Economic and Spatial Effects of Land Value Taxation in an Urban Area: An Urban Computable General Equilibrium Approach

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ABSTRACT. *This paper studies the effects of switching from a capital property tax to a land value tax, using an urban computable general equilibrium model calibrated to the features of the Atlanta, Georgia, area. Our model differs from prior simulation studies in that we assume that residents own a fixed amount of land rather than assuming an absentee landowner, we consider three income groups rather than just one, we consider cases in which housing capital is not completely mobile, and we allow for a labor-leisure choice.* (JEL H21, H71)

I. INTRODUCTION

Given the limited reliance on land value taxation in the United States (Bourassa 2009), most of the research that addresses the effects of switching from a capital property tax to a land value tax is theoretical or involves numerical simulations; see Anderson (2009) for a review of the empirical literature. The models used in the simulation studies can be classified as either nonurban or urban. The former category includes the models of Follain and Miyake (1986), England (2003), Nechyba (1998), Haughwout (2004), and Wang (2011), while there are three papers, by Sullivan (1984, 1985) and DiMasi (1987), that incorporate an urban model in a computable general equilibrium (CGE) model. An urban CGE model, as opposed to a nonurban model, allows for the consideration of how the spatial features, such as rent and density gradients, of an urban area are affected by a switch to a land value tax (LVT).[1] This paper constructs an urban CGE model to study the effects of switching from a capital property tax to a LVT and builds on the work of Sullivan and DiMasi.

DiMasi (1987) generalized and extended the long-run analysis of Brueckner (1986) through the use of an urban spatial general equilibrium model with an endogenous amount of land in urban use. Basically, DiMasi's model is a monocentric urban model of spatial location with costly commuting. The urban area consists of a central business district (CBD) in which a composite nonhousing good is produced, and a residential area in which individuals consume housing services at varying distances from the CBD. DiMasi assumes that the urban area contains a fixed population of households with identical preferences and labor skills, and that the labor supply is fixed. Land and capital are owned by absentee landowners. The edge of the residential area occurs where the rental value of residential land equals the exogenously given rental rate on agricultural land. The price of the nonhousing good is exogenously given under the assumption that the urban economy is small enough for the price to be set in a national market. DiMasi adopts a nonnested constant elasticity of substitution (CES) functional form for the production and utility functions and calibrates the model using data from the Boston area.

DiMasi reports that switching to a LVT from a capital property tax does not generate sufficient revenue to completely replace the property tax, and thus he considers a graded

[1] We make no distinction between land value and site value taxation.

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property tax system in which land is taxed more heavily than improvements. He finds that adopting a graded property tax results in a decline in land and housing prices, increases in housing improvements per unit of land, increases in population density, and a contraction of the urban boundary. He calculates the welfare gain of residents for a metropolitan-wide move to the graded property tax system to be 6.6% of the tax revenue.

Sullivan (1985) analyzed the effects of a switch from a LVT to a residential property tax, while Sullivan (1984) considered a switch from a LVT to an industrial property tax. Sullivan's two models are essentially the same and produce consistent results. However, there are some differences between DiMasi's model and Sullivan's models. Sullivan assumes a small, open city in which the number of households is not fixed and the household utility level is given exogenously. Sullivan also analyzes a model of a closed region with three identical cities, one of which switches from a LVT to a property tax, either residential or industrial. Sullivan's two models are simulated using hypothetical data. He finds that (1) the property tax reduces the aggregate labor supply, causing the city's wages and population to decrease; (2) since the city is open and labor is fully mobile, landowners bear the entire burden of both the property tax and the land tax; (3) the property tax reduces the net return on land by more than the total tax revenue, so landowners are worse off with the adoption of the property tax. Sullivan reports welfare loss of 6.5% of tax revenue for the switch to a residential property tax and 4.6% for the switch to an industrial property tax.

The present study develops a model similar to those of DiMasi and Sullivan but differs from the previous research in three significant ways. First, while DiMasi and Sullivan assume an absentee landowner, an assumption of most urban models, we assume that residents own a fixed amount of land and capital, which is a more realistic and interesting assumption. Our assumption obviously means that the rental income of a household is endogenously determined. Second, in addition to a model with one income group, we consider a model with three income groups, which allows us to capture the distributional effects of a switch to a LVT as well as the change in the geographic distribution by income group. Third, we consider cases in which housing capital is completely mobile, is only partially mobile, and is completely immobile. This allows us to consider the long-term and short-term effects of switching from a capital property tax to a LVT. Unlike DiMasi, we allow for a labor-leisure choice, so that labor supply is variable. Unlike Sullivan, the computation and assumptions regarding parameters are made based largely on actual demographic, physical, and economic data; in particular, our model is calibrated using the features of the Atlanta, Georgia, urban area. In addition, we consider both a fixed and variable CBD and urban area. Table 1 provides a comparison of the main features of our model with the models of DiMasi and Sullivan and how the features of our model differ across the various extensions that we explore.

II. THE BASIC MODEL

Description of the Model

In this subsection we present the assumptions underlying the model, starting with the general features of the metropolitan economy.[2] The urban area is located in a flat featureless plain of homogenous quality. There is a CBD in which the production of a composite nonhousing good occurs. Land rent within the CBD is assumed to be uniform. The CBD is surrounded by a residential sector, in which housing services are produced. The residential sector is surrounded by an agricultural sector that is not explicitly modeled; the land rent for agricultural use is exogenously given. The boundary of the CBD is determined by the relationship between the highest land rent for residential use and the land rent for the CBD, while the boundary of the urban area is determined at the distance where the land rent of the residential area equals the exogenously given agricultural land rent.

[2] For a discussion of the standard monocentric urban model, see Muth (1967) and Brueckner (1987).

