This approach differs from most previous approaches in several ways. First, some previous work has been based on partial equilibrium analysis (for example, Pollock and Shoup (1977)) which necessarily leaves out potentially important forces. Ours operates within a fully general equilibrium model. Second, the primary focus in other work has been either on very local urban economies (DiMasi (1987)) or on national reforms (Nechyba (1998)), while this study focuses the analysis on the state level. Third, previous work has been based purely on small, open-economy models that assume factor prices are determined exogenously by the world market, whereas this study attempts to be careful about the circumstances under which such an assumption is appropriate, identify when it is not, and alter the model to reflect this when such a change is important to the analysis. Fourth, much of the previous literature has focused solely on shifting taxes from capital to land, while this study attempts to consider real world distortionary taxes of different types that might be part of a comprehensive tax reform effort. Finally, this study aims not so much at giving a precise answer to the question of what will happen under a land tax reform, but rather attempts to recognize that "the answer" is likely to differ substantially in different economic settings. As a result, our focus will be on trying to gain some general lessons of what might be important for policy makers to consider in their particular situations.

As indicated above, we will proceed in several steps. First, Section 2 lays out the model that is used throughout the rest of the paper. Section 3 outlines the method by which different state economies and tax systems are calibrated under different assumptions. The substantive policy analysis then begins in Section 4 where we consider introducing revenue neutral tax reforms of different types (each raising the tax on land rents) into a "typical" U.S. state under a variety of different assumptions. We then settle on what we consider the most plausible assumptions and derive simulation estimates for each of the 50 states in Section 5. Section 6 proceeds to consider how results might differ if—rather than a single state conducting such tax reforms unilaterally—the tax reform movement were a more national phenomenon that was conducted in many states simultaneously. Finally, Section 7 offers some distributional caveats, and Section 8 concludes with a brief synopsis as well as thoughts on unresolved issues and prospects for future research.

II. The Model

As in Nechyba (1998), the value of land is determined as the present discounted value of future rents assuming the land is put to its optimal use. The model allows for different types of land to have different expected future rents—which will later be reflected as different state economies will be characterized by such differences in land type.[4] More specifically, land type is characterized by a set of parameters α, β, ρ, and γ that enter into

[4] As is done in Nechyba (1998), it is also possible for the model to incorporate heterogeneous land within a state rather than simply across states. Issues that are raised by such a feature of the model are discussed in detail in Section 7. For now we simply note that throughout the current study, we will allow land to differ across state but assume it to be homogeneous within a state.

the production process most suited to that type of land. Production on land of type $L=(\alpha, \beta, \rho, \gamma)$ then follows the process

$$y_L = f_L(k,\ell,n) = \left(\alpha\left(\beta k^{-\rho} + (1-\beta)\ell^{-\rho}\right)^{\gamma/\rho} + (1-\alpha)n^{-\gamma}\right)^{-1/\gamma} \tag{1}$$

where k, ℓ, and n are the quantities of capital, land (of type L) and labor invested in production. Note that this is a generalization of a version of the production function used in Nechyba (1998) where

$$y_L = f_L(k,\ell) = \left(\beta k^{-\rho} + (1-\beta)\ell^{-\rho}\right)^{-1/\rho} \tag{2}$$

More precisely, the function (1) is a nested CES (constant elasticity of substitution) production function that simplifies to the less general non-nested CES function (2) when $\alpha=0$—i.e. when labor plays no role in production.

