

OPTIMAL COMMODITY TAXATION WHEN LAND
AND STRUCTURES MUST BE TAXED
AT THE SAME RATE

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CESIFO WORKING PAPER NO. 1522
CATEGORY 1: PUBLIC FINANCE
AUGUST 2005

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Abstract

We show that the optimal property tax rate rises with the ratio of land rents to structure and land development costs. California's high ratio of income to property tax revenue and the distribution of Federal housing subsidies thus appear geographically misplaced. Proportional taxation of non-housing commodities is not optimal, even when elasticities with respect to wages are identical. Absent externalities, the desirability of transportation taxes and "anti-sprawl" growth controls hinge on the relative importance of time versus money in commuting costs.

JEL Code: H21, R13.

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We thank Richard Arnott, Thomas Knapp, and seminar participants at the North American Regional Science Council, UC Berkeley, University of Missouri and the Missouri Economic Conference for helpful comments.

1 Introduction

This paper asks what role property taxes play in an optimal commodity tax scheme. The question is motivated by the crucial role of property taxes in financing public goods in the United States. In 2004, state and (mostly) local governments raised over \$324 billion in property tax revenue, an amount equal to more than 20 percent of state and local expenditures and close to 10 percent of all US government outlays, exclusive of federal defined benefits. Property taxes are the second largest source of tax revenue in the United States after the individual income tax, again excluding social insurance and retirement receipts.¹

US property taxes are economically interesting in part because they combine a tax on land rents with distortive taxes, at the same rate, on land development and housing structures. Taxes on pure rents are generally desirable but distortive taxes on commodities in infinitely elastic supply are typically undesirable, even in second-best settings in which income taxes distort leisure choice.

In this paper, we take as given that land and structures are taxed at the same rate, without asking what political forces lead to the equality of rates that exists almost everywhere and without asking whether taxes on pure land rents would generate sufficient government revenue to obviate distortive taxes.²

We distinguish pure rents accruing to land owners from the cost of developing raw land. Development generates costs of site preparation, which we assume to be constant in quantity, and the opportunity cost of any foregone agricultural profits, which we assume are zero.

Despite the importance of property taxes to overall public revenue, to our knowledge, there has been no prior economic analysis of optimal commodity taxation under the constraint that land rents be taxed at the same rate as structures and raw land development. The desirability of taxes on pure land rents has been familiar since at least George (1879), and Haughwaut (2004) shows through a simulation that there is considerable deadweight burden to failing to separate land from structure taxation in New York City. Papers that have considered profits in general, such as Munk (1978, 1980), and Auerbach and Hines

¹Estimates based on US Census Bureau (2005) and US Office of Management and Budget (2005).

²Pittsburgh, PA has employed a land tax, as have some Commonwealth countries. Pure land rents are subject to some federal taxation through capital gains taxes and taxes on rental income. Very large owner housing capital gains are also taxed, and real property forms part of taxable estates. Back of the envelope calculations suggest that confiscating land rents would generate revenues close to but most likely below total current government spending levels. Davis and Heathcote (2004) estimate that residential land has a total value equal to approximately 50 percent of one year's gross domestic product. Assuming residential land is worth at least two-thirds of total US land value, this implies that total land value is less than 75 percent of one year's GDP. Even if the rental dividend and capital gains summed to as much as high as 10 percent, that would mean confiscation of land rents would generate revenues equal to 7.5 percent of GDP each year. Federal state and local spending, exclusive of defined benefit programs, appears to be slightly above this level. Counting defined benefits, the gap is much larger.

(2003), suggest that the presence of land rents may lead to important modifications to the first order conditions that characterize second-best commodity taxes. However, these papers do not provide clear guidance on how the presence of land rents affects actual tax rates. Brueckner and Kim (2003) show that property taxes have ambiguous effects on the quantity of land used by a fixed number of consumers, but do not consider the efficiency of property taxes in a world with alternative sources of revenue and elastic labor supply.

Our analysis shows that the optimal property tax rate is increasing in the ratio of land rents to total property value. While this result holds quite generally and may seem obvious, there are important US policies that result in reduced effective tax rates on housing in the ratio of land rent to property value. The best known examples of states with limited property taxes and high income taxes are California and Massachusetts, states in which land value represents a relatively very large fraction of property value. At the federal level, as documented by Gyourko and Sinai (2003), tax benefits to homeownership are concentrated in Coastal states. Again, these are states where we show that the tax burden on housing should be the highest, not the lowest.

Figures 1 and 2 illustrate these geographic phenomena. Each of these figures uses a measure of land cost per acre as a proxy for the share of land rents in real estate values. This is a valid approximation if variation in land costs is driven more by residential potential than by agricultural opportunity cost and if the elasticity of substitution between land and structures is less than one. We regard both of these as most likely true.

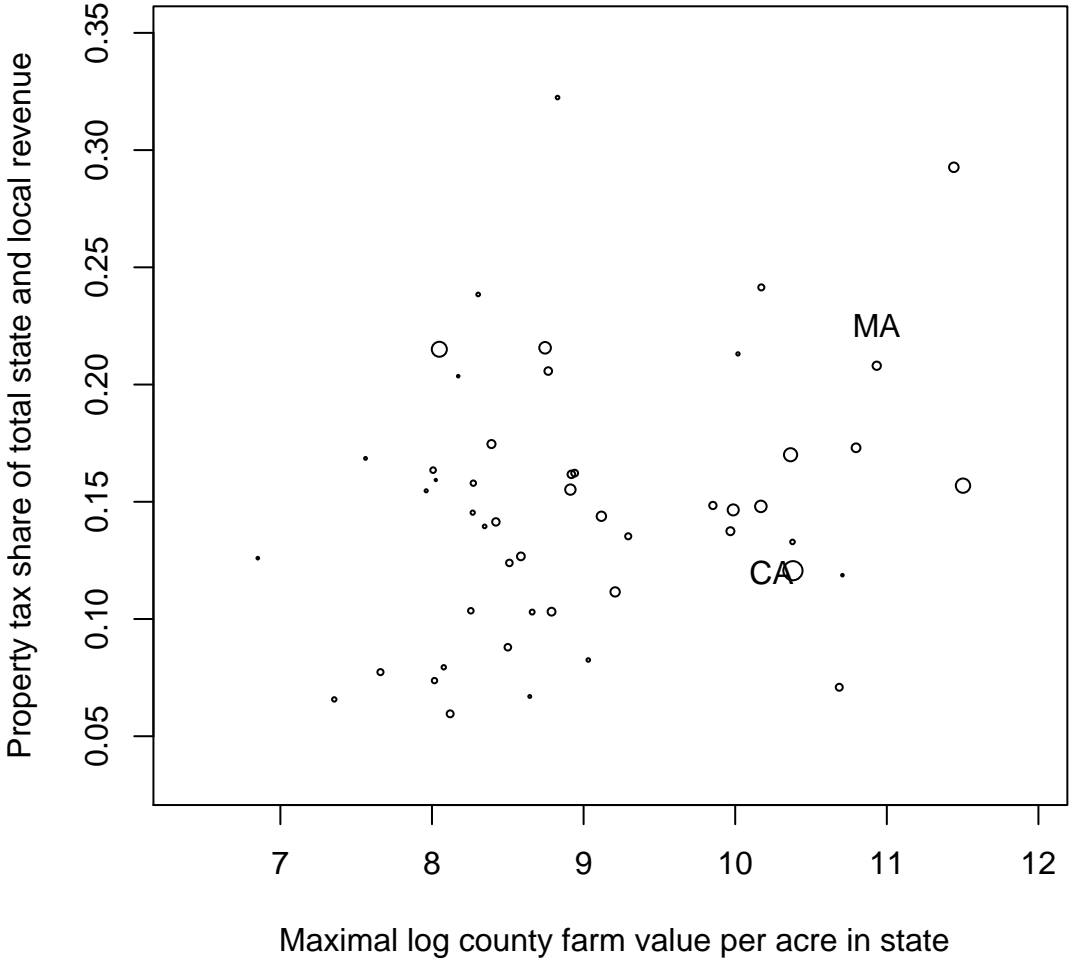
Figure 1 demonstrates that there is a positive but weak empirical relationship between land costs and the share of state and local revenues generated by property taxes. Despite the weak relationship, California clearly has among the highest land values and among the lowest property tax rates, particularly among large states. California has notably draconian property tax limitations, due to Proposition 13, which cut property tax rates upon passage and exempts capital gains on homes from property taxation, as well as the *Serrano* ruling, which provides a very strong disincentive to raise property tax rates. Massachusetts' Proposition 2 $\frac{1}{2}$ places weaker constraints on local governments, as indicated by that state's relatively normal ratio of land value to property tax burden.³