TABLE 1

Comparisons of Model Specifications of Alternative Studies

	DiMasi (1987)	Sullivan (1985)	Sullivan (1984)	Current Study (Basic)	Current Study (Extension 1)	Current Study (Extension 2)
Sectors	Housing; nonhousing good	Housing; export good	Housing; nonhousing good	Housing; nonhousing good	Housing; nonhousing good	Housing; nonhousing good
Land ownership	Absentee	Absentee	Absentee	Resident owns fixed amount of land	Resident owns fixed amount of land	Resident owns fixed amount of land
Capital ownership	Absentee	Absentee	Absentee	Resident owns fixed amount of capital	Resident owns fixed amount of capital	Resident owns fixed amount of capital
Production function type	CES	CES	CES	CES	CES	CES
Utility function type	CES	C-D	C-D	Nested CES	Nested CES	Nested CES
CBD size	Fixed	Variable	Variable	Variable	Variable	Variable
Urban size, residential rings	Variable, many residential rings, endogenous ring number	Variable, one residential ring	Variable, one residential ring	Fixed number of residential rings, fixed and endogenous ring width	Fixed number of residential rings, fixed ring width	Fixed number of residential rings, endogenous ring width
Trade	Not explicitly considered	Not explicitly considered	Not explicitly considered	Nonhousing good, capital, and land are traded in solution for counterfactual scenarios.	Nonhousing good, capital, and land are traded in solution for counterfactual scenarios.	Nonhousing good, capital, and land are traded in solution for counterfactual scenarios.
Data and model area	Boston metropolitan area	Artificial data, small city area	Artificial data, small city area	Atlanta metropolitan area	Atlanta metropolitan area	Atlanta metropolitan area
Labor-leisure choice	Fixed amount of labor	Fixed nonleisure time, some of which is allocated to commuting	Fixed nonleisure time, some of which is allocated to commuting	Labor-leisure choice is applied	Labor-leisure choice is applied	Labor-leisure choice is applied
Income groups	Single income group	Single income group	Single income group	Single income group	Single income groups	Three income groups
Mobility of housing capital	Perfectly mobile	Perfectly mobile	Perfectly mobile	Perfectly mobile	Durable and semidurable	Perfectly mobile
Population level	Fixed	Not fixed	Not fixed	Fixed	Fixed	Fixed
Other characteristics	Split-rate property tax	Split-rate property tax	Industrial property tax, division of capital	Pure land tax, split-rate property tax	Pure land tax	Pure land tax

Note: CBD, central business district; C-D, Cobb-Douglas; CES, constant elasticity of substitution.

The urban area has a fixed number of individuals. Since we analyze the effects of imposing a LVT throughout the urban area, assuming a given population is appropriate.[3] Each worker makes a round trip per day to the center of the CBD. The transportation network is assumed to be radial and dense, so that all trips follow a linear pattern and are completed at a constant speed. The cost of commuting involves a fixed cost per mile and a fixed cost per unit of time.

Capital is supplied perfectly elastically to the urban area at a fixed price. Thus, capital can be either exported or imported, depending on the demand for capital relative to the capital endowment of the urban residents. The nonhousing good can be exported. All markets, including factor and product markets, are taken to be perfectly competitive.

Two equal-yield tax systems are considered: a standard capital-land property tax in which land and improvements (capital) are taxed equally, and a LVT in which land is taxed while improvements are not. We also consider a graded property tax in which land is taxed at a higher rate than improvements. It is assumed that tax revenues are distributed equally to all individuals; this equal distribution of tax revenue assumption makes the expenditure side of the government's budget neutral so that we can capture the effects of tax policies only. Taxes are modeled as applying to the use of capital and/or land, and thus producers (of either housing or the nonhousing good) pay the rental price for capital and land plus the property or land tax.

The choice problem facing an individual residing at distance d from the center of the CBD is to maximize utility subject to budget and time constraints. Utility is a function of the consumption of a nonhousing good, consumption of housing services at distance d, and leisure. A worker has a fixed amount of time that can be allocated to labor, leisure, and commuting. Income comprises earnings from labor activities, rent on capital that the individual owns, rent on owned land in the urban area and in the agricultural sector, and distributed tax revenue, less out-of-pocket expenses from commuting. Each individual is assumed to own a fixed share of all land so that the land rent each individual earns is the same for all individuals. We initially consider only one income class but relax this assumption in Section V.

The producers of housing are profit-maximizing firms that use capital and land at distance d to produce housing at distance d. The composite nonhousing good is produced by profit-maximizing firms using capital, land in the CBD, and labor. All production is according to constant returns to scale technology. Some of the composite nonhousing goods can be traded to individuals who live outside the urban area; it is assumed that the export price is the same as the domestic price.

It is assumed that each resident owns a uniform amount of land throughout the initial (benchmark) urban area. While the urban area can expand or contract with a change in tax structure, the land endowment of each individual is fixed. The fixed pattern of landownership is necessary, since otherwise it biases the evaluation of policies that increase the size of urban area. How to treat landownership is an important issue in urban economic models, and how landownership is treated affects the change in welfare resulting from changes in tax policy.

Generally, in analytical models, absentee landownership is adopted to avoid analytical difficulties. Absentee landownership means that the change of land rent does not affect the income of an individual, but still affects the production costs of housing and nonhousing goods. Our approach regarding landownership is consistent with Sasaki's (1987) approach in the following sense: (1) the income of residents is endogenously determined; and (2) the amount of landholding for each individual is fixed. The difference from Sasaki's approach is that the current model includes endogenous wage income, rental income from capital holding, and income from exports.

Findings from Sasaki (1987) and the current paper suggest that some comparative statics results from the urban model with resident landownership and endogenous income can differ from the traditional findings of the urban model with absentee landownership and exogenous income. One example is that the

[3] See Brueckner and Kim (2003, 12).

increase in commuting cost may increase the welfare of residents in the endogenous income setting due to the increase of rental income from land, while in the exogenous income setting with absentee landownership, the increase of commuting cost unambiguously decreases the welfare of residents.

We allow for the possibility that some capital and/or land is rented from nonresidents. We have specified the model so that the net value of capital and land rented from nonresidents is nonnegative. Firms finance the rent of land and capital not owned by residents by exporting the nonhousing good to nonresidents. Thus, we have balance of the monetary flows between the urban area and the rest of the economy.

In equilibrium the following conditions must hold. Individuals cannot increase utility by moving farther from or closer to the CBD. Prices must be such that all product and factor markets clear. Theory would imply that the rental price of land in the CBD must equal the highest rent for residential land, while the residential land rental rate gross of the tax at the edge of the urban area must equal the exogenously given agricultural land rental rate. In actuality, the price of residential land at the border of the CBD is much lower than in the CBD. Thus, in simulations we require that the residential land value at the border of the CBD be a constant fraction of the price of land in the CBD. The trade balance is not required to meet the budget constraint, due to the existence of the monetary commuting cost. Profit must equal zero for all production. We require that any tax policy change must be revenue neutral.

For the computation we initially segment the residential area into a set of 10 concentric rings; we force rings 1 through 10 to be of equal thickness in each simulation. When the boundary of the urban area expands, the thickness of the CBD and of each ring increases, and when the boundary of the urban area contracts, the thickness of the CBD and of each ring decreases.[4] All workers residing in a given ring are treated, for commuting purposes, as if each lives at the midpoint of the ring.

TABLE 2
Definitions of Parameters

Variable	Definition
α	Intensity of leisure preference over the other goods
β	Intensity of capital use over land in housing sector
δ	Elasticity of substitution among factors in housing production function
$\overline{K}$	Total, fixed capital endowment
λ	Elasticity of substitution among factors in nonhousing good production function
π	Intensity of land use in nonhousing good sector
$\overline{r_K}$	Price of capital, fixed, capital is perfectly elastically supplied
j	Parameter to represent a residential ring (total 10 residential rings)
σ	Elasticity of substitution between leisure and the other goods in utility function
ξ	Elasticity of substitution between housing and nonhousing goods
TPOP	Total, fixed population level
Uarea	Benchmark urban area
μ	Scale parameter of nonhousing good production function
ψ	Scale parameter of housing production function
v	Intensity of housing preference over nonhousing goods
ω	Intensity of capital use over land and labor uses in nonhousing goods sector
Agr	Agricultural land rent

Taxes are imposed on the users of capital or land and are equal to the rental rate charged by the owner times the tax rate. Thus, with full capitalization of a land tax, the user price (rental rate) of land will not change with a change in the tax rate, but the owner's return will fall by the amount of the tax under the fixed CBD and urban boundary model.

