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The Unequal Geographic Burden of Federal Taxes and Its Consequences: A Case for Tax Deductions?

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Abstract

Because federal income taxes are based on nominal incomes, workers with the same real incomes pay more taxes in high-cost areas than in low-cost areas, without receiving more in benefits. In the United States, workers in cities offering above-average nominal wages – cities with high productivity, low quality-of-life, or inefficient housing sectors – can expect to pay 30 percent more in federal taxes, on average, than identical workers with the same real incomes in cities offering below-average nominal wages. Federal taxes induce workers to leave high-wage areas, which according to a calibrated model, lower long-run employment levels in these areas by about 15 percent and land and housing prices by 25 and 4 percent; the opposite occurs in low-wage areas. This leads to an inefficient distribution of employment, costing about 0.28 percent of total income a year, or $34 billion in 2005. Workers will locate more efficiently if taxes are appropriately indexed to local wage levels; indexing taxes to local costs may also improve efficiency although it would induce too many workers to live in expensive, high quality-of-life cities. Deductions in the tax code, for housing and property taxes, index taxes partially to local costs, helping workers locate somewhat more efficiently, but creating larger losses by distorting consumption choices. Changes in relative wages and housing prices across cities over the 1980s and 1990s are roughly consistent with predicted changes from federal tax changes, but are too noisy to calibrate the model directly.

Keywords: Federal taxation, general-equilibrium tax incidence, geographic inequality, locational efficiency, mortgage-interest tax deduction, cost-of-living, tax capitalization, compensating wage differentials, quality-of-life.

JEL Numbers: H24, H5, H77, J61, R1

1 Introduction

Although wage and cost-of-living differences across cities in the United States are increasingly large, economists do not understand clearly how these differences interact with federal taxes and benefits. Because federal taxes are based on nominal incomes, workers with the same real incomes pay more taxes in high-cost areas than in low-cost areas, without receiving more benefits. Realizing this, the Tax Foundation argues:

> the nation is not only redistributing income from the prosperous to the poor, but from the middle-income residents of high-cost states to the middle-income residents of low-cost states. (Dubay 2006)

While the Tax Foundation has suggested a flat tax to remedy this problem (Hoffman and Moody 2003), politicians from high-cost areas have proposed indexing federal taxes and benefits to local prices, arguing that workers with the same real incomes should pay the same nominal taxes. Recently, the President's Advisory Panel on Federal Tax Reform (2005) suggested eliminating or reducing tax deductions for local taxes and home-mortgage interest, a reform which would increase taxes more in high-cost areas. The Panel did suggest that mortgage-interest deductions be capped according to local housing prices, implicitly providing a cost-of-living adjustment in the tax code; however, the existing economic literature provides no strong rationale for this adjustment.

This paper extends the literature on income taxation to the locational decisions of workers in a spatial economy, providing an analysis of how federal taxes (and transfers) fall unevenly across workers in different geographic locations, and how this affects local prices, employment, and welfare nationwide. Federal income taxes indeed fall disproportionately on workers in cities where employers pay higher nominal wages to compensate for higher costs-of-living; these are cities which likely have high worker productivity or inefficient housing or local-public sectors. In contrast, taxes may fall less on workers in cities which are expensive solely because of a better quality-of-life: such workers are likely paid lower nominal wages, since they implicitly receive an untaxed "income" from living in a nicer area.

Because workers in cities with higher nominal wages face higher federal-tax burdens but are not compensated with greater amounts of federal spending, they are induced to move to cities with lower nominal wages. As a result, unequal federal taxes lower relative employment levels and property values in high-wage cities, while doing the opposite to low-wage cities. The resulting geographic distribution of employment is

inefficient, reducing overall welfare: this welfare loss is proportional to the variance of wage differentials across cities, the marginal tax rate, and the sensitivity of local employment to local taxes.

This tax distortion cannot be eliminated with a flat-tax. It can be eliminated by indexing taxes to an "ideal" wage index, controlling for worker characteristics, so that a worker pays the same taxes regardless of where she lives, or to an "ideal" cost-of-living index which accounts for quality-of-life differences, which does the same. A cost-of-living index which ignores quality-of-life differences neutralizes tax differences across cities with productivity differences, as wages track prices in these cities, but subsidizes workers for living in nicer areas, since they pay lower taxes because of lower wages and higher prices. Although the current U.S. tax system does not explicitly index taxes to local costs, it implicitly does so through the favorable tax treatment of housing and local public goods, primarily through tax deductions for mortgage interest and local taxes. The "indexation effect" from such deductions is only partial, albeit stronger the more inelastic is household demand for housing and local-government goods.

Besides presenting these formal results, I present quantitative evidence on the impact of differential federal taxation across metropolitan areas in the United States using an empirical simulation. Workers with the same (observable) skills can expect to pay 30 percent more in federal income-taxes in high-wage cities than in low-wage cities. The federal government effectively taxes workers for living in most large cities, particularly in the West and Northeast, while subsidizing workers to live in small cities and towns, particularly in the South. From a local perspective, this represents a horizontal transfer of about 300 billion dollars each year from high-wage areas to low-wage areas, independent of vertical redistributional considerations. Analysis of spending data confirms that cities with higher federal tax burdens do not receive more federal spending.

In the long run, federal taxes reduce employment by 15 percent and lower housing and land values by 4 and 25 percent in high-wage areas, while having the opposite effect in low-wage areas. Distortions caused in the geographic distribution of employment cause a welfare loss of 0.28 percent of GDP, or $34 billion a year; differential federal spending across areas may magnify this loss. The size of this welfare loss appears to be similar in size to the loss created from the favorable tax treatment of housing and local public goods, a loss which has received far greater attention in the literature. In fact, this favorable tax treatment helps workers to locate more efficiently, diminishing the welfare loss from misplaced employment by about $4 billion a year; nevertheless, this amount is not enough to overcome the drawbacks of this tax treatment, especially if it is possible to index taxes to local wage levels. Interestingly, whether or not the deductions are

eliminated, tax-reform simulations suggest that indexing taxes to local cost-of-living would help workers locate more efficiently, even without a quality-of-life adjustment.

Previous research about how federal taxes interact with local price differences contains some important findings, but has been too narrow or informal to guide policy comprehensively. Wildasin (1980) finds that, when workers are mobile, federal taxes on labor income may cause workers to locate inefficiently across cities offering different wages, but focuses mostly on mathematical conditions characterizing efficiency, rather than describing the impact of uneven taxation. Glaeser (1997) argues that federal transfer levels should not be tied to local price levels, as this effectively subsidizes recipients to live in expensive, high quality-of-life cities. More generally, Kaplow (1996a) and Knoll and Griffith (2003) consider taxes together with transfers, and acknowledge that productivity differences may also affect local costs-of-living, leading them to consider the benefits of indexing taxes to local wages. Although insightful, their informal and preliminary arguments raise the need for more rigorous quantitative analysis, especially as it remains unclear what the exact implications are of not indexing the tax code, whether on prices, employment, or welfare.[1]

How tax deductions interact with local prices across cities has been studied even less. Research by Gyourko and Sinai (2003, 2004) and Brady et al. (2003) tabulates how mortgage and local tax deductions benefit high-cost areas more than others, but neither remarked on how these deductions may offset the unequal burden of federal taxes and help workers locate more efficiently. Reviews of the pros and cons of tax deductions for mortgage interest (e.g. Glaeser and Shapiro 2003) or local taxes (e.g. Kaplow 1996b), do not remark on these possible offsetting effects either.

This paper begins by laying out a model with different cities in a trading equilibrium sharing mobile workers. City characteristics generate differences in costs-of-living, wages, and federal tax burdens. Section 3 uses this model to describe the amount of differential taxation that arises across cities in equilibrium, and how this affects local prices. Section **??** examines how the distribution of employment is distorted by taxes, and demonstrates how the deadweight loss from this distortion can be reduced to standard Harberger triangles. Then, section 5 considers the desirability of indexing taxes to local wages or costs-of-living; it also demonstrates how tax deductions for locally-produced goods, such as housing, produces an effect similar to cost-indexation, albeit with a twist.

[1] For example, Kaplow (1996a) holds prices fixed and argues for an index formula that would not equalize nominal tax payments across identical workers, so that locational inefficiencies would still occur. Knoll and Griffith (2003), in their argument, assume that a flat-tax on income would not change prices or reallocate resources; this assumption, as shown below, does not hold in general equilibrium.

Section 6 calibrates the model and simulates how differential taxes affect local prices, employment, and overall welfare, taking into account differential federal spending patterns. In the process, it provides new estimates of productivity and quality-of-life differences across cities, taking into account the role of taxes. The section finishes by examining how changing deduction levels or indexing taxes would change welfare through worker location and consumption decisions. Section 7 discusses how the model's predictions are affected by changing its assumptions, such as allowing for heterogenous workers or endogenous agglomeration economies. Section 8 compares actual price and wage changes in the 1980's and 1990's with those predicted by changes in the tax code, providing a preliminary empirical assessment of the model. The last section concludes. Considerable detail on theory, calibration, data, and extensions are left to the Appendix.

2 Theoretical Set-Up

To explain why local prices and taxes differ across cities, this paper adapts a model from Rosen (1979) and Roback (1980, 1982, 1988), inspired by general equilibrium trade theory. The national economy is closed and contains many cities, indexed by j, which trade with each other and share a homogenous population of workers. These workers consume a numeraire traded good, x, and a non-traded "home" good, y, with local price p^j. While workers are identical, cities differ in three types of exogenous amenities. Quality-of-life, Q^j, may be affected by weather, crime, scenic beauty, or geographic location. Productivity in the traded-good sector, A_X^j (or "trade-productivity"), may be due to natural advantages, such as proximity to a natural harbor or natural resources, or to various agglomeration economies, due to learning, matching, or sharing (Duranton and Puga, 2004). Productivity in the home-good sector, A_Y^j, (or "home-productivity") may be due to natural advantages; regulations in the housing market, good or bad; or political factors affecting the efficiency of the local public sector. Although some amenities may indeed be endogenous, it is safe to take them exogenously if federal taxes do not significantly affect their relative levels across cities. Average amenity values are normalized to one, i.e. $\bar{Q} = \bar{A}_X = \bar{A}_Y = 1$.

Firms produce traded and home goods out of land, capital, and labor. Factors receive the same payment in either sector. Land, L, is fixed in supply in each city at L^j, and is paid a city-specific price r^j. Capital, K, is fully mobile and is everywhere paid the price $\bar{\imath}$. The supply of capital in each city is denoted K^j, with the aggregate level of capital fixed at K_{TOT}, thus $\sum_j K^j = K_{TOT}$. Labor, N, is also fully mobile, but because workers care about local prices and quality-of-life, wages, w^j, may vary across cities. Workers have

identical tastes and endowments; each supplies a single unit of labor, so the number of workers in a city, N^j, is synonymous with its labor supply. The total number of workers is fixed at N_{TOT}, so $\sum_j N^j = N_{TOT}$. Workers own identical diversified portfolios of land and capital, which pay an income $R = \frac{1}{N_{TOT}} \sum_j r^j L^j$, from land and $I = \bar{\imath} \frac{K_{TOT}}{N_{TOT}}$, from capital. Total income $m^j \equiv R + I + w^j$ varies across cities only as wages vary. Out of this income workers may pay two types of taxes to the federal government: an income tax $\tau(m)$, and a city-specific head tax T^j. Negative tax values represent a transfer from the government. A neutral lump-sum tax, $\bar{T}$, can be imposed by uniformly increasing T^j or adding to $\tau(m)$. Deductions are introduced in Section 5.

Workers' preferences are modeled by a utility function $U(x, y; Q)$, quasi-concave and homothetic over x and y, and increasing in Q. The expenditure function for a worker in city j is

$$e(p^j, u; Q^j) \equiv \min_{x,y} \left\{ x + p^j y : U\left(x, y; Q^j\right) \geq u \right\}$$

Q is assumed to enter neutrally into the utility function, so that it does not affect the elasticity of substitution, σ_D, and is normalized so that a one-percent increase in Q increases utility as much as a one-percent increase in income, thus $e(p^j, u; Q^j) = e(p^j, u)/Q^j$, where $e(p^j, u) \equiv e(p^j, u; 1)$. Assuming identical workers with inelastic labor supply abstracts away from issues of individual labor supply and redistribution, and focuses attention on the spatial decisions of workers.[2] As workers are fully mobile, their utility must be the same across all inhabited cities, implying that if higher prices or lower quality-of-life must be compensated with after-tax income:

$$e(p^j, \bar{u})/Q^j = m^j - \tau(m^j) - T^j \tag{1}$$

where $\bar{u}$ is the level of utility attained. While full mobility is a strong assumption, it seems justified given that widespread income taxation has been around for several decades, allowing multiple generations to migrate in response to its incentives. These incentives need not be consciously pursued, but merely a consequence of workers being more likely to stay in places where they feel well-off, or of firms moving jobs across cities to lower production costs without making their workers worse off. Moreover, the mobility condition need not apply to all workers, but only a sufficiently large subset of mobile "marginal" workers

[2]This follows from a CES utility function $U(x, y; Q) = Q[\alpha x^{1-1/\sigma_D} + (1-\alpha) y^{1-1/\sigma_D}]^{\sigma_D/(\sigma_D - 1)}$. Homothetic preferences imply that the income elasticity of goods is equal to one. The model generalizes easily to a case with heterogenous workers that supply different fiixed amounts of labor if these workers are perfect substitutes in production, have identical homothetic preferences, and earn equal shares of income from labor.

(Gyourko and Tracy, 1989).

Operating under perfect competition, firms produce traded and home goods are according to the functions $X^j = A_X^j F_X^j(L_X^j, N_X^j, K_X^j)$ and $Y^j = A_Y^j F_Y(L_Y^j, N_Y^j, K_Y^j)$ – production quantities are given in upper-case – where F_X and F_Y are concave and exhibit constant returns to scale in the three factors. All factors in a city are fully employed, so $L_X^j + L_Y^j = L^j$, $N_X^j + N_Y^j = N^j$, and $K_X^j + K_Y^j = K^j$. Because of constant returns to scale, production in each city can be modeled with a single price-taking profit-maximizing firm; furthermore, marginal costs in each sector equal unit costs, given in the traded-goods sector by

$$\begin{aligned} c_X(r^j, w^j, \bar{\imath}; A_X^j) &\equiv \min_{L,N,K} \left\{ r^j L + w^j N + \bar{\imath} K : A_X^j F(L, N, K) = 1 \right\} \\ &= c_X(r^j, w^j, \bar{\imath})/A_X^j \end{aligned}$$

where $c(r, w, i) \equiv c(r, w, i; 1)$. A symmetric definition holds for the unit cost function in the home-good sector, c_Y. As markets are competitive, firms make zero profits in equilibrium, so that for given output prices, more productive cities must pay higher rents and wages to achieve zero profits:

$$c_X(r^j, w^j, \bar{\imath})/A_X^j = 1 \tag{2}$$

$$c_Y(r^j, w^j, \bar{\imath})/A_Y^j = p^j \tag{3}$$

in all cities j with production.[3]

Instead of modeling the public sector at all levels - federal, local and state - this analysis reduces the public sector to a single "federal" government. As local taxes determine the level of locally provided government goods, the local public sector does not need to be explicitly modeled. If local government goods are provided efficiently, as in the Tiebout (1956) model, these goods can be treated simply as goods consumption, part traded and part non-traded. Efficiency differences in the local public sector can be absorbed into either Q or A_Y. Federal taxes, on the other hand, are not tied to local benefit levels. For example, the benefits of national defense are equally shared, whatever the distribution of federal taxes.[4]

[3] Each sector has three partial (Allen-Uzawa) elasticities of substitution in production for each combination of two factors, where $\sigma_X^{LN} \equiv \left(\partial^2 c/\partial w \partial r\right) / \left(\partial c/\partial w \cdot \partial c/\partial r\right)$ is the partial elasticity of substitution between labor and land in the production of X, etc. Because productivity differences are Hicks-neutral, they do not affect these elasticities of substitution. Productivity differences that are not Hicks-neutral have essentially the same impact on relative price differences across cities, but not on relative quantity differences.

[4] Since state tax levels are only partially tied to local government provision, especially in large states, state government may be

The federal government does more than provide public goods: it also gives transfers to workers, sometimes in kind. In this model, it matters whether workers who pay higher federal taxes receive more transfers. For example, workers in the U.S. who live in high-wage areas pay more in federal payroll taxes, and then receive higher Social Security benefits later in life, regardless of where they live; thus, the marginal benefit of paying these taxes should be subtracted from the effective marginal income tax rate. On the other hand, workers who pay more in payroll taxes do not receive more Medicare when they retire. Federal means-tested benefits increase the effective marginal tax rate, although this is complicated by eligibility requirements for programs which vary by state or county. Furthermore, some benefit levels are tied to local prices, such as housing programs, although these programs tend to be fairly small. Insomuch as they are provided efficiently, goods provided by the federal government at the local level may be thought of as transfers, or negative head taxes.[5]

In the model, the federal government collects tax revenues and makes transfers, and uses the net balance, $\sum_j N^j \left[\tau\left(m^j\right) + T^j\right]$, to make purchases. For simplicity, assume the government buys traded goods from the market and uses it to produce a federal public good. The amount of federal public good is held fixed, and since it benefits workers everywhere equally, its benefits do not need explicit modeling.

With the public sector now incorporated, it is now possible to develop the notation for relative income, cost, and expenditure shares, which are used to express the results below. For workers denote the expenditure shares of traded goods, home goods, and taxes as $s_x^j \equiv x^j/m^j$, $s_y^j \equiv p^j y^j/m^j$, and $s_T^j = [\tau\left(m^j\right) + T^j]/m^j$, with $s_x^j + s_y^j + s_T^j \equiv 1$; denote the shares of income received from land, labor, and capital income as $s_R^j \equiv R/m^j$, $s_w^j \equiv w^j/m^j$, and $s_I^j \equiv I/m^j$, which also sum to one. For firms, denote the cost shares of land, labor, and capital in the traded goods as $\theta_L^j \equiv r^j L_X^j/X^j$, $\theta_N^j \equiv w^j N_X^j/X^j$ and $\theta_K^j \equiv \bar{\imath} K_X^j/X^j$; denote similar costs shares in the home goods sector as ϕ_L^j, ϕ_N^j, and ϕ_K^j. Because of constant returns to scale, $\theta_L^j + \theta_N^j + \theta_K^j = \phi_L^j + \phi_N^j + \phi_K^j = 1$.

3 Taxes and Prices Across Cities

This analysis starts by examining how a head tax on workers in a single city raises wages and lowers land and home-good prices. Although federal governments typically do not impose such taxes, it helps deal with

considered part local and part federal.

[5] Intergovernmental transfers that increase the supply of local government goods can be treated in a similar way; it should be kept in mind that federal matching rates for many programs (e.g. Medicaid) decline with average state income. The complicated nature of all of these transfers makes it useful to consider some types of federal transfers separately from an overall tax schedule.

locally-targeted government spending, and makes it easier to understand how federal income taxes operate in Part B. The income-tax analysis reveals that workers across all cities effectively pay a head tax (or subsidy) equal to the income-tax rate times the wage differential offered in a city due to its characteristics.