Figure 2 shows that there is a strong positive relationship between land values and federal tax subsidies to homeowners. In sum, the tax burden on owner occupied housing, by far the largest component of real estate value, appears empirically to decrease rather than increase with the land rent share of value.

A second notable result follows from the analysis of Munk (1978): proportional taxation

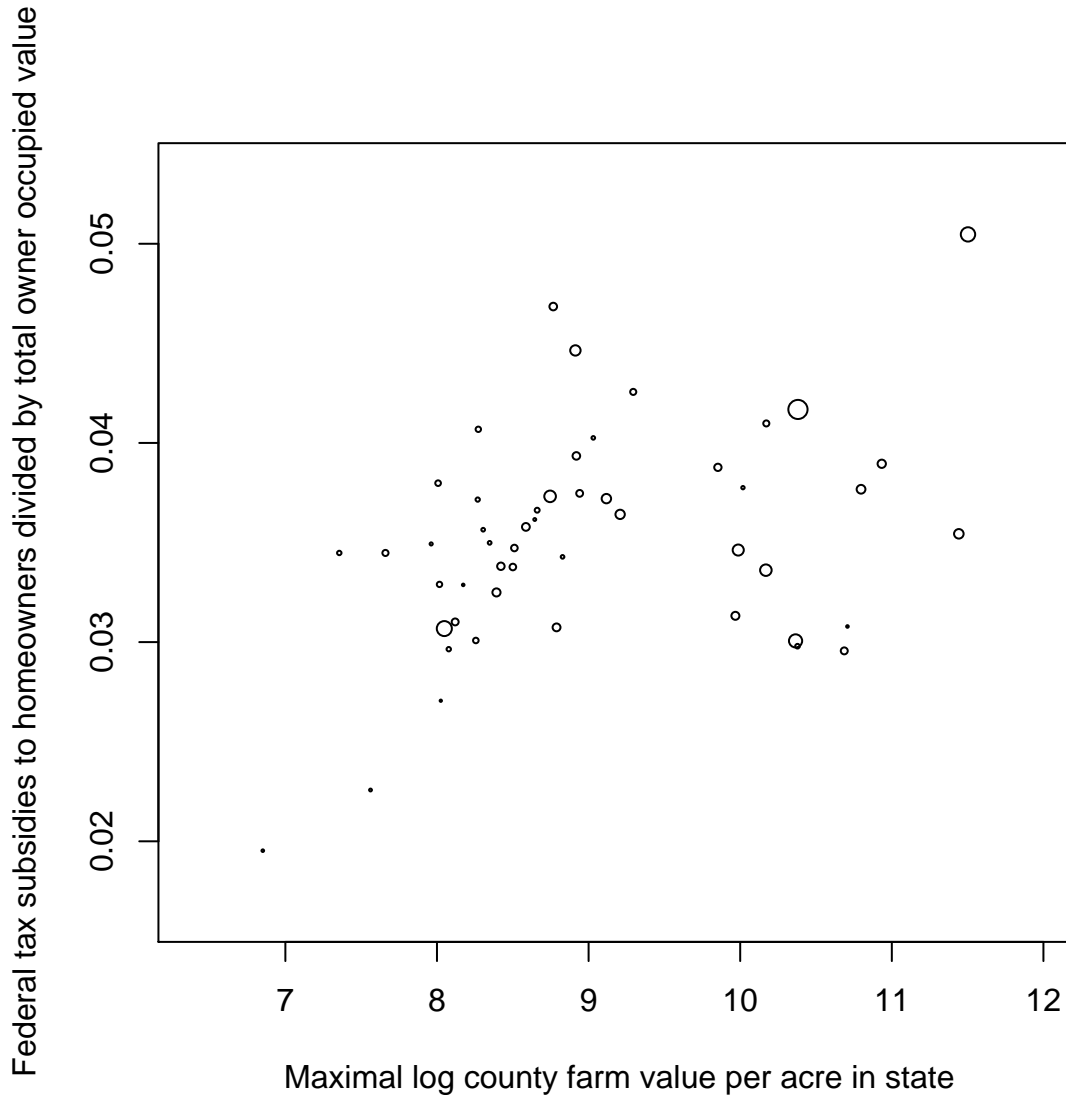
³We cannot be certain whether California has it wrong or if the other 49 states do, as our result concerns relative, not absolute optimal property tax levels.

Figure 1: Relationship between land value and property tax share of total state and local revenues, US States in 2002



Notes: Land value at the state level is approximated by the maximal per acre value of farm real estate in the 2002 US Agricultural Census within each US state. The maximal value is considered because most real estate is located in urbanized areas, so that an average across counties would not be representative. Variation in land values is driven primarily by residential potential, as can be inferred from perusal of land listings at realtor.com. Property tax share is measured as total state and (almost entirely local) property tax revenue divided by total state and local revenue. Bubble sizes are proportional to state population. Tax data comes from the 2002 *Census of Governments*.

Figure 2: Relationship between land value and federal subsidies to homeownership



Notes: Land value at the state level is approximated by the maximal per acre value of farm real estate in the 2002 US Agricultural Census within each US state. The maximal value is considered because most real estate is located in urbanized areas, so that an average across counties would not be representative. Variation in land values is driven primarily by residential potential, as can be inferred from perusal of land listings at realtor.com. Federal tax subsidies are calculated based on data presented in Gyourko and Sinai (2004) and our own division of two figures presented therein. The numerator of the subsidy rate is the total dollars of federal homeownership subsidies and the denominator is the total value of owner occupied housing. Part of the subsidy is attributable to the act of homeownership, and these subsidies are not available to residential or commercial landlords. Bubble sizes are proportional to state population.

of non-housing commodities is generally not optimal, even with equal compensated elasticities with respect to the wage rate. Land development and consumption of structures are discouraged by property taxes, so there is reason for the tax code to subsidize complements for these goods, including real estate development itself, and tax substitutes.