Functional Form of the Model's Equations

In this subsection we present the specific functional forms of the equations used in the simulations. The definitions of all parameters and variables are shown in Tables 2 and 3,

[4] DiMasi (1987, 1988) programmed the model differently to reflect the endogenous boundary of the urban area. He made the number of rings variable so that when the urban area expands, the number of rings increases, and when the urban area contracts, the number of rings decreases. One the other hand, Sullivan (1984, 1985) has one CBD and one residential area, and the width of each area becomes wider or narrower due to policy changes.

TABLE 3
Definitions of Variables (Defined as in Equilibrium)

Variable	Definition
L_{CBD}	Land demanded for the production of nonhousing good in CBD
$H(j)$	Housing demanded (per household) in each ring
K	Total capital demanded for all uses
$K_H^D(j)$	Capital demanded for housing production in each ring (per household)
$LEIS(j)$	Leisure demanded in each ring (per household)
$L_H^D(j)$	Land demanded for housing production in each ring (per household)
$M(j)$	Income level net of commuting cost in each ring (per household)
$N(j)$	Number of households in each ring
$NH(j)$	Total nonhousing goods demanded in each ring (per household)
$NHOU$	Total nonhousing goods produced
$A(j)$	Area of ring j
$r_L(j)$	Land rent for housing production in each ring
r_{LN}	Land rent of CBD
TAX	Total tax revenue raised in the economy
$Mcost(j)$	Monetary commuting cost in each ring (round trip)
TKN	Total capital demanded for the production of nonhousing goods
tl	Tax rate on land rent
ts	Tax rate on capital rental
$U(j)$	Utility level in each ring (per household)
W	Wage rate
$WL(j)$	Labor supplied for nonhousing goods production (per household)
WS	Total labor employed for nonhousing goods production
TAX	Tax revenue

Note: CBD, central business district.

respectively. Utility is formulated using a nested function. First, as a subsystem the preference between the nonhousing good and housing is specified by a CES utility function. Then the preference between leisure and the composite good (housing and the nonhousing good) is specified as a second CES function. The use of the (nested) CES function is common in CGE modeling since it is relatively easy to handle and allows alternative substitution parameters. By using a nested function, it is possible to reflect differences in the elasticity of substitution between housing and nonhousing good and between leisure and all goods. Thus, the utility function of an individual living in ring j is expressed as

$$U(j) = (\alpha \cdot LEIS(j)^{(\sigma - 1/\sigma)} + \{(1-\alpha) \cdot [\nu \cdot H(j)^{(\xi - 1)/\xi} + (1-\nu) \cdot NH(j)^{(\xi-1)/\xi}]^{\xi/(\xi-1)}\}^{(\sigma - 1/\sigma)})^{(\sigma/\sigma - 1)}. \quad [1]$$

For the housing and nonhousing good production functions we use CES functions, and thus, housing production in each ring is given by

$$H(j) = \psi \cdot [\beta \cdot K_H^D(j)^{(\delta-1)/\delta} + (1-\beta) \cdot L_H^D(j)^{(\delta-1)/\delta}]^{\delta/(\delta-1)}, \quad [2]$$

while total nonhousing good production is given by

$$NHOU = \mu \cdot [\omega \cdot TKN^{(\lambda-1)/\lambda} + \pi \cdot L_{CBD}{}^{(\lambda-1)/\lambda} + (1 - \varpi - \pi) \cdot WS^{(\lambda-1)/\lambda}]^{\lambda/(\lambda-1)}. \quad [3]$$

Equations [1], [2], and [3], along with budget constraints, are used to derive the expenditure function, cost functions, and demand functions for outputs and for inputs (in the interest of space the derived equations are not presented). Since the rental price of capital is fixed, no capital supply function is needed. Since we assume that the city is a circle, the distance from the CBD to the jth ring is expressed as miles from the center of the CBD to the midpoint of each ring.

Tax revenue raised in the economy is given by

$$TAX = K \cdot \overline{r_K} \cdot ts + (r_{LN} \cdot tl \cdot L_{CBD}) + (\sum_j r_L(j) \cdot tl \cdot N(j) \cdot L_H(j)) + tl \cdot Agr \cdot (Uarea - \sum_j A(j) - L_{CBD}). \quad [4]$$

Per household income in each ring is expressed as

$$M(j) = LEIS(j) \cdot W + WL(j) \cdot W + \frac{\overline{r_K} \cdot \overline{K}}{TPOP} + \frac{\sum_j r_L(j) \cdot L_H(j)}{TPOP} + \frac{r_{LN} \cdot L_{CBD}}{TPOP} + \frac{Agr \cdot (Uarea - \sum_j A(j) - L_{CBD})}{TPOP} + \frac{TAX}{TPOP} - Mcost(j). \quad [5]$$

Equilibrium requires that the sum of population across all rings equals total population, that utility (welfare) is equal across all rings for each household, that the vector of prices clears all markets for both inputs and outputs, that the land rent of the urban boundary equals a given agricultural land rent, and the land rent of the first ring equals a certain percentage of that of the CBD.

III. DATA

To create the benchmark for our model, we use data that reflect the basic features of the Atlanta urban region, including the population, land area, housing price, land price, wage rate, and level of property taxes. The data are for 2003, which was chosen because of data availability and to avoid the effects of the Great Recession on the value of the variables. The region consists of 10 counties, Cherokee, Clayton, Cobb, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry, and Rockdale, and closely resembles the Atlanta urbanized area. We assume that the region is consistent with the urban model presented above, but we do not capture all of the features of the Atlanta region.

The household, rather than the individual, is the unit of analysis since certain variables such as housing units are relevant only to households. This leads to a bit of a complication when considering commuting and labor supply; these issues are addressed below. We parameterized the model so that in the benchmark case the value of variables that vary geographically, for example land rent, in the 5th residential ring equals the average value for the region, that is, the value for a representative household. The values of many of the variables in the benchmark were readily available, while others had to be calculated. In the rest of this section we outline how the data were generated; the details of how the benchmark data were developed are available from the authors.

The urban area has 1.4 million households and 2,981 square miles of land. Assuming that the shape of region is a circle (which approximates reality), the radius is 30.58 miles. The density pattern of the region roughly fits the monocentric urban framework. Data from the Atlanta Regional Commission (ARC) allowed us to allocate land area to residential and commercial-industrial use.