3.1 City-Specific Head Taxes

The system of equations given by the free-mobility and zero-profit conditions (1), (2), and (3), implicitly define the prices w, r, and p, as a function of the head tax T. Assume that the level of utility $\bar{u}$ is given, as in a relatively small city, and ignore the income tax. Differentiating implicitly with respect to T creates a system of three equations in three unknowns: the price changes dw, dr, and dp. These equations are log-linearized with the help of Shepard's Lemma, share definitions, and the notation $d\hat{w} = dw/w$, etc. (notation which helps in Part B, below), to produce:

$$s_w d\hat{w} - s_y d\hat{p} = dT/m \tag{4a}$$

$$\theta_L d\hat{r} + \theta_N d\hat{w} \qquad = 0 \tag{4b}$$

$$\phi_L d\hat{r} + \phi_N d\hat{w} - \quad d\hat{p} = 0 \tag{4c}$$

omitting superscript j. According to (4a), head taxes as a fraction of total income, dT/m, must be accompanied with wage increases or cost-of-living decreases: in equilibrium, real after-tax incomes cannot change because of head taxes. Equations (4b) and (4c) demonstrate how wage and rent changes must offset to keep unit costs equal to prices.[6]

The percent price changes may be solved for using Cramer's Rule and the accounting identities[7] $s_R = (s_x + s_T)\theta_L + s_y\phi_L$ and $s_w = (s_x + s_T)\theta_N + s_y\phi_N$. Land rents decrease in proportion to taxes according to

$$d\hat{r} = -\frac{1}{s_R}\frac{dT}{m} \tag{5}$$

[6]The approach here is similar to that of Harberger (1962), Jones (1965), Mieszkowski (1972) and other incidence analyses. In particular, it resembles a model with one good and one immobile factor shown in Kotlikoff and Summers (1987), with each city operating as a different sector. A key difference is that the mobile factor, labor, responds not only to its own factor price, w, but also to the price of the locally produced good, p, so that w can vary across cities.

[7]These identities assume that the shares of income *paid* to factors in city j, are equal to the shares of income *received* by workers in city j. This assumption is exactly true if production and preferences functions are Cobb-Douglas, or if workers live in a nationally-representative "average city." Otherwise, these identities should be treated as useful approximations; as workers hold diversified portfolios of land and capital, shares of income received depend on aggregate shares of income paid over all cities, not just the home city.

As $s_R = rL/Nm$, (5) can be re-expressed in level terms as $dr \cdot L = -N \cdot dT$, which means that head-taxes are fully capitalized into land rents: land, the sole immobile factor, ultimately bears the full burden of the head-tax. The percent wage change

$$d\hat{w} = \frac{\theta_L}{\theta_N} \frac{1}{s_R} \frac{dT}{m} \tag{6}$$

is positive as nominal wages rise to compensate workers for living in a more heavily taxed city. Firms can pay workers more as they substitute cheaper land for dearer labor, although the wage increase is likely to be smaller than the rent decrease as $-d\hat{w}/d\hat{r} = \theta_L/\theta_N$, a cost ratio which should be well below one. The price change

$$d\hat{p} = -\left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right) \frac{1}{s_R} \frac{dT}{m} \tag{7}$$

is negative if home goods are more cost intensive in land relative to labor than traded goods, i.e., if $\phi_L/\phi_N > \theta_L/\theta_N$, a likely case as non-traded goods consist primarily of housing and other immobile goods. Thus, workers are compensated for higher taxes through lower local goods prices as well as higher wages. If home goods consist of more than land, i.e. $\phi_L < 1$, then the home-good price falls by less than the land-rent, i.e. $d\hat{p}/d\hat{r} < 1$. It is also straightforward to show that housing prices fall more than wages rise, i.e. $-d\hat{p}/d\hat{w} > 1$.

In conclusion, a head tax in a single city should decrease land rents be a relatively large amount, decrease home-good prices by a moderate amount, and raise wages by a small amount. A differential head subsidy (with $dT < 0$), taking the form of a direct payment, or possibly some kind of local government grant, should produce opposite and equal effects on prices.

3.2 Federal Income Taxes

While the previous analysis looked at the comparative static effect of head taxes on prices in a single city, the following analysis looks at how prices vary cross-sectionally across cities with different amenities in the presence of an income tax. Assume that there enough cities varying in the three amenities, Q, A_X, and A_Y to form a continuum around a city with average amounts of each amenity. Now, the equilibrium conditions (1), (2), and (3) implicitly define the prices w,r, and p, (and the income tax, τ, which depends on them) as a function of Q, A_X, and A_Y. These conditions can be log-linearized around the average city to express a city's price differentials in terms of its amenity differentials. Cross-sectional differentials are expressed in logarithms so that, for any variable z, $\hat{z}^j = \log z^j - \log \bar{z} \cong \left(z^j - \bar{z}\right)/\bar{z}$, expresses the percent difference

in city j of z relative to the (geometric) average $\bar{z}$. Values in the absence of taxes are subscripted with zero, e.g. $\hat{z}_0^j$; values in the presence of taxes are not subscripted, as these are observed. The relative change in z in city j due to taxes is denoted $d\hat{z}^j = \hat{z}^j - \hat{z}_0^j$, which corresponds to the previous notation with head taxes. In the average city $\hat{z}^j = \hat{z}_0^j = d\hat{z}^j = 0$ for any variable z; letting E take expectations over cities, weighted by population, this means $E[\hat{Q}^j] = E[\hat{A}_X^j] = E[\hat{A}_Y^j] = 0$. Log-linearizing (1), (2), and (3), as planned, produces equations describing how prices co-vary with amenities[8]

$$s_w\hat{w} - s_y\hat{p} = \tau' s_w\hat{w} - \hat{Q} \tag{8a}$$

$$\theta_L\hat{r} + \theta_N\hat{w} \qquad = \hat{A}_X \tag{8b}$$

$$\phi_L\hat{r} + \phi_N\hat{w} - \quad \hat{p} = \hat{A}_Y \tag{8c}$$

The first equation includes the term $\tau' s_w\hat{w}$ on the right-hand side, which is the income tax differential paid by workers because of wage differences, $\tau' s_w\hat{w} = \tau'\hat{m} \equiv d\tau/m$. For example, if a city offers 10 percent higher wages, the share of income from wages is 75 percent, and the marginal tax rate is 33 percent, then workers of the city pay additional taxes equal to 2.5 percent of income. It is similar to the differential head tax, dT/m, in (4a), except that it depends on an endogenous wage differential, $\hat{w}$, rather than being set arbitrarily. From (8a), taxes have an effect on prices similar to a lower quality-of-life.

As the extra tax term depends on the wage differential, $\hat{w}$, this needs to be solved for first:

$$\hat{w} = \hat{w}_0 + \underbrace{\frac{\theta_L}{\theta_N}\frac{1}{s_R}\overbrace{\tau' s_w\hat{w}}^{d\tau/m}}_{d\hat{w}} = \frac{1}{1 - \frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\tau'}\hat{w}_0 \tag{9}$$

where

$$\hat{w}_0 = \frac{1}{\theta_N s_R}\left(s_y\phi_L\hat{A}_X - \theta_L\hat{Q} - s_y\theta_L\hat{A}_Y\right) \tag{10}$$

relates how wages are higher in cities with above-average trade-productivity and lower in cities with above-average quality-of-life or home-productivity.[9] The first equality of (9) expresses the wage differential as the

[8] These equations should be treated as first-order approximations, evaluated at the average city, so that the share values correspond to national averages, and the accounting identities mentioned earlier apply exactly.

[9] Expressions for price differentials without taxation functionally equivalent to (10), (13a), and (13b) are found in Roback (1980) although she does not make use of log-linearization, non-labor income, or the simplifications available from accounting identities. Equation (8a) implies that quality-of-life valuations using the Rosen-Roback framework should scale down wage differentials by a factor of $1 - \tau'$. Gyourko, Kahn, and Tracy (1999, equation 11) develop expressions similar to (9) and (12a) for wage and rent changes in the presence of local income taxes in the simpler case where $\phi = 1$. However, their expressions look very different, as they are not log-linearized or simplified in the same way, and they are given different interpretations based on local taxes. These

sum the pre-tax differential and the income tax effect. Although recursive, this result demonstrates that that cities paying a positive wage differential without income taxes, pay an additional wage differential because of taxes. The non-recursive solution is given by the second equality in (9) in combination with (10). As the term multiplying $\hat{w}_0$ is larger than one, $|\hat{w}| > |\hat{w}_0|$, income taxes increase the dispersion of wages across cities.[10]

Combining $d\tau/m = \tau' s_w \hat{w}$, (9), and (10), the amount of additional income taxes paid in a city in terms of local amenities is

$$\frac{d\tau}{m} = \tau' \frac{1}{1 - \frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\tau'} \frac{s_w}{\theta_N s_R} \left(s_y \phi_L \hat{A}_X - \theta_L \hat{Q} - s_y \theta_L \hat{A}_Y \right) \tag{11}$$

In parallel with wage differences, income taxes fall more heavily on cities with high trade-productivity, and more lightly on cities with higher quality-of-life or home-productivity. The income tax here operates as if the federal government first imposed a general lump-sum tax to generate its revenues, and then imposed city-specific head taxes according to (11) based directly on amenity levels.

Land rent and home-good price differentials can be decomposed similarly:

$$\hat{r} = \hat{r}_0 - \underbrace{\frac{1}{s_R}\tau' s_w \hat{w}}_{d\hat{r}} \tag{12a}$$

$$\hat{p} = \hat{p}_0 - \underbrace{\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N \right) \frac{1}{s_R}\tau' s_w \hat{w}}_{d\hat{p}} \tag{12b}$$

where

$$\hat{r}_0 = \frac{1}{s_R} \left(\hat{Q} + s_x \hat{A}_X + s_y \hat{A}_Y \right) \tag{13a}$$

$$\hat{p}_0 = \frac{1}{\theta_N s_R} \left[\left(\theta_N \phi_L - \theta_L \phi_N \right) \hat{Q} + \phi_L s_w \hat{A}_X - \theta_L s_w \hat{A}_Y \right] \tag{13b}$$

analyses do not refer to federal taxes or deductions.

[10] Expanding the term multiplying $\hat{w}_0$ in (9), the after-tax wage differential may be written as the original wage differential plus a sequence of ever smaller tax-induced wage differentials, as the tax on the initial wage difference raises wages, further raising taxes, further raising wages, and so on:

$$\hat{w} = \hat{w}_0 \sum_{n=0}^{\infty} \left(\frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\tau' \right)^n = \hat{w}_0 + \left(\frac{\theta_L}{\theta_N}\frac{1}{s_R} \right) \sum_{n=0}^{\infty} \frac{d\tau_n}{m}$$

$d\tau_n/m = \left(\frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\tau' \right)^n \tau' s_w \hat{w}_0$ represents the value of each incremental tax, beginning with the additional tax $d\tau_0/m$ from $\hat{w}_0$.

Both land rents and home-good prices increase with quality-of-life and trade-productivity, although land rents rise and home-good prices fall with home-productivity. (12a) and (12b) reveal how additional federal taxes paid from amenity differences are capitalized into land rents and home-good prices just as differential head taxes are in (5) and (7). Thus, taxes lower relative land and home-good values values in cities with above-average trade productivity, or below-average quality-of-life or home productivity.

The effect of taxes on price differentials can be shown graphically by simplifying the model so that home goods are made directly from land, meaning $\phi_L = 1$ and $p = r/A_Y$; to save on notation, also ignore non-labor income. Figure 1 illustrates how taxes affect price differentials between a city with higher traded productivity, say Chicago (labeled with "C"), and an "average" city, say Nashville,[11] with productivities $A_X^C > 1$ and $\bar{A}_X = 1$. The zero-profit conditions, $c_X(r, w) = A_X$ slope downwards as wages must fall as rents rise to keep profits at zero. Firms in Chicago can afford to pay higher wages and rents, putting its zero-profit condition to the upper-right of the Nashville's. The free mobility condition $e(r, u) = w$, slopes upwards as wages must rise with rents in order for workers to be indifferent between either city. In equilibrium, shown at $\bar{E}$ and E_0^C for the two cities, Chicago is more crowded than Nashville and pays workers a compensating differential $w_0^C - \bar{w}$ to compensate workers for the higher cost-of-living reflected in $r_0^C - \bar{r}$.

With a federal income tax, firms in Chicago must pay workers a larger wage differential to compensate workers for the higher costs, as workers pay for these costs out of after-tax income. Thus, taxes make it more expensive to hire workers in Chicago, leading firms to cut employment. To simplify, suppose the federal government imposes an income tax which makes zero net revenue across cities, so that a worker in Nashville, with an average wage, pays no tax, $\tau(\bar{w}) = 0$, though she faces a positive marginal tax rate, $\tau' > 0$.[12] The mobility condition for workers, $e(r, u) = w - \tau(w)$, is now in terms of the net wage, $w - \tau(w)$, so that the gross wage, w, must increase more to compensate for higher rents.[13] Workers in Chicago at the old equilibrium E_0^C are now worse off than in Nashville, as the old compensating differential is not enough after taxes to make up for the higher cost-of-living. Only after workers leave ($dN^C < 0$),

[11] By "average," I mean average in wages and rents, which the data in the simulation below reveal; Nashville may be exceptional in many other ways. The examples of Chicago and Miami are also based on results from the data below. The example of Dallas is inspired by Malpezzi (1996), which finds that housing prices in Dallas may be low partly because of low housing regulation.

[12] An income tax generating positive revenues is simply the sum of this income tax plus a neutral lump-sum tax. The previous equilibrium could be reinterpreted as already having this lump-sum tax in place, so that the comparison can be reframed as between a uniform lump-sum tax and an income tax that leaves workers equally well off.

[13] The slope of the indifference curve is equal to the amount of home-good consumed, divided by the marginal net-of-tax rate, i.e. $y/(1 - \tau')$.

causing rents to fall by dr^C and wages to rise by dw^C in Chicago, is equilibrium re-established at E^C. By making Chicago relatively more expensive, the income tax discourages workers from working there, similar to how taxes discourage work by raising the cost of effort relative to leisure.

Like a productive city, a city offering a higher quality-of-life, say Miami, attracts a disproportionate number of workers, raising costs-of-living, except that, as compensation, these workers receive a nicer environment rather than a higher wage. Because land is fixed in supply and used in production, local labor demand curves are downward sloping; a larger supply of workers in the nicer city lowers the wage. This equilibrium is shown in Figure 2, with Nashville and Miami (City "M"), each having qualities-of-life $\bar{Q} = 1$ and $Q^M > 1$. Both cities have the same productivity, and so share the same zero-profit condition. Yet, the mobility condition for workers in Miami is located to the lower-right, as workers are willing to accept lower wages or pay higher rents to live there. In equilibrium, shown in E_0^M, workers in Miami pay the rent premium $r_0^M - \bar{r}$, and receive the negative wage differential $w_0^M - \bar{w}$.

Putting in the income tax $\tau(w)$ as before, because residents of Miami receive below-average wages, they pay below-average taxes, which in this case implies a subsidy. A worker is now more willing to bid down her wage to live in Miami, as a one dollar reduction in income implies only a $1 - \tau'$ dollar reduction in consumption. With this effective tax-rebate for quality-of-life, workers in Miami are better-off than average at the old equilibrium, E_0^M: workers are induced to move to Miami ($dN^M > 0$) until rents are driven up by dr^M and wages are driven down by dw^M to make Miami no more attractive than other cities. To the extent that higher quality-of-life is bought through lower wages, its tax treatment is similar to untaxed fringe benefits: firms located in a city on a beach share tax advantages similar to firms that offer a tax-deductible company car.

The third case of a city better at producing home goods, say Dallas, looks much like Figure 2, as wages go further in Dallas ($A_Y^D > \bar{A}_Y = 1$), making residents there better off for a given wage-rent combination. In equilibrium, wages will be lower and land rents higher than average, but the price of home goods, p, will be lower than average, $p^D < \bar{p}$. Because they are paid lower wages, Dallas residents pay lower taxes, creating the same tax advantage and effects seen in Miami.

Although the federal income tax may have many desirable properties when spatial concerns are ignored, it is curiously distributed across cities with different amenities. By falling more heavily on workers in cities offering higher wages, the income tax acts as an arbitrary head tax on cities with characteristics that lead to higher wages, whatever those characteristics may be. The tax is distortionary as amenities are the

characteristics of cities, which workers choose by deciding where to live, and not the innate characteristics of workers themselves. There is no obvious economic rationale for why the federal government should tax cities differentially in this manner.

4 Employment andEfficiency

In order for taxes to influence prices, factors must move across cities and sectors, and the most important factor is labor. By inducing workers to move away from high-wage areas towards low-wage areas, federal taxes misallocate workers across areas, leading to an efficiency loss. Just as differential head taxes and federal income taxes of the same size, i.e. $dT = d\tau$, have the same effects on prices, the same holds true of quantities, so long as labor supply is inelastic: no separate treatment is required.

4.1 Employment Effects

By making high wage cities more expensive to live in, the federal income tax changes the distribution of employment across cities. The employment effect of a differential tax can be written

$$d\hat{N} = \varepsilon \cdot \frac{d\tau}{m} \tag{14}$$

where ε is the elasticity of local employment with respect to taxes as a percentage of total income. In principle, this elasticity is estimable directly without reference to the theoretical model. Since the income tax differential $d\tau/m = \tau' s_s \hat{w}$ is also calculable directly from data, employment effects can be calculated independently of the model with an estimate of ε.

Nevertheless, the theoretical model does imply a particular value for ε: its derivation is left to Appendix A. When partial (Allen-Uzawa) elasticities are constant within each sector,

$$\begin{aligned}\varepsilon = -\frac{1}{(\theta_N s_R)^2}\{&(s_x + s_T)\theta_L\theta_N\left(\theta_L + \theta_N\right)\sigma_X + \frac{s_x s_y}{s_x + s_y}\left(\theta_N\phi_L - \theta_L\phi_N\right)^2\sigma_D \\ &+ s_y[\phi_L\phi_N\left(\theta_L + \theta_N\right)^2 + \phi_K\left(\phi_N\theta_L^2 + \theta_N^2\phi_L\right)]\sigma_Y\}\end{aligned} \tag{15}$$

Although a function of many parameters, this elasticity is unambiguously negative (if $\phi_L/\phi_N > \theta_L/\theta_N$), and depends on essentially three components, each tied to a different elasticity of substitution. Because of free mobility, workers need a higher wage or face lower home-good prices if they are to pay higher taxes;

for prices to adjust in this way, employment must fall. Overall, the higher the elasticities of substitution, the less sensitive are price changes to employment changes, and therefore the more employment must fall for the necessary price changes to occur: the higher σ_X the more slowly firms offer higher wages as employment falls; the higher σ_D the more slowly home-good prices drop as home-good demand falls; the higher σ_Y the more slowly home-good prices drop through home-goods supply as land rents fall.

