How "Smart" is the Split-Rate Property Tax?
Evidence from Growth Patterns in Pennsylvania

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Abstract

Urban sprawl has become a policy concern of national prominence. Land or split-rate taxes are one potential way to address this issue. In theory, such taxes can lower the land/capital ratio. This in turn can raise the density of housing units where it is applied, if the average quality/size of each housing unit does not increase by enough to offset an effect on the number of housing units. This research explores these issues, looking at a panel of land uses and demographics in Pennsylvania. We confirm the theoretical prediction that the capital/land ratio increases. We also find that the primary effect is in more housing units, rather than bigger or nicer units, suggesting the split rate tax is potentially a powerful anti-sprawl tool.

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Introduction

In the last third of the 20th century, urban sprawl by one measure was increasing at a rate of about 2.5% per year in the United States, a rate which would double the size of cities every 29 years (Burchfield et al. 2006). As a consequence, the problem of urban sprawl has moved from being a pre-occupation of urban planners and land reformers to the mainstream. By the year 2000, the issue climbed into the national spotlight as a poll showed that 18 percent of Americans viewed sprawl as the top issues facing their community, tied for the highest response (Burchfield et al. 2006), and as Al Gore highlighted the problem in his campaign for the Presidency. Moreover, recent studies have provided strong evidence that households place a high value on the open space lost to sprawl (see e.g. McConnell and Walls 2005).

While some have argued that sprawl is nothing more than a socially efficient response to the increasing affordability of the automobile, a superior mode of transportation, (Glaeser and Kahn 2003), most economists have linked inefficient levels of sprawl to externalities (traffic congestion, open space, pollution), subsidized infrastructure, and distortionary real estate taxes.[1] Targeting these factors in varying degrees are a number of tools available to the urban planner to reduce sprawl. Among other options, these tools include gasoline taxes, improving mass transit and pedestrian access in the inner city, zoning laws, purchases of land or development rights, and impact fees. Communities have increasingly experimented with these solutions, trying transferable development right programs in states like Maryland (McConnell et al. 2006) and placing measures to publicly purchase open space on local ballots (Kotchen and Powers 2006, Banzhaf et al. 2006).

One of oldest proposals for injecting more "smarts" into urban growth is the land or split-rate tax. This fiscal tool mitigates the distortions inherent in a property tax, which by taxing structures increases the land/capital ratio. In theory, a pure land tax would not be distortionary, since land is given in fixed supply. However, such taxes may not be acceptable politically because of their distributional implications or simply for being misunderstood. A compromise between a standard property tax and the pure land tax, the split-rate tax still taxes structures but at a lower rate than land.[2] Land or split-rate taxes are in force in Australia, Denmark, and parts of Indonesia (Youngman and Malme 1994). Although not widespread in the US, the split rate tax has been adopted in about 18 Pennsylvania cities.

[1] For excellent overviews on these issues, see Brueckner (2001) and Nechyba and Walsh (2004).

[2] For historical background and an overview of the economics of land and split-rate taxation, see Schwab and Harris (1998). For additional context on politics and the status of the split-rate movement, see Hartzok (1997).

The starting point for understanding the split-rate tax's effect on sprawl is that it should alleviate the property tax's distortionary effect on the land/capital ratio, increasing the capital stock on each unit of land. This has been called the "improvement effect." The intuition then is that if a city needs to house a certain number of households, and if each household requires a given level of capital (i.e. housing) consumption, a lower land/capital ratio implies that the city is more dense and so chews up less land to house those residents. The potential weakness in this logic is the second premise: that the size of housing will remain more or less constant (Brueckner 2001, Brueckner and Kim 2003, Song and Zenou 2006). In addition to distorting the land/capital *ratio*, the property tax distorts a household's consumption of capital. Thus, switching from a property tax to a land or split rate tax also what has been called a "dwelling size effect": housing units may simply become bigger (or nicer). If the latter effect is big enough then the dwelling size effect may actually offset the improvement effect, so that the city sprawls even more (even as the land/capital ratio falls). In this case, the split-rate tax would be counter-productive (at least as an anti-sprawl measure). Brueckner and Kim (2003) and Song and Zenou (2006) suggest that this may well happen if the substitutability between housing and other consumption is high enough.

There have been few empirical tests of the actual effect of the split rate tax. Oates and Schwab (1997) and Plassmann and Tideman (2000) show that the split-rate tax increases development activity as measured by building permits. This finding suggests the split-rate tax does have the expected effect on the land/capital ratio. Whether the aggregate increase in capital is the result of the improvement effect or of the dwelling size effect is unclear.