For the social accounting matrix we need total expenditures, including expenditures on leisure, for the representative household. To calculate this we start with income data from the U.S. Census Bureau. To include leisure value, we need to know total leisure time and the unit value of time for the representative household. We use the American Time Use Survey from the Bureau of Labor Statistics and average daily commuting time as reported by the ARC in order to determine the benchmark allocation of time over the day. We use the wage rate to value leisure time.

We calculated average annual expenditures on housing, inclusive of the property tax. The approximate average effective property tax rate for the region is 1.6% of market value. To convert that to a tax on annual housing cost we assume an interest rate of 7%, which is the interest rate in January 2003 for a 30-year fixed rate conventional mortgage as reported by the Federal Reserve Bank. Thus, the effective property tax rate on annual housing consumption, exclusive of the property tax, is 22.9%. This translates to a tax rate of 18.9% on the tax inclusive price.

We need to divide the annual housing cost, exclusive of the property tax, into two parts: land and structure. Using data from the Georgia Department of Revenue we calculated the average land value for residential, commercial, and agricultural use.[5] We take the average residential lot size and the average land value for a suburban community as the benchmark value for the 5th ring. Since land price embodies expenditure for nonbuilding capital invested in the land, we follow Muth's prac-

[5] Property is assessed annually at the county level, with significant state oversight. The quality of the assessments is very good, with the average appraised value equal to 94% of sales value and a coefficient of dispersion equal to 12.5, and the assessors are instructed to assess land and improvements separately. This suggests that land values are likely to be closely related to true land value, but the state does not evaluate that. Accurate assessment of land is a frequently cited issue for administering a LVT (Franzsen and McCluskey 2008). However, Chapman, Johnston, and Tyrrell (2009) show that assessment errors have a small effect on the efficiency of LVTs.

tice of reducing it by one-half to obtain a price for raw land (Muth 1967). This allows us to divide the annual expenditure for housing into the value of raw land and the value of the structure.

In equilibrium the rental rate for land in the 10th ring should equal the rental rate for agricultural land. In the benchmark we force the urban area to have a radius of 30.58 miles and the values of the 5th ring to reflect values for a representative household for a suburban area approximately 15 miles from the CBD. The width of each ring in the benchmark is 2.14 miles. We assume that the rental value of agricultural land equals the rental rate of land inclusive of the tax in the 10th ring. We then fixed the rental value of agricultural land for all other simulations to be equal to that value.

We divide the expenditure for the nonhousing good into payments for the three factors: labor, land, and capital. This was accomplished using an input-output table for the Atlanta urban region for the production of all goods except housing.[6]

For household commuting cost we use an average total nontime transportation cost per mile of 73.4 cents; this is based on 51.7 cents per mile times the average household size of 2.65 times the worker to population ratio of 0.536. Distance is based on location in the 5th residential ring. For the representative household, which is assumed to live in the 5th ring, we calculate the value of commuting time using the average one-way commuting time per day in the metro Atlanta of 30.5 minutes and the wage rate. To calculate the time and monetary cost of commuting for households living in other residential rings, we assume a constant commuting speed.

Finally, we need to select parameter values for the utility and production functions. Regarding the elasticity of substitution for the production of the nonhousing good, according to Pessoa, Pessoa, and Rob (2005) the elasticity of substitution between capital and labor is 0.7. We take this value for the nonhousing good production function. Regarding the elasticity of substitution between capital and land for housing production, the literature (see Conder and Larson 1998) suggests that the value ranges between 0.6 and 0.8; we assume a value of 0.7.

TABLE 4
Calibrated Parameter Values

Parameter	Value
Intensity of leisure preference over the other goods (α)	0.275
Intensity of capital use over land in housing sector (β)	0.713
Intensity of land use in nonhousing good sector (π)	0.074
Intensity of housing good preference over nonhousing good (υ)	0.368
Intensity of capital use over land and labor in nonhousing good sector (ω)	0.296

Regarding the elasticities of substitution in the nested utility function, for the first level there are no published studies of the elasticity of substitution between leisure and nonleisure goods. Generally, other studies have adopted a Cobb-Douglas function, which has an elasticity of substitution of one. We choose a value of 0.7. Yang (2005) reports an elasticity of substitution between housing and nonhousing goods of 0.145. Since this value seems very small, we use 0.2 for the value of the elasticity of substitution for the second level.

We calibrate the functions' coefficients, other than those coefficients specified above, by inverting the factor demand or product demand functions and then using the benchmark data to solve for the value of the coefficients. The values of the functions' coefficients are calibrated so that the output of the CGE model under the existing tax regime reflects the benchmark data. Note that as previously mentioned, the elements of the benchmark data whose value varies geographically are set for the fifth residential ring and reflect either the value for a representative household or the value for a suburban area located 15 miles from the CBD. Table 4 presents the values of the calibrated coefficients. These values are consistently applied to the utility and production functions in all applications. Capital is the numeraire, so the price of capital, net of taxes, is fixed.

[6] For extracting this information, we used IMPLAN (IMPLAN Group 2009).

TABLE 5
Initial Benchmark Simulation

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	9,940.00	16,668.52	61.25	1.48
2	8,490.42	16,314.14	54.86	1.34
3	7,144.38	15,959.76	48.55	1.20
4	6,005.42	15,605.38	43.07	1.07
5	4,970.00	15,251.00	37.76	0.95
6	4,038.13	14,896.62	32.64	0.83
7	3,209.79	14,542.24	27.73	0.72
8	2,485.00	14,200.52	23.09	0.62
9	1,967.29	13,846.14	19.79	0.52
10	1,449.58	13,504.41	15.91	0.43

Note: Area of central business district (square miles) = 265.39; radius of urban area (miles) = 30.57; tax on capital and land = 22.9%.

IV. EMPIRICAL RESULTS

This section presents the results of the simulations assuming one income group.[7] We first present the benchmark results and then consider a change in the tax regime from the capital property tax to a LVT. In this section the policy change is analyzed alternatively under the conditions of fixed boundaries of the CBD and urban area and under endogenous boundaries. In actuality, the price of residential land at the border of the CBD is much lower than in the CBD. Thus, in the simulations we require that the residential land value at the border of the CBD is a constant fraction of the price of land in the CBD. In Section V we consider the case with three income groups and a model in which housing capital is less then perfectly mobile.

The Benchmark

Table 5 contains the benchmark results obtained when the model was solved with the benchmark data for the Atlanta urban area. The results are consistent with but not identical to the benchmark data and are consistent with the monocentric model, that is, rent and density gradients are negatively sloped.

[7] The models were solved as complementary problems using *GAMS (General Algebraic Modeling System)*, software sold by GAMS Development Corporation, Washington, D.C.

The Effects of Switching to a LVT

Now consider the effects of replacing the capital property tax with an equal-yield LVT. The results are contained in Table 6 (for the model with fixed CBD and urban boundaries) and Table 7 (for the model with endogenous CBD and urban boundaries).