4.2 Locational Inefficiency and Deadweight Loss

Without taxes, or with just uniform lump-sum taxes, the spatial distribution of employment is efficient, or "locationally efficient" (Wildasin 1980). When workers move in response to federal income taxes, the resulting distribution of workers becomes inefficient. Appendix A derives the deadweight loss due to this inefficiency by calculating how much revenue the government loses when it replaces a neutral lump-sum tax with an income tax, holding the utility of workers constant. This deadweight loss, expressed as a fraction of national income, is proportional to the size of the differential head tax times the induced change in migration.

$$\frac{DWL}{\bar{m} \cdot N_{TOT}} = \frac{1}{2} E\left[\frac{d\tau^j}{m} d\hat{N}^j\right]$$

This expression is consistent with Harberger's (1964) formula that a deadweight loss, with no other distortion present, is given by one-half times the tax times the change in the quantity taxed. While this result may seem conventional, it is encouraging that this formula can capture all of the distortions in production and consumption, and that the distribution of amenities can be ignored. Furthermore, as $d\hat{N}^j = \varepsilon \cdot d\tau^j/m$ the deadweight loss

$$\frac{DWL}{\bar{m} \cdot N_{TOT}} = \frac{1}{2} \text{Var}\left(\frac{d\tau^j}{m}\right) \cdot \varepsilon \tag{16}$$

can be calculated using only data on the variance of income tax differentials and ε. Since $d\tau^j/m = \tau^j s_w \hat{w}^j$ the deadweight loss increases with the variance of wage differences across cities. Furthermore, if the tax schedule is progressive (or generally convex), then τ^j and $\hat{w}^j$ are positively correlated, so that the deadweight loss will be greater than for a flat-tax (τ^j constant) generating equal revenue, although a flat-tax would merely reduce the distortion, without eliminating it. The deadweight loss is zero only if $\tau^j s_w \hat{w}^j$ is constant across cities, in other words, if tax burdens are uniform across all regions.

5 Indexation and Deductions

Since income taxes make workers locate inefficiently, it is worth considering policies to remedy this problem. Taxes can be indexed to either local wages or costs-of-living: while the former solution is ideal, it is more difficult to implement.[14] Allowing workers to deduct home-good expenditures from income taxes serves to partially index taxes to local costs if demand is inelastic, and may improve locational efficiency, although it creates a possibly larger inefficiency of its own.[15]

5.1 Wage Indexation

Income taxes may be indexed to wages by letting workers deduct $w^j - \bar{w}$, the level wage differential due to amenities, from taxable income; equivalently, labor income could be divided by $1 + \hat{w}^j = w^j/\bar{w}$. With this indexation, a worker's income taxes do not depend on where she lives, effectively turning the income tax into an efficient neutral lump-sum tax.

In a setting where workers can earn different amounts within the same city, indexed income taxes need to correct for the fact that a workers's wages will change across cities, without giving a tax break to workers in cities where more workers with high earnings-ability live. This creates practical difficulties in finding a suitable wage index which measures how the price of a standard unit of labor changes across cities. The measurement of $w^j - \bar{w}$ must represent the causal effect of a city on a worker's wages, a quantity which may be difficult to estimate if different types of workers sort into cities according to their earnings ability, which can only be imperfectly observed. One could mistake a city as one offering high wages, when it just a city where high-ability workers live.[16] Also, different types of workers may experience different wage effects $\hat{w}^j$ from amenity differences (Roback 1988, Moretti 2004), meaning that labor income may need to be indexed differently for different types of workers. However, if worker tastes are sufficiently similar, the

[14] Only a handful of U.S. federal programs are indexed to local prices. Federal Housing Administration loan insurance is guaranteed up to the level of local median home prices. Department of Housing and Urban Development (HUD) public housing and rental vouchers programs are fairly unique, using local income levels to determine eligibility while using a local index of "Fair Market Rents" to determine benefits. The income limits are calculated by taking percentages, e.g. 80 percent, of median household incomes in a metropolitan area. No adjustments are made for differences in worker characteristics across cities. In Canada, Low Income Cut-Offs (LICOs), used to calculate poverty and determine eligibility for some programs, increase with the population size of a community.

U.S. Congressmen have proposed legislation to index taxes and transfers to regional cost-of-living repeatedly: the Tax Equity Act, to index taxes, the Poverty Data Correction Act, to index the poverty line, and the COLA Fairness Act, to index Social Security payments. Although none of these bills have passed, similar legislation is proposed almost every Congress, the most recent being the Tax Equity Act of 2005.

[15] Subsections 5.1 and 5.2 summarize, formalize, and expand on more intuitive discussions of indexation given in Kaplow (1997) and Knoll and Griffith (2003).

[16] See Gyourko, Mayer, and Sinai (2006) for an interesting model of income-sorting across cities.

income differentials of different workers are likely to be highly correlated across cities (See Appendix D.3). Furthermore, the effect of a city on a worker's wages may not appear immediately after a worker moves into a city. For instance, wage gains from living in a productive city may come slowly as a worker learns from those around her, a process which could take many years (Glaeser and Maré 2001).

5.2 Cost-of-Living Indexation

Indexing taxes to local cost-of-living may be easier than indexing taxes to wages as the prices of homogenous goods across cities are easier to measure than homogenous units of labor. A cost-of-living index may be defined as $\kappa(p) = e(p, \bar{u}) / e(\bar{p}, \bar{u})$, where $\bar{p}$ is the average home-good price.[17] A cost-indexed income tax would presumably divide income by this cost-of-living index, so $\tau = \tau(m/\kappa(p)))$. The additional amount of income taxes paid can be found by taking the total derivative, revealing $d\tau/m = \tau'(s_w\hat{w} - s_y\hat{p})$: naturally, taxes will increase with wages, but decrease with local home-good prices.

With cost-of-living indexation, the system of equations determining price differentials (8) is unaffected except for the free-mobility condition given by (8a), which now becomes (evaluated at the average city, where $\kappa = 1$)

$$s_y\hat{p} - s_w\hat{w} = \hat{Q}/\left(1 - \tau'\right) \tag{17}$$

This statement says that workers are willing to take a larger fall in gross real income for an increase in quality-of-life: indexation reduces the real consumption a worker gives up for when her gross real income falls. Substituting in $d\tau/m = \tau'(s_w\hat{w} - s_y\hat{p})$ reveals that cost indexation causes taxes to fall sharply with quality-of-life.

$$\frac{d\tau}{m} = -\frac{\tau'}{1 - \tau'}\hat{Q} \tag{18}$$

Compared with the effect of income taxation with no indexation, seen in (11), cost indexation has the benefit of eliminating tax differences across cities differing in either type of productivity (A_X or A_Y); across these cities, wages rise in step with costs, $\hat{w} = (s_y/s_w)\hat{p}$, so indexing with costs is equivalent to indexing with wages. The drawback to cost indexation is that in nicer cities workers receive two tax advantages: they owe fewer taxes for paying higher prices and for receiving lower wages. The government effectively subsidizes quality-of-life. While this may sound like a welfare improving policy, welfare actually decreases as taxes

[17] If taxes are not flat, then $e(p, u)$ should be reinterpreted as referring to gross (before-tax) expenditures, rather than net (after-tax) expenditures.

induce too many workers to crowd into nice cities.[18]

As with the regular income tax, tax differentials under cost-indexed taxes have an effect on prices similar to city-specific head taxes, now given by (18). Cross-sectional price differentials across cities are the same as pre-tax differentials ($\hat{w}_0, \hat{r}_0, \hat{p}_0$) given in equations (10), (13a), and (13b), with $\hat{Q}$, replaced with $\hat{Q}/(1-\tau')$: nicer cities have even lower wages and higher land and home-good prices than before. The effect on local employment levels and deadweight loss may be found by substituting (18) into equations (14) and (16) above. Since, relative to unindexed taxes, cost-indexation makes tax differentials vary more with quality-of-life, but not with productivity differences, it is unclear whether indexing taxes will improve or reduce welfare. The answer depends on how amenities are distributed, which is an empirical question to be answered in Section 6.

As cost-of-living indexation leads to welfare losses because it ignores quality-of-life differences, it is worth considering an ideal price index that correctly accounts for quality-of-life, i.e. $\kappa(p,Q) = e(p,\bar{u})/e(\bar{p},\bar{u}) \times 1/Q$. Taxes indexed with $\kappa(p,Q)$ increase with Q enough so that workers are taxed equally across all cities: quality-of-life adjusted cost-indexation is equivalent to wage-indexation. Unfortunately, adjusting a cost-of-living index for quality-of-life differences is likely to be as difficult as finding a correct wage index, especially as workers are likely to value components of quality-of-life (e.g. weather, location) differently. Calculating how workers value these components differently may require a suitable wage index, bringing back the original problems of wage indexation.

5.3 Home-Good Deduction

Thus far I have ignored that the income tax code confers a number of advantages to consuming housing and locally-provided government goods; goods which may be thought of primarily as home goods. Homeowners benefit from a number of tax advantages in housing consumption as they are not taxed for the rent they implicitly "pay" themselves when living in their own home, and as they can deduct mortgage interest from their income taxes (see Rosen 1985, Poterba 1992). Locally provided government goods are also effectively subsidized by the federal government as local taxes can be deducted from income taxes. Since most locally-provided government goods, such as education and public safety, are produced locally, these deductions may be thought to apply primarily to home goods, too. Together, these advantages may be

[18] This implicit subsidization is noted by Glaeser (1998) using a different model, although he does not consider how cost-of-living indexation corrects for distortions across cities with differing productivity.

modeled (bluntly) by allowing households to deduct a fraction $\delta \in [0,1]$ of home-good expenditures, py, from their federal income taxes so that taxes paid are $\tau\left(m - \delta py\right)$. δ should be less than 1 as deductions do not apply to certain taxes (e.g. payroll), and as many home goods, such as haircuts or restaurant meals, are not deductible. Nor are these deductions available to all workers: many renters and home-owners do not itemize deductions for mortgage interest or local taxes.

Totally differentiating the tax schedule, the additional tax paid by workers in a city depends positively on the wage and negatively on home-good price and consumption:

$$\frac{d\tau}{m} = \tau' \cdot \left[s_w \hat{w} - \delta s_y \left(\hat{p} + \hat{y}\right)\right] \tag{19}$$

Appendix A shows that y falls with p according to the compensated own-price elasticity for home goods, $\eta^c < 0$, and with higher quality-of-life, so that $\hat{y} = \eta^c \hat{p} - \hat{Q}$, thus

$$\frac{d\tau}{m} = \tau' s_w \hat{w} - \delta\tau'(1 - |\eta^c|) s_y \hat{p} + \delta\tau' s_y \hat{Q} \tag{20}$$

With an increase in price of $\hat{p}$, the share of expenditures in home goods increases by $s_y\left(1 - |\eta^c|\right)\hat{p}$, which is positive if $|\eta^c| < 1$, i.e. compensated demand for home goods is price inelastic. Substituting the two additional terms into the right-hand side of (8a) and solving completely with (8b) and (8c)

$$\frac{d\tau}{m} = \frac{\tau' s_w \hat{w}_0 - \delta\tau'\left(1 - |\eta^c|\right) s_y \hat{p}_0 + \delta\tau' s_y \hat{Q}}{1 - \tau' \frac{\theta_L}{\theta_N}\frac{s_w}{s_R} - \delta\tau'\left(1 - |\eta^c|\right)\frac{s_y}{s_R}\left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right)} \tag{21}$$

The pre-tax differentials, $\hat{w}_0$, and $\hat{p}_0$, seen in (10) and (13b), depend on amenity values making (21) a closed-form expression in terms of amenity differentials - the full expression is shown in the Appendix equation (A.14).

From (20) or the numerator of (21), the tax differential tax depends on three effects:

Wage-Tax Effect The first term, $\tau' s_w \hat{w}$, relates how taxes increase with wages, as before.

Partial-Indexation Effect The second term, $-\delta\tau' s_y\left(1 - |\eta^c|\right)\hat{p}$, describes how taxes change with an increase in the compensated home-good price. If $|\eta^c| < 1$, workers in higher-cost areas claim larger deductions, producing an implicit form of price indexation. If $\delta = 1$ and $\eta^c = 0$ this term equals $-s_y \hat{p}$, producing full cost-indexation. Otherwise, the indexation effect is only partial, with the degree

of indexation increasing in δ and decreasing in $|\eta^c|$.

Quality-of-Life Income Effect The third term, $\delta\tau' s_y \hat{Q}$, reflects that in nicer cities, workers face higher home-good prices without being compensated by higher wages. Residents of nicer areas consume less of all goods, including home goods. With higher Q, home-good expenditures fall by more than the partial-indexation effect implies, leading to fewer tax deductions.[19]

The term in the denominator of (21) now reflects two multiplier effects: cities taxed more heavily see wages rise, raising taxes through the wage-tax effect; they also see home-good prices fall, raising taxes through the partial-indexation effect.

With deductions, workers in cities good at producing traded goods or bad at producing home goods still pay higher-than-average taxes because the wage-tax effect dominates the partial-indexation effect. It is ambiguous whether workers in nicer cities pay relatively lower taxes with a deduction: the quality-of-life income effect may override the partial-indexation effect and the wage-tax effect combined, so that tax burdens could rise with quality-of-life. Numerical results below present examples of it going either way, although it seems likely that taxes still fall with quality-of-life.

The effect of the income tax with deductions on prices and employment in cities can be found by treating $d\tau/m$ from (21) as a city-specific head tax, and using the associated formulas from Section 3. However, the deadweight loss formula (16) captures only the welfare loss due to the locational inefficiency of workers. The home-goods deduction, by reducing the relative price of home goods by $\delta\tau'$, induces workers to consume too many home goods. This important distortion, already heavily studied in the housing market (e.g. Rosen, 1985), may create large welfare losses, typically given by the deadweight-loss approximation, as a percentage of income

$$\frac{1}{2} s_y \eta^c \left(\delta\tau'\right)^2 \tag{22}$$

While many have tried to find reasons for why it may be beneficial to subsidize housing or local public goods, it appears that none have considered that the deduction may help workers locate more efficiently across cities. While tax-reformers may still find it desirable to eliminate deductions to keep individuals from consuming too much housing or local government goods, they should take into account the fact that

[19] That the reduction in home goods consumption is proportional to s_y depends on the assumption of no complementarities between home-good consumption and amenities, and that the elasticity of home-good consumption to income, $\varepsilon_{y,m}$ is equal to one. If $\varepsilon_{y,m} \neq 1$ then the quality-of-life income effect is $Ds_y\varepsilon_{y,m}\hat{Q}$. With complementarities between home goods consumption and quality-of-life, the effect is smaller.

workers could locate more inefficiently across cities if the deduction is taken away. An optimal tax reform might involve eliminating existing deductions for home goods in the tax code while simultaneously indexing income taxes to local wages or quality-of-life adjusted costs.

A system of home-mortgage deduction caps indexed to local prices, as proposed by the President's Advisory Panel, will either act like the deduction δ, if home-owners purchase below the cap; or partly like direct cost indexation, if home-owners purchase beyond the cap. In the latter case, residents in high-cost areas receive an effective tax rebate equal to $k\delta\tau' s_y \hat{p}$, where k is the ratio of the cap to actual home-good expenditures, without the incentive to purchase more home goods on the margin. If the intention of the cap is to induce individuals to own a home, without inducing them to consume too much housing, then k should be set to less than one, with the level of indexation given by $k\delta$. Whether this capped deduction encourages workers to locate more efficiently depends on whether cost indexation does the same.

6 Calibration, Estimation, and Simulation

It is possible to use the theoretical model above to simulate the effects of differential federal taxation across cities in the United States. This requires calibrating the economic parameters and estimating wage, price, spending, and quality-of-life differentials for metropolitan areas. With these in place, the simulation can be used to analyze how the uneven distribution of federal taxes affects prices, employment, and welfare nationwide, and to consider the benefits of indexing the tax code or of eliminating the preferential tax-treatment of home goods.

6.1 Calibrating the Model

A general overview and some important details of the calibration are discussed here, with other details left to Appendix B.[20] The cost, income, and expenditure shares are fairly straightforward to measure, although since there is still some uncertainty over them, round fractions are used for ease. Looking first at factor income shares, labor (s_w) receives about 75 percent of income (Krueger 1999); capital (s_I), 15 percent (Poterba 1998); and land (s_R), 10 percent (Keiper et al. 1961). Based on information from the Consumer Expenditure Survey (2002) and the Bureau of Economic Analysis (2006), households appear to spend about one-third of income on home goods (s_y), 10 percent on "federal" public goods (s_T), and the remaining on

[20]The calibration draws from similar calibrations in Rappaport (2006) and Shapiro (2006), although the model, as well as the choices made here, are fairly different.

traded goods (s_x): home goods and traded goods implicitly include locally-provided government goods. Based on evidence from Beeson and Eberts (1986) and Rappaport (2006), the cost share of land in traded goods (θ_L) appears to be low, no more than 5 percent, while capital (θ_K) takes about 15 percent of costs and the remaining 80 percent going to labor (θ_N). The cost share of land in home goods (ϕ_L) is higher at 20 percent (McDonald 1981, Roback 1982); the cost share of capital (ϕ_K) is taken at 15 percent, with the remaining 65 percent going to labor (ϕ_N). These cost shares are consistent with the income and expenditure shares; furthermore, results are generally not highly sensitive to altering the share estimates by a small amount.[21] The most sensitive cases are handled by showing results from alternative calibrations.

Direct estimates of the two necessary elasticities are available: the compensated own-price elasticity of demand for home-goods (taken as housing), η^c, and the elasticity of employment with respect to local taxes ε. Based on traditional (e.g. Rosen 1979, 1985) and slightly more recent studies of housing demand (e.g. Goodman and Kawai 1986), the value for η^c is taken at -0.67, although it could be slightly higher or lower.

The value for ε taken is -6 based on two methods, each yielding similar estimates. First, it is based on direct reduced-form estimates from Bartik's (1991) meta-analysis of the effect of how local taxes affect local levels of output and employment, controlling for local public spending. Second, it is inferable by directly calibrating (15), with share and elasticity-of-substitution parameters taken from the literature. The value of -6 is in the conservative range for either method.

The marginal federal income tax rate (τ') is taken as the sum of the average marginal tax rate from TAXSIM (Feenberg and Coutts 1993) and the marginal payroll tax rate, net of additional Social Security benefits (Boskin et al. 1987). In 2000 this gives a marginal rate of 0.346. The deduction level (δ) is determined by taking the average marginal tax reduction from home-mortgage interest deduction in TAXSIM, multiplying it by the fraction of taxpayers who itemize, weighted by Adjusted Gross Income from the Statistics on Income, and diving it by τ'. In 2000 this yields $\delta = 0.421$. State income and sales taxes are ignored, although some fraction should likely be included since these tax rates should affect mobility decisions within states. Ignoring these taxes makes the estimates here more conservative.

[21] The exceptions to this rule involve the two smallest shares: the income share of land, s_R, and the cost share of land in traded-good production, θ_L. The inverse of s_R, shows up in all of the price equations above, making the predictions sensitive to its value. The 10 percent value chosen for this share is on the high side of most estimates, making the predicted effects shown below conservative. The cost share of land in traded-goods production, θ_L, determines how responsive wages are to labor supply changes, and hence the sensitivity of wages (and the taxes that depend on them) to quality-of-life, home-goods productivity, and the tax burden itself. The 5 percent value for this share is slightly on the high side if "land" is taken literally, but reasonable if it captures other immobile factors.