2.1. Land Owner Maximization Problem

For illustration, we initially assume that there are no taxes and that land owners maximize profits. More precisely, an owner of one unit of land of type $L=(\alpha, \beta, \rho, \gamma)$ takes the domestic wage w and the domestic rental rate r as given and hires labor and capital so long as their marginal products are less than or equal to w and r. Thus, setting marginal products of capital and labor (holding ℓ —the units of land—fixed at 1) equal to r and w, we get

$$\alpha\beta\left(\alpha\left(\beta k^{-\rho} + (1-\beta)\right)^{\gamma/\rho} + (1-\alpha)n^{-\gamma}\right)^{-(\gamma+1)/\gamma}\left(\beta k^{-\rho} + (1-\beta)\right)^{(\gamma-\rho)/\rho} k^{-(\rho+1)} = r$$
$$(1-\alpha)\left(\alpha\left(\beta k^{-\rho} + (1-\beta)\right)^{\gamma/\rho} + (1-\alpha)n^{-\gamma}\right)^{-(\gamma+1)/\gamma} n^{-(\gamma+1)} = w \tag{3}$$

When solved for k and n, these two equations give $k^*_L(r,w)$ and $n^*_L(r,w)$—the optimal levels of capital and labor per unit of type L land at domestic wage and capital rental rates w and r. While each land owner takes w and r as given, their actual levels in the economy arise, of course, endogenously—as described in the following sections.

2.2. Wages and Capital Rental Rates in a Small Open Economy

An assumption often made in virtually all economic models investigating land taxes—and one that is maintained throughout Nechyba (1998)—is that labor and capital are fully mobile across jurisdiction boundaries (i.e. the economy is "open"), and that the economy that is modeled is small relative to the world economy (i.e. the economy is "small"). Under this *small open economy assumption*, after tax wages and capital rental rates are always equal to the world wage and the world rental rate—and these world rates are exogenous parameters in the model. Put differently, the small open economy assumption is equivalent to assuming that labor and capital are infinitely elastically supplied at the world wage and capital rental rates.

Thus, for a small open economy, and in the absence of any factor taxes,

$$w = \overline{\mathrm{w}} \text{ and } r = \overline{\mathrm{r}} \tag{4}$$

where w is the domestic wage, r is the capital rental rate, and ($\overline{\mathrm{w}}$, $\overline{\mathrm{r}}$) are the world wage and world rental rate respectively. The equilibrium before and after tax wage and rental rates in a small open economy are therefore determined entirely by the exogenous values of $\overline{\mathrm{w}}$ and $\overline{\mathrm{r}}$. Put differently, the wage rates are not a result of a domestic labor and capital market clearing because the wage and rental rates must be equal to the wages and rental rates offered in the world market.

This small open economy assumption simplifies the analysis greatly and may be sufficiently realistic when the model is applied to very small regions in a large economy. For example, given that a local government is a relatively small part of a large national labor and capital market with both labor and capital quite mobile across local jurisdictional boundaries, an infinite elasticity of labor and capital supply may seem like a plausible assumption. In this case, the "world" wage and capital rental rates would simply be the prevalent U.S. wage and capital rental rates, and the supply of capital and labor in the economy are assumed as infinitely elastic at those rates—primarily because of the mobility of these factors.

Neither labor nor capital, however, are nearly as mobile internationally as they are within the U.S., nor is labor in particular as mobile across state boundaries as it is within a state or smaller region. Furthermore, the U.S. represents a substantial portion of the world economy. Therefore, while the small open economy assumption may sometimes be plausible in the case of smaller states, it is certainly not realistic when the model is asked to estimate the impact of a simultaneous implementation of land taxes across all states (whether done individually by the states or centrally by the federal government). In other words, for the U.S. as a whole it would be quite restrictive and unrealistic to assume infinitely elastic supply of labor or capital. We will argue below that capital is relatively mobile within the U.S., which implies that the small open economy assumption for capital is appropriate for state level decisions. However, it seems implausible (given empirical estimates in the literature) to assume that factors such as labor are infinitely elastic in supply even within the U.S. Therefore, the model is next expanded to allow for deviations of the small open economy assumption.