In the benchmark case (Table 5) the capital property tax rate on tax inclusive rental value is 18.9%. To be revenue neutral a tax on just land rent must be 82.9% (that is, taxes paid divided by the sum of the user price of land and taxes paid) in the case of fixed boundaries (Table 6). We find that switching to a LVT is fiscally feasible, while, as noted above, DiMasi (1987) did not, a result likely due to the substantially higher property tax rate in Boston. However, the required LVT for our model is very high. England (2007) calculated the required LVT rate for a revenue-neutral switch from a capital property tax to a LVT for five cities, assuming no economic response to the tax change. He found that such a switch for Chicago and Milwaukee was not feasible, but that it was feasible for Philadelphia, Washington, D.C., and Phoenix, although the LVT tax rates would be very high for Philadelphia and Washington, D.C.

Switching to a LVT, given fixed CBD and urban area boundaries, results in a reduction in land rent and the price of housing service exclusive of the tax. For example, for the 1st

TABLE 6
Land Value Tax Reform Simulation with Fixed Central Business District and Urban Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	1,346.04	13,972.70	72.47	1.53
2	1,138.96	13,630.98	64.51	1.37
3	931.88	13,301.91	55.68	1.23
4	724.79	12,972.84	45.83	1.09
5	621.25	12,656.43	41.78	0.96
6	517.71	12,327.36	37.19	0.83
7	414.17	11,998.30	31.99	0.71
8	310.63	11,681.89	25.96	0.60
9	207.08	11,352.82	18.86	0.50
10	207.08	11,036.41	20.77	0.40

Note: Area of central business district (square miles) = 265.39; radius of urban area (miles) = 30.57; wage change relative to user price of capital = 24.62%; tax on capital = 0%; tax on land = 89.2%.

ring, the land rent falls from $9,940 for the benchmark case to $1,346 with a LVT, a decrease of 86.5%, while the price of housing services falls from $16,669 to $13,973, a decrease of 16.2%. Furthermore, the land rent gradient becomes flatter.[8] Note that the land rental rate at the boundary of the urban area is much smaller than the land rental rate in the agricultural sector ($1,450 as reported for the 10th ring in Table 5). Landowners bear the entire burden of the tax on land rent since it is not possible for landowners to avoid the tax when the boundaries of the CBD and urban area are fixed.

The elimination of the tax on capital increases the housing capital density (the ratio of capital to land), and lowers the user price of capital,[9] but the user price of land does not change since the land tax is fully capitalized. This obviously provides an incentive to use more capital for the production of the nonhousing good and housing. Furthermore, the lowered user price of capital means a lower cost of production, and as a result the efficiency of the economy increases. Population density for the urban area does not change since the boundaries of the CBD and urban area (and population) are fixed in the current scenario. However, population shifts toward the CBD and thus density increases in the rings closer to the CBD and decreases in the rings closer to the edge of the urban area.

Note that the wage rate (relative to the user price of capital) increases by 24.6%. Assuming that the fixed rental price of capital is one, the user price of capital is 1.229 in the benchmark simulation, while the user price of capital is one after the tax reform.[10] We divided the nominal wage rate by the user price of capital and then calculated the change in wage rate relative to the user price of capital.

Regarding the change in the wage rate, there are two countervailing forces: a substitution effect and an efficiency effect. The substitution effect suggests that the reduced user price of capital due to the tax reform would replace some labor with capital to the point that the elasticity of substitution allows. This decreases labor demand, which would decrease the wage rate. On the other hand, the efficiency effect suggests that the reduced cost of production due to the reduced user price of capital increases demand for labor, which

[8] Using an exponential form of the density gradient function, we find that the slope becomes more negative.

[9] Note that although the rental price of capital is fixed and assumed to be one, the user price of capital is not constant because of the tax on capital under the capital property tax. Pollock and Shoup (1977) estimated the effect of a reduction in the property tax rate on capital and an increase in the tax on land and found a substantial increase in capital intensity.

[10] The benchmark property tax rate (22.9%) is applied here. Although the rental price of capital is fixed as numeraire, the user price of capital with the property tax is 1.229. Note that the tax inclusive tax rate on the user price of capital is 18.9%.

would increase the wage rate. Depending on the relative sizes of the two forces, the wage rate relative to capital cost can either increase or decrease as a result of the tax reform. Here, the efficiency effect applies to all production factors.

Of course, the supply side of each factor must also be considered in order to determine the change in the user prices of each factor. For land, under the assumption of fixed CBD and urban area, the supply curve is vertical, so any increase in demand leads to an increase of land rent, while for capital the supply curve is horizontal at an international price equal to one, so the change in demand for capital does not affect the tax exclusive rental price of capital. The supply status of labor lies between land and capital since households are allowed a labor-leisure choice. In our case, the efficiency effect dominates and leads to the increase of wage rate relative to capital cost.[11]

The change in the money metric measure of welfare (i.e., the equivalent variation) due to the tax change divided by tax revenue is 19.2%. This is somewhat larger than what DiMasi (1987) reports in considering a change to a split-rate property tax. The difference is due, at least in part, to the fact that DiMasi does not completely eliminate the property tax on capital.

Turn now to the case of endogenous boundaries (Table 7). Brueckner and Kim (2003) find that there are two countervailing effects of the property tax regarding the urban size: the improvement (i.e., number of housing units) effect and the dwelling size effect. The property tax depresses the amount of improvements, and given no change in dwelling size this will reduce population density and spur the spatial expansion of the urban area. However, dwelling size falls as a result of increased price of housing services, which results in an increase in population density, thereby reducing the size of the urban area. Thus, in theory the effect of a property tax on the size of the urban area is indeterminate.

Song and Zenou (2006) claim that the property tax contracts the size of the urban area. However, we obtain the oppose result. We find that improvements per unit of land increase and population per unit of improvement falls with the switch from a property tax to a LVT. The net effect is for population density to increase (compare Tables 5 and 7), so that the urban area contracts when a LVT replaces the property tax. Note that the size of the CBD also contracts. Our results are consistent with the findings of Banzhaf and Lavery (2010), who use data from Pennsylvania to study the effect of split-rate property taxes on the capital-land ratio and the size of urban areas.[12] Their findings are contrary to those of Song and Zenou.

The radius of the urban area decreases from 30.57 miles to 25.41, a decrease of 16.9%, while the area of the CBD falls from 265.39 square miles to 223.31 square miles, a decrease of 15.9%, with the adoption of a LVT. And, because the fixed population resides in a smaller area, population density increases in each ring and the density gradient becomes steeper. Land rent and the housing service price do not decrease as much as when the boundaries are fixed. With endogenous boundaries, the tax on land rent is not neutral, which makes consumers bear a small portion of the land tax, and so the decrease in land rent and housing service price is not as large as in the case of the fixed boundary.