6.2 Income Tax Differentials By Amenity Levels

As indicated by equation (20), tax burdens are higher in cities with higher wages, and with a deduction, lower prices. Since prices and wages depend fundamentally on amenities, it is possible to calculate how tax liabilities change cross-sectionally across cities with different levels of amenities. Table 1 presents how income tax differentials change as a percentage of income with a one-percent increase in each type of amenity, using (A.14) in the Appendix. Three parameters are varied in the table: the deduction level, δ, in the columns, the share of income devoted to land, θ_L, in the super-columns, and the compensated elasticity of home goods demand, η^c, in the rows.[22]

The numbers in this table illustrate how cities with higher trade-productivity are taxed quite heavily, while nicer cities receive a moderate tax rebate, and cities with higher home-productivity receive a smaller rebate. In the extreme case with where demand is completely inelastic $\eta^c = 0$, a full housing deduction eliminates tax differences across cities varying in either type of productivity, but increases the subsidy to nicer areas.[23] With a unit elasticity $\eta^c = -1$, the deduction has no effect except to diminish the tax advantage of cities with a higher quality-of-life, as there is only a quality-of-life income effect and no partial-indexation effect. If the cost share of land is low enough, the quality-of-life income effect can even outweigh the primary wage-tax effect, making tax liability increasing with quality-of-life.

6.3 Estimates of Wage, Price, and Spending Differentials

Wage and home-good price differentials are estimated using 5 percent samples of Census data from the 1980, 1990, and 2000 Integrated Public Use Microdata Series (IPUMS). Home-good price differentials are based off of housing-price differentials, as the latter are the most important determinant of cost-of-living differences (Shapiro 2006). Differentials are calculated at the Metropolitan Statistical Area (MSA) level using 1990 OMB definitions, extended using constant-geography definitions to 1980 by Deaton and Lubotsky (2003), and to 2000 by Greulich (2005). Consolidated MSAs are treated as a single city (e.g. San Francisco includes Oakland and San Jose), as well as all non-metropolitan areas of each state. This classification produces a total of 295 "cities" of which 47 are non-metropolitan areas of states. More details are given in Appendix C.

[22] A one-percent increase in A^X (A^Y) increases domestic product by $s_x + s_T$ (s_y) of one percent, since that is the share of income spent on x (y). A one percent increase in Q is equivalent to a full one-percent increase in income.

[23] The effects of full cost-of-living indexation is not shown as the effects are trivial: cities with high quality of life are subsidized at a high rate of $\tau' / (1 - \tau') = 0.53$.

Inter-urban wage differentials are calculated from the logarithm of hourly wages for full-time workers, ages 25 to 55. These differentials need to control for skill differences across workers in cities to provide a meaningful analogue to the representative worker in the model. To take this into account, log wages are regressed on city-indicators (μ_j^w) and on extensive controls (X_{ij}^w), fully interacted with gender, for education, experience, race, occupation, industry, and veteran, marital, and immigrant status, in an equation of the form $\log w_{ij} = X_{ij}^w \beta^w + \mu_j^w + \varepsilon_{ij}^w$. The estimates μ_j^w are used as the wage differential, it being interpreted as the causal effect of city amenities on a worker's wage. Identifying this differential correctly raises the same problems as finding a proper wage index. Most important in this context, workers with different unobserved skills must not sort into particular cities. This assumption is not likely to hold completely: Glaeser and Maré (2001) estimate that up to one third of the urban-rural wage gap may be due to selection, suggesting that perhaps only two thirds of wage differences are valid, although this issue deserves greater investigation. At the same time, it is possible that the estimates could be too small as some worker characteristics, such as occupation or industry, could depend on where the worker locates.[24]

Both housing values and gross rents reported in the Census are used to calculate home-good price differentials. To avoid measurement error from imperfect recall or rent control, the sample includes only units that were moved into in the last ten years. Price differentials are calculated in a manner similar to wage differentials, using a regression of rents and values on flexible controls (fully interacted for rental property) for type and age of building, size, rooms, acreage, commercial use, presence of kitchen and plumbing facilities, and number of residents per room. Proper identification of housing rent differences requires that average unobserved housing quality does not vary systematically across cities.[25]

Since federal spending differentials are also investigated, spending amounts across MSAs in 1990 and 2000 (1980 is unavailable) are calculated using data from the Consolidated Federal Funds Report (CFFR), available from the U.S. Census of Governments. These spending amounts are divided into three categories: (i) government wages and contracts, (ii) benefits to non-workers, and (iii) other spending. The first category consists of federal government purchases of goods and labor services; if these purchases are made at cost,

[24]There are obvious problems to assuming that workers have similar endowments and tastes, pay the same marginal tax rate, and are equally sensitive to productivity differences. However, as shown in Appendix D.3, workers with different tastes and endowments can be aggregated without serious complication, so long as each is weighted by their share of income (which is effectively done, although it has little impact on the estimates). Furthermore, many workers receive little other than labor income. However, given the static nature of the model, a worker's choices should be modeled to account for a worker's permanent income, which includes a large non-labor component, especially if implicit rental earnings from one's own home are included.

[25]This issue may not be grave as Malpezzi et. al. (1998) determine that housing price indices derived from the Census in this way perform as well or better than most other indices. The overall simulation is not affected much if wage and price differentials are estimated using only home-owners or only renters.

they should not be considered transfers.[26] The second category includes spending, such as Social Security and Medicare, which benefits individuals who are fairly inactive in the labor market, including retirees and full-time students. The remaining category of other spending reflects spending which is more likely to be location-specific and benefit workers. It includes most government grants, such as for welfare, Medicaid, infrastructure, and housing subsidies. Spending differentials are adjusted to control for a limited set of population characteristics in a city, such as average age and percent immigrant or minority, to provide a spending differential more applicable to a representative worker.

Table 2 presents the average raw and adjusted wage, housing-price, and federal-spending differentials for selected MSAs, Census regions, and MSA sizes in 2000. Figure 3 graphs wage differentials against housing-price differentials with circular markers, increasing in size for larger cities, and with non-metro states marked with crosses. We see that most large cities tend to have above-average wages and prices; and, across cities of the same size, wages and prices tend to be higher in the Northeast and in the West. Overall, wages and housing prices exhibit a strong positive correlation, with a regression line, weighted by employment, having a positive slope close to one half.

6.4 Identifying Productivity and Quality-of-Life

As seen in equations (19) and (20), calculating the tax differentials across cities in the presence of a deduction, requires knowledge of $\hat{w}$, $\hat{p}$, and either $\hat{y}$ or $\hat{Q}$. Since $\hat{y}$ is not observed, $\hat{Q}$ is used as it can be inferred by a properly amended version of (8a) given in Appendix equation (A.13). Recall that, in equilibrium, a lower after-tax real income in a city indicates a higher quality-of-life

The productivity differentials, $\hat{A}_X$ and $\hat{A}_Y$, are not needed to calculate tax differentials, but they do shed light on the simulation and the cities in it. Unfortunately, without a separate measure of land rents, it is impossible to determine $\hat{A}_X$ separately from $\hat{A}_Y$. Data on land rents is not used, as there is no widespread or reliable data source across MSAs. Using the model, it is possible to infer the price of land from observed wages and prices by rearranging equation (8c)

$$\hat{r}^j = \frac{1}{\phi_L}\left(\hat{p}^j - \phi_N \hat{w}^j + \hat{A}_Y^j\right) \tag{23}$$

Using equation (8b) this inferred rent can be used to determine $\hat{A}_X^j$. Without a measure of $\hat{A}_Y^j$, I assume that

[26] See Weingast et al. (1981) for situations when such spending should be treated partly as transfers.

all cities have equal home-productivity, i.e.. $\hat{A}_Y^j = 0$ for all j, to infer the land rent and trade-productivity differentials.[27]

Estimates of quality-of-life and trade-productivity in 2000 are shown in Figure 4 and reported in Table 3. Their calculation can be better understood by comparing this figure with Figure 3; the latter marks an indifference curve passing through an average city with $\hat{w} = \hat{p} = 0$. The quality-of-life in a city depends on how far its marker is to the lower-right perpendicularly of this curve. Also shown is a "pseudo iso-cost" curve through an average city, which is based on the scenario where $\phi_L = 1$ so that $r = p$.[28] In this case, traded productivity in a city depends on how far its marker is to the upper-right perpendicularly to this curve.[29] In the more general case with $\phi_L < 1$, used in Figure 4 ($\phi_L = 0.20$), this exact transformation no longer works, although it produces fairly similar estimates.

Some interesting geographic patterns emerge in amenity differentials. According to the normalizations used – where a one-percent increase in Q is equivalent to a one-percent increase in income, and a one-percent increase in A is equivalent to a one-percent decrease in costs – productivity differences appear to be larger than quality-of-life differences. Also productivity and quality-of-life differentials have a mild positive correlation. The most productive cities are primarily in the Northeast (e.g. New York, Boston), the Midwest (e.g. Chicago, Detroit), and the West Coast (e.g. San Francisco). Many coastal cities have a higher quality-of-life (e.g. Miami, Honolulu, San Diego) while some cities have higher wages relative to rents, suggesting lower quality-of-life (e.g. Detroit, Pittsburgh).[30] Small cities and non-metropolitan states typically have lower productivity, but have quite variable quality-of-life.

[27]Cities with relatively high home-good productivity have these differentials underestimated: the bias for $\hat{r}^j$ is $-\hat{A}_Y^j/\phi_L$, which currently calibrated at $-5\hat{A}_X^j$ is potentially large; the bias for $\hat{A}_X^j$ is $-\theta_L \hat{A}_Y^j/\phi_L$, which currently calibrated at $-\hat{A}_X^j/4$ is considerably smaller. Of course, $\hat{A}_Y^j = 0$ is likely to be false: for instance, Glaeser et al. (2005) and Quigley and Raphael (2006) have argued that housing prices differ across cities because of housing restrictions. Although measures of regulatory variables are available for a number of cities (e.g. Malpezzi 1996), without land rent information it is still impossible to determine A^Y. Note, that to deal with inelastic production a second order version of (23) with $\sigma_Y = 0.67$ is used to estimate $\hat{r}_j$. To imagine graphically how land rents are calculated, imagine isorent lines on this graph, which are downward sloping, with slope $-1/\phi_N$. Rents increase towards the upper right.

[28]The slopes of an indifference curve, holding quality-of-life constant, and an isocost curve, holding productivity constant, are given by

$$\left(\frac{\hat{w}}{\hat{p}}\right)_{\hat{Q}=0} = \frac{s_y}{s_w}\frac{1-\delta\tau'\left(1-|\varepsilon^c_{y,p}|\right)}{1-\tau'}$$
$$\left(\frac{\hat{w}}{\hat{r}}\right)_{\hat{A}^X=0} = -\frac{\theta_L}{\theta_N}$$

[29]Although many papers have estimated productivity and quality-of-life in different cities using the Rosen-Roback framwork, typically with $\phi_L = 1$, none illustrate this transformation graphically.

[30]It may also be that these cities, having experienced recent economic declines, are out of equilibrium, and have an over-abundance of housing relative to their workforce.

6.5 The Effect of Federal Taxes Across Cities

Using the base calibration and estimates of $\hat{w}$, $\hat{p}$, and $\hat{Q}$ for 2000, Table 4 reports estimates of tax differentials and its effects across twenty notable cities among those with the smallest and largest tax burdens, as well as different regions and city-sizes. Tax differentials under the presumed actual regime with $\delta = 0.421$ are in column 1; tax differentials if δ were to set to zero are in column 2.[31] The two are graphed against each other in Figure 5, along with a kernel density estimate of tax differentials with the deduction. The amount of differential taxation is substantial: the mean absolute deviation of tax differentials equals 2.6 percent of income, implying that a worker moving from a low-wage city to a high-wage city can expect to pay 30 percent more in federal taxes. This represents a horizontal transfer of $300 billion (in 2005) from workers in high-wage areas to similarly-skilled workers in low-wage areas.[32] Federal tax burdens are highest in large productive cities in the Northeast, Midwest, and West Coast, while most small towns and non-metropolitan areas, particularly in the South, receive a large tax break. Without the deduction, the average tax differential would be 0.3 percent wider, making the geographic distribution of federal taxes even more unequal. Figure 5 shows how eliminating the deduction would almost monotonically increase the tax differential gradient by 12 percent.

These tax differences are considerable relative to typical differences in local taxes. A permanent two percent tax on incomes imposed by a local government without any compensating services would be considered a fiscal disaster: yet, the federal government is imposing this situation on cities such as Chicago, New York and San Francisco. On the other hand, a free transfer equal to two percent of income might be thought of as a minor fiscal miracle: in relative terms this is what workers in some cities such as Little Rock and San Antonio, as well as most non-metropolitan areas, effectively receive from the federal government.

Because the tax differentials are fairly large, the size of the tax effects on prices and employment are often considerable, as seen in Table 4. Taking New York as an example, federal taxes here raise wages by 3 percent, lower (long-run) housing prices by 8 percent, and land prices by 39 percent. The employment effect is especially striking, stating that employment is 25 percent lower because of unindexed federal taxes. This effect may seem too large, but it may be reasonable in the long run, such as since World War II, when

[31] Since the existing tax systems has a deduction, the tax differentials with no deduction are based on the counterfactual wage without a deduction; this wage can be determined from the model.

[32] The 30 percent figure is based on an average federal tax rate of 17 percent which takes into account federal income taxes and payroll taxes, appropriately adjusted (Congressional Budget Office 2003). This is calculated by multiplying the mean absolute deviation of tax differentials, 0.256, by GDP in 2005 of $12.4 trillion. Using AGI instead would result in a figure about two-thirds the size.

federal taxes first affected the average worker. The rise of the income tax is certainly consistent with the large migration of people and jobs over the last sixty years from the high-wage "rust-belt," to the low-wage "sun-belt" (Kim and Margo, 2004).

The nationwide effects for a number of different calibrations are given in Table 5. The economic and tax parameters of these calibrations are displayed in the first panel, followed by the mean absolute deviations in outcomes (which is more informative than standard deviations and symmetric around the median), and the deadweight loss of taxation over the economy. All effects are averaged using the total population sizes of each area as weights.

The benchmark case, shown in column 1, reveals the overall significance of differential federal taxation nationwide. On average, residents of a city pay 2.6 percent more or less in federal taxes because of amenity differences. Up or down, these taxes affect relative land rents by 26 percent and housing prices by 4.1 percent. The wage effects are only 4 percent, although the employment effects are quite large, changing levels by an average of 15 percent. This creates a substantial deadweight loss of about 0.28 percent of GDP a year, or $34 billion total in 2005. As these numbers are based on a calibrated model, they should not be taken too literally, but they do give a sense of the order of magnitude of the costs of locational inefficiency caused by federal taxes. It should also be borne in mind that parameters in the model are chosen to make these estimated effects relatively conservative.[33]

Alternative calibrations in Table 5 are shown in columns to the right. Column 2 devotes all land to home-good production, keeping the total share of income to land constant: in this case wage differentials are unaffected by taxes while home-good price differentials are more affected. In column 3, the cost shares of land in both sectors are reduced proportionally by one-half, with mobile capital taking up the remaining costs; the effect on land prices double, while no other quantities change.

Column 4 shows that if the elasticity of employment to taxes, ε is increased in to -9.6, the elasticity if preferences and production are Cobb-Douglas, then the implied employment effects and deadweight loss are increased proportionally. Column 5 shows that if the compensated own-rice demand elasticity for home goods, η^c, is half the size supposed at -0.33, then tax differentials are lower as the partial-indexation effect from the home-good deduction is stronger, resulting in smaller tax effects. Column 6 considers the possibility that the estimated wage differentials are too large, and cuts them to two-thirds their original size:

[33]Employment and deadweight loss predictions are not highly dependent on the model. In the case with $\delta = 0$ all that is necessary to calculate differential taxes, employment effects, and deadweight loss are $\hat{w}$, s_w, τ', and $\varepsilon_{N,T/m}$ and the most basic of economic incidence models.

this lowers differential taxes and their effects by a third, and deadweight loss by five-ninths. Column 7 reveals if the deduction were ignored, measured tax differentials and their effects would be larger.

6.6 Federal Spending

Differences in the federal tax burden would not present much of a problem if the distribution of federal spending compensated workers for the unequal burden of federal taxes. To explore this question, Table 6 reports coefficients from regressions of spending differentials, both raw and adjusted, on tax differentials in 1990 and 2000. In the raw differentials there is a positive correlation with federal purchases (wages & contracts), a negative correlation with non-worker benefits, and no correlation with other spending, the category closest to a locational transfer. Once population characteristics are controlled for correlations for all categories are generally negative and insignificant. These results confirm that the distribution federal spending does not work to offset the distribution of federal taxation. Although the federal government tends to make greater purchases (with wages and contracts) in areas with higher taxes, and thus higher wages, this is because the government is purchasing more skilled labor.

The effect of differential federal spending is added to the simulation in column 8 of Table 5 by treating other spending as a city-specific head-transfer, subtracting it from tax differentials, with numbers reported in column 3 of Table 4. Even though the correlation with taxation is weak, just by increasing the overall variance in net federal taxes, spending differentials exacerbate the existing distortions created by differential taxation: it increases the average tax differential from .26 to .28, resulting in larger price and employment effects, and a larger deadweight loss of over $40 billion.

6.7 Simulating Tax Reform

Although admittedly simple, this model may provide some insight on the social welfare benefits of eliminating tax deductions or of indexing taxes to local prices or wages. These results suggest that both wage and cost-of-living indexation would be welfare improving, and that cutting tax deductions for home-goods would improve welfare by improving consumption efficiency, although it would slightly reduce locational efficiency.

Six different reforms are examined in Table 7: under these hypothetical reforms, it reports average tax differentials, price and employment effects, and the deadweight losses due to the locational inefficiency of employment from (16), and consumption inefficiency from the overconsumption of home goods from

(22).[34] All reforms are based on the benchmark calibration. Column 1 shows what is taken as the existing situation, modeled in Column 1 of Table 5. Welfare losses due to locational inefficiency and to home-good overconsumption are of similar size, in the range of 0.2 to 0.3 percent of GDP per year. Column 2 examines the consequences of eliminating the deduction for home goods entirely: although this would raise taxes in high-wage cities and increase the amount of locational inefficiency by $4 billion, eliminating the loss from over-consuming home goods improves overall welfare much more. Column 3 shows how raising the deduction produces an opposite effect.

Column 4 presents the case where the deduction is eliminated but taxes are indexed to local costs, a case similar in spirit but more extreme than the reform proposed by the President's Advisory Panel. This situation proves to be better than the situation without indexing, shown in column 2, as it improves the locational efficiency of employment. Column 5, presents the ideal case where the deduction is eliminated altogether and income taxes are indexed perfectly to wages, so that all welfare losses are eliminated.

If taxes are indexed to local wages but tax deductions are not eliminated, column 6 reveals that most locational inefficiencies would be eliminated except for those due only to the deduction for home goods.[35] In column 7 we see that indexing taxes to local costs, would reduce overall locational inefficiencies, despite the fact that it would favorably treat nicer areas, which already benefit from the current tax system.