Although they do not look at land or split-rate taxes, Song and Zenou (2006) correlate the size of census urbanized areas with average property tax rates. They find a *negative* correlation, suggesting that the dwelling size effect dominates the improvement effect. However, they average-out intra-city differences in tax rates. Moreover, their focus on the footprint of *urbanized* areas rather than the wider metro area perhaps raises more questions than it answers. If lower property taxes encourage density, they might well increase the urbanized portion of a metro area, while still shrinking the over-all footprint of the metropolis.

This paper is to our knowledge the first to test the density effects of the split rate tax. In comparison to Song and Zenou's work on property tax rates, we focus on measures of structural and population density in each local jurisdiction as a function of its own tax structure, rather than wider averages. In particular, we use the 1970, 1980, 1990, and 2000 US Censuses to construct the evolution of the population and housing stock in Pennsylvanian Census tracts over time. We focus on Pennsylvania because the majority of split-tax jurisdictions are located in that state.

Exploiting the fact that most jurisdictions with the split-rate tax adopted it in the 1980s, we identify the effect of the split-rate tax from changes in pre-existing trends in each area. In each normalized tract (with a fixed land area over time), we look at the total number of rooms (a proxy for the land/capital ratio), the total number of housing units (the density effect), and the average # of rooms per housing unit (the dwelling size effect). As an alternative proxy for the density effect, we also look at population density. Confirming the findings of Oates and Schwab (1997) and Plassman and Tideman (2000), we find evidence that the split-rate tax does lower the land/capital ratio as expected (as proxied by the total number of rooms). We also find it is much more likely that this effect comes from more houses in a given land area rather than bigger houses. Our central estimates, based on linear fixed effects regression, are that a split rate tax increases the growth in the total number of rooms by about 3-6 percentage points per decade (in the first decade or two after adoption) *relative* to control areas. There is a small and statistically insignificant effect on the average number of rooms per housing unit, and a 2-5 percentage point increase in the number of housing units. The point estimates are slightly larger but statistically insignificant using an alternative non-parametric matching procedure. Over-all, it appears that the split-rate tax is potentially useful as a weapon in the anti-sprawl arsenal. However, as we discuss below, it would be important to use this tool at the appropriate points in the spatial structure of the city.

Background on the Split-Rate Tax

Since the physiocratic movement of François Quesnay in the last years of the *ancient regime*, economists have periodically stressed the virtues of land taxes over other types of taxes. Quesnay and the physiocrats stressed that such taxes were non-distortionary because they captured the material value of economic outputs, as provided by nature, and did not discourage investment. Henry George, in contrast, argued in his *Progress and Poverty* that such taxes would benefit the poor by increasing the labor/land ratio in the production process, increasing the returns to labor.

More recently, modern economists have shown that in a simple, static setting, land taxes are less distorting than property taxes and are likely to reduce the incentive for cities to sprawl (as defined by population density). The reasoning is straightforward. If land supply is taken as given, with resource allocation effecting only capital, then taxes on land can have no effect on those resource allocations. The property tax taxes capital as well as land, reducing the resources devoted to development. By taxing capital, property taxes reduce the capital/land ratio (relative to no tax or to a land tax). In other words, they give an incentive for land to be developed less intensely, resulting in sprawling cities which use more land to house their citizens. For formal derivations of this result under different modeling assumptions, see Brueckner (1986), Capozza and Li (1994), England and Ravichandran (2007), Oates and Schwab (1997), Mills (1998) and Nechyba (1998).

For this reason, some economists and anti-sprawl activists favor a simple land tax. However, not taxing capital improvements at all may not be practical or equitable, and would not be optimal when there are taxes on other uses of capital.[3] A compromise is the split-rate tax. The split-rate tax taxes both land and improvements, but does so at differing rates, with more weight put on the land tax. Accordingly, its virtues are qualitatively

[3] In this case, the optimal tax would equalize the marginal deadweight loss on all distortionary taxes. It is also important to note that the mortgage tax deduction is another source of distortions working in the opposite direction.

similar to those of a pure land tax. Table 1 provides an example. Under a single rate property tax, land and improvements are both taxed at 5%. Under the split-rate tax, land is taxed at a rate of 7.5% and improvements are taxed, but at a lower rate of 2.5%. In this case, land with a value of $50,000, if given a "small" improvement also worth $50,000, would yield equal revenues of $5,000 using either system. However, a "big" improvement worth $100,000 would lead to a tax bill of $7,500 under the single rate system but only $6,250 under the split-rate system. If a developer were indifferent between the two developments under the single tax, switching to a split-rate system would induce him to prefer the higher-density project.