This finding, reminiscent of the analysis of Goulder and Williams (2003), suggests that “anti-sprawl” measures that further discourage raw land development have previously unidentified adverse consequences. However, consideration of property values dictates consideration of the geographical distribution of employment. In a “monocentric city” setting, we find that if time costs dominate direct transportation costs of commuting, then anti-sprawl measures such as land use regulations and transportation taxes can be welfare improving. This possibility arises because anti-sprawl measures reduce the distortion to labor supply caused by income taxes. This condition happens to be most likely met in the same markets that should have high property tax rates due to high land values. Anti-growth measures thus appear better geographically distributed than property tax burdens. In general, it is not easy to dismiss regulation of property markets on efficiency grounds, even absent externalities.

We generate analytical results concerning property taxes in a very simple, static setting. We consider a Robinson Crusoe economy with the sole complication that land on Crusoe’s island is in limited supply and thereby generates pure profits. We introduce the possibility of occupying land not located on the island (such as swimming in the ocean) as a crude means of allowing for differentiated land quality. We then test our analytical results through simulations of the more developed, but still stylized, monocentric city model adapted by Alonso (1960) from the work of von Thunen and further explicated by, e.g., Wheaton (1977). In this model, the differentiation of land is based on continuous distance from a single employment center.

The result that property taxes should be higher where land value is greater should be robust to changing the specification of what drives land value and to considerations of congestion or environmental externalities. However, our results concerning the desirability of anti-sprawl measures would likely require modification if we allowed for the development of endogenous subcenters, as in Helsley and Sullivan (1991) and Lucas and Rossi-Hansberg (2002) or if we considered congestion or environmental quality.

We consider taxation in a “city state,” in that only a single public good is financed by income, property, and commodity income taxes and in that there is no potential for mobility or sorting across communities. To the extent that local and federal spending needs are fixed, we can interpret the optimal level of the property tax as reflecting the optimal sum of local and federal taxes on property.

We do not address redistributive considerations, inter-jurisdictional strategic behavior,

or local political economy. Issues such as the desirability of encouraging Tiebout sorting through property tax deductibility in a world with distortive redistribution are thus left to future research. Land use controls play an important role in the extent of Tiebout sorting, so we view our results on their desirability as complementary to results found elsewhere, rather than as a final word.⁴

The roles of savings decisions and investment dynamics in housing markets are pushed aside because we consider a static model, meant to approximate a steady state. Again, we do not see this approximation as a problem for the interpretation of our result that property taxes should be greater in areas where land values represent a large share of property values. However, the desirability of subsidies for commodities that are complements to structures and raw land development hinges on whether the net effect of taxes on housing prices is greater than or less than the effect on all other commodities.

The literature on the welfare consequences of asymmetric treatment of housing to date, e.g. Rosen (1985), Berkovec and Fullerton (1992), and Gervais (2002), has focused on the various ways in which the federal tax code favors investment in housing over investment in other forms of capital. We suspect that the net effect of federal, state, and local taxes is to place a burden on the consumption of housing commodities relative to other commodities, but leave the accounting exercise to future research.

The remainder of the paper proceeds as follows: Section 2 presents analytical results in the island setting. In Section 3, we draw analogies between the island economy and the “monocentric city” environment and describe numerical simulations of such an economy that generally confirm the analytical results of Section 2. Section 4 concludes.

2 Analysis of an Island Economy

2.1 Land Set Up

We consider an individual who lives on an island and does not trade with the outside world. We assume that demand for island land is sufficiently strong that under all the optimal or constrained optimal tax schemes we consider, all of the island’s land area, \bar{L} , is occupied and the after-tax price that the consumer is willing to pay for land, q_L , exceeds the cost of readying land for consumption. We define units of island land and all commodities so that the cost of producing one unit, absent taxes, is equal to one unit of a numeraire commodity.

⁴If sorting across jurisdictions of housing value is strong, then residential property taxes provide the payer with services equivalent in cost to the tax. In this case the effect of a tax on property on demand for all goods is more complicated than we allow for in this setting. Empirically, jurisdictions are quite heterogeneous (see, e.g. Epple and Sieg (1999), Davidoff (Forthcoming)).

We allow for the possibility that the individual might wish to consume additional land somewhere other than the island. We assume that such land, consumed in quantity b , is in infinite supply at a constant cost of 1, but is less desirable than island land. We will sometimes refer to L as “desirable” land and b as “border” land. This model, close to that of Ortalo-Magné and Rady (2002), is meant to approximate a world in which land is heterogeneous in value, and more valuable land close to amenities or highly compensated employment is in short supply.

The consumer owns 100 percent of a price taking land development company that distributes profits lump sum to the consumer. The firm thus takes a land price of $\frac{q_L}{1+\tau_L}$. The assumption that all land is consumed at any optimum leads to the following:

Remark 1 *Because all island land is consumed at any optimum ($L = \bar{L}$) and land is supplied competitively,*

1. $\frac{q_L}{1+\tau_L} > 1$ and
2. $\frac{\partial q_L}{\partial \tau_L} = 0$.

2.2 Other Commodities

We assume that other than land, all commodities are produced using linear and reversible technology. One unit of labor, z , produces one unit of a numeraire commodity c . This consumption good can be converted one-for-one into housing structures h , any arbitrary other good, g , or for development of land on or off the island. The consumer’s endogenous valuation of a unit of land on the island is q_L . We adopt the Debreu sign convention, so that z is a negative number. As z falls, the amount of labor supplied increases. The tax rate on labor τ_z is a negative number (since consumer price of labor is lower than producer price), so that $\tau_z z$ is direct labor tax revenue.

We will at times make use of an assumption that island land is a hicksian substitute for both border land and for structures. That is, we assume the derivative of hicksian demand for island land with respect to both structures and border land is negative; notationally, we write $S_{Lh} \leq 0$, $S_{Lb} \leq 0$. That different types of land would be substitutes should not be controversial. That land and structures would be substitutes may seem counter-intuitive. However, Thorsnes (1997) finds that a Cobb-Douglas specification for housing development cannot be rejected, implying hicksian substitution.⁵

⁵Making matters somewhat more complicated, island land will be built to a higher density than border land (reflected in the familiar geographic density gradient), rendering island land relatively more complementary to structures than border land. In interpreting our results, we will assume that in areas with higher land prices, land represents a larger fraction of real estate values. This is consistent with Cobb-Douglas production as long as real land prices rise relative to structure prices over time (which they have, historically).

The consumer's preferences over c , b , g , L , and z give rise to an expenditure function that is assumed to be well behaved in the sense that it is homogeneous of degree zero and is increasing and concave in both prices and utility.