2.3. Wages and Rental Rates in Large Economies

We begin by introducing the functions $\overline{\mathrm{w}}$ and $\overline{\mathrm{r}}$ for world wages and rental rates defined as

$$\overline{w}(N, \varepsilon_{\mathrm{n}}) = \overline{\mathrm{w}} N^{1/\varepsilon_{\mathrm{n}}} \text{ and } \overline{r}(K, \varepsilon_{\mathrm{k}}) = \overline{\mathrm{r}} K^{1/\varepsilon_{\mathrm{k}}} \tag{5}$$

where ε_n and ε_k are the elasticities of supply of labor and capital, and *N* and *K* are the total quantity of labor and capital employed in the domestic economy. Thus, the domestic economy is assumed to potentially be large enough to impact the world wage and rental rates—or alternatively it is assumed sufficiently isolated through barriers to factor mobility that domestic factor prices can differ from world prices. Domestic wages and rental rates again have to be equal to those world rates in equilibrium; i.e. in the absence of taxes on factors,

$$w = \overline{w}\left(N^*, \varepsilon_n\right) \text{ and } r = \overline{r}\left(K^*, \varepsilon_k\right) \tag{6}$$

where N^* and K^* represent the equilibrium levels of domestic labor and capital. Note that as ε_n and ε_k approach infinity, these functions simply approach the constants $\overline{\mathrm{w}}$ and $\overline{\mathrm{r}}$— the world wages and rental rates under the small open economy assumption. Alternatively, as ε_n and ε_k approach 0, the supplies of labor and capital become entirely inelastic, the polar opposite of what arises under the small open economy assumption. One interpretation of such inelastic supplies would be that labor and capital are entirely immobile across international borders and that consumption, savings, and leisure decisions are unaffected by wage and rental rates.

2.4. Taxes

We will assume that the tax system is such that each factor of production can potentially be taxed at some proportional tax rate and that these tax rates may differ over different factors. Thus, $\mathbf{t} = (t_k, t_l, t_n)$ is a feasible tax system so long as each element of the tax vector lies between 0 and 1. The addition of taxes to the model does not alter any of the optimization equations for land owners—except that *w* and *r* must now refer to before-tax wages, and land owners now take the before-tax wages and rental rates and thus the taxes on labor and capital as given. Using the more general specification of world wages and rental rates of equation (5), the before tax domestic wages and capital rental rates are then transformed to

$$w = \frac{\overline{\mathrm{w}} N^{1/\varepsilon_n}}{\left(1 - \mathrm{t}_n\right)} \text{ and } r = \frac{\overline{\mathrm{r}} K^{1/\varepsilon_n}}{\left(1 - \mathrm{t}_k\right)} \tag{7}$$

As a result, $k_L^*(r,w)$ and $n_L^*(r,w)$ now are implicitly also functions of tax rates on capital and labor. Note, however, that labor and capital investments do not depend on the tax rate on land rents. In addition, $k_L^*(r,w)$ and $n_L^*(r,w)$ are now also functions of the endogenously determined total units of labor and capital demanded in the economy (which individual land owners take as given). We therefore now turn to the determination of equilibrium in the labor and capital markets.

2.5. Equilibrium in the Factor Markets

Under the small, open economy assumption, r and w in all the expressions above are always equal to the constants $\bar{w}$ and $\bar{r}$ adjusted by domestic tax rates. Thus, under small open economy assumptions, equilibrium in the factor markets for labor and capital is immediate from the exogenously specified world market conditions because total domestic labor and capital demand are never large enough to impact world factor prices. However, when the small open economy assumption is relaxed, r and w depend on the total quantity of labor and capital supplied in the domestic economy. While each individual land owner takes these quantities as given, the sum of all labor and capital hired on all the land plots in equilibrium—N^* and K^*—must be equal to the quantities which individual land owners take as given. Henceforth we will denote the before tax domestic wages and rental rates that arise in equilibrium as w^* and r^* respectively, where

$$w^* = \frac{\bar{w}(N^*)^{1/\varepsilon_n}}{(1-t_n)} \quad \text{and} \quad r^* = \frac{\bar{r}(K^*)^{1/\varepsilon_n}}{(1-t_k)} \tag{8}$$

N^* and K^* arise from the individual decisions of many land owners—or from the decision of a "representative" land owner in the case of homogeneous land—as described in Section 2.8.