The claim that land taxes are less distorting than property taxes requires three qualifications. The first qualification we have already emphasized, and it motivates our empirical work. As pointed out by Brueckner (2001) and Brueckner and Kim (2003), relative to land taxes, property taxes reduce the amount of housing capital consumed by each household. Thus, while relative to land taxes they are associated with higher land/capital ratios, they are also associated with lower capital/household ratios. Sprawl, as represented by population density (i.e. number of households per unit land) would be the product of these two partially offsetting effects:

$$\frac{Land}{Household} = \frac{Land}{Capital} x \frac{Capital}{Household}. \qquad (1)$$

Even if the split rate tax lowers the land/capital ratio, in theory the effect of a higher capital/household ratio can offset it so there is no effect on density. Brueckner and Kim (2003) tentatively conclude from simulation exercises that the density effect is likely to hold. However, they do find a perverse effect of more sprawl for some parameter values, with the dwelling size effect swamping the improvement effect (see also Song and Zenou 2006).[4] Accordingly the extent of the density effect remains an open question even in theory, and certainly as an empirical question. (For an interesting extension, see too the work by Colwell and Turnbull 2003 comparing this result to that of area and frontage taxes.)

The second qualification arises when we consider a dynamic setting. When the future time profile of rents differs between two uses of land—and when land is taxed at its current *value*, rather than its "highest and best" use—a land tax might also be distorting (Mills 1981, Capozza and Li 1994).[5] Oates and Schwab (1997) illustrate this point with the following example. Suppose landowners can earn rents of $1,000 forever when they develop their land now for use A, but if they wait one period they can develop it for use B

[4] Notably, this perverse effect is guaranteed under Cobb-Douglas preferences or CES preferences whenever the elasticity of substitution between housing and other consumption is greater than one. It remains possible even for elasticities less than one. The intuition is that when housing and other consumption are highly substitutable, the property tax creates a greater distortion on the housing capital consumed, as households substitute other goods more readily. Song and Zenou (2006) also find this effect in a non-CES preference function in which the elasticity is always greater than one.

[5] Feldstein (1977) also discusses the effect on savings decisions and the stock of productive capital.

and begin earning rents of $1,100. At a 10% discount rate, both options would yield a present value of $10,000, and developers would be indifferent between them. If actual rents were taxed at the same rate, or if land were taxed at its highest and best use, developers would remain indifferent and the land tax would be non-distortionary. But if land is taxed at its current *value*, the developers would face a tax on the value of idle land while waiting to develop for purpose B. This "timing effect" consequently favors early development for use A. In this case, the land tax creates a distortion in favor of early development.

To the extent that land values are assessed at current uses, this effect reinforces the likelihood that split-rate communities would have higher density (since land is developed sooner). Thus, while it qualifies the *normative* conclusion that land taxes are non-distortionary, this insight actually strengthens the positive or *empirical* claims associated with the density effect.

A third and final qualification pertains to the interpretation of higher density communities as reducing sprawl or as being part of a "smart growth" strategy. This interpretation seems straightforward when we think of a city as being a single jurisdiction—as in most theoretical models such as Brueckner (1986), Brueckner and Kim (2003), and Song and Zenou (2006). When the only jurisdiction reduces its density, it uses more land and sprawls further. In this case, the split-rate tax would indeed be a reasonable part of a "smart growth" strategy. When there are multiple jurisdictions within a single metro area, however, a further distinction must be made. A jurisdiction on the fringe of the metro area could adopt the split-rate system, increasing its density. If its jurisdiction's boundaries are fixed, the increased density would come from a higher population. From the perspective of the wider metro area, however, this increased density on the fringe might look like *more* sprawl, particularly if citizens are pulled from the inner city.

The lesson here is that the split-rate tax would remain an important weapon in the arsenal against sprawl, but one that would have to be applied at the appropriate place spatially. We abstract from this issue, looking only at the empirically testable relationship between a jurisdiction's tax system and its housing stock and population density. Accordingly, we do not claim that our empirical work shows that the split-rate tax, as employed in Pennsylvania, has resulted in less sprawl. Nor do we even claim that our measurable outcomes of housing and population density in narrowly defined locations are a proxy for sprawl.[6] Our more narrow interpretation is simply that the split-rate tax appears to be an effect tool in increase density *in those locations where it is applied*. City officials could then use such a tax to increase density *where desirable* for encouraging smart growth.

Previous Empirical Work

Given the interest in the split-rate tax among advocates and the attention given to it in theoretical models of urban economics, there has been surprisingly little empirical research on its effects. In part, this is because few jurisdictions have experimented with

[6] See Burchfield et al. (2006) and Galster (2001) for more sophisticated approaches.

the tax. Even so, a number of cities in Pennsylvania do provide the opportunity to test the effect of the system. Two major studies have taken advantage of these experiments. Oates and Schwab (1997) focus on Pittsburgh, which in 1979 raised its tax on land to more than five times its rate on structures. Looking at building permits, Oates and Schwab assess the effect of this reform on building activity, using a difference-in-difference methodology in which the change in activity around 1979 in Pittsburgh is compared to the change in a set of control cities. As predicted by theory, they find that relative to other cities, Pittsburgh experienced a significant increase in building activity following its adoption of the split-rate tax, relative to other Midwestern cities. Indeed, most cities experienced continued declines in activity while Pittsburgh experienced a rapid increase.