2.3 Government

The government requires G units of numeraire and wishes to raise this amount while leaving the consumer as well off as possible. We consider taxation of labor income and other commodities, assuming the numeraire is untaxed and that the government takes limits on the tax rate on pure profits τ_π and other commodity taxes, $\{\tau_i\}$, as exogenously given.

As is standard in the optimal tax literature following Diamond and McFadden (1974), we evaluate the “dual” problem for a welfare maximizing government. The government minimizes the consumer expenditures required to attain utility level u given the profits and prices that arise from taxes sufficient to raise G in revenue. Mathematically, the problem is:

$$\min_{\{\tau_i\}, q_L} \mathcal{L} = E(q, u) - \bar{L} \left(\frac{q_L}{1 + \tau_L} - 1 \right) (1 - \tau_\pi) \quad (1)$$

$$+ \lambda \left(G - \sum_{i \neq L} x_i p_i \tau_i - \bar{L} \left(\frac{q_L \tau_L}{1 + \tau_L} + \left(\frac{q_L}{1 + \tau_L} - 1 \right) \tau_\pi \right) \right) \quad (2)$$

$$+ \mu (L - \bar{L}) + \sum_{i \in \Omega} \phi_i (\tau_i - \bar{\tau}_i). \quad (3)$$

Notation is summarized in Table 1. We scale commodity units such that all non-land producer prices (p_i , $i \neq L$) are set equal to one. λ is the shadow value of a dollar of tax revenue; because this is a minimization in which taxes are distortive, we know that this value is greater than 1. The Lagrangian coefficient μ can be interpreted as the welfare cost or benefit that would arise if a foreign entity were to offer a small quantity of additional island land for sale to the consumer at the price q_L but would not redistribute profits or pay taxes. The government must obey this constraint that exactly \bar{L} of island land is available when setting tax rates, and hence implicitly changing the consumer price of land. The Lagrangian coefficients ϕ_i reflect the welfare effect of increasing or decreasing the exogenously determined tax rates on non-housing commodities $\{\bar{\tau}_i\}$. We assume that \mathcal{L} is convex in the taxes available.

Table 1: Notation

Symbol	Interpretation
τ_π	Tax on profits, exogenously fixed
$\tau_i, i \neq \pi$	Tax on commodity i
τ_L	Common tax rate on $L, h,$ and b .
ϕ_i	Lagrangian coefficient on the constraint that $\tau_i = \bar{\tau}_i$.
Ω	Set of tax rates that are constrained in the optimization
z	Leisure (negative, as is its tax rate τ_z)
c	Numeraire consumption, untaxed
L	Land consumption
h	Structure consumption
b	Consumption of inferior quality land not located on the island.
g	Any other good in infinitely elastic supply.
λ	Shadow value of an additional dollar of government revenue
μ	Lagrangian coefficient on the equality of land supply and demand.
$S_{ij}(\eta_{ij})$	Compensated derivative (elasticity) of demand for good i with respect to the price of good j .

2.4 Optimal Tax Rules

If a tax on island land can raise all needed revenues, i.e. if $G \leq \bar{L}(q_L - 1)$, then optimal tax policy is to restrict taxation to profits from island land. Such optimal taxation could arise from either an island land tax or from a pure profit tax. This follows from the lump sum nature of profit taxation and the satisfaction of the welfare theorems. Mathematically, the gain to a small increase in τ_π is given by:

$$\frac{\partial \mathcal{L}}{\partial \tau_\pi} = \frac{q_L}{(1 + \tau_L)^2} (1 - \lambda). \quad (4)$$

The net effect is to reduce the minimand \mathcal{L} because $\lambda > 1$ when taxes are distortive. While the benefits of profit taxes are clear, we assume that τ_π is constrained to equal zero throughout the rest of this paper.

2.4.1 Optimal Constrained Property Taxes

In almost all jurisdictions in the United States, property taxes are levied at the same rate on both land and structures, development costs are not exempt for owner occupied homes, and agricultural land is taxed at agricultural opportunity cost rather than residential value. Hence property taxes distort both structure consumption and the quantity of agricultural land consumed. We thus assume that $\tau_h = \tau_b = \tau_L$.

We now analyze the optimal unconstrained property tax rate τ_L under the assumption

that all commodities other than other than income and property are untaxed, either through constraints $\{\bar{\tau}_i = 0\}$ or because it is optimal not to tax these commodities. This case warrants special focus because non-taxation of commodities (absent profits) is optimal under conditions first identified by Corlett and Hague (1953). We consider whether commodity taxes or subsidies are desirable from the starting point of zero commodity taxation below. In this special case, denoting by S_{ij} the compensated demand derivative of good i with respect to the price of good j , the welfare effect of a change in the property tax rate τ_L is:

$$\frac{\partial \mathcal{L}}{\partial \tau_L} = (1 + \tau_L)^{-1}(H)(1 - \lambda) - \lambda(\tau_z(S_{zh} + S_{zb}) + \tau_L(S_{hh} + 2S_{bh} + S_{bb})) + \mu(S_{Lh} + S_{Lb}). \quad (5)$$

In equation(5), we have used the notation $H \equiv L \frac{q_L}{1 + \tau_L} + (h + b)(1 + \tau_L)$ to denote the total opportunity cost of real property. Rearranging, we find:

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial \tau_L} &= H(1 + \tau_L)^{-1}(1 - \lambda) \\ -H &\left(\lambda \left(\tau_z \frac{S_{zh} + S_{zb}}{(b + h)(1 + \tau_L)} + \tau_L \frac{S_{hh} + 2S_{bh} + S_{bb}}{(b + h)(1 + \tau_L)} \right) + \mu \frac{S_{Lh} + S_{Lb}}{(b + h)(1 + \tau_L)} \right) \frac{(b + h)(1 + \tau_L)}{H} \end{aligned} \quad (6)$$

As long as taxes generate welfare losses (so that $\lambda > 1$), the first part of the right hand side of equation (6) is negative. Hence, if τ_L is chosen optimally, so that $\frac{\partial \mathcal{L}}{\partial \tau_L} = 0$, the second part of the right hand side must be positive. This implies:

Result 1 *All else equal, the optimal property tax rate is increasing in the ratio of island land value to total real estate value. Also, if the ratio of land values to property values is sufficiently large, a move from pure labor tax to a mixed system of labor and property taxes is welfare improving.*

To provide some intuition, the first part of the welfare effect of a property tax is the gain from a lump sum transfer from the consumer to the government. The second part is the optimally adverse effect of tax distortions to demand for structures and land development. These distortions relate to weighted elasticities of the tax base and the demand for limited island land with respect to the price of structures and border land. As the land share of property value rises, property taxes' welfare effects approach those of a pure land tax.