Overall, the best reform would eliminate both consumption and locational inefficiencies. This would require eliminating the tax advantages for housing and local public goods, unless some other reason can be found for preserving them, while at the same time indexing taxes to wages or local costs (hopefully quality-of-life-adjusted). The President's Advisory Panel recommendation of implicitly including some kind of price indexation through deduction caps appears to be a move in this direction, as there is no adjustment for quality-of-life, and as many households do not itemize deductions and as renters do not benefit from these deductions.

[34] Technically, this formula does not apply to this setting as it is based on a partial equilibrium analysis with a perfectly elastic supply of housing. The setting here is in general equilibrium with an imperfectly elastic supply of housing, as land is fixed in supply. Incorporating these supply conditions, using the standard Harberger (1962) approach, reduces the effective elasticity, and the deadweight-loss, by approximately 10 percent; in a partial equilibrium setting this corresponds to a supply elasticity of 6, a plausible value.

[35] If there were no true wage differences across cities to produce the wage-tax effect, this number could be added to the deadweight loss from the favorable tax-treatment of home goods.

7 Extensions

Since the model presented made some rather drastic simplifications for analytical tractability, it is worth considering how its predictions are altered by relaxing or changing some of its assumptions. One obviously incorrect assumption is that people own a diversified portfolio of land and capital, as people typically own land and housing where they live; this assumption keeps utility constant across workers even as taxes affect relative property values across cities. Without this assumption, increases in the federal income tax rate should differentially benefit land-owners in low-wage cities while hurting those in high-wage cities.

The model also assumes that land-owners supply a fixed amount of land, and workers supply a fixed amount of labor. Relaxing these assumptions has no effect on the set of equations (8a), (8b), and (8c), determining price differentials across cities – a kind result of duality theory. These assumptions do affect results concerning how quantities change in the model. For example, elastic labor supply increases the responsiveness of employment to taxes given in equation (15), a result seen in equation (D.1) in the Appendix. However, the calibration above relies on a direct estimate of ε which should already take into account any kind of deviations from the standard model.

Equation 3 implies that the supply of home goods adjusts so that unit costs equal prices. As home goods consist mainly of durable housing, this adjustment could take considerable time. In the short-run, the amount of housing is relatively fixed. One way of modeling this is to artificially augment the definition of "land" to include the housing stock, letting $\phi_L = 1$. In this short-run model, housing directly bears the burden from tax changes, making housing-price changes larger, and employment changes smaller.

Another assumption which can be challenged is that workers are fully mobile. Appendix D.2 considers the case when otherwise identical workers have different tastes for living in a particular city. When taxes are raised on workers in that city, "marginal" workers, with weaker tastes leave, while "inframarginal" workers, with stronger tastes, stay. In equilibrium, taxes are only partly capitalized into land rents, and wages and home-good prices adjust less than in the full-mobility case. This way, in high-wage cities, higher federal taxes fall partly on land and partly on the workers who stay, as their real after-tax incomes fall, making them strictly worse off than the typical worker located elsewhere. Similarly, workers who prefer low-wage cities see their after-tax incomes rise, and are made better off.

Workers can differ substantially in tastes, endowments, and skills. A model with two mobile worker types can be used to analyze these issues; formal details of such a model are presented in Appendix D.3.

On the whole aggregating multiple worker types does not present major obstacles in determining price effects, although it does seriously complicate results involving quantities. Nevertheless some interesting qualitative conclusions can be drawn. First, workers who are more sensitive to quality-of-life differences will sort disproportionately into (what they consider) nicer cities: by sorting disproportionately into these areas and taking low wages, these types pay relatively few taxes. Workers who receive a larger share of their income from non-labor sources also tend to pay fewer taxes as they are more prone to live in low-wage cities that are nice or home-productive, rather than in trade-productive cities. It is more difficult to assess the relative tax burdens of workers with a strong tastes for home goods as these workers tend to avoid both nice and trade-productive cities in favor of home-productive cities; their relative burden depends on the distribution of amenities. Overall, heterogeneity implies that workers will be taxed differently depending on their tastes or endowments. Efficiency or equity considerations could justify this if living in nicer or less trade-productive areas is complementary to work, or is associated with having low earnings capacity (e.g. Atkinson and Stiglitz, 1976; Saez 2003). Neither of these complementarities appear obvious. Nor is it clear that individuals who receive a larger share of income from non-labor sources should be taxed less.

Workers with different skills may also face different marginal tax rates because of what they earn, and therefore face different incentives over where to live. Although federal income taxes rise with income, unskilled workers with families may face higher marginal tax rates than skilled workers because of the earned income tax credit and means-tested welfare programs, such as Medicaid: together these can produce effective marginal tax rates as high as 90 percent (Blundell and MaCurdy, 1999). As a result unskilled workers may have a greater incentive to leave high-wage areas than skilled workers, especially as they are less likely to itemize deductions. In this way federal taxes may affect the geographic mix as well as distribution of labor, causing there to be relatively too few unskilled workers in high-wage areas. Through worker complementarities, this could cause wages of skilled workers in these areas to fall, and wages of unskilled workers to rise, making up for the many federal benefits they forego by not living in a low-wage area.

Workers with different skills may also differ in their mobility. As seen in Appendix D.4, immobile workers in cities where mobile workers earn high wages are likely to be made worse off because of unindexed federal taxes, although this is not completely certain. If taxes cause mobile workers to leave, immobile workers' wages should fall, but so should home-good prices. If mobile and immobile workers are sufficiently substitutable in production, prices could fall enough, relative to wages, for the real incomes of

immobile workers to rise. However, if mobile and immobile workers are sufficiently substitutable, immobile workers' wages will be close to mobile workers' wages. Thus, immobile workers will pay higher taxes where mobile workers do, meaning that they too pay above-average taxes, and because they are unable to leave to escape the tax, are likely to be worse off.

Another simplification made is that all traded goods are homogenous, when in fact cities may specialize in different types of export production. If exported goods are not perfect substitutes in consumption, cities may not be price-takers in their own exported good, and differential taxes may raise the relative price of goods produced in high-wage cities. In this way, higher differential taxes may be passed on to consumers across the country.[36] For example, if firms in New York exclusively provide financial services to the rest of the country, they may be able to raise the price of these services to pass on the costs of having to pay their workers higher wages because of taxes. By changing relative prices, federal taxes may induce consumers to overconsume goods produced in low-wage, under-taxed areas.

Finally, it may be imprudent to assume that amenity levels can be taken exogenously. While many amenities may be relatively unaffected by tax-induced changes, because of agglomeration economies, productivity in goods, especially traded goods, may be affected by the scale of production in a city. This case is explored briefly in Appendix D.5. As federal taxes induce workers to leave high wage cities in fairly large numbers, this exodus could have a substantially negative effect on productivity. If agglomeration effects are sufficiently strong, then federal taxes may cause wages in high wage cities to fall, rather than rise as predicted in equation (9). Predicted changes in land rents and housing prices due to taxes do not change in sign; in fact, they are magnified through productivity changes.[37]

8 A Preliminary Empirical Assessment

The model makes a number of potentially testable predictions of how wage and price differentials across cities should change as federal income tax rates change. Ignoring for now tax deductions, which have only a small impact, an increase in τ' should lower relative housing prices, and possibly raise wages, in high-wage cities, while doing the opposite in low-wage cities. Tax rate cuts over the 1980s, followed by tax rate hikes in the 1990s provide the potential for testing this hypothesis, as well as the validity of the calibration.

[36] A related analysis with local taxes is found in Wildasin (1986, pp. 103-105).

[37] Also, as agglomeration economies come from externalities, cities in the absence of taxes may not be of optimal size: depending on the type of externality and how the market operates, federal taxes may help or prevent cities from attaining their optimal size.

Furthermore, precise estimates would allow the model to be calibrated directly off of econometric results, rather than through inferred econometric parameters.[38]

Figure 7 graphs wage and price differential changes across cities in the 1980s and 1990s relative to the initial wage differential at the beginning of each decade. Also in the figure is a line plotting how much these differentials are predicted to change, according to the calibration, because of federal tax rate changes, assuming that otherwise these differentials would not have changed. The figure for housing price differentials contains two predicted plots, one for "long-run" price changes, given by the main model, and a second, steeper prediction for "short-run" price changes, which treat the housing stock as fixed (i.e. with $\phi_L = 1$). The graphs make evident that price and wage differentials changed substantially over each decade, and in erratic ways which are not strongly correlated with the predictions. This suggests that there are important confounding, and potentially non-random, factors unrelated to taxes which are affecting these differentials. This makes it difficult to test the model since it is unknown what the counterfactual differentials would have been in the absence of tax-rate changes.

Table 8 presents corresponding regression coefficients, with no controls (except a constant), and with four region-indicator controls, along with tests of whether actual wage and price changes are consistent with predicted wage and price changes. Standard errors are clustered by region to deal with the possibility of common regional shocks. Housing prices in high-wage areas did rise in the 1980s and fall in the 1990s, although by more than the model predicts. Wage changes are close to zero but of the wrong sign, at least according to the baseline model. Prices and wages appear to be moving together, possibly a sign of productivity shocks across cities. Generally, because of the impreciseness of these estimates, the results do not provide conclusive evidence about whether or not the model is correct. The predicted changes and actual changes in wages and prices are not terribly close, but the data are quite noisy, so that tests have little power, and most of the predictions cannot be rejected. Even the case of wage changes between 1990 and 2000 falling rather than rising is not particularly damning as there is virtually no predicted change, as many other changing factors are influencing relative wages, and as division bias could be biasing the coefficient downwards.[39]

[38] Looked at differently, the results below can be interpreted as the first strong test of the Rosen-Roback model. Most other uses of this framework have been used to try to price the value of amenities, without having a prior about what these values should be, meaning that there were no restrictions to test. However, presumably a dollar in taxes should be worth a dollar to workers, and if the model is well-calibrated, then we should know exactly how much an extra dollar in taxes should affect local prices. Differences between empirical estimates and calibrated ones may then reflect a weakness of the model, rather than the calibration.

[39] Looking at changes in state and local income tax rates, Gyourko and Tracy (1991) find that prices fall and wages rise with higher tax rates, but their estimates are quite imprecise (especially once group effects are accounted for) and difficult to interpret as they use only limited controls for state and local services, and include a cost-of-living control variable, which is highly correlated

Unfortunately, changes in wage and price differentials are too noisy to provide a convincing test of the model or, better, a direct calibration. As the hypothesis tests typically reject zero effect as much or more than the predictions, there is reason to believe that important non-random factors are influencing the regression estimates. The large amount of unexplained variation in how differentials are changing over time suggests that additional empirical research may be needed on why these differentials change to provide a better test of the hypothesis considered here.

9 Conclusion

A strong case can be made that federal taxes are distributed unequally across equivalent workers in different cities: if nominal incomes do indeed depend on where a worker lives, then so must federal tax burdens. This unequal geographic tax burden appears to have serious consequences for local prices and employment levels. Politicians from cities offering higher nominal wages have a legitimate reason to complain that their constituents pay a disproportionate share of federal taxes, and to endorse a tax-indexation scheme to remedy this problem, especially as this would help workers locate more efficiently and raise national welfare. The welfare loss from locational inefficiency, at over $30 billion a year, is enough to justify action and funding for research and data-collection to help better understand and remedy this problem.

While tax deductions appear to help workers locate more efficiently, the effect is not strong enough to offset the consumption inefficiencies caused by these deductions; moreover, locational efficiency is better achieved by indexing taxes than by providing deductions. The President's Advisory Panel recommendation to set mortgage deduction caps according to local prices does have some economic justification, although it does suffer from some shortcomings: it gives no break to renters and non-itemizers in high-wage areas, and mortgage deduction caps are not adjusted for quality-of-life differences, so that tax-payers are still subsidized to live in nicer areas.

This work suggests a number of possible directions for further research. For example, skilled and unskilled workers are likely to face different effective marginal tax rates, which could lead to an inefficient skill-mix of workers across cities. While skilled workers tend to face high marginal tax rates, they also tend to benefit most from tax deductions. Workers eligible for a number of federal transfer programs, such as unskilled workers with families, may face the highest effective marginal tax rates, and be most-induced to

with housing prices.

leave high-wage cities. Unskilled workers ineligible for most federal benefits, such as young workers, or even illegal immigrants, may be more likely to take unskilled jobs in high-wage cities.

Dual-earner couples may also be especially sensitive to federal taxes, since these couples may experience the largest earnings gain from moving to large expensive cities, where both earners can find good employment matches. Federal taxes may be encouraging these so-called "power couples" to move to smaller communities, where only one earner may have a good employment match, and the other may find it advantageous to turn to untaxed household production. Although the focus here has been on workers, individuals with no labor income may also locate inefficiently because of tax deductions, which encourage them to live in nicer areas. The federal government may want to exclude non-workers from these tax deductions as well as any future tax indexation schemes. Finally, looking beyond taxes, the empirical analysis above suggests that changes in wage and price differentials across cities over time need to be better understood and deserve closer examination.

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A Additional Theoretical Details

A.1 System of Equations

The entire system consists of fourteen equations in fourteen unknowns, with four exogenous parameters: Q, A^X, A^Y, and T. The first three equations (1) (2) and (3) determine the prices of land, labor, and the home good, r, w and p. With these prices given, the budget constraint and the consumption tangency condition determine the consumption quantities x and y,

$$x + py = w + R + I - T - \tau(w) \tag{A.1}$$

$$(\partial U/\partial y) \,/\, (\partial U/\partial x) = p \tag{A.2}$$

R, I, and T are given. Changes in output (X, Y), employment (N_X, N_Y, N), capital (K_X, K_Y), and land use (L_X, L_Y) are determined by nine equations in the production sector: six statements of Shepard's Lemma

$$\partial c_X/\partial w = N_X/X,\ \partial c_X/\partial r = L_X/X,\ \partial c_X/\partial i = K_X/X \tag{A.3}$$

$$\partial N_Y/\partial w = N_Y/Y,\ \partial c_Y/\partial r = L_Y/Y,\ \partial c_Y/\partial i = K_Y/Y \tag{A.4}$$

and three equations for total population, the land constraint, and total home-good production per capita

$$N_X + N_Y = N \tag{A.5}$$

$$L_X + L_Y = L \tag{A.6}$$

$$Y = yN \tag{A.7}$$

A.2 City-Specific Head Taxes and Quantity Changes

Determining the effects of tax deductions and deadweight loss requires calculating home-good consumption and employment changes due to differential taxation. With inelastic land and labor supply, head taxes and differential income taxes of the same magnitude have the same effects on prices and quantity differentials, and so head taxes are modeled.

A.2.1 Consumption

The budget constraint (A.1) and tangency condition (A.2) can be log-linearized to yield

$$s_x d\hat{x} + s_y \left(d\hat{p} + d\hat{y}\right) = s_w d\hat{w} - \frac{dT}{m} \tag{A.8}$$

$$d\hat{x} - d\hat{y} = \sigma_D d\hat{p} \tag{A.9}$$

Subtracting (4a) from (A.8) and substituting in (A.9) and (7) yields

$$d\hat{y} = -s_x^* \sigma_D d\hat{p} = -s_x^* \sigma_D \frac{1}{s_R}\left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right)\frac{dT}{m} \tag{A.10}$$

where $s_x^* = s_x/\left(s_x + s_y\right) = s_x/(1 - s_T)$ is the expenditure share on x out of after-tax income. By lowering home-good prices, taxes induce workers to consume more home goods.

A.2.2 Production

Moving on to the production sector, differentiating and log-linearizing the Shepard's Lemma conditions (A.3) and (A.4) gives six equations of the following form

$$d\hat{N}_X = d\hat{X} + \theta_L \sigma_X^{LN}\left(d\hat{r} - d\hat{w}\right) + \theta_K \sigma_X^{NK}\left(d\hat{\imath} - d\hat{w}\right) \tag{A.11}$$

These expressions make use of partial (Allen-Uzawa) elasticities of substitution. Log-linearizing the constraints (A.5), (A.6), and (A.7)

$$\begin{aligned}(s_x + s_T)\theta_N d\hat{N}_X + s_y \phi_N d\hat{N}_Y &= s_w d\hat{N} \\ (s_x + s_T)\theta_L d\hat{L}_X + s_y \phi_L d\hat{L}_Y &= 0 \\ d\hat{N} + d\hat{y} &= d\hat{Y}\end{aligned}$$

Substituting in known values of $d\hat{r}, d\hat{w}, d\hat{\imath}(=0)$, and $d\hat{y}$, from (5), (6), (A.10) and rearranging gives a system of nine equations in nine unknowns, written below in matrix form

$$\begin{bmatrix} 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 \\ s_x'\theta_N & 0 & 0 & 0 & s_y\phi_N & 0 & 0 & 0 & -s_w \\ 0 & s_x'\theta_L & 0 & 0 & 0 & s_y\phi_L & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} d\hat{N}_X \\ d\hat{L}_X \\ d\hat{K}_X \\ d\hat{X} \\ d\hat{N}_Y \\ d\hat{L}_Y \\ d\hat{K}_Y \\ d\hat{Y} \\ d\hat{N} \end{bmatrix} = \begin{bmatrix} -\frac{\theta_L}{\theta_N}\left(\left(\theta_L + \theta_N\right)\sigma_X^{NL} + \theta_K \sigma_X^{NK}\right) \\ \left(\theta_L + \theta_N\right)\sigma_X^{NL} + \theta_K \sigma_X^{LK} \\ \theta_L(\sigma_X^{NK} - \sigma_X^{LK}) \\ -\phi_L\left(\frac{\theta_L + \theta_N}{\theta_N}\right)\sigma_Y^{NL} - \phi_K \frac{\theta_L}{\theta_N}\sigma_Y^{NK} \\ \phi_N\left(\frac{\theta_L + \theta_N}{\theta_N}\right)\sigma_Y^{NL} + \phi_K \sigma_Y^{LK} \\ \phi_N \frac{\theta_L}{\theta_N}\sigma_Y^{NK} - \phi_L \sigma_Y^{LK} \\ 0 \\ 0 \\ s_x^* \phi_N\left(\frac{\phi_L}{\phi_N} - \frac{\theta_L}{\theta_N}\right)\sigma_D \end{bmatrix} \frac{1}{s_R}\frac{dT}{m}$$

where $s_x' = s_x + s_T$ is the total share of expenditures spent on traded goods, including government spending. The system is solved by inverting the matrix, yielding long expressions. If partial elasticities within sectors are assumed equal, $\sigma_Y^{NL} = \sigma_Y^{LK} = \sigma_Y^{NK} = \sigma_Y$, as in constant elasticity of substitution (CES) production, the solution for $d\hat{N}$ simplifies to equation (15).