Plassmann and Tideman (2000) similarly test the effect of the split-rate system by looking at building permits, but do so looking at the complete set of Pennsylvania cities that have adopted the tax, using other Pennsylvania cities as controls. Like Oates and Schwab, they find that the split-rate tax has a statistically significant impact on the number of permits issued. However, they do not find clear evidence that it increases the value of those permits.

Both of these papers are carefully conducted and, taken together, provide strong evidence of the split rate tax's effect on construction activity. However, neither paper explores the effect of the split rate tax on the fundamental outcomes of policy interest: population and housing density. Construction permits may reflect commercial activity or additions and tear-downs. Increased commerce might increase the total capital/land ratio without affecting population density and the total amount of land used. Additions and tear-downs would represent the dwelling size effect without affecting density.

Song and Zenou (2006) regress the size of urbanized areas on the population of those areas and property tax rates. They do not look at the split-rate tax directly, but in looking at the property tax do explore the fundamental economic relationships of the density, improvement, and dwelling size effects. They find that urbanized areas with higher property tax rates are smaller. They interpret this finding to mean that the dwelling size effect dominates, but they do not test this explanation directly. Moreover, it is not clear whether urbanized areas or metropolitan statistical areas or some other measure is the appropriate spatial scale. It could well happen that lower property taxes shrink the over-all metro area, in part by increasing density in those areas that just fail to qualify as "urbanized" in the US Census. Moreover, in looking at the size of combined urbanized area, their empirical work closely follows theoretical monocentric city models. However, in reality, cities are composed of multiple jurisdictions with different tax rates. In their empirical work, Song and Zenou combine these into a single over-all average tax rate. Yet any differences between property tax rates within a metro area should be reflected in differences in density across those areas. Lower property tax rates at the fringe of the metro areas might increase density there relative to the core, for example, thereby increasing sprawl by their measure.

New Empirical Strategy

We employ a new strategy which directly tests the effect of the split-rate tax on proxies for the density, improvement, and dwelling size effects. In addition, we look at local areas (US Census tracts) rather than averaging different tax policies across a wider area.

Our basic empirical strategy can be summarized with the following regression model. Our outcomes of interest are the total number of rooms per unit land area (TOTRM) as a proxy for the capital/land ratio (i.e. the improvement effect), the average number of rooms per dwelling unit (AVGRM) as a proxy for the dwelling size effect, and the number of housing units per land area (HU) as well as the population per land area (POP) as proxies for the density effect. We employ a simple reduced form approach in which the percentage change in these outcomes over decade *t* in census tract *i* in jurisdiction *j* is a function of a tract-specific fixed effect, an average decade effect, a vector of lagged demographic and land use variables (*X*), and the property tax structure. For example, the total room outcome is modeled as

$$PCT\Delta TOTRM_{ijt} = \alpha_i + \beta_t + \gamma X_{ijt-1} + \delta SR_{jt} + \varepsilon_{ijt}, \quad (2)$$

where *SR* is a dummy variable indicating whether the jurisdiction had a split rate tax during the period in question and ε_{ijt} is a normally distributed error.

This basic specification recently has been used by Banzhaf and Walsh (2007) and Card, Mas, and Rothstein (2007) in other applications involving demographic transitions. For now, we highlight four features of this model. First, note that the use of percentage changes allows a simple decomposition in which $\delta^{TOTRM} \approx \delta^{AVGRM} + \delta^{HU}$.[7] That is, re-arranging equation (1) and writing it in log form, the total improvement effect is approx-imately the sum of the density and dwelling size effects.

Second, note that the unit of observation in this model is the census tract, yet tax rates are set at the wider jurisdictional level. Moulton (1990) has demonstrated that OLS standard errors can be biased in this case. Following a recent suggestion by Bertrand et al. (2004), standard errors are clustered at the jurisdiction level. Such clustering allows for a juris-diction-level random effect ($\varepsilon_{ijt} = \eta_j + u_{ijt}$) and non-specified error correlation within the jurisdiction. That is, $\mathrm{Cov}(\varepsilon_{ijt},\varepsilon_{kj\tau}) \neq 0$ but $\mathrm{Cov}(\varepsilon_{ijt},\varepsilon_{kl\tau}) = 0$ for $j \neq l$.