2.5 Desirability of Commodity Taxes and Land Use Regulations

We now ask what the consequences of property taxes and land rents are for taxation of non-housing commodities and for land use regulations. Before doing so, we recall a central result of commodity tax theory due to Corlett and Hague (1953):

Result 2 *Suppose all elasticities of demand for all commodities with respect to the wage rate η_{iz} are identical and that all goods (including land) are in infinitely elastic supply. Then the optimal tax rate on all commodities is zero.*

With inelastic land supply, starting from taxes only on property and income ($\bar{\tau}_g = 0, \forall g$), we now consider the welfare effect of a small tax on some commodity g . From the problem (1), there is a welfare gain if $\phi_g > 0$. To sign ϕ_g , we use the first order condition:

$$\phi_g = g(\lambda - 1) + \lambda(\tau_z S_{zg} + \tau_L(S_{gh} + S_{gb})) - \mu S_{Lg}. \quad (7)$$

Proportional taxation of non-housing commodities is optimal only if all commodities g have the same value (zero) for the right hand side of (7). However, equal compensated elasticities with respect to wage rate are enough only to ensure that all commodities have equal values for the first two terms on the right hand side of equation (7). Proportional taxation requires also equal compensated elasticities with respect to the price of structures and both types of land. This condition is plainly violated for goods directly related to housing or transportation and for related goods such as energy. The necessary deviations from proportional taxation are likely considerable: transportation and housing alone represented 52 percent of US consumer expenditures in the 2003 *Consumer Expenditure Survey*.

If we assume that all commodities have equal demand elasticities with respect to the wage rate and that structures and border land are substitutes for island land, then if $\mu > 0$, taxes are desirable on commodities that are complements for structures and border land and that are substitutes for desirable land. This follows from the fact that the property tax forces an otherwise border tax on structures and border land which leads to too little demand for these commodities and too much demand for island land.

We now ask under which conditions a positive value for μ is plausible. Recall that a positive value for μ implies that a welfare gain would arise if a price-taking foreign entity were to offer a small quantity of island land without sharing profits or paying taxes. Optimal choice of q_L in the minimization problem (1), implies the first order condition:

$$\mu = S_{LL}^{-1} \left(\frac{q_L \tau_L}{1 + \tau_L} (\lambda - 1) + \lambda (\tau_z S_{zL} + \tau_L (S_{Lh} + S_{Lb})) \right) \quad (8)$$

Equation (8) illustrates three effects of adding foreign island land to the economy. The first effect (unambiguously welfare destructive) is that property taxes on the taxable portion of land fall. Second, if leisure and island land are substitutes, tax revenue increases, pushing μ towards positivity. The third effect, likely rendering μ negative, is substitution towards island land and plausibly away from taxed structures and border land. While it is not easy

to sign the net effect, it is clear that μ is more likely to be positive as island land becomes a stronger substitute for leisure and as the property tax rate falls.

From equations (6), (7), and (8), we obtain the following:

Result 3 *From a starting point of taxes only on labor and property, welfare gains are larger for small taxes on substitutes for structures and border land than for complements, and:*

- *If μ is positive, then a small tax (subsidy) on commodity g is more desirable if g is a complement (substitute) for island land. This case is more likely as island land is a stronger substitute for leisure and a weaker substitute for structures and border land, so that the property tax is larger.*
- *If μ is negative, then a small tax (subsidy) is more desirable on commodities that are substitutes (complements) for island land. This case is more likely as island land is a stronger complement for leisure and a stronger substitute for structures and border land, so that the property tax is smaller.*

Complementarity with island land demand is relatively more important than with structure and border land as island land demand is more inelastic.

Because property taxes discourage structures and border land, taxes are called for on goods that further diminish demand for these goods and subsidies for goods that increase their demand. This correction also operates through complementarities with land demand.

The commodity tax principles laid out in Result 3 provide some clear guidance with respect to land use regulations. Regulations that discourage structures or development of raw land are harmful not only for their distortive effects, but also because they compound the distortive effects of property taxation.

If real property is net subsidized due to federal deductions and exemptions (we do not think this is the case) then it is complements, rather than substitutes, for structures and raw land development that should be taxed. Further, in that case, land use regulations that limit the size of structures and discourage land development are welfare increasing. However, the comparative statics laid out in Result 3 are unaffected by the sign of the property tax.

Result 3 makes clear that substitution between components of real property and labor supply affect optimal commodity taxation. Modern urban economics is focused on exactly such relationships. Urban land is generally thought to hold value, that is to approximate “island” instead of “border” land, in large part due to proximity to places of work. People who must travel to work are compensated by lower prices for the undesirable land they consume. If urban land consumption leads to greater labor supply, we know from Corlett

and Hague (1953) that taxes and regulations should encourage urban land consumption and discourage raw land development. If it is suburban land that is a greater substitute for labor, the opposite will hold. As we will see in the next section, the nature of the costs to living far from work critically determine whether island (urban) or border (suburban) land is a stronger substitute for leisure.

3 The Monocentric City

In the Alonso (1960) model of land rents, value above opportunity cost does not arise from an absolute limit on the quantity of developable land, but rather through differentiation of better and worse locations. Well-located land is relatively valuable because consumers must pay increasing transportation costs as the distance from their lot to a central location (their place of work) grows.

In this section we present some theoretical and simulation results regarding property taxation in the equilibrium characterized by differentiated land quality. Taxing profits is still optimal. In a numerical example we show that our theoretical results from the last section carry over to the “monocentric city” framework, at least in the focal case of Cobb-Douglas utility that we consider.

3.1 Description of the environment

A fixed population of identical consumers now choose not just lot size but also a single lot location. Living at a location of distance x from the origin of a half-line generates transportation costs in numeraire of $x \times \rho_{money}$ and costs in time of $x \times \rho_{time}$. For the consumers to be indifferent among locations, it must be that land rents just compensate for this. When lot size is freely chosen and untaxed, and when the border between agricultural and residential land use is at distance \bar{x} , rent at location x is given by

$$\psi(x) = R_A + \int_x^{\bar{x}} \frac{\rho_{money} + \rho_{time}(1 - \tau_z)}{L(s)} ds. \quad (9)$$

This cost of a unit of land at distance x can be decomposed into the development cost R_A and the “land rent” or “profit” represented by the integral in equation (9).

As above, all land is owned by development companies that distribute profits in equal shares to each consumer. We assume that this is a competitive industry and hence development of land occurs up to the distance \bar{x} where consumers’ willingness to pay for that land equals the cost of development, R_A . Land past \bar{x} has no value.

We parameterize the simulations to generate reasonable expenditure shares for land and structures.⁶ Another goal of the parameterization is to generate sufficient land rents to fund all government revenues. This does not reflect a strong belief that land rents could fund all revenue needs, but rather provides a benchmark against which to measure the deadweight loss arising from less efficient tax schemes. In the main simulations presented, this leads to a relatively small revenue requirement of less than 10 percent of output. As shown in Table 6 in the Appendix, the extent of deadweight loss from inefficient taxation grows with the government’s revenue needs once the land rent funding requirement is dropped.

We endow each consumer with the following Cobb-Douglas utility function:

$$U = \ln(c) + 0.25 \ln(l) + 0.25 \ln(h) + \ln(1 + z - \rho_{time} * x), \quad (10)$$

where the time cost of travel ρ_{travel} and the money cost of travel ρ_{money} are both set to be .5 as a baseline. The gross wage is normalized to be one and the land return R_A is set to .1. Across simulations, total (labor) production in our economy ranged from 0.51 to .57. The gross land profits in this economy average approximately .07.