A.3 Deadweight Loss

The deadweight loss incurred can be measured by looking at how the government's revenue changes when it replaces a small uniform lump-sum tax across all cities, T, with an income tax at rate τ, holding the utility of workers constant. The constant utility assumption is maintained if workers in the average city see no change in their income, i.e. $\tau\bar{m} = -T$. The net revenue collected from city j is then $G^j = \left(\tau m^j + T\right) N^j = \tau\left(w^j - \bar{w}\right) N^j$ which is positive in cities with above average wages. Differentiating totally with respect to τ^j

$$dG^j = \left[\left(w^j - \bar{w}\right) N^j + \tau^j N^j \frac{dw^j}{d\tau} + \tau^j \left(w^j - \bar{w}\right) \frac{dN^j}{d\tau}\right] d\tau^j$$

Equations (9) and (14) give the derivatives $dw^j/d\tau = m^j \left(\theta_L/\theta_N\right)\left(s_w/s_R\right)\hat{w}^j$ and $dN^j/d\tau = \varepsilon N^j s_w \hat{w}^j$. Using these together with the first-order approximation $w^j - \bar{w} = \hat{w}^j w^j = \hat{w}^j s_w m^j$,

$$dG^j = N^j m^j \left[s_w \hat{w}^j + \tau^j \frac{\theta_L}{\theta_N}\frac{1}{s_R}\hat{w}^j + \tau^j \left(s_w \hat{w}^j\right)^2 \varepsilon\right] d\tau^j$$

Taking the approximation around the average share values, ε, and m^j, then since $E\left[\hat{w}^j\right] = 0$,

$$E\left[dG^j\right] = Nm \cdot E\left[\left(s_w \hat{w}^j\right)^2 \tau^j d\tau^j\right] \varepsilon$$

which is negative since $\varepsilon < 0$. Integrating over $d\tau^j$ and substituting in $\tau^j s_w \hat{w}^j = d\tau^j/m$ gives a triangle approximation of the deadweight loss as a percentage of national income, given in equation (16).

A.4 Housing Deduction

Incorporating the home goods deduction requires amending some of the results above. As the income tax is now $\tau = \tau\left(m - \delta p y\right)$, the mobility condition (8a) and the log-linearized budget constraint (A.8) change to

$$\begin{aligned} \hat{Q} &= \left(1 + \delta\tau'\right) s_y \hat{p} - \delta\tau' s_y \hat{y} - \left(1 - \tau'\right) s_w \hat{w} \\ s_x \hat{x} &= -\left(1 - \delta\tau'\right) s_y \hat{p} - \left(1 - \delta\tau'\right) s_y \hat{y} + \left(1 - \tau'\right) s_w \hat{w} \end{aligned} \tag{A.12}$$

Adding these expressions gives

$$\hat{Q} + s_x \hat{x} = -s_y \hat{y}$$

Substituting in $\hat{x} = \hat{y} + \sigma_D \hat{p}$, and using $\eta^c = -s_x^* \sigma_D$

$$\hat{y} = -(\hat{Q} + s_x \sigma_D \hat{p})/(s_x + s_y) = \eta^c \hat{p} - \frac{1}{1 - s_T}\hat{Q}$$

This expression is used in (20), although s_T is set to zero there for expositional ease. Substituting back into (A.12) and using $s_y^* \equiv s_y/(s_x + s_y)$

$$\left(1 - \delta\tau' s_y^*\right)\hat{Q} = \left[1 - \delta\tau'\left(1 + \eta^c\right)\right] s_y \hat{p} - \left(1 - \tau'\right) s_w \hat{w} \tag{A.13}$$

Combining this equation with the zero-profit conditions (8b) and (8c) makes it possible to solve completely for $d\tau/m$ in terms of all of the amenities

$$\frac{d\tau}{m} = \tau' \frac{\left[1-\delta(1+\eta^c)\right]\frac{s_y}{s_R}\left(\frac{s_w\phi_L}{\theta_N}\hat{A}^X - \frac{s_w\theta_L}{\theta_N}\hat{A}^Y\right) + \left\{s_y\delta\left[1-(1+\eta^c)\frac{1}{s_R}\left(\phi_L - \phi_N\frac{\theta_L}{\theta_N}\right)\right] - \frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\right\}\hat{Q}}{1-\tau'\left[\frac{s_w}{s_R}\frac{\theta_L}{\theta_N} + \delta(1+\eta^c)\frac{s_y}{s_R}\left(\phi_L - \phi_N\frac{\theta_L}{\theta_N}\right)\right]} \tag{A.14}$$

This expression is the same as equation (21) in the text, which substitutes in pre-tax differential values of $\hat{w}_0$ and $\hat{p}_0$ from equations (10) and (13b).

B Parameter Calibration

Calibrating the economic parameters in this model makes it possible to predict the impact of differential federal taxation on wages, prices, rents, worker populations, and deadweight loss. In this appendix, I explain my choices of tax parameters, elasticities, and cost, income, and consumption shares for the United States.

B.1 Cost, Income, and Consumption Shares

There are twelve cost, income, and consumption share parameters, but because of income identities, only six are independent. For example, choosing $s_w, s_I, \theta_L, \phi_L, s_y$, and s_T gives values of $\theta_N, \theta_K, \phi_L, \phi_K, s_x$, and s_R. Therefore, only estimates of any six shares are necessary, although information on other shares can help cross-validate these estimates. Unfortunately, information collected from different sources is not entirely consistent: some judgment is needed to find the most plausible calibration.

Looking first at income shares, Krueger (1999) makes a strong case that the share of income to labor, s_w, should be close to 0.75. Estimates from Poterba (1998) imply that the income share to capital, s_I, should be higher than 0.12, probably in the neighborhood of 0.15. This leaves approximately 10 percent left for the income derived from land. This is consistent with Keiper et al., (1961) who finds the share of income from land in 1956 was between 0.04 and 0.12, depending on the rate of return used.[40]

Turning next to expenditure shares, Shapiro (2006) argues that the share of home goods is 0.34 by regressing ACCRA Cost of Living composite index onto the index for housing alone, finding that the regression fits well and has a slope of 0.34. My own studies using 2005 ACCRA data show a higher slope at 0.39. However, this index excludes government provided goods. Looking at the most important home good, housing, the 2000 Census files suggest that only 23 percent of expenditures is spent on housing, while the Consumer Expenditure Survey (Bureau of Labor Statistics 2002), suggest this figure is 33 percent. Since home goods consist of more than just housing, taking $s_y = 1/3$ seems reasonable, although it may be slightly higher.

To determine the share of income spent by the "federal" government, I look at how much income is spent on public goods that workers cannot choose according to where they live. According to the Bureau of Economic Analysis, the U.S. Federal government spent 5.9 percent of GDP on defense and non-defense expenditures (this has since risen to 7.1 percent), suggesting a lower bound. Total government expenditures at all levels equals 14.5 percent of GDP, although this includes many locally-provided goods which are tied to local taxes, so this is likely an upper bound. Unfortunately the BEA does not give a break-down of what goods are tied to local taxes. It is also unclear how to treat interest payments, which were then 2.8 percent of GDP. Overall, it seems reasonable to take s_T at a middle value of 10 percent. The simulation is not particularly sensitive to choices of s_y or s_T if other parameters are held fixed.

Although the overall income shares of labor and capital in the economy are heavily studied, few have determined separate cost shares of labor, land, and capital separately in home and traded goods; one exception is Rappaport (2006), although the calibration here differs somewhat. Some earlier studies (McDonald 1981, Roback 1982) suggest that land's cost-share of housing, ϕ_L, is around 20 percent. More recent studies suggest this cost share has risen over time, especially in more expensive cities (Glaeser et al. 2005, Davis and Heathcoate 2005), making plausible shares as high as 30 percent. However, since home goods include more than just housing, a parameter choice of $\phi_L = 0.20$ seems reasonable.

[40] The values Keiper reports were at a historical low. The total land value was found to be about 1.1 times GDP. A rate of return of 9 percent would justify using $s_R = 0.10$. More recent estimates of land's income share are not available.

Work by Beeson and Eberts (1989), Ciccone (2002) and Rappaport (2006) suggests that the cost-share of land in traded goods, θ_L, is small, likely under 4 percent. However, these studies may take the meaning of "land" too literally for this model, which may encompass other immobile factors. A slightly larger value of $\theta_L = 0.05$ is used as the baseline in order to produce results consistent with land's income share of 10 percent, as reflected in the income identity $s_y\phi_L + (s_x + s_T)\theta_L = (1/3)(0.2) + (2/3)(0.05) = 0.10 = s_R$. Furthermore, a cost share for land of 5 percent implies that one third of land is used for traded goods production, a fraction which seems more consistent with existing evidence.[41]

This last free parameter needed is capital's share in traded or home goods, θ_K or ϕ_K. For lack of better information, these are both taken to be 15 percent; the parametrization is not highly sensitive to changes in these shares.[42]

B.2 Elasticities

Finding elasticities is more challenging than finding shares. It is complicated by the fact that differences in tastes or in production technology can lead to sorting behavior across cities, which make elasticities of substitution measured at the national scale larger than elasticities measured at the city or individual level. Fortunately, the two reduced-form elasticities needed for the simulation here have been estimated independently and at the city level.

The compensated elasticity of home-good demand with respect to its price, η^c, is needed to determine the extent of indexation conferred through a home goods tax deduction. Using the Slutsky equation $\eta^c = \eta + s_y^*\varepsilon_{y,m}$, where η is the uncompensated price elasticity and $\varepsilon_{y,m}$ is the income elasticity. Since there are no studies of this elasticity directly, the elasticities of housing consumption are used in its place. The most cited elasticity figures are given by Rosen (1979, 1985), with an uncompensated price elasticity of -1 and an income elasticity of 0.75, implying $\eta^c = -1 + (10/27)(3/4) = -0.72$. Using data on a single city and applying a concept of permanent income, Goodman and Kawai (1986) find it hard to reject a value of $\varepsilon_{y,m} = 1$ (validating the homotheticity assumption) and find a slightly lower value of $\eta = -.95$, implying $\eta^c = -0.58$. Goodman (1988) and Ionnides and Zabel (2003) find even lower values, suggesting that the estimates given by Rosen may be slightly high. For the calibration, a value of $\eta^c = -0.67$ is adopted as the baseline, implying a mild partial indexation effect. Note, η^c provides the elasticity of substitution value of $\sigma_D = -\eta^c/s_x^*$, which under the current calibration is $\sigma_D = 0.9$, close to the Cobb-Douglas case with $\sigma_D = 1$.

The elasticity of employment with respect to taxes as a percentage of income, ε, is essential in determining the employment effects and deadweight loss from uneven federal taxation. One way is to find direct estimates, while the other is to infer $\varepsilon_{NT/m}$ theoretically through equation (15), although this latter option requires knowing all share and substitution parameters, and that the model is literally true. For example, allowing for elastic labor and land supply, does not change the predicted price effects, but it does increase elasticity for ε; ignoring these effects will produce a conservative estimate. Substituting in the share parameters already calibrated into this equation yields

$$\varepsilon = -3.54\sigma_X - 5.90\sigma_Y - 0.53\sigma_D \tag{A.15}$$

revealing that ε is particularly sensitive to the choice of σ_Y. If preferences and production are assumed to be Cobb-Douglas, so that $\sigma_X = \sigma_Y = \sigma_D = 1$ then ε would be -9.97. This case seems unlikely: a value

[41] Keiper et al. (1961) find that about 52.5 of land value is in residential uses, a 22.9 percent in industry, 20.9 percent in agriculture.

[42] Studies of housing rarely distinguish labor and capital costs, however, studies of the construction industry (Cassimatis, 1969) find the costs share of labor, materials, capital depreciation, and overhead, to be approximately 30, 45, 2, and 23 percent. These figures ignore a number of other labor-intensive inputs to housing, including sales and maintenance. The amount of capital embodied in a house is tricky to define in this static model. Materials and traded goods appear to be largely indistinguishable as both have prices set by trade. In practice this difference proves to be largely semantic rather than substantial.

of $\sigma_D = 0.9$ has already been determined, and the elasticities of substitution in production σ_X and σ_Y may be significantly less than one.

Conventional measures of the elasticity of substitution between labor and capital in the national economy, which might correspond most closely to σ_X, tend not to reject a value of one (e.g. Berndt, 1976). However, Antras (2004) as well as other studies, going as far back as Lucas (1969), have found that these estimates may be biased upwards, and that the elasticity is closer to 0.7. One result from trade theory is that because of specialization in production, a city-level elasticity is likely to be lower than the macro elasticity, making a lower estimate seem more reasonable. Given this consideration, $\sigma_X = 0.67$ seems reasonable.

Estimates of the elasticity of substitution between land and non-land factors in the housing production, which may correspond most closely to σ_Y, range from one to as low as 0.3. (McDonald 1981, Epple et al. 2006), with a midrange value of $\sigma_Y = 0.67$ appearing plausible. However, as there is considerable uncertainty over this parameter, additional information is very useful.

Because the model may not be literally true, and because it is sensitive to σ_Y, looking for direct estimates of ε seems preferable to inferring through equation (15). In a meta-analysis, Bartik (1991) looks at 48 inter-area studies and finds that the average elasticity of output to local taxes as a percent of taxes (not total income) is -0.25. Studies more fitting to the model exhibit somewhat larger elasticities: 30 studies with public service controls have an average elasticity of -0.33; the 12 studies with fixed-effect controls have an average elasticity of -0.44. Taking the -0.33 elasticity and multiplying it times 20, the ratio of total costs to local taxes' cost share (about 5 percent), gives an elasticity of output to local taxes as a percent of total costs (or income) of $\varepsilon_{Out,T/m} = -6.67$. Assuming that output is taken as a mix of traded-good and home-good production, weighted by their expenditure shares, it is possible to solve for the elasticity of total output with respect to taxes; using the share parameters already calibrated, this is given by

$$\varepsilon_{Out,T/m} = \left[\left(s_x + s_T \right) \hat{X} + s_y \hat{Y} \right] / \left(dT/m \right) = -3.25\sigma_X - 5.52\sigma_Y - 0.84\sigma_D \tag{A.16}$$

Combining (A.16) with (A.15) it is possible to eliminate σ_Y

$$\varepsilon = 1.07\varepsilon_{Out,T/m} - 0.07\sigma_X + 0.37\sigma_D$$

Note that this formula is not especially sensitive to the values of σ_X and σ_D: it depends primarily on the value of $\varepsilon_{Out,T/m}$. Substituting in $\varepsilon_{Out,T/m} = -6.67$, $\sigma_X = 0.67$, and $\sigma_D = 0.9$, yields a value of $\varepsilon = -6.83$. This is consistent with a value of $\sigma_Y = -0.68$, close to σ_X, and in the mid-range of acceptable values. A value of $\varepsilon_{NT/m} = -6$ is taken in the main calibration for the sake of being conservative, although it could be larger.[43]

B.3 Tax Structure

The marginal tax rate on wage income is determined by adding together federal marginal income tax rate and the effective marginal payroll tax rate. Marginal income tax rates are taken from TAXSIM, which gives the average marginal federal income tax rate in 2000 of 25.1 percent. In 2000, Social Security (OASDI) and Medicare (HI) tax rates were 12.4 and 2.9 percent on employer and employee combined. Estimates from Boskin et al. (1987, Table 4) show that the marginal benefit from future returns from OASDI taxes is fairly low, generally no more than 50 percent. HI taxes emulate a pure tax (Congressional Budget Office

[43] The elasticity would be slightly larger (-6.92) if the conversion were based on partial equilibrium formulas, as in Bartik (1991).

Note that Bartik's meta-analysis has undergone significant scrutiny, although it has been largely upheld for tax-effects when public services are held constant (Phillips and Goss 1995).

A well cited figure by Blanchard and Katz (1992) is that the elasticity of employment with respect to wages is -2.5. Dividing this by $s_w = 0.75$, gives a smaller number of $\varepsilon_{NT/m} = -3.25$. However, their estimate allows for all kinds of employment shocks, not just those with taxes, making the relevance of their estimate to this application questionable.

2005). These facts suggest including half of the Social Security tax and all of the Medicare tax to the federal income tax rate, adding 9.5 percent to the income tax rate in 200, to produce 34.6 percent. Marginal tax rates for 1980 and 1990 calculated in the same fashion are 36.2 and 31.5 percent.

Determining the deduction level requires taking into account the fact that many households do not itemize deductions. According to the Statistics on Income, although only 33 percent of tax returns itemize, they account for 67 percent of reported Adjusted Gross Income (AGI). Since the income-weighted share is what matters, 67 percent is multiplied by the effective tax reduction given in TAXSIM, in 2000 given by 21.6 percent, and divided by $\tau' = 0.346$ to produce a deduction level $\delta = 0.421$. Deduction levels in 1980 and 1990 are 0.523 and 0.456.

In summary, the following values are taken for the calibration

$$\begin{array}{lllllll} s_x = 0.57 & \theta_L = 0.05 & \phi_L = 0.20 & s_R = 0.10 & \eta^c = -0.67 & \tau' = 0.345 \\ s_y = 0.33 & \theta_N = 0.80 & \phi_N = 0.65 & s_w = 0.75 & \varepsilon = -6 & \delta = 0.421 \\ s_T = 0.10 & \theta_K = 0.15 & \phi_K = 0.15 & s_I = 0.15 & & \end{array}$$

C Data and Estimation

United States Census data from the 1980, 1990, and 2000 Integrated Public-Use Microdata Series (IPUMS), from Ruggles et. al. (2004), are used to calculate wage and housing price differentials. The wage differentials are taken for the logarithm of hourly wages for employed workers ages 25 to 55, who report working at least 30 hours a week, 26 weeks a year. The MSA assigned to a worker is determined by their place of residence, rather than their place of work, as the latter is not as sharply indicated in the data files. The wage differential of an MSA by taking the coefficient on an indicator function for residence in that MSA from a regression of log hourly wages on a set of covariates at the individual level. The covariates for the raw differential consist only of a constant; for the adjusted differential, used in the simulation, the covariates consist of

- 9 indicators of educational attainment;
- a quartic in potential experience, and potential experience interacted with years of education;
- 9 indicators of industry at the one-digit level (1950 classification);
- 9 indicators of employment at the one-digit level (1950 classification);
- 4 indicators of marital status (married, divorced, widowed, separated);
- an indicator for veteran status, and veteran status interacted with age;
- 5 indicators of minority status (Black, Hispanic, Asian, Native American, and other);
- an indicator of immigrant status, years since immigration, and immigrant status interacted with black, Hispanic, Asian, and other;
- 2 indicators for not speaking English well and for not speaking English at all.

Regressions are run separately for men and women and use census person weights. From that a predicted wage is calculated independent of MSA to form a new weight equal to the predicted wage times the person weight. These weights are needed since (see Appendix D.3 below) since workers need to be weighted by their share of income, and are used to rerun the same regression, from which the actual wage differentials are calculated. Since the regressions are run separately for men and women, wage differentials for both

sexes are averaged together, using as weights the sum of each sex's adjusted individual weights in each city. In practice, this weighting procedure has only a minute effect on the estimated wage differentials.

Housing price differentials are calculated using the logarithm reported gross rents and housing values. Only housing units moved into within the last 10 years are included in the sample to ensure that the price data are fairly accurate. The differential housing price of an MSA is calculated in a manner similar to wages, except using a regression of the housing value or rent on a set of covariates at the unit level. The covariates for the adjusted differential are

- 9 indicators of building size;
- 9 indicators for the number of rooms, 5 indicators for the number of bedrooms, number of rooms interacted with number of bedrooms, and the number of household members per room;
- 2 indicators for lot size;
- 7 indicators for when the building was built;
- 2 indicators for complete plumbing and kitchen facilities;
- an indicator for commercial use;
- an indicator for condominium status (owned units only).