Third, note that the policy variable of interest, *SR*, is a simple indicator for weather or not the jurisdiction has a split rate tax over the relevant time period. However, a split-rate jurisdiction in which the tax on land is only slightly higher than the rate on structures

[7] More precisely, $(1 + \delta^{TOTRM}) = (1 + \delta^{AVGRM})(1 + \delta^{HU})$. The approximation is off by the factor $\delta^{AVGRM} \cdot \delta^{HU}$, which can be expected to be small. It is also important to note that this identity is only valid for a given observation. Estimated coefficients may differ from this pattern unless they are consistently weighted.

We use the "midpoint formula" for computing the percentage change, using the average of the beginning and ending values in the denominator. In contrast to using the beginning value, this approach allows computation of percentage changes when baseline values are zero. Percentage changes using this formula are necessarily bounded between -2 and +2.

might not have any perceivable differences from a single-rate jurisdiction, whereas a jurisdiction with a much higher rate on land might. To account for inter-jurisdictional differences in the reliance on land taxes, we also consider a model in which we replace the indicator variable *SR* with the ratio of the land tax rate to the split tax rate (averaged over the course of the decade). This ratio is of course one for all non-split-rate jurisdictions and greater than one for split-rate jurisdictions.[8]

Fourth and finally, note that the presence of the tract fixed effect α_i in the context of a differenced dependent variable implies that the effect of land taxation is identified off of differences from pre-existing trends relative to control communities. This is a difference-in-difference-in-differences model. The effect δ of introducing the split rate tax in community j at time t is estimated from the difference in the level of the outcome variable from the previous period, relative to the community-specific time path of such differences, and relative to other communities. For the *SR* model, this effect is the only identified from communities that adopt the split rate tax sometime between 1980 and 2000. For the tax-ratio model, it is identified from communities that change their land-to-structure tax ratio during this period. (The 1970-80 period is required to establish the pre-existing trend with the fixed effect.)

These fixed effects thus control for any unobservables that affect the time path of split rate communities differently from other communities. Nevertheless, one might be concerned that deviations from long term time paths are randomly correlated in space with adoption of the split rate tax. For example, the split rate tax was adopted in a number of western Pennsylvanian towns in the 1980s, and it may be that in the 1980s western Pennsylvania generally saw an acceleration (or deceleration) in the growth of the capital/land ratio or in the growth of population density, for reasons unexplained by the variables in the model. To control for any such effects that are distributed smoothly in space, the X vector in the model includes an interaction between the decade effects β_t and the communities' location in terms of degrees latitude, degrees longitude, and the interaction of latitude and longitude. In this way, the decade-specific effect is not only an intercept shifter, but rather an entire spatial surface. This surface represents a smooth function in space of decade-specific deviations from communities' long-term time trends. The effect of the split-rate tax is the discontinuous jump at jurisdictional boundaries off of this smooth surface.

The fixed effects also reduce any concern about the endogeneity of the split rate tax. While communities might adopt the tax in response to a shrinking tax base, any endogeneity in the model would have to be with differences from pre-existing trends. Moreover, we restrict the effect of *SR* in the model to those jurisdictions that had adopted it in the first half of the decade. Furthermore, in sensitivity analyses we consider various other lags in the split-rate variable. In these cases, any endogeneity would have to be with *forecasted* future differences from pre-existing trends. We believe this is unlikely to be a problem, but acknowledge it as an area for future research.

[8] An alternative approach would be to allow the tax rate on land and on structures to enter the model separately. Unfortunately, we do not observe the property tax rate in a number of non-split-rate jurisdictions, so such an approach would require discarding a large portion of the sample.

As we discuss in more detail below, we also consider a number of other approaches in sensitivity analyses. These approaches include a non-parametric matching estimator (Abadie and Imbens 2006, Dehejia and Wahba 2002, Heckman et al. 1997, Rosenbaum and Rubin 1983).

Data

As previously noted, we test for the effects of a split-rate tax among jurisdictions in Pennsylvania, where towns have shown particular interest in the split-rate tax. Table 2 lists the 18 Pennsylvania cities using the split rate tax over this period, the year it was adopted, and the range in the tax ratio. As shown in the table, most cities adopted the split rate tax in the 1980s and 1990s. Consequently, census data from 1970-2000 is sufficient to document changes in population density before and after the adoption of the split-rate system for these cities, controlling for pre-existing trends. In the basic model in which the split-rate system is treated as a dummy variable, focusing on this period eliminates Harrisburg, Pittsburgh, and Scranton. However, these three cities still contribute the estimated effects of land taxes in models that account for changing land-to-structure tax ratios. Two cities, Hazleton and Uniontown, abandoned the split rate tax shortly after adopting it. These two jurisdictions are dropped from the analysis. Since 2000, three cities (including Pittsburgh) have also abandoned the split-rate tax, but three other jurisdictions have newly adopted it. These data were collected from Center for the Study of Economics.