The revenue-neutral land tax rate in the case of endogenous CBD and urban boundaries is 66.8%, which is lower than the 89.2% in the case of fixed CBD and urban boundaries. Due to the spatial contraction of the urban area and the replacement effect due to the elimination of the tax on capital, the housing capital density is greater than in the case of fixed boundaries. The change in welfare for the case of endogenous boundaries over the benchmark is 18.2% of tax revenue. This is slightly smaller than the change in welfare for the fixed-boundary case because in the case of variable boundaries the amount of residential land increases and thus there is not complete capitalization of the LVT.

[11] Nominal wage rates were decreased due to the tax reform. This is due to the elimination of the "inflation effect," that is, from the elimination of the tax on capital rental.

[12] See also Cho, Lambert, and Roberts (2010).

TABLE 7
Land Value Tax Reform with Variable Central Business District and Urban Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	5,591.25	14,681.46	88.46	1.85
2	4,970.00	14,403.02	81.54	1.72
3	4,348.75	14,124.58	74.10	1.59
4	3,831.04	13,858.79	67.92	1.46
5	3,313.33	13,580.35	61.25	1.34
6	2,899.17	13,314.57	56.01	1.22
7	2,485.00	13,036.12	50.31	1.11
8	2,070.83	12,770.34	44.05	1.00
9	1,760.21	12,504.55	39.48	0.89
10	1,449.58	12,238.77	34.40	0.79

Note: Area of central business district (square miles) = 223.31; radius of urban area (miles) = 25.41; wage change relative to user price of capital = 30.37%; tax on capital = 0%; tax on land = 66.8%.

Split-Rate Simulation

Because the tax rate with a LVT is very high and because DiMasi considers a switch to a split-rate tax, we consider a split-rate property tax. We set the tax rate on capital equal to 12.0% and set the tax rate on land so that the result is revenue neutral; the resulting tax rate on land equals 50.6%, which implies a somewhat higher ratio than the one-to-three ratio adopted by DiMasi. The results of the simulation in the case of fixed CBD and urban boundaries are presented in Table 8. The direction of the changes from the benchmark (Table 5) are, as would be expected, the same as the effects of a adopting a full LVT (Table 6), but the size of the effects with a split-rate tax are smaller. Given the similarities in the results, we do not discuss the split-rate results. We also consider the case of variable CBD and urban boundaries with similar but smaller effects than those for the full LVT (Table 7); in the interest of space these results are not reported. The change in welfare for the fixed boundary case is 8.8%, which is similar to the welfare effects reported by DiMasi.

V. EXTENSIONS

In this section we consider four extensions: a model with three income classes, immobile housing capital, absentee landlords, and variations in some of the parameters.

Results for a Model with Three Income Groups

In this section we consider the case with three income groups: a high-income group (Group 1), a middle-income group (Group 2), and a low-income group (Group 3). There are a few existing studies of the effect on equity of a switch to a LVT.[13] England and Zhao (2005) find that a switch to a LVT in Dover, New Hampshire, would increase the tax burden on single-family residential property, and further that this increase is regressive, while Bowman and Bell (2008) obtain just the opposite results for Roanoke, Virginia. Plummer (2010), who studied Tarrant County, Texas, obtains results consistent with Bowman and Bell. The limitation of these studies is that they are static estimates and thus do not allow for any of the changes that result from a switch to a LVT.

Based on the actual distribution of income, we assume that 22% of the households are in Group 1, 31% are in Group 2, and 47% are in Group 3. The income groups are associated with different land and capital holdings and different labor productivities. It is assumed that Group 1 has 1.5 times the land and capital endowment of Group 2, and that Group 3 has

[13] There have been attempts to estimate how a switch to a LVT would affect the taxes paid by different types of property; see, for example, Cuddington (1978).

TABLE 8
Split-Rate Tax Reform Simulation with Fixed Central Business District and Urban Boundaries

Ring	Housing Land Rent per Acre of Land	Housing service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	6,005.42	15,390.22	65.02	1.50
2	5,177.08	15,048.50	58.85	1.35
3	4,348.75	14,706.77	52.06	1.21
4	3,623.96	14,365.05	45.84	1.08
5	2,899.17	14,023.33	38.92	0.95
6	2,381.46	13,681.60	34.08	0.83
7	1,863.75	13,339.88	28.58	0.72
8	1,449.58	12,998.16	23.96	0.61
9	1,138.96	12,669.09	20.45	0.51
10	828.33	12,340.02	16.29	0.42

Note: Area of central business district (square miles) = 265.39; radius of urban area (miles) = 30.57; wage change relative to user price of capital = 23.8%; tax on capital = 12.0%; tax on land = 50.6%.

one-half the endowment of Group 2. The labor markets for each income group are distinguished so that the wage rate for each income group is separately determined. In the benchmark, the relative wage rates have the same distribution as the land and capital endowments. We now have three utility and household budget equations, with the corresponding changes in the demand for housing and the nonhousing good and supply of labor.

The other features of the original benchmark model are retained for the three income classes benchmark, except for the elasticity of substitution between leisure and nonhousing goods. In particular, for Group 2 we retain the original elasticity value of 0.7, while for Groups 1 and 3, we assume elasticities of 0.8 and 0.6, respectively, in order to allow for differences in preferences. Some of the results for the benchmark simulations for three income groups (Table 9) differ from the results for the original benchmark simulation (Table 5). It is almost impossible to produce the exact same benchmark values given the different setting of the three income group model. We tried to calibrate the new model so that the results of the benchmark are as close as possible to the benchmark results in Table 5; however, there are some differences. For example, tax revenues are larger, the radius of the urban area is slightly greater, and the land rental value at the urban boundary is smaller in the benchmark model with three income groups than in the original benchmark simulation. The three income group benchmark values for land rental rate and the price of housing services in the 5th ring, however, are the same as in the original benchmark model. We assume that tax revenues are distributed to all households according to the ratio of endowments of land and capital among income groups in order to make the public expenditure side neutral; specifying the use of the tax revenue is important in evaluating the tax reform. Of particular note is that in the benchmark simulation (Table 9), Group 3 lives in the central residential rings, Group 1 lives in the outer rings, and Group 2 lives in between.[14] This pattern is consistent with that of the Atlanta area in 2002.

We consider a switch to a LVT in the model with variable boundaries (Table 10). This simulation produces changes from the benchmark that are generally consistent with those from the simulations with one income group (compare Tables 7 and 10). Consistent with the case of the single income group model, density increases since the urban area becomes smaller with the LVT. The high-income group becomes more concentrated in the outer rings, while the middle-income group moves closer in.

[14] To ensure that the benchmark generated the observed pattern of household distribution, we slightly adjusted commuting costs.