The first round of regressions use the census housing weights, while the second round uses as weights the census housing weight times the MSA-indpendent predicted housing price from the regression on owned units. Actual home-good price differentials are calculated by averaging house-value and rent differentials, using as weights the sum of each type's adjusted weights. Weighting has only a minute impact on these differentials, but is used since it is methodologically more correct.

Federal spending differentials are calculated using the Consolidated Federal Funds Report (CFFR) which reports spending for different programs by county. Counties can be matched to MSAs without difficulty, except for New England where New England County Metropolitan Areas (NECMAs) are used in place of MSAs to calculate the spending differential. Spending in MSAs including capitals may be biased upwards as spending targeted to a state may be labeled as applying to the capital. To reduce volatility in the data, spending is averaged over two years, the stated year, and the previous year (e.g. 1999 and 2000).

Total federal spending in 2000 is worth $5,740 per capita or 16.5 percent of GDP. Federal spending is divided into three categories: (i) wages and contracts, (ii) transfers to non-workers, and (iii) other spending. Wages and contracts are worth about $1,450 per capita, or 4 percent of GDP, and includes

- federal wages and salaries, both military and civilian;
- procurement contracts, defense and non-defense.

Transfers to non-workers are worth about $2,850 per capita, or 8.3 percent of GDP, and includes

- Social Security payments;
- Medicare payments;
- 25 percent of Medicaid and CHIP;
- government pensions;
- veterans' benefits;

- benefits to college students (mainly loans).

Other spending is worth about $1,500 per capita, or 4 percent of GDP, and includes

- 75 percent of Medicaid and CHIP;
- housing programs, including Section 8;
- most welfare programs, including TANF and Food Stamps;
- most other government grants, such as for transportation.

The raw spending differentials are calculated by taking the residual of the logarithm of per capita federal spending from a regression on a constant, weighted by population per city. The adjusted spending differentials are calculated in the same way, except that the regression includes the following variables

- average years of schooling and the proportion in four educational attainment categories (dropout, high school degree, associates degree, bachelors degree or more);
- average age, average potential experience, percent under 18, and percent 65 or older;
- percent married;
- percent veteran;
- the percentage in each of the 5 minority groups;
- the proportion in each of the immigrant variables described above.

Since data are not available at the available at the individual level, these covariates are more parsimonious than those used at the individual or housing-unit level to avoid "over-fitting" the data. Regressions are weighted by population per city. Spending differentials are multiplied by their share of GDP so that, like tax differentials, they are measured as a fraction of total income.

D Theoretical Extensions

D.1 Elastic Factor Supplies

As mentioned in the text, adding variable factor supplies does not change the basic price results although it does affect the movement of factors, namely labor. Denoting the elasticity of land supply to an increase in rents as $\varepsilon_{L,r}$ and the elasticity of labor supply to an increase in (real) wages as $\varepsilon_{h,w}$ then the elasticity of local employment to taxes is given by

$$\varepsilon^{variable} = \varepsilon - \frac{1}{s_R}\varepsilon_{L,r} - s_w \frac{\left(s_x + s_T\right)\theta_L + s_y\left(\theta_N\phi_L - \theta_L\phi_N\right)}{\left(s_R\right)^2\left(s_x + s_T\right)\theta_N}\left[\frac{\theta_L}{\theta_N} + s_y\left(\phi_L - \phi_N\frac{\theta_L}{\theta_N}\right)\right]\varepsilon_{h,w}$$

where ε is the elasticity from the previous formula (15). Higher taxes lower land supplies, decreasing the available supply of land to produce with and live on, lowering the number of workers. Higher taxes also increase pre-tax real wages by increasing the nominal wage and lowering the price of home-goods. Workers respond by increasing their labor supply, so that firms have to hire a smaller number of workers to achieve the same labor input, lowering the amount of needed workers. Also workers consume more in home-goods per capita, so that with a fixed or diminishing supply of land, worker density must decrease.

D.2 Imperfect Mobility

Imperfect mobility can be modeled by assuming that individuals have different tastes for living in different cities. For a given city, say Chicago, let the taste for living in Chicago be given by ξ_i, so that the expenditure function for a potential resident i is given by

$$e(p, u, Q, \xi_i) = e(p, u)/(Q\xi_i)$$

where ξ_i represents a taste parameter for living in Chicago. For the marginal entrant

$$e(p, \bar{u})/(Q\xi_k) = m - T \tag{A.17}$$

where k indexes the marginal individual, and $\bar{u}$ is the reservation utility, which is equal across workers. Fully differentiating (A.17),

$$s_w\hat{w} - s_y\hat{p} = \frac{dT}{m} - \hat{\xi}_k$$

Assume that ξ_i is distributed Pareto with parameter $1/\psi$

$$F\left(\xi_{i'}\right) = 1 - \left(\frac{\underline{\xi}}{\xi_i}\right)^{1/\psi}, \ \xi_i \geq \underline{\xi}$$

A larger value of ψ implies a thicker tail to the distribution; the larger ψ, the more tastes for living in Chicago vary across the population. Each city could in principle have a different ψ value. For some given constant, μ, the population in Chicago is $N = \mu \Pr(\xi_i \geq \xi_k) = \mu[1 - F\left(\xi_k\right)] = \mu\left(\underline{\xi}/\xi_k\right)^{1/\psi}$, thus

$$\log N = \log \mu + \frac{1}{\psi}[\log \underline{\xi} - \log \xi_k]$$

Fully differentiating, $\hat{N} = -\hat{\xi}_k/\psi$, so that the worker-mobility condition in (A.17) can be rewritten as

$$s_w\hat{w} - s_y\hat{p} = \frac{dT}{m} + \psi\hat{N} \tag{A.18}$$

From this equations, ψ represents the elasticity of a workers' marginal willingness to pay to live in the given city, as a fraction of total income. In other words, if the population of the city is artificially lowered by one percent, the marginal willingness to pay rises by ψ percent, indicative of a downward sloping demand curve to live in Chicago. Equation (A.18) also produces an upward sloping supply cuve of workers to Chicago.

Using this condition to replace (4a) and solving as before, the elasticity of workers with respect to taxes is now a function of ψ, with

$$\varepsilon(\psi) = \frac{\varepsilon(0)}{1 + \psi\left[\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right) - \varepsilon(0)\right]} \tag{A.19}$$

where $\varepsilon(0)$ is the elasticity given in (15), which assumed homogenous tastes, i.e. $\psi = 0$. This formula relates how a higher ψ is associated with lower mobility. The case of imperfect mobility arises as $\psi \to \infty$ with $\varepsilon(\infty) = 0$. The effects of taxes on prices also depends on the product of ψ and the elasticity $\varepsilon(\psi)$

$$d\hat{r} = -\frac{1+\psi\varepsilon(\psi)}{s_R}\frac{dT}{m}$$
$$d\hat{w} = \frac{1+\psi\varepsilon(\psi)}{s_R}\frac{\theta_L}{\theta_N}\frac{dT}{m}$$
$$d\hat{p} = -\frac{1+\psi\varepsilon(\psi)}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right)\frac{dT}{m}$$

It is straightforward to show that the product $\psi\varepsilon(\psi)$ must fall between -1 and 0, and is decreasing in ψ, so that the impact of taxes on local prices is reduced by greater immobility. However, even with complete immobility the price effects are non-zero and have the same sign as the case with perfect mobility as the limit

$$\lim_{\psi\to\infty}\psi\varepsilon(\psi) = \frac{\varepsilon(0)}{\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right) - \varepsilon(0)}$$

is strictly greater than -1. Because $\varepsilon(0) < \varepsilon(\psi)$, equation (A.19) implies an upper bound for ψ of $\left[\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right) - \varepsilon(\psi)\right]^{-1}$, which according to the main calibration is $[17/32+6]^{-1} = 32/209 \cong 0.15$. The product $\psi\varepsilon(\psi)$ is then bounded above by $(32/209)\times 6 = 192/209 \cong 0.92$, so that price effects are bounded below by 8 percent of the values posited in equations (5) to (7). Unfortunately, without a concrete value of ψ it is hard to say whether the true effects on prices lie closer to 8 percent or 100 percent of these values. Given the persistence of federal tax differentials, it may be reasonable to assume that mobility is fairly perfect in the long run, so that the effects are closer to 100 percent.

With less than full capitalization into prices, a local tax on workers falls not just on land, but on workers who do not move. The welfare change of these non-moving inframarginal workers, expressed as a compensating variation divided by total income, is given by their change in real income

$$\begin{aligned}\frac{1}{m}d\left[w - e(p,u)\right] &= s_w d\hat{w} - s_y d\hat{p} - \frac{dT}{m}\\ &= \psi\varepsilon\left(\psi\right)\frac{dT}{m}\\ &= \frac{\psi\varepsilon(0)}{1+\psi\left[\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right) - \varepsilon(0)\right]}\frac{dT}{m}\end{aligned}$$

The relative burden of the tax borne by labor relative to land is given by

$$\frac{\frac{1}{m}d\left[w - e(p,u)\right]}{s_R d\hat{r}} = \frac{\psi\varepsilon(0)}{1+\psi\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right)}$$

which lies between 0 and $\varepsilon(0)/\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right)$.

D.3 Multiple Worker Types

Assume there are two types of fully mobile workers, referred to using "a" and "b" as superscripts, and that each type is employed in every city. For simplicity and brevity assume that $\phi_L = 1$ so that $p = r/A_Y$. The

three equations defining the system are

$$e^a(r/A_Y, \bar{u}^a)/Q^a = w^a + R^a - \tau^a \tag{A.20a}$$
$$e^b(r/A_Y, \bar{u}^b)/Q^b = w^b + R^b - \tau^b \tag{A.20b}$$
$$c_X(w^a, w^b, r) = A_X \tag{A.20c}$$

This is very similar to the model in Roback (1988), although she assumes that $s_w^a = s_w^b = 1$, that $A^Y = 1$ everywhere, and does not include taxes. Let the share of total income accruing to type a worker be $\mu^a = N^a m^a / \left(N^a m^a + N^b m^b\right)$, with the other share $\mu^b = 1 - \mu^a$. Log-linearizing and solving the system reveals the wage differential for a type a worker

$$\hat{w}^a = \frac{1}{s_R s_w^a}\left\{s_y^a s_x \hat{A}_X + s_x \theta_L \left(\frac{d\tau^a}{m^a} - \hat{Q}^a - s_y^a \hat{A}_Y\right)\right\} + \frac{\mu^b}{s_R s_w^a}\left\{\left[s_y^b\left(\frac{d\tau^a}{m^a} - \hat{Q}^a\right) - s_y^a\left(\frac{d\tau^b}{m^b} - \hat{Q}^b\right)\right]\right\} \tag{A.21}$$

where an analogous expression holds for $\hat{w}^b$. Comparing this equation with (10), the new effect that comes into play is given by the term beginning with μ^b: a-type wages are higher in cities where a-types pay higher taxes or receive fewer quality-of-life benefits relative to b-types.

Define the following income-weighted averages

$$s_x = \mu^a s_x^a + \mu^b s_x^b,\ s_y = \mu^a s_y^a + \mu^b s_y^b$$
$$\hat{Q} = \mu^a \hat{Q}^a + \mu^b \hat{Q}^b,\ \frac{d\tau}{m} = \mu^a \tau'^a s_w^a \hat{w}^a + \mu^b \tau'^b s_w^b \hat{w}^b$$

The rent differential and the average wage differential, weighted by wage-income shares, are

$$\hat{r} = \frac{1}{s_R}\left(\hat{Q} + s_x \hat{A}_X + s_y \hat{A}_Y - \frac{d\tau}{m}\right) \tag{A.22}$$
$$\hat{w} \equiv \frac{1}{s_w}\left(s_w^a \mu^a \hat{w}^a + s_w^b \mu^b \hat{w}^b\right) = \frac{1}{\theta_N s_R}\left[s_y \hat{A}_X - s_y \theta_L \hat{A}_Y + \theta_L\left(\frac{d\tau}{m} - \hat{Q}\right)\right] \tag{A.23}$$

which are analogous to the previous expressions given in (13a) and (10) with homogenous types, except that now the quantities in the model refer to income-weighted averages. The relative wage difference

$$\hat{w}^a - \hat{w}^b = \frac{1}{s_R}\left\{\left(\frac{s_y^a}{s_w^a} - \frac{s_y^b}{s_w^b}\right) s_x \hat{A}_X\right\} + \frac{1}{s_R}\left\{\left(s_x \theta_L + s_w \frac{s_y^b}{s_w^b}\right)\frac{1}{s_w^a}\left(\frac{d\tau^a}{m^a} - \hat{Q}^a\right) - \left(s_x \theta_L + s_w \frac{s_y^a}{s_w^a}\right)\frac{1}{s_w^b}\left(\frac{d\tau^b}{m^b} - \hat{Q}^b\right)\right\}$$

determines the relative levels of employment: in the CES case, workers paid higher wages are employed less, with the amount determined by the elasticity of substitution.

$$\hat{N}^a - \hat{N}^b = -\sigma_X\left(\hat{w}^a - \hat{w}^a\right) \tag{A.24}$$

If workers have similar tastes, receive equal shares of income from labor, and pay the same marginal income tax rates, so that $s_y^a = s_y^b$, $s_w^a = s_w^b$, $\hat{Q}^a = \hat{Q}^b$, and $\tau'^a = \tau'^b$, then $\hat{w}^a = \hat{w}^b$ and $\hat{N}^a = \hat{N}^b$: workers simply supply different "efficiency units" of labor to each city.

Relative tax differentials paid depend on both the relative wage and on relative employment.

$$\left(\frac{\widehat{N^a d\tau^a/m^a}}{N^b d\tau^b/m^b}\right) = \hat{N}^a + s_w^a \hat{w}^a - \hat{N}^b - s_w^b \hat{w}^b = \left(s_w^a - \sigma_X\right)\hat{w}^a - \left(s_w^b - \sigma_X\right)\hat{w}^b$$

It is unclear whether workers receiving a higher relative wage in a city pay a higher relative tax burden, as fewer live of those workers will live in the city. If $\sigma_X \geq \min\left\{s_w^a, s_w^b\right\}$ then sorting effects dominate wage effects, so that workers receiving a lower wage in a city pay a larger relative share of its income tax burden because they are more numerous.

Although the expressions are complicated, a number of conclusions can be drawn by assuming workers are equal in all but one dimension. First, workers who put greater value on quality-of-life (set $\hat{Q}^a > \hat{Q}^b$, $s_y^a = s_y^b$, and $s_w^a = s_w^b$) will take relatively lower wages and be more populous in nice cities; because they paid less and sort disproportionately into low-wage cities, these workers pay lower taxes, and are relatively better off. Workers who receive more of their income in non-wage form (set $s_w^a < s_w^b$, $s_y^a = s_y^b$, and $\hat{Q}^a = \hat{Q}^b$) find it more advantageous to live in nice cities and to avoid productive cities: although within a given city, these workers will pay the same tax differentials as other types ($s_w^a \hat{w}^a = s_w^b \hat{w}^b$), because they sort disproportionately into low-tax cities they end up paying less total taxes. Workers with a strong taste for home goods, ($s_y^a > s_y^b$, $s_w^a = s_w^b$, $\hat{Q}^a = \hat{Q}^b$) are paid higher wages and are less populous in nice or productive cities: the overall effect on their tax burdens is indeterminate. Finally, workers paying higher marginal tax rates ($\tau'^a > \tau'^b$) respond more strongly to the incentive to avoid productive cities and seek nicer cities.

If productivity differences affect only one type of worker equation (A.20c) becomes

$$c_X(w^a/A_X^a, w^b, r) = 1$$

Log-linearized this is

$$\theta_N^a \hat{w}^a + \theta_N^b \hat{w}^b + \theta_L \hat{r} = \theta_N^a \hat{A}_X^a$$

the price differentials in (A.22) and (A.23) remain unchanged once $\hat{A}_X$ is replaced with $\theta_N^a \hat{A}_X^a$, the effective cost-reduction from an increase in type-a's productivity. The level of relative employment in (A.24) must be amended to

$$\hat{N}^a - \hat{N}^b = -\sigma_X\left(\hat{w}^a - \hat{w}^a\right) + \left(\sigma_X - 1\right)\hat{A}_X^a$$

If $\sigma_X > 1$ then cities with $\hat{A}_X^a > 0$ hire relatively more type-a workers than wage differentials alone imply.

D.4 Mobile and Immobile Workers

Now we consider price differentials across cities with where a-types are fully mobile and b-types are fully immobile. Furthermore, let $A_Y = 1$, $\phi_L = 1$ and $\theta_L = \theta_K = 0$, so that the following equations hold

$$\begin{aligned} e^a\left(r, \bar{u}^a\right)/Q^a &= w^a + R^a - \tau^a \\ c_X(w^a/A_X^a, w^b/A_X^b) &= 1 \\ N^a y^a + N^b y^b &= L \\ \frac{\partial c_X/\partial w^a}{\partial c_X/\partial w^b} &= \frac{A_X^a N^a}{A_X^b N^b} \end{aligned}$$

The welfare of b-types is given implicitly by $e^b(r,u^b)/Q^b = w^b + R^b - \tau^b$ where u^b is endogenous. Log-linearizing these conditions, we have

$$s_w^a \hat{w}^a - s_y^a \hat{r} = -\hat{Q}^a + dT^a/m^a \tag{A.25a}$$

$$\theta_N^a \hat{w}^a + \theta_N^b \hat{w}^b = \theta_N^a \hat{A}_X^a + \theta_N^b \hat{A}_X^b \tag{A.25b}$$

$$\hat{N}^a + \sigma_X \left(\hat{w}^a - \hat{w}^b\right) = (\sigma_X - 1)\left(\hat{A}^a - \hat{A}^b\right) \tag{A.25c}$$

$$\mu^a \hat{N}^a + \mu^b s_w^b \hat{w}^b - \left[\mu^a s_x^a \sigma_D^a + \mu^b \left(s_y^b + s_x^b \sigma_D^b\right)\right] \hat{r} = \mu^a \hat{Q}^a + \mu^b dT^b/m^b \tag{A.25d}$$

The left-hand side of the (A.25d) can be rewritten as $\mu^a \hat{N}^a + \mu^b s_w^b \hat{w}^b + \left(\mu^a s_y^a - |\eta^u|\right) \hat{r}$ where

$$\eta^u = -\left[\mu^a \left(s_y^a + s_x^a \sigma_D^a\right) + \mu^b \left(s_y^b + s_x^b \sigma_D^b\right)\right]$$

is the uncompensated own-price demand elasticity for home-goods.