Our analysis is at the Census tract level. To maintain consistency in these boundaries over time, we utilize Geolytics' Neighborhood Change Database, which normalizes all populations to the 2000 census boundaries. Table 3 summarizes the demographic data. The variables in the top panel are the various outcomes of interest. The table shows that, simply looking at the raw data, it appears that split rate cities are losing population and certainly not growing as fast as jurisdictions with conventional property taxes. The variables in the second panel are the control variables (the *X* variables of equation 2). It appears that split-rate jurisdiction are more dense on average, are poorer, and have an older and less valuable housing stock. A good part—but not all—of these differences are driven by Pittsburgh.

Results

Our estimates are summarized in Table 4. The table shows the estimated value of the four parameters of interest, i.e. the parameter δ in Equation 2 along with its estimated robust standard error. Since each outcome of interest represents a separate regression, the R^2 from each regression is also reported (in square brackets). Models 1 and 2 use the split-rate dummy as the variable of interest. Models 3 and 4 use the land-to-structure tax ratio (which also allows changes in Pittsburgh, Scranton, and Harrisburg to contribute to the estimated effects). Models 1 and 3 are unweighted; models 2 and 4 weight the observations by the number of housing units in the tract (averaged over the beginning and end of each decade).

The first set of results indicates that, as predicted, the split-rate tax has a positive effect on the capital/land ratio, increasing the total number of rooms in the jurisdiction by 5-6 percentage points over pre-existing trends relative to control districts, within the first decade or two of adoption. The effect is still positive, but somewhat lower, when we account for the tax ratio. In models 3-4, a move from the simple property tax (with a ratio of 1) to a 2-to-1 land-to-structure tax ratio increases the total number of rooms by about 1 percentage point. Since the average split rate jurisdiction has a ratio of about 4-to-1, we can roughly triple the estimates in models 3-4 to make them comparable to models 1-2. The increase of 3 percentage points according to these models is then somewhat lower than models 1-2, but still substantial. These results are perfectly consistent with the improvement effect predicted by economic theory and with previous results on construction permits (Oates and Schwab 1997, Plassmann and Tideman 2000).

The second set of results indicates that there is at most a modest "dwelling size effect." According to models 1 and 2, the growth in the size of the average dwelling unit appears no different in split-rate communities than other communities. According to models 3 and 4, there is a small but statistically significant effect of about 0.2 percentage points (0.6 percentage points for a 4:1 tax ratio), accounting for about one-fifth of the total increase in rooms.

The third and fourth set of results directly address the central policy question. Does the split-rate tax have a density effect, which might make it useful as an anti-sprawl policy tool? Our results suggest it does. Models 1 and 2 estimate an effect for the average split-rate jurisdiction of about 5 more percentage points in the growth of housing units over pre-existing trends relative to control districts, within the first decade or two of adoption. They estimate similar effects on the change in population growth rates. Models 3 and 4 estimate an effect of about 0.6 percentage points on the growth of housing units for a 2:1 tax ratio, or about 2 percentage points for the typical 4:1 tax ratio. Somewhat surprisingly, these two models do not identify any population effects. This may be because in equilibrium, smaller households are located into the high-ratio split-rate communities, or it may be because occupancy rates have not yet caught up with new construction. Or it may simply be because of more noise in the data (the point estimates from models 1 and 2 also cannot be rejected). The question warrants further research.

We subject these estimates to a number of robustness checks. First, rather than confine the split-rate indicator to jurisdictions that had adopted the tax by the midpoint of the decade, we consider any adoption of the split-rate tax over the decade or alternatively only jurisdictions that had adopted the tax by the beginning of the decade. (The analog of the latter model in the tax-ratio model is to use the tax ratio at the beginning of the decade rather than the average tax ratio over the decade.) Second, we consider the effect of dropping Pittsburgh and Philadelphia from the model. Third, we restrict regressions of each outcome to only those Census tracts with available measures for all outcomes.[9]

[9] When a tract goes from zero rooms and housing units to non-zero, our measure of the percentage change in these variables is still defined, but the measure of the change in the average number of rooms is not defined. The approach taken in this sensitivity analysis drops these observation from all regressions, rather than from just the dwelling size effect regressions.

Fourth and finally, we consider differences in logs of the dependent variable rather than percentage changes. Our results are qualitatively unchanged using any of these alternative approaches.

We also consider a much more different approach. Rather than use an OLS regression model as represented by equation (2), we consider a non-parametric "matching" model (Abadie and Imbens 2006, Dehejia and Wahba 2002, Heckman et al. 1997, Rosenbaum and Rubin 1983). The model is of the form:

$$PCT\Delta TOTRM_{ijt} = \alpha_i + \beta_t + f(X_{ijt-1}) + \delta SR_{jt} + u_{ijt}, \qquad (3)$$

Rather than use all control jurisdictions, this approach selects only those control jurisdictions that are most similar to each treatment jurisdiction in terms of the X variables. It then directly matches those cases, differencing the dependent variable. The approach is non-parametric because the γ are never estimated: equation (3) can allow for an arbitrarily complex function $f(X_{it})$. Because the X's are very similar for treatment and control pairs, they simply cancel out in the comparison. This approach has the further advantage of allowing the econometric errors u to be correlated with the X's. Unlike the case of OLS, they need only have the same expected value for the treatment and control cases; they do not need to have an expected value of zero.