TABLE 9

Three Income Groups Benchmark with Variable Central Business District and Urban Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Dist. of Household 1 (%)	Dist. of Household 2 (%)	Dist. of Household 3 (%)	Population Density per Acre	*K/L* Ratio for Household 1	*K/L* Ratio for Household 2	*K/L* Ratio for Household 3
1	15,721.43	18,402.80			53.57	1.95			68.07
2	10,295.00	17,063.57		2.14	46.43	1.45		50.61	50.61
3	8,165.00	16,428.59		31.69		0.58		43.02	
4	6,390.00	15,828.25		31.19		0.50		36.31	
5	4,970.00	15,251.00		29.94		0.42		30.37	
6	3,803.57	14,696.84	18.92	5.04		0.24	25.12	25.12	
7	3,093.57	14,315.85	22.26			0.18	21.74		
8	2,485.00	13,946.41	21.12			0.16	18.65		
9	1,977.86	13,576.97	19.68			0.14	15.83		
10	1,521.43	13,219.07	18.04			0.12	13.28		

Note: Area of central business district (square miles) = 288.72; radius of urban area (miles) = 31.23; tax on capital and land = 22.9%.

TABLE 10

Three Income Groups Land Value Tax Reform with Variable Central Business District and Urban Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Dist. of Household 1 (%)	Dist. of Household 2 (%)	Dist. of Household 3 (%)	Household Density per Acre	*K/L* Ratio for Household 1	*K/L* Ratio for Household 2	*K/L* Ratio for Household 3
1	10,852.86	15,620.44			50.62	2.17			79.31
2	7,860.71	14,685.29			49.38	1.78			63.19
3	5,882.86	13,957.96		29.67		0.65		51.71	
4	4,817.86	13,507.70		29.82		0.57		45.04	
5	3,905.00	13,068.99		29.35		0.51		38.95	
6	3,144.29	12,653.37	13.94	11.16		0.33	33.39	33.39	
7	2,687.86	12,353.19	22.70			0.23	29.69		
8	2,231.43	12,064.57	22.08			0.21	26.24		
9	1,876.43	11,775.94	21.20			0.18	23.03		
10	1,521.43	11,487.32	20.08			0.16	20.05		

Note: Area of central business district (square miles) = 274.59; radius of urban area (miles) = 28.43; wage change relative to user price of capital for Group 1 = 10.68%; wage change relative to user price of capital for Group 2 = 13.68%; wage change relative to user price of capital for Group 3 = 22.22%; tax on capital = 0%; tax on land = 44.5%.

TABLE 11
Land Value Tax Reform with Immobile Housing Capital and Fixed Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	2,692.08	18,604.95	60.63	1.46
2	2,277.92	18,263.23	53.58	1.33
3	1,967.29	17,921.51	48.48	1.20
4	1,656.67	17,579.78	42.87	1.08
5	1,346.04	17,250.72	36.72	0.96
6	1,138.96	16,908.99	32.85	0.85
7	931.88	16,592.58	28.52	0.74
8	724.79	16,263.51	23.67	0.64
9	621.25	15,947.10	21.77	0.54
10	414.17	15,618.04	15.67	0.46

Note: Area of central business district (square miles) = 247.43; radius of urban area (miles) = 30.26; wage change relative to user price of capital = 26.35%; tax on capital = 0%; tax on land = 80.0%.

LVT reform benefits residents of all income groups. Although the urban land area is endogenously determined, landowners bear almost all of tax burden of the LVT. The price of housing services falls by more in the residential rings in which the low-income groups live. The wage rate relative to capital cost decreased by 10.7% for Group 1, increased by 13.7% for Group 2, and increased by 22.2% for Group 3, in other words, switching from a capital property tax to a revenue-neutral LVT is progressive.

Simulations with Immobile Housing Capital

Next we consider models for which housing capital is perfectly immobile and for which housing capital is partially mobile. These extensions model the short-term, namely, the case in which the stock of housing capital does not fully adjust to the switch to a LVT. For these simulations we assume that the boundaries of the CBD and the urban area do not change. Note that the supply of capital for the nonhousing good is still perfectly elastic.

Tables 11 and 12 contain the results with housing capital completely immobile and partially mobile housing capital, respectively. For the completely immobile housing capital, we assume that $K_{\mathrm{H}}^{\mathrm{D}}(j)$ is constant for all j, while for partially mobile case we set the value of $K_{\mathrm{H}}^{\mathrm{D}}(j)$ equal to the difference between the value of $K_{\mathrm{H}}^{\mathrm{D}}(j)$ in the benchmark and half of the difference between the value of $K_{\mathrm{H}}^{\mathrm{D}}(j)$ in the perfectly mobile case (Table 6) and in the benchmark. Note that Table 6 contains the equivalent results for the case of perfectly mobile housing capital. Switching to a LVT decreases the land rent of the 1st ring from \$9,940 for the benchmark (Table 5) to \$2,692, a decrease of 72.9%, in the case of immobile housing capital (Table 11) to \$1,864, a decrease of 81.2%, in the case of partially mobile housing capital (Table 12), to \$1,346, a decrease of 86.4%, in the case of perfectly mobile housing capital (Table 6). The same pattern holds true for the other rings. Thus, the more mobile the housing capital, the greater the decrease in land rent is as a result of the tax reform. This results because with the switch to a LVT, the use of capital for housing increases the more mobile is housing capital.

We have shown that the decrease of land rent decreases the price of housing service when housing capital is perfectly mobile. However, with immobile housing capital, housing prices increase.

As housing capital becomes more mobile, the capital-to-land ratio increases. When housing capital is perfectly immobile (Table 11) the capital-to-land ratio and population density should be the same as in the benchmark simulation (Table 5) since the housing capital stock, residential land area, and population are the same, the small differences shown in the tables being due to rounding in the simulations.

TABLE 12
Land Value Tax Reform with Partially Mobile Housing Capital and Fixed Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	1,863.75	15,972.42	66.58	1.49
2	1,553.13	15,643.35	58.13	1.35
3	1,346.04	15,301.63	52.97	1.21
4	1,138.96	14,972.56	47.24	1.08
5	931.88	14,643.49	40.94	0.95
6	724.79	14,314.42	33.84	0.83
7	621.25	13,985.36	31.01	0.72
8	414.17	13,668.95	22.19	0.62
9	310.63	13,352.54	18.03	0.52
10	310.63	13,023.47	19.64	0.43

Note: Area of central business district (square miles) = 260.67; radius of urban area (miles) = 30.49; wage change relative to user price of capital = 24.91%; tax on capital = 0%; tax on land = 85.6%.

The wage rate relative to the user price of capital increases by 24.6% for the simulation with perfectly mobile housing capital (Table 6), and 24.9% for the model with partially mobile housing capital (Table 12) and 26.4% for the model with immobile housing capital (Table 11). This result holds because the reduction in the user price of capital increases the capital-to-labor ratio in the nonhousing sector, which increases the wage rate.

The increase in welfare is much smaller when capital is immobile. For the case of perfectly immobile housing capital, the increase in welfare (equivalent variation) relative to tax revenue is 5.9%. If all capital (housing and nonhousing) were perfectly immobile, the capital property tax would be a tax on factors with perfectly inelastic supply, and thus a reduction in the tax on capital and an increase in the tax on land would be fully capitalized into prices, and thus there would be no change in welfare.