Under this formulation, land profits are bounded because the source of land profits (land expenditures) are one quarter of consumption expenditure. As travel costs rise, demand for location close to the center increases, rents rise and land consumption falls, with land expenditures fixed by functional form. Hence, the land rent share of aggregate property value rises with travel costs.

3.2 Available tax and other policy tools

In this setting there are more policy tools available to the government than in our island setting. We will consider the following tools: 1) land profit taxes, 2) land taxes, 3) structure taxes, 4) labor income taxes, 5) gasoline taxes, and 6) land use regulations.

Land profit taxes are the only non-distorting taxes in this setting. Even constant *ad valorem* taxes on land value) are distorting since they affect the boundary condition for development. Property taxes, as above, are assessed at equal rates on land rent and structures.

Gasoline taxes are proportional to commuting distance and land use regulations are non-tax tools that allow the government to choose the boundary between developed and unused land. Here, the justification for these “environmental” interventions is that they provide additional instruments beyond the property tax affecting land consumption, which itself

⁶We generate expenditures of 50%. Direct expenditures on housing, not including capital gains or opportunity cost of capital (and excluding indirect real estate costs embedded in consumer goods) were 32% of consumer expenditures in the 2003 *Consumer Expenditure Survey*.

consists of two dimensions (consumption of location and development of raw land). We thus suspect that welfare optimality of market gas prices and development extent would be a knife-edge, despite the absence of any environmental or congestion externalities.

We consider only strict quantity constraints in terms of land use regulations, conjecturing that location-specific, price-based regulation can do no worse. We allow the government to choose between forced restrictions on the amount of land used in the equilibrium (through growth boundaries such as implemented in the Portland, Oregon region) and “development mandates” which require land developers past the break-even market distance \bar{x} . A real world analogy to these mandates is the subsidy to land development that occurs when suburban developers do not bear the full cost of infrastructure and other public goods through impact fees. A finding that pushing city limits past equilibrium levels is optimal implies that growth controls impose efficiency costs.

3.3 Basic simulation results

In Table 2 we present the results of some basic simulations that do not allow for gas taxes or growth controls. The simulations compare the efficiency and equilibrium properties of different tax regimes in our monocentric city specification. All the comparisons are made on a utility constant basis, where the underlying utility level is picked to correspond to the equilibrium utility attained by consumers without any taxes or unearned income.

Before commenting on the properties of the different tax instruments two general remarks on the properties of equilibrium are warranted. First, under our Cobb-Douglas specification and baseline government revenue requirement (approximately 9% of the gross labor compensation/production in the economy), no tax regime generates very large deadweight losses. The average DWL ranges between 1 and 2 percent of the tax revenue. For the combination of labor and property taxes, the marginal DWL equals approximately 4% of the additional revenue.⁷ Second, the land price ratio between city center and agricultural land is smaller than typically observed in metropolitan areas at only approximately 10.

Our basic simulations confirm the efficiency of profit taxation (it is also easy to show this theoretically). If the only constraint on the equilibrium is lack of profit taxes, so that land and structures can be taxed at different rates, then the optimal tax policy consists (mostly) of land taxes and labor taxes at relatively high rates (land taxes at 25%). In this simulation the revenue share is divided approximately 60-40 between labor and property taxes.

A move from unconstrained land and structure taxes to property taxes drastically changes the structure of optimal taxes. The constrained optimal property tax rate is only 4.5% and

⁷The marginal DWL was calculated by discrete approximation evaluating a 1% increase in the government’s revenue requirement.

Table 2: Basic simulation results

Scenario	I	II	III	IV
Revenue requirement	.0500	.0500	.0500	.0500
Travel Costs				
Time cost of travel	.5000	.5000	.5000	.5000
Money cost of travel	.5000	.5000	.5000	.5000
Tax Rates				
Labor tax	.0000	.0530	.0927	.0770
Land Tax	.0000	.2574		.0449
Structure Tax	.0000	.0088		.0449
Profit tax	.6493			
Revenue Shares				
Labor tax	.0000	.5805	1.0000	.8332
Land Tax	.0000	.4024		.0834
Structure Tax	.0000	.0171		.0834
Profit tax	1.0000			
Equilibrium Statistics				
Total (Gross) Profits	.0770	.0571	.0731	.0704
Total Production	.5615	.5480	.5391	.5410
Relative Output Effect		-.0241	-.0398	-.0364
Gross land price at center	1.0994	.8738	1.0530	1.0196
City border	.2296	.2111	.2269	.2251
Relative Border Effect		-.0804	-.0117	-.0196
EV Calculation				
EV from no tax	.0500	.0506	.0511	.0510
EV from profit tax	.0000	.0006	.0011	.0010
Relative average DWL		.0121	.0213	.0194

Note to Table 2. Scenarios: I) No constraints on the tax instruments, II) only labor tax, land tax and structures tax available, III) only labor tax available and IV) only labor and property tax (land and structures at the same rate). The relative output and relative border effects measure the relative change in the respective variable from the efficient tax (scenario I) baseline.

the revenue share of property taxes is only approximately 16%. Thus the distortion on structures demand in our specification has a huge effect on the optimal tax policy.

Some of the results in Table 2 are sensitive to parameter choices. In terms of comparative efficiency costs of the different tax instrument sets, with the low revenue requirement, pure labor taxes seem to have approximately twice the deadweight loss of unconstrained land, structures and labor taxes. The policy set most relevant to real world applications (combination of property and labor taxes, scenario IV) has a deadweight loss that is closer to pure labor taxes (scenario III) than to the unconstrained use of land, structures and labor taxes (scenario II). We conclude in this scenario that the failure to separate land from structures imposes considerable economic burden. With a larger government revenue requirement, as demonstrated in Table 6 in the Appendix, the loss in disallowing separate land and structure taxes is considerably smaller than the loss in moving from property and income taxes to income taxes alone. Further, the property tax share of revenue rises with revenue needs.

The low deadweight burden in Table 2 is seen to be an artifact of low revenue needs.

3.4 The effect of land value on optimal tax policy

Table 3: Land rents share of property value and tax policy

Scenario	V	VI	VII	VIII
Revenue Requirement	.0500	.0500	.0500	.0500
Travel Cost				
Time Cost	.5000	1.0000	.2500	.0010
Money Cost	.5000	1.0000	.2500	.0010
Tax Rates				
Labor tax	.0770	.0752	.0780	.0797
Land Tax	.0449	.0600	.0314	-.0082
Structure Tax	.0449	.0600	.0314	-.0082
Revenue Shares				
Labor tax	.8332	.7668	.8876	1.0270
Land Tax	.0834	.1166	.0562	-.0135
Structure Tax	.0834	.1166	.0562	-.0135
Total Net Expenditure				
Land	.0929	.0971	.0895	.0826
Structures	.0929	.0971	.0895	.0826
Agricultural Land	.0225	.0148	.0325	.0818
$(b + h)/H$.6211	.5763	.6816	.9950
Gross land price at center	1.0196	1.9144	.5656	.1019
City border	.2251	.1483	.3250	.8177
Profits	.07046	.0823	.0570	.0008

Note to Table 3 Scenarios: V) our baseline case of property taxes with time cost and money cost of travel both set to .5, VI) baseline with both travel cost doubled, VII) baseline with both travel cost halved and VIII) baseline with both travel costs set to .001.