Following Rosenbaum and Rubin (1983) we match "treatment" and "control" observations in the same year on the predicted probability (from a first-stage probit) that a Census tract has the split-rate tax. We restrict these matches to the area of "overlapping support," the range of the data where both treatment and control observations are located, thereby dropping two split-rate tracts as well as a number of dissimilar controls. We match each split-rate tract to four treated controls in an effort to gain efficiency in the estimator, although results are very similar when matching to a single most similar control tract. Finally, we regression-adjust the outcome variables for any small differences in the X variables between the treatments and matched controls.

Table 5 shows the estimated effects, i.e., the estimates of δ from Equation (3), along with robust standard errors computed as suggested by Abadie and Imbens (2006). The estimates are similar to the fixed effects regression estimates reported in Table 4. The point estimates are slightly larger, with housing unit density effects of about 7 percentage points in the unweighted model and 10 percentage points in the weighted model. However, the standard errors are larger and most of the effects are not significant at conventional levels. The housing unit density effects have one-tail p-values of about 0.29 in the unweighted model and 0.18 in the weighted model. This is not surprising given the demands this approach requires from the data.

Conclusions

The split-rate tax is a long-advocated tool that should lead to greater economic efficiency. Our results indicate that it should also lead to “smarter” growth patterns. We find that capital-land ratios increase in those areas with split-rate taxes and higher land-structure tax ratios. Moreover, the dwelling size effect appears to be modest, so that most of this increased capital implies greater density for the city. Adopting the split-rate tax results in a 2 to 10 percentage point increase in the growth of the density of housing units in the first couple of decades, and a 0 to 7 percentage point increase in the growth of population density, depending on the model.

These findings are roughly consistent with the findings of Oates and Schwab (1997) and Plassman and Tideman (2000) on construction activity. They stand in marked contrast, however, with the recent finding by Song and Zenou that urbanized areas with higher average property tax rates are more compact. We might reconcile these findings in the following way. Suppose that in cities with lower property tax rates at the city's edge, density is increased at the edge relative to the inner city, compared with cities with uniform property tax rates. At the micro level, density would be higher where property taxes are lower. At the city level, cities with lower taxes average tax rates would be bigger. Further detailed exploration of the spatial structure of actual cities appears to be warranted.

In any case, this explanation underscores the point that any effect of land or split-rate taxes on increasing density is not guaranteed to decrease sprawl. If these fiscal tools are applied in exurbs or rural areas, any resulting increase in density would by most measures represent an increase in sprawl. While our results suggest that these fiscal tools have a place in the urban planner's toolkit, like any tool they would have to be used in the right time and place.

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Tables

Table 1. Comparison of Single and Split-Rate Tax Systems

	Single Rate System	Split-Rate System
Land Tax Rate	5%	7.5%
Improvement Tax Rate	5%	2.5%
Assessed Land Value	$50,000	$50,000
Land Tax Bill	$2,500	$3,750
Small Improvement Value	$50,000	$50,000
Big Improvement Value	$100,000	$100,000
Tax Bill on Small Improvement	$2,500	$1,250
Tax Bill on Big Improvement	$5,000	$2,500
Total Tax Bill with Small Improvement	$5,000	$5,000
Total Bill with Big Improvement	$7,500	$6,250

Table 2. Pennsylvania Split-Rate Cities as of 2000

	Year First Adopted	Last Year	Land-Structure Tax Ratio Lowest	Land-Structure Tax Ratio Highest	1990 Population
Aliquippa	1988	--	11.3	16.2	13,374
Allentown	1997	--	1.5	4.7	105,090
Clairton	1989	--	4.7	4.8	9,656
Coatesville	1991	2006	1.6	2.1	11,038
Connellsville	1992	2003	6.5	7.7	9,229
Dubois	1991	--	2.3	3.9	8,286
Duquesne	1985	--	2.0	2.6	8,845
Harrisburg	1975	--	1.4	4.0	52,376
Hazleton	1991	1992	3.2	3.4	24,730
Lock Haven	1991	--	2.1	3.8	9,230
McKeesport	1980	--	3.7	5.3	26,016
New Castle	1982	--	1.8	4.0	28,334
Oil City	1989	--	1.2	3.2	11,949
Pittsburgh	1913	2001	2.0	5.8	369,379
Scranton	1913	--	2.0	5.5	81,805
Titusville	1990	--	3.4	4.1	6,434
Uniontown	1992	1992	5.5	5.5	30,472
Washington	1985	--	3.6	17.5	15,791

SOURCE: Center for the Study of Economics and US Census.