Absentee Landownership

In this subsection we consider the case in which all land in the urban economy is owned by nonresidents. The change to an assumption of absentee landlords changes the income equation and trade flow equation. As a result of the absentee landlord assumption, any change in land rents due to tax policy changes has no effect on the incomes of residents. This landownership assumption affects the various changes resulting from a shift from a capital property tax to a LVT. We assume variable boundaries for this simulation.

The effects of LVT reform under the setting of absentee landownership can be seen by comparing the results from the new absentee landowner benchmark simulation (Table 13) and the results with a LVT (Table 14). To see how the effects of switching to a LVT differ depending on the ownership of land, compare the differences between Tables 13 and 14 and between Tables 5 and 7.

The decrease in land rents under absentee landownership is less than under resident landownership. For example, with absentee landownership the land rent of the 1st ring due to the adoption of a LVT decreases from $9,713 in the absentee landowner benchmark (Table 13) to $5,874, a decrease of 39.5%, in the simulation with a LVT (Table 14). In the case with the resident landownership, the land rent of the 1st ring due to LVT reform decreases from $9,940 (Table 5) to $5,591 (Table 7), a decrease of 43.8%. Similar differences hold true for the prices of housing services as well. The results are consistent with the setting that residents' incomes do not decrease as a result of the decrease of land rents due to LVT reform.

As a result of LVT reform, the wage rate relative to user price of capital increases by 35.4% in the simulation with absentee landownership, which is greater than the 30.4%

TABLE 13
Absentee Landownership Benchmark with Variable Central Business District and Urban Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	9,714.09	16,566.62	61.92	1.46
2	8,358.64	16,234.52	55.77	1.33
3	7,116.14	15,902.42	49.82	1.20
4	5,986.59	15,570.33	44.12	1.08
5	4,970.00	15,251.00	38.69	0.96
6	4,066.36	14,918.90	33.56	0.85
7	3,275.68	14,599.58	28.78	0.74
8	2,597.95	14,267.48	24.44	0.64
9	2,033.18	13,948.15	20.58	0.54
10	1,581.36	13,628.82	17.35	0.46

Note: Area of central business district (square miles) = 258.45; radius of urban area (miles) = 30.30; tax on capital = 22.9%; tax on land = 22.9%.

TABLE 14
Land Value Tax Reform with Absentee Landownership and Variable Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	Capital per Acre of Land	Household Density per Acre of Land
1	5,873.64	14,637.89	92.31	1.85
2	5,195.91	14,369.66	84.57	1.71
3	4,631.14	14,114.20	78.22	1.59
4	4,066.36	13,845.97	71.36	1.47
5	3,501.59	13,590.51	64.00	1.35
6	3,049.77	13,335.05	58.18	1.23
7	2,597.95	13,066.81	51.83	1.12
8	2,259.09	12,811.35	47.27	1.01
9	1,920.23	12,555.89	42.27	0.91
10	1,581.36	12,300.43	36.72	0.81

Note: Area of central business district (square miles) = 218.72; radius of urban area (miles) = 25.30; wage change relative to user price of capital = 35.42%; tax on capital = 0%; tax on land = 65.7%.

increase in the simulation with resident landownership.

Alternative Elasticity of Substitution in Production

Finally, we consider the initial model with variable CBD and urban area boundaries but with an elasticity of substitution between factors for nonhousing goods, λ, of 0.7 rather than 0.3 (Table 15).[15] We compare these results to those in Table 7 (which contains the results for a LVT with the original elasticities and variable CBD and urban area boundaries). The lower production elasticity (Table 15) results in a much larger CBD and a slightly larger urban area. Housing prices and land rents, the capital-to-land ratio, and the population density are smaller with the smaller elasticity.

[15] When we decreased the elasticity of substitution among factors for housing and nonhousing goods simultaneously we did not see a significant difference.

VI. CONCLUSION

LVTs are employed in many counties (Franzsen and McCluskey 2008). In the U.S., LVTs (including split-rate property taxes) have been used in several jurisdictions in Pennsylvania, in Hawaii, and in a few isolated

TABLE 15
Sensitivity Analyses of Land Value Tax Reform with Variable Boundaries

Ring	Housing Land Rent per Acre of Land	Housing Service Prices per Unit, per Year	K/L Ratio Capital Amount per Acre of Land	Household Density per Acre of Land
1	3,313.33	13,656.29	62.70	1.57
2	3,106.25	13,491.76	60.22	1.49
3	2,795.63	13,339.88	55.59	1.42
4	2,588.54	13,188.00	52.81	1.34
5	2,381.46	13,036.12	49.90	1.27
6	2,174.38	12,884.25	46.84	1.20
7	1,967.29	12,732.37	43.60	1.13
8	1,760.21	12,580.49	40.18	1.06
9	1,656.67	12,428.62	39.00	0.99
10	1,449.58	12,276.74	35.22	0.93

Note: Area of central business district (square miles) = 566.99; radius of urban area (miles) = 27.49; wage change relative to user price of capital = 32.73%; tax on capital = 0%; tax on land = 67.9%.

places such as Arden, Delaware, and Fairhope, Alabama (see Bourassa [2009] and Dye and England [2010] for a discussion of the use of LVTs in the United States). Much of the literature on LVTs has focused on administrative issues such as the ability to accurately value land (Bell, Bowman, and German 2009), but there are several empirical studies, including simulations, that have explored various effects of LVTs (Anderson 2009).

We have considered the effects of shifting from a capital property tax to a LVT using an urban CGE model that is benchmarked to the Atlanta metropolitan area. Our paper extends the work of DiMasi (1987), which is the only other research on LVTs that uses an urban CGE model. Our model differs from DiMasi's in several ways: we consider both fixed and endogenous boundaries for the CBD and urban area; we consider both a LVT and a split-rate tax; we assume that residents own a fixed amount of land, rather than assuming an absentee landowner; we consider three income groups rather than just one; we consider cases in which housing capital is not completely mobile; and we allow for a labor-leisure choice.

Unlike DiMasi, who found that a LVT was not fiscally viable, we find that a LVT can generate sufficient revenue to replace the property tax. For our benchmark model, we find that a revenue-neutral switch from a capital value property tax to a LVT, or a split-rate tax, results in a reduction in land rent and the tax exclusive price of housing. We find that the land rent gradient becomes flatter while the population density and housing capital gradients become steeper. Contrary to Song and Zenou (2006), but consistent with Banzhaf and Lavery (2010) we find that a LVT increases the size of the urban area when we allow the boundary to vary. When we allow for three income classes, we find that the switch to a LVT is income progressive. In addition, in a more realistic world where housing capital is durable, for the LVT reform, a higher LVT rate was required to secure the same tax revenue, but a higher real wage increase was achieved due to the reform. And the increase in welfare is much smaller when capital is immobile. Finally we find that a switch to a LVT increases welfare by 19.2% of tax revenue in the case of fixed urban boundaries and by 18.2% in the case of endogenous boundaries.

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