2.6. Land Rents

Land rents for one unit of land of type L depend on the marginal product of that unit of land in production—which in turn depends on the optimal levels of capital and labor evaluated at equilibrium wage and rental rates: $k^*_L(r^*,w^*)$ and $n^*_L(r^*,w^*)$. Deriving the expression for the marginal product of land and setting $l = 1$, we get a gross of tax rental rate for land type L of

$$R_L(r^*,w^*) = \alpha(1-\beta)\left[\alpha\left(\beta(k_L^*)^{-\rho}+(1-\beta)\right)^{\gamma/\rho}+(1-\alpha)(n_L^*)^{-\gamma}\right]^{-(\gamma+1)/\gamma}\left[\beta(k_L^*)^{-\rho}+(1-\beta)\right]^{(\gamma-\rho)/\rho} \tag{9}$$

where k^*_L and n^*_L are functions of r^* and w^*. Finally, the price of a unit of land of type L—denoted $P_L(r^*,w^*)$—is simply the present discounted value of expected, after-tax, future rental flows; i.e.

$$P_L(r^*,w^*) = \sum_{i=0}^{\infty}\frac{(1-t_\ell)R_L(r^*,w^*)}{(1+\delta)^i} = \frac{(1-t_\ell)R_L(r^*,w^*)}{\delta} \tag{10}$$

where δ is the discount rate.

2.7. Equilibrium Tax Revenue

For any tax system $\mathbf{t}=(t_k,t_l,t_n)$, tax revenue from one unit of land type L is then given by

$$TR_L\left(t_k,t_\ell,t_n\right)=t_k r^* k_L^*\left(r^*,w^*\right)+t_\ell R_L\left(r^*,w^*\right)+t_n w^* n_L^*\left(r^*,w^*\right) \qquad (11)$$

Note that the tax on land is modeled here as a tax on unimproved land *rents* and not as a tax on unimproved land *value*. It is of course true that a tax on land rents can easily be mapped into an economically equivalent tax on land value in this model.

Suppose, then, that the government faces an exogenous revenue requirement $\overline{TR}$. The set of feasible tax systems that satisfy this revenue requirement is given by

$$\left\{\left(t_k,t_\ell,t_n\right)\in[0,1]^3 \,\middle|\, \sum_{\substack{\text{all land}\\ \text{plots}}} TR_L\left(t_k,t_\ell,t_n\right)=\overline{TR}\right\} \qquad (12)$$

2.8. A Model with Homogeneous Land

In Nechyba (1998), we argued that one important distributional issue arising in debates over land taxes may arise if different types of land are affected differently under land tax reforms. We return to this issue in this paper in Section 7. Until then, however, we will make the simplifying assumption that all land in the economy is homogeneous, and we will investigate the impact of land tax reforms on the average land owner within the economy without making reference to second-order distributional issues arising from the potential existence of heterogeneity in land.

The total quantity of land in the economy will be denoted L = [0,1], with each point on this unit interval representing one plot of land. Each land owner then maximized profits on his one unit of land in the way described above, with all land owners behaving the same in equilibrium. For the economy as a whole, we have to sum across all land plots, but the measure of all land is normalized to 1. Thus, we can simply look at one land owner's choices of n and k and know N and K for the economy as whole. Put differently, we can model the economy in the homogeneous land case by evaluating one representative land owner's maximization problem, and different economies will have different "average" land types yielding different representative land owners.

III. Calibration—Bringing in the Data

In the policy analysis below, we will attempt to come to conclusions about the prospects of land taxation in different contexts. More precisely, we would like to be able to relate the model introduced above to the particular circumstances in which different states find themselves. If we can find a way to translate key aspects of state economies to particular parameters of the model, we can simulate the impact of land taxation in different states under the assumption that the state we are investigating is the only state undertaking tax