Table 3. Demographic Characteristics of Census Tracts (Mean Values)

Variable	Split-Rate Jurisdictions	Single Rate Jurisdictions
Pct Change in Rooms	6.0%	26.4%
Pct Change in Rooms/Unit	2.5%	1.7%
Pct Change in Housing Units	3.6%	24.9%
Pct Change in Population	-5.6%	17.0%
Population per sq mi	8,104	4,898
Households per sq mi	3,250	1,834
Rooms per sq mi	17,947	10,680
Average # rooms per unit	5.2	5.8
Pct housing units > 30 yrs old	75.3%	52.5%
Pct housing units < 10 yrs old	5.4%	12.9%
Pct Age > 65	15.9%	12.7%
Pct Age < 18	22.5%	23.7%
Pct Black	21.1%	7.8%
Pct Hispanic	1.0%	1.8%
Average Household Income	22,703	29,276
Pct Hholds Upper Income*	1.8%	2.4%
Pct Hhold in Poverty	17.9%	9.3%
Pct Unemployed	8.5%	5.3%
Pct Housing Units vacant	8.8%	5.8%
Average monthly rent	247	277
Average housing value	34,510	53,798
Pct owning home	53.3%	65.5%
Pct No High School Diploma	35.1%	27.9%
Pct Bachelors Degree	13.5%	15.5%
Degrees Latitude	40.59	40.46
Degrees Longitude	-79.15	-77.05
Average Tract Size (sq mi)	2.56	15.13
N	956	11,584

Each tract appears three times. Pct changes are 1970-80, 1980-90, and 1990-2000. Level variables are for 1970, 1980, and 1990.

*Defined as $50,000 in 1970, $75,000 in 1980, and $125,000 in 1990.

Table 4. Effects of Split-Rate Tax on Outcomes of Interest

		Model 1	Model 2	Model 3	Model 4
	Policy Variable	SR Dummy	SR Dummy	Tax Ratio	Tax Ratio
	Weighted?	No	Yes	No	Yes
Outcome	**Proxy**				
Capital/Land Ratio	Pct Change in Total # Rooms	0.0633** (0.0311) [0.93]	0.0470*** (0.0179) [0.94]	0.0107*** (0.0041) [0.93]	0.0084*** (0.0031) [0.94]
Size Effect	Pct Change in Avg # Rooms per Unit	0.0010 (0.0104) [0.66]	-0.0015 (0.0053) [0.69]	0.0025** (0.0013) [0.65]	0.0021* (0.0014) [0.69]
Density Effect	Pct Change in # Housing Units	0.0540** (0.0329) [0.92]	0.0510*** (0.0204) [0.94]	0.0065* (0.0044) [0.92]	0.0063** (0.0030) [0.94]
Density Effect	Pct Change in Population	0.0523** (0.0287) [0.93]	0.0397** (0.0209) [0.94]	0.0017 (0.0040) [0.93]	3.6e-6 (0.0036) [0.94]

For each outcome/model, the first number listed is the estimate (i.e. δ) from Equation 2. The second number in parentheses is the robust standard error of the estimate, clustered at the jurisdiction level. The third number in square brackets is the R^2 of the regression. All regression control for tract-specific fixed effects, the variables listed in the second panel of Table 3 plus squares of those terms, and decade interactions with latitude, longitude, and latitude*longitude. See Equation 2 for the specification.
***1-tail test significant at 1%, **5%, *10%.

Table 5. Effects of Split-Rate Tax on Outcomes of Interest (Matching Models)

		Model 5	**Model 6**
	Policy Variable Weighted?	SR Dummy No	SR Dummy Yes
Outcome	**Proxy**		
Capital/Land Ratio	Pct Change in Total # Rooms	0.0661 (0.1405)	0.0915 (0.1078)
Size Effect	Pct Change in Avg # Rooms per Unit	-0.0138 (0.0178)	0.0205** (0.0106)
Density Effect	Pct Change in # Housing Units	0.0746 (0.1340)	0.0981 (0.1060)
Density Effect	Pct Change in Population	0.0373 (0.1371)	0.0743 (0.1083)

For each outcome/model, the first number listed is the estimate (i.e. δ) from Equation 3. The second number in parentheses is the robust standard error of the estimate, following the approach of Abadie and Imbens (2006).
All regression control for tract-specific fixed effects, the variables listed in the second panel of Table 3 plus squares of those terms, and decade interactions with latitude, longitude, and latitude*longitude. See Equation 3 for the specification.
***1-tail test significant at 1%, **5%, *10%.