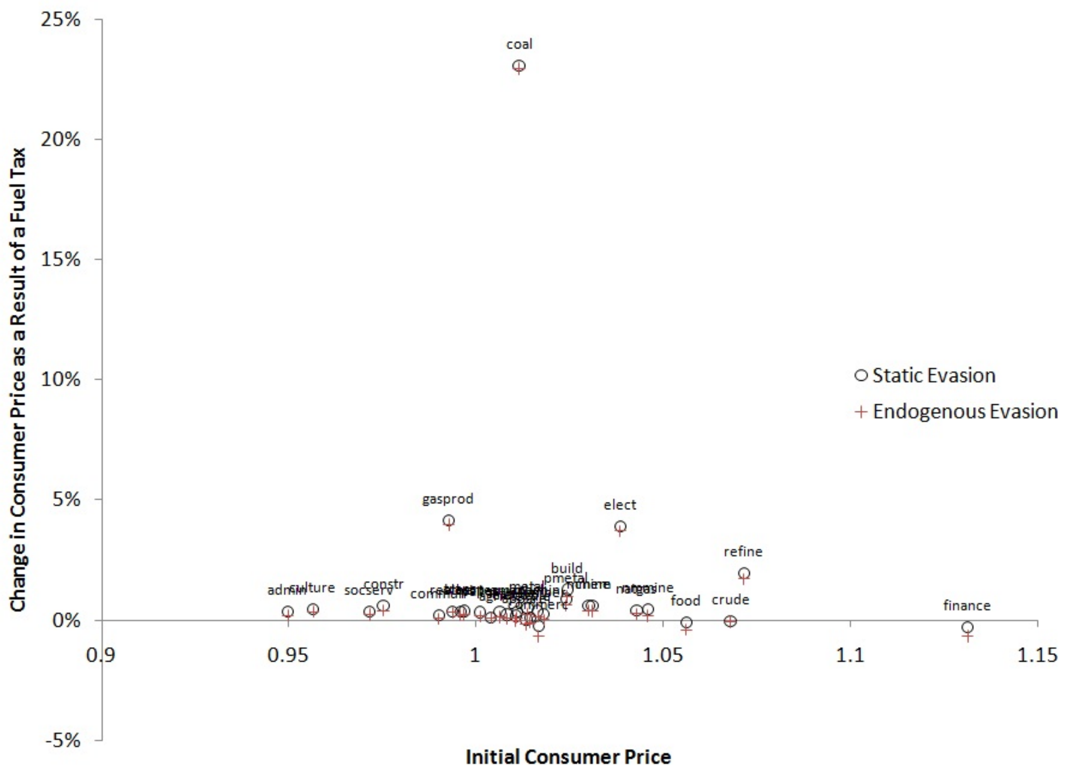
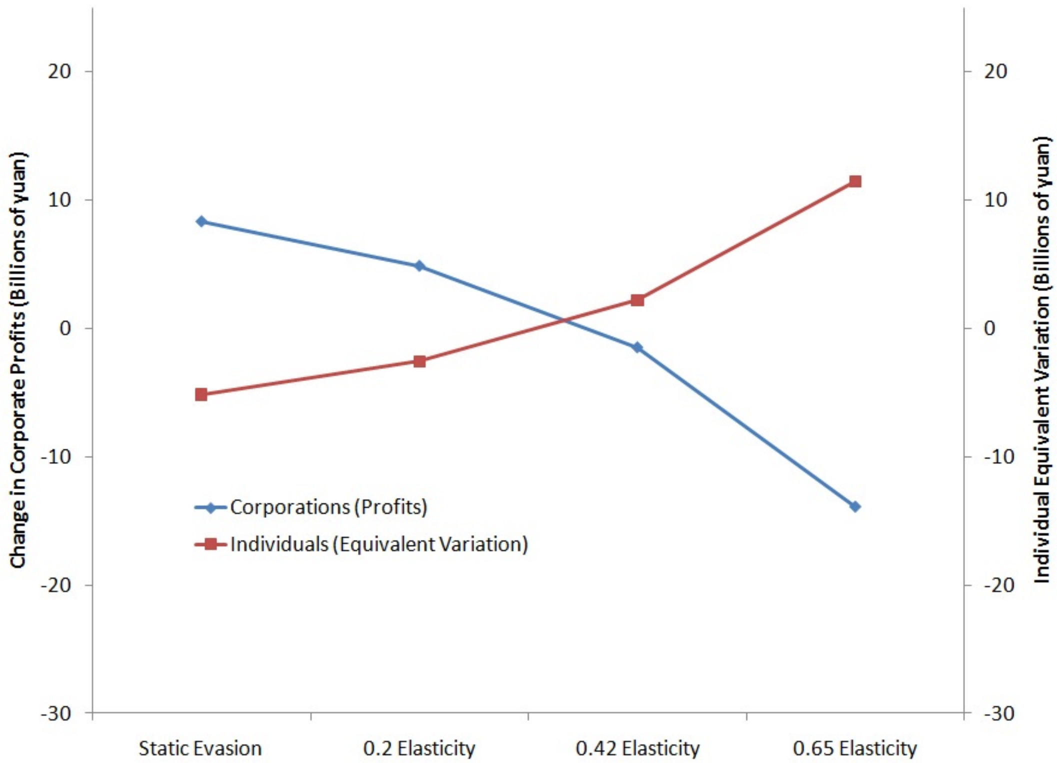


Figure 5: Corporate Profits and Individual Welfare as a Result of the Fuel Tax Policy



Notes: Each column of this graph represents the result of one simulation. The simulation combines a new fuel tax with an equal tax cut on the sales tax, VAT, and business income tax. All units are in billions of yuan.