In columns V-VIII of Table 3, by varying travel costs (and hence the ratio of land profits to property value), we obtain the result consistent with our island model that the property tax grows with the ratio of land rents to property values.⁸ In column VIII we show that when the land profits are trivially small we can generate negative optimal property taxes.

3.5 “Environmental” Policies

3.5.1 Gasoline taxes

In Columns IX-XII of Table 4 we show the results of expanding the policy set to include gasoline taxes. Our simulations indicate that the level of gasoline taxes (and even whether a tax or a subsidy is called for) depends crucially on the structure of real estate taxation.

⁸The variable $(b + h)/H$ in the table is the after tax expenditure on land development and structures over total real estate expenditure.

Table 4: Gasoline taxes and land use policy

Scenario	IX	X	XI	XII	XIII	XIV
Revenue Requirement	.0500	.0500	.0500	.0500	.0500	.0500
Travel Cost						
Time Cost	.5000	.5000	.5000	.5000	.5000	.5000
Money Cost	.5000	.5000	.5000	.5000	.5000	.5000
Tax Rates						
Labor tax	.0000	.0526	.0859	.0727	.0759	
Land Tax	.0000	.3057		.0399	.0480	1.0000
Structure Tax	.0000	.0069		.0399	.0480	
Profit tax	.6493					
Gas Tax	.0000	-.0332	.0479	.0417		
Revenue Shares						
Labor tax	.0000	.5766	.9290	.7883	.8223	
Land Tax	.0000	.4596		.0749	.0889	1.0000
Structure Tax	.0000	.0135		.0749	.0889	
Profit tax	1.0000					
Gas Tax	.0000	-.0497	.0710	.0619		
Equilibrium Statistics						
Total (Gross) Profits	.0770	.0539	.0744	.0718	.0696	.0270
Total Production	.5615	.5482	.5407	.5422	.5414	.5615
Relative Output Effect		-.0237	-.0371	-.0344	-.0358	.0000
Gross land price at center	1.0994	.8198	1.1043	1.0661	1.0110	.5496
Gross land price at border					.0936	.0499
City border	.2296	.2122	.2208	.2201	.2299	.2297
Relative Border Effect		-.0756	-.0380	-.0413	.0016	.0005
EV Calculation						
EV from no tax	.0500	.0506	.0510	.0509	.0510	.0500
EV from Profit tax	.0000	.0006	.0010	.0009	.0010	.0000
Relative average DWL		.0117	.0198	.0184	.0191	.0000

Note to Table 4. Scenarios: IX) No constraints on the tax instruments, X) labor, land, structures and gas taxes available, XI) only labor and gas taxes available, XII) labor, property and gas taxes available, XIII) labor taxes, property taxes and land use policy available and XIV) land taxes and land use policy available. Gas tax is expressed as a unit tax distance traveled. The discrepancy between city border in columns IX) and XIV) is due to less accurate algorithm (using numerical instead of analytical derivatives) in column XIV). The value 1.000 for the land taxes in column XV) is purely incidental and has no special significance (in fact, it is not exactly equal to one with higher precision).

If land and structure taxes are unconstrained, then as shown in column X a gasoline subsidy is called for. Like land use mandates in the next section, here gasoline subsidies are used to mitigate the distortion of land taxes on the development boundary. Unlike land use mandates, gasoline subsidies do not permit us to replicate first best outcomes.

If, however, we are in the more realistic property tax setting or solely labor and gasoline tax setting, then the second best intuitions seem to be a better guide for gasoline taxes. As shown in columns XI and XII, these situations call for significant taxation of gasoline (raising approximately 7 percent of tax revenue through gasoline taxes). It seems that now the interaction of gasoline tax with the time cost of travel is relevant for optimal policy:

taxing gasoline makes individuals live closer to city center and hence less averse to supplying labor. Simulations show in Table 7 in the Appendix show that increasing the time cost of travel generate larger gasoline taxes and seem to validate this logic.

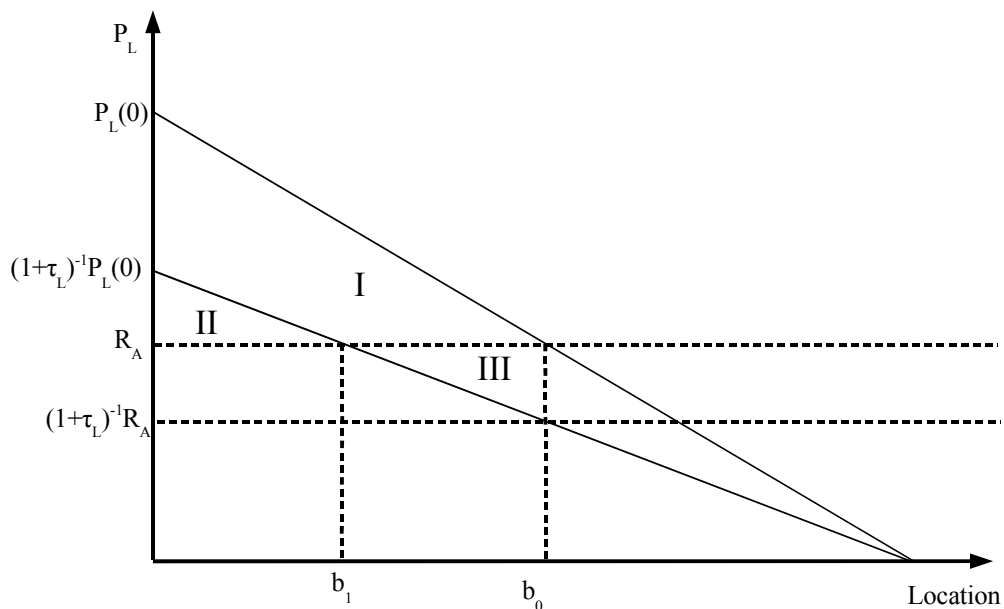
3.5.2 Land use policy

We now ask whether the government could by restricting land use (by setting a development boundary) increase economic efficiency when the first best tax policy tools are not available. To this question our answer will be that it depends on the specific circumstances.

We will first establish a result that points towards the completely opposite policy direction: that it would be optimal to mandate development (or subsidize it using targeted boundary subsidies) beyond the point where the firms themselves find it profitable to develop if the government has to raise tax revenue without the use of profit taxes.

Lemma 1 *For a small government revenue requirement land use policy and unconstrained land taxes can replicate the first best outcome.*

Figure 3: Illustration of Lemma 1



A sketch of proof of 1 is given in Figure 3. In the figure, the original land-market equilibrium border is at b_0 . For simplicity the figure is drawn with a linear land-price

Table 5: Travel cost and land use policy

Scenario	XV	XVI	XVII	XVIII
Revenue Requirement	.0500	.0500	.5000	.0500
Travel Cost				
Time Cost	.5000	1.0000	.0000	5.0000
Money Cost	.5000	.0000	1.0000	.0000
Tax Rates				
Labor tax	.0762	.0774	.0725	.0662
Land Tax	.0474	.0614	.0424	.1137
Structure Tax	.0474	.0614	.0424	.1137
Gross land price at center	1.0115	.9686	1.0467	4.2938
Gross land price at the border	.0936	.1000	.0880	.1051
City border	.2299	.2295	.2300	.0814

Note to Table 5. *Scenarios: XV) Baseline property and gasoline tax with money and time cost of travel set to .05, XVI) time cost set to 1, no money cost, XVII) money cost set to 1, no time cost and XVIII) time cost set to 5, no money cost.*

gradient. In this original equilibrium the profits of the land developers are given by area I+II. Holding utility constant, introduce a tax τ_L . This rotates the gross land-price gradient down and would push the border to b_1 . Using the land development mandate the government can push the border back to b_0 . Now profits are equal to II-III. Government's revenue equals I+III. Simple calculation now shows that the change in profits (and thus the change in representative consumer's unearned income) is equal to -I-III, i.e. minus one times the government's revenue. Thus this policy raises revenue with no deadweight loss.

We thus see that when land taxes are feasible and revenue requirements are small, imposing binding restriction on land use (as opposed to a building mandate) cannot be welfare improving. Infrastructure subsidies that have the same effect on the boundary as the mandate can be welfare improving. Column XIV in Table 4 verifies Lemma 1 numerically. In Tables 4 and 5, we show the optimal cost of development at the urban fringe. In the absence of development mandates or restrictions, the cost to developers is equal to .1.

Column XIII in Table 4 shows that in our baseline case this logic carries over to the true second best situation where we incorporate land use policy with property and labor taxation. Note that in this case the land use policy does not make much difference in terms of efficiency.

Table 5 shows that as long as money costs of travel are not too much smaller than time costs, development mandates are optimal. With a sufficiently large relative time cost of travel it is possible to overturn this result on undesirability of land use constraints (columns XVII, where the border land value is with higher precision higher than .1 and XIX). Note that these present a very moderate case for land use restrictions in these simulations raising the border land price at most by approximately 5%. However, they leave open the possibility that

with different specifications of key parameters (including travel cost and utility functions) a stronger case for land use constraints to augment property taxes. Further, we see that development restrictions make more sense in regions where time costs are a relatively large share of travel costs. Back of the envelope calculations strongly suggest that coastal areas are thus more appropriate locations for development restrictions than are inland areas, and this seems to match the distribution of regulations found by Linneman et al. (1990).

4 Conclusions

In this paper we have developed a framework for evaluating the optimal level of property taxes under different institutional settings and for understanding the interactions between property taxes and other commodity taxes.

Property taxes make up an important part of both empirical and simulated optimal government revenues. We find in simulations that constraints on the set of available property tax tools can generate relatively large deadweight burdens. In a Cobb-Douglas monocentric city economy in which all revenues could be gained through a land profit tax, there are substantial distortions to first failing to remove opportunity costs from taxed land rents and second requiring a common tax rate on land and structures. As the revenue need rises, the revenue share of property taxes also rises, so that the welfare cost of failing to tax property at all rises relative to the cost of distorting land development and structure consumption.

We also find that under preferences that satisfy conditions commonly thought to lead to the optimality of proportional taxation, non-trivial taxes or subsidies may in fact be optimal based on different commodities' complementarities with urban land. Confirming conjectures based on analysis of a Robinson Crusoe economy, we find in a monocentric setting that the desirability of "anti-sprawl" measures such as gasoline taxes or urban growth boundaries hinges critically on whether travel costs stem mostly from time or direct costs.

Notably, some of our results contrast starkly with US tax policy. Whereas we find that property taxes should increase with the land share in real estate markets, tax limitations in California and Massachusetts, as well as the geographic distribution of housing tax subsidies, guarantee that the property tax burden is lowest in these states. A countervailing consideration is that we might think of the United States as one large region, in which the coastal states represent desirable land. If productivity is greater in these areas, we have seen that policies which render these areas more attractive may undo some of the damage done to labor supply through income taxation. This might excuse federal policy in part, but offers no excuse for the apparent irrationality of relative property tax burdens.

The geographic distribution of land use regulations appears more efficient than the dis-

tribution of tax burdens on real property. Land use regulations compound the distortion of the property tax on demand for raw land development. In the coastal areas where raw land is a smaller component of property values and time costs of travel have greater relative weight than money costs, such constraints have more beneficial effects through increasing the labor and land tax bases.

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Appendix

Table 6: Revenue requirement and optimal tax policy

Scenario	XIX	XX	XXI	XXII	XXIII	XXIV
Revenue Requirement	.1000	.1000	.1000	.2000	.2000	.2000
Travel Cost						
Time Cost	.5000	.5000	.5000	.5000	.5000	.5000
Money Cost	.5000	.5000	.5000	.5000	.5000	.5000
Tax Rates						
Labor tax	.1189	.1529	.1963	.2736	.2907	.5630
Land Tax	.5582	.1255		1.5998	.6159	
Structure Tax	.0289	.1255		.2166	.6159	
Revenue Shares						
Labor tax	.6289	.7895	1.0000	.6364	.6506	1.0000
Land Tax	.3441	.1053		.2820	.1747	
Structure Tax	.0270	.1053		.0816	.1747	
EV Calculation						
EV from no tax	.1031	.1046	.1054	.2222	.2303	.2654
EV from profit tax	.0031	.0046	.0054	.0222	.0303	.0654
Relative average DWL	.0306	.0463	.0539	.1109	.1517	.3272

Note to Table 6. Scenarios: XIX) higher revenue requirement, land taxes available, XX) higher revenue requirement, only property and income taxes available, XXI) higher revenue requirement, only income taxes available, XXII) highest revenue requirement, land taxes available, XXIII) highest revenue requirement, only property and income taxes available and XXIV) highest revenue requirement, only income taxes available.

Table 7: Gasoline taxes and travel cost composition

Scenario	XXV	XXVI	XXVII	XXVIII
Revenue Requirement	.0500	.0500	.0500	.0500
Travel Cost				
Time Cost	.5000	1.0000	0.0000	1.5000
Money Cost	.5000	0.0000	1.0000	.0000
Tax Rates				
Labor tax	.0727	.0727	.0727	.0704
Land Tax	.0399	.0399	.0399	.0482
Structure Tax	.0399	.0399	.0399	.0482
Gas Tax	.0417	.0781	.0054	.1217
Revenue Shares				
Labor tax	.7883	.7344	.8423	.6812
Land Tax	.0749	.0749	.0749	.0929
Structure Tax	.0749	.0749	.0749	.0929
Gas Tax	.0619	.1158	.0080	.1330

Note to Table 7. Scenarios: XXV) baseline case with property, income and gasoline taxes, XXVI) same tax instruments, only time cost of travel, XXVII) same tax instruments, only money cost of travel and XXVIII) same tax instruments, no money cost of travel and time cost at higher level.

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