To simplify further assume tastes are homogenous, $s_y^a = s_y^b = s_y$, that each type of worker gets the same share of income from wages, $s_w^a = s_w^b = s_x$, and that productivity differences are neutral, $A_X^a = A_X^b = A_X$. Solving the above conditions then yields

$$\hat{w}^a = \frac{-|\eta^u| \hat{Q}^a + s_y \left(\frac{\theta_N^a}{\theta_N^b}\sigma_X + s_x\right) \hat{A}_X + \left(|\eta^c| + s_y \theta_N^b\right) \frac{dT^a}{m^a} - s_y \theta_N^b \frac{dT^b}{m^b}}{s_x |\eta^u| + s_y \frac{\theta_N^a}{\theta_N^b} \sigma_X} \tag{A.26a}$$

$$\hat{w}^b = \frac{|\eta^u| \hat{Q}^a + \left(\frac{s_x |\eta^u|}{\theta_N^a} + s_y (\sigma_X - 1)\right) \hat{A}_X - \left(|\eta^c| + s_y \theta_N^b\right) \frac{dT^a}{m^a} + s_y \theta_N^b \frac{dT^b}{m^b}}{s_x \frac{\theta_N^b}{\theta_N^a} |\eta^u| + s_y \sigma_X} \tag{A.26b}$$

$$\hat{r} = \frac{\theta_N^a \sigma_X \hat{Q}^a + s_x \left(\theta_N^a \sigma_X + \theta_N^b\right) \hat{A}_X - \theta_N^a \left(\theta_N^b + \sigma_X\right) \frac{dT^a}{m^a} - s_x \left(\theta_N^b\right)^2 \frac{dT^b}{m^b}}{s_x \theta_N^b |\eta^u| + s_y \theta_N^a \sigma_X} \tag{A.26c}$$

$$\hat{N}^a = \sigma_X \frac{|\eta^u| \hat{Q}^a + s_x |\eta^c| \hat{A}_X - \left(|\eta^c| + s_y \theta_N^b\right) \frac{dT^a}{m^a} + s_y \theta_N^b \frac{dT^b}{m^b}}{s_x \theta_N^b |\eta^u| + s_y \theta_N^a \sigma_X} \tag{A.26d}$$

Similar to the case with two mobile-worker types, an improvement in the quality-of-life for mobile workers, Q^a, draws in more of these workers, lowering their wages, and raising the wages of immobile workers as well as local prices. However, the quality-of-life for immobile workers, Q^b, has no impact on prices. Higher overall productivity, A_X, draws in more workers and raises rents and wages for both types, unless $s_x |\eta^u| < s_y \theta_N^a (1 - \sigma_X)$, which seems unlikely: even if $\sigma_X = 0$, this would require $\theta_N^a > |\eta^u| \, s_x / s_y$, where the left-hand side is bounded above by one, while the right-hand side of is calibrated at two.

Higher taxes on mobile workers, dT^a, causes them to leave, with the remaining mobile workers paid more in equilibrium, while immobile workers are paid less. A subtle effect occurs with, higher taxes on immobile workers, dT^b, as this lowers rents in the city, attracting mobile workers who are willing to take lower wages, thus raising the wages of immobile workers.

The welfare of mobile workers is set nationally by the outside reservation utility $\bar{u}^a$, but the welfare of

immobile workers is set locally by their change in real income:

$$\frac{d[m^b - e(r,u^b;Q^b)]}{m^b} = \hat{Q}^b + \frac{\left(s_x\left|\eta^u\right| - s_y\sigma_X\right)\theta_N^a\hat{Q}^a + \left(s_x\left|\eta^u\right| - s_y\right)\hat{A}_X}{s_x\theta_N^b\left|\eta^u\right| + s_y\theta_N^a\sigma_X} + \frac{\left(s_y\sigma_X - s_x\left|\eta^c\right|\right)\theta_N^a\frac{dT^a}{m^a} - \left(s_x\theta_N^b\left|\eta^c\right| + s_y\theta_N^a\sigma_X\right)\frac{dT^b}{m^b}}{s_x\theta_N^b\left|\eta^u\right| + s_y\theta_N^a\sigma_X}$$

To begin with, these results show that immobile types are not necessarily made better off by improvements in overall productivity or by an improved environment for mobile workers, as these raise both rents and wages of immobile workers. Above averages taxes on immobile workers, which as seen above, should occur in cities where A_X or Q^a is high, or Q^b is low, will certainly make immobile workers worse off, with only a small amount being passed on to land. Higher taxes on mobile workers, will lower the welfare of immobile workers if $s_x\left|\eta^c\right| > s_y\sigma_X$, such as if the substitutability of workers is relatively low, so that wage losses are larger than price decreases.

If productivity differences are large, so that $\hat{A}_X$ tends to vary more than $\hat{Q}^a$, or substitutability of labor, σ_X, is high, then wage differentials of mobile and immobile will be highly correlated. The validity of the argument on page 5 that the main results in the text hold with only a sufficiently large subset of mobile workers, who are otherwise identical, corresponds to the case where $\sigma_X \to \infty$. This yields $\hat{w}^a = \hat{w}^b = \hat{A}_X$, with $\hat{r} = (\hat{Q}^a + s_x\hat{A}_X - \frac{dT^a}{m^a})/s_y$, which are the appropriate simplifications of the formulas in (9) and (12a).

D.5 Agglomeration Economies

Returning to the one-worker type case, suppose that because of agglomeration economies, productivity depends on the number of workers producing the traded good: $A_X^j = A_X^{0j}\left(N^j\right)^\gamma$, where γ measures the percent increase in productivity from a percent increase in a city's population. Amending condition (8b) to include these economies

$$\theta_N\hat{w} + \theta_L\hat{r} = \hat{A}_X^0 + \gamma\hat{N}_X$$

Introducing an endogenous quantity differential, $\hat{N}_X$, into the initial system of equations (8) determining price differentials, makes the model considerably harder to solve. To make matters simple, assume $\theta_N = 1$, $\phi_L = 1$ and consider only the effects of a head tax, so $p = r$, and $w = A_X$. In this case, the wage and price differentials are

$$d\hat{w} = -\frac{\gamma s_x\sigma_D}{s_R - \gamma s_x^2\sigma_D}\frac{dT}{m}$$
$$d\hat{r} = -\frac{1}{s_R - \gamma s_x^2\sigma_D}\frac{dT}{m}$$

Stability requires $s_R > \gamma s_x^2\sigma_D$. Comparing these to the case where $\gamma = 0$, agglomeration effects imply that higher tax burdens lower local wages as local productivity falls when workers leave. Even if $\theta_L > 0$, if γ is sufficiently larger than θ_L, this productivity loss can dominate the wage increase due to substitution towards land. Land rent and home-good price changes are still negative and even larger with agglomeration economies.

TABLE 1: TAX DIFFERENTIALS DUE TO AMENITY DIFFERENCES (dτ/m)

Amenity Type	Deduction Level (δ) 0%	42%	100%	Deduction Level (δ) 0%	42%	100%
	$\varepsilon_{y,p}$=0.0 θ_L=0.05			$\varepsilon_{y,p}$=0.0 θ_L=0.00		
Quality-of-Life (Q)	-0.19	-0.25	-0.36	0.00	-0.13	-0.39
Trade-Productivity (A^X)	0.26	-0.16	0.00	0.32	0.22	0.00
Home-Productivity (A^Y)	-0.06	-0.04	0.00	0.00	0.00	0.00
	$\varepsilon_{y,p}$=-0.67 θ_L=0.05			$\varepsilon_{y,p}$=-0.67 θ_L=0.00		
Quality-of-Life (Q)	-0.19	-0.17	-0.13	0.00	0.00	0.00
Trade-Productivity (A^X)	0.26	0.23	0.19	0.32	0.29	0.24
Home-Productivity (A^Y)	-0.06	-0.06	-0.05	0.00	0.00	0.00
	$\varepsilon_{y,p}$=-1.0 θ_L=0.05			$\varepsilon_{y,p}$=-1.0 θ_L=0.00		
Quality-of-Life (Q)	-0.19	-0.13	-0.04	0.00	0.05	0.13
Trade-Productivity (A^X)	0.26	0.26	0.26	0.32	0.32	0.32
Home-Productivity (A^Y)	-0.06	-0.06	-0.06	0.00	0.00	0.00

Differential taxes, calculated using equation (A.14), represent the percentage change in tax burden as a percent of income with a one percent increase in each type of amenity. Using benchmark calibration, s_Y=0.33, s_R=0.10, θ_N=0.80, ϕ_N=0.65, τ=0.3455. Remaining parameters used in benchmark calibration marked in gray.

TABLE 2: WAGE, HOUSING PRICE AND FEDERAL SPENDING DIFFERENTIALS, 2000
Raw amd adjusted for observable population characteritics

	Population	Wage Differential		Housing Price Differential		Federal Spending Differential, Other Spending	
	Size	Raw	Adj.	Raw	Adj.	Raw	Adj.
Main city in MSA/CMSA							
San Francisco, CA	7,051,730	0.30	0.24	0.73	0.77	0.000	-0.002
New York, NY	19,875,235	0.23	0.21	0.41	0.44	0.005	-0.004
Washington, DC	4,896,958	0.25	0.16	0.41	0.27	0.017	0.014
Boston, MA	3,250,846	0.23	0.14	0.43	0.43	0.009	0.005
Detroit, MI	4,910,231	0.17	0.13	0.11	0.12	-0.006	-0.004
Chicago, IL	9,080,658	0.16	0.12	0.26	0.24	-0.006	-0.003
Los Angeles, CA	16,517,899	0.04	0.12	0.34	0.41	-0.006	0.003
Philadelphia, PA	6,181,697	0.17	0.12	0.11	0.08	0.006	0.006
Seattle, WA	3,038,785	0.16	0.08	0.38	0.33	-0.001	-0.012
Atlanta, GA	3,258,673	0.09	0.07	0.20	0.05	-0.006	-0.013
Mobile, AL	540,100	-0.15	-0.14	-0.27	-0.25	-0.005	0.002
Knoxville, TN	804,491	-0.14	-0.15	-0.24	-0.24	-0.005	-0.007
Oklahoma City, OK	1,157,773	-0.13	-0.15	-0.30	-0.29	0.003	-0.002
Columbus, GA	875,236	-0.22	-0.15	-0.48	-0.42	-0.007	-0.007
Huntington, WV	520,250	-0.18	-0.17	-0.66	-0.55	0.004	0.004
El Paso, TX	676,220	-0.28	-0.17	-0.39	-0.36	-0.003	-0.001
Steubenville, OH	575,016	-0.18	-0.17	-0.46	-0.44	-0.007	0.001
Johnson City, TN	985,334	-0.24	-0.22	-0.57	-0.47	-0.008	-0.010
McAllen, TX	565,800	-0.43	-0.22	-0.73	-0.62	0.004	-0.008
Springfield, MO	659,672	-0.27	-0.24	-0.36	-0.37	-0.013	-0.005
Region							
Northeast	54,096,432	0.11	0.07	0.12	0.12	0.004	0.000
Midwest	64,356,624	-0.01	-0.04	-0.13	-0.14	-0.002	-0.001
South	99,751,674	-0.07	-0.07	-0.16	-0.16	-0.002	-0.001
West	63,217,176	0.04	0.04	0.26	0.28	-0.001	0.001
MSA Population							
Non-MSA	47,660,820	-0.17	-0.15	-0.34	-0.31	0.004	0.005
MSA, pop<500,000	37,714,735	-0.11	-0.11	-0.22	-0.21	-0.004	-0.001
MSA, pop>500,000	60,462,698	-0.03	-0.05	-0.11	-0.12	-0.001	-0.002
MSA, pop>1,500,000	71,540,847	0.08	0.04	0.13	0.09	-0.001	-0.001
MSA, pop>5,000,000	64,042,806	0.16	0.16	0.35	0.37	-0.002	-0.002
United States	281,421,906	0.15	0.13	0.33	0.31	0.014	0.011
	total	(standard deviations for United States)					

Wage and housing price data taken from the U.S. Census 2000 IPUMS. Wage differentials based on the average logarithm of hourly wages for full-time workers ages 25 to 55. Housing price differentials based on the average logarithm of rents and housing prices for units moved in within the last 5 years. Adjusted differentials are city-fixed effects from individual level regressions on extended sets of worker and housing covariates. Federal spending data taken from the CFFR and includes most government grants, including most Medicaid, housing, and welfare programs. Spending differentials based on the logarithm of per capita spending. Adjusted differentials are residual differences from city-level regressions on a limited set of population covariates.

TABLE 3: IMPUTED QUALITY-OF-LIFE, TRADE-PRODUCTIVITY, AND LAND-RENT DIFFERENTIALS, 2000

Main city in MSA/CMSA	Quality-of-Life	Productivity	Land Rent
Main city in MSA/CMSA			
San Francisco, CA	0.13	0.31	2.39
New York, NY	0.04	0.23	1.31
Washington, DC	0.01	0.17	0.77
Boston, MA	0.07	0.18	1.44
Detroit, MI	-0.02	0.11	0.20
Chicago, IL	0.02	0.14	0.73
Los Angeles, CA	0.08	0.17	1.43
Philadelphia, PA	-0.03	0.09	0.04
Seattle, WA	0.07	0.13	1.21
Atlanta, GA	-0.02	0.05	0.01
Mobile, AL	-0.01	-0.16	-0.89
Knoxville, TN	-0.01	-0.16	-0.82
Oklahoma City, OK	-0.02	-0.17	-1.11
Columbus, GA	-0.06	-0.23	-2.11
Huntington, WV	-0.10	-0.25	-2.20
El Paso, TX	-0.03	-0.21	-1.50
Steubenville, OH	-0.06	-0.25	-2.22
Johnson City, TN	-0.04	-0.28	-2.20
McAllen, TX	-0.09	-0.29	-2.39
Springfield, MO	0.00	-0.25	-1.24
Region			
Northeast	0.00	0.07	0.21
Midwest	-0.03	-0.07	-0.78
South	-0.02	-0.09	-0.70
West	0.07	0.09	1.03
MSA Population			
Non-MSA	-0.03	-0.19	-1.32
MSA, pop<500,000	-0.01	-0.13	-0.86
MSA, pop>500,000	-0.02	-0.07	-0.56
MSA, pop>1,500,000	0.01	0.04	0.24
MSA, pop>5,000,000	0.04	0.18	1.14
United States (standard deviations)	0.05	0.16	1.23

Imputed rents, productivity, and quality-of-life based on adjusted wage and price differentials shown in Table 2, using model with deductions and equations (A.13), (8b), and (23) in text. Calibrated effects from benchmark case, s_y=0.33 θ_L=0.0 θ_N=0.80 ϕ_T=0.20 ϕ_N=0.65 $\varepsilon_{v,n}$=-.67, δ=0.42

TABLE 4: TAX DIFFERENTIALS ACROSS CITIES AND THEIR EFFECTS ON PRICES AND EMPLOYMENT, 2000

Tax Payment Rank		Tax Differential			Tax Differential Effects			
		With deduction (1)	No deduction (2)	With deduction & spending (3)	Wages (4)	Housing Price (5)	Land Rent (6)	Employment (7)
	Main city in MSA/CMSA							
1	San Francisco, CA	0.058	0.064	0.060	0.036	-0.092	-0.578	-0.347
2	New York, NY	0.049	0.055	0.053	0.030	-0.078	-0.487	-0.292
3	Washington, DC	0.038	0.043	0.024	0.024	-0.061	-0.382	-0.229
4	Boston, MA	0.033	0.036	0.028	0.020	-0.052	-0.326	-0.195
5	Detroit, MI	0.029	0.033	0.033	0.018	-0.046	-0.291	-0.175
6	Chicago, IL	0.029	0.033	0.032	0.018	-0.046	-0.291	-0.174
7	Los Angeles, CA	0.028	0.031	0.025	0.018	-0.045	-0.280	-0.168
8	Philadelphia, PA	0.027	0.030	0.021	0.017	-0.042	-0.266	-0.160
9	Seattle, WA	0.020	0.022	0.031	0.012	-0.031	-0.196	-0.118
10	Atlanta, GA	0.016	0.018	0.029	0.010	-0.025	-0.157	-0.094
201	Mobile, AL	-0.033	-0.037	-0.035	-0.021	0.053	0.330	0.198
213	Knoxville, TN	-0.034	-0.039	-0.027	-0.021	0.055	0.342	0.205
214	Oklahoma City, OK	-0.035	-0.039	-0.033	-0.022	0.055	0.347	0.208
222	Columbus, GA	-0.036	-0.041	-0.030	-0.023	0.058	0.365	0.219
240	Huntington, WV	-0.040	-0.044	-0.044	-0.025	0.064	0.400	0.240
243	El Paso, TX	-0.041	-0.046	-0.040	-0.025	0.065	0.406	0.244
244	Steubenville, OH	-0.041	-0.045	-0.042	-0.025	0.065	0.407	0.244
268	Johnson City, TN	-0.051	-0.057	-0.040	-0.032	0.081	0.507	0.304
271	McAllen, TX	-0.052	-0.057	-0.044	-0.032	0.082	0.516	0.310
284	Springfield, MO	-0.056	-0.063	-0.051	-0.035	0.090	0.562	0.337
	Region							
1	Northeast	0.016	0.018	0.017	0.010	-0.026	-0.163	-0.098
3	Midwest	-0.010	-0.011	-0.009	-0.006	0.015	0.095	0.057
4	South	-0.016	-0.017	-0.014	-0.010	0.025	0.155	0.093
2	West	0.011	0.012	0.010	0.007	-0.017	-0.107	-0.064
	MSA Population							
5	Non-MSA	-0.035	-0.040	-0.040	-0.022	0.056	0.354	0.213
4	MSA, pop<500,000	-0.027	-0.030	-0.025	-0.017	0.042	0.266	0.160
3	MSA, pop>500,000	-0.011	-0.013	-0.009	-0.007	0.018	0.114	0.068
2	MSA, pop>1,500,000	0.009	0.010	0.010	0.006	-0.014	-0.090	-0.054
1	MSA, pop>5,000,000	0.037	0.041	0.039	0.023	-0.058	-0.367	-0.220
	United States (std dev)	0.030	0.034	0.033	0.019	0.048	0.304	0.182
	United States (mean abs dev)	0.026	0.029	0.028	0.016	0.041	0.257	0.154

Tax differentials calculated using equation (20) with and without deduction. Tax effects calculated using tax differential with deduction and equations (5), (6), (7), and (14).Calibrated effects from benchmark case, s_y=0.33 θ_L=0.05 θ_N=0.80 ϕ_L=0.20 ϕ_N=0.65 $\varepsilon_{y,p}$=-.67, $\varepsilon_{N,T/m}$=-6, δ=0.5

TABLE 5: ESTIMATED EFFECTS OF TAX DIFFERENTIALS ACROSS ALL CITIES FOR DIFFERENT CALIBRATIONS, 2000

	Benchmark case	Smaller θ_L Larger ϕ_L	Smaller s_R	Larger $\varepsilon_{N,T/m}$ (Cobb-Douglas)	Smaller $\varepsilon_{y,p}$	Wage diffs two-thirds size	Deduction Ignored	With Federal Spending
Economic Parameters	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Home goods share s_y	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333
Traded good land share θ_L	0.050	**0.000**	**0.025**	0.050	0.050	0.050	0.050	0.050
Traded good labor share θ_N	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
Home good land share ϕ_L	0.200	**0.300**	**0.100**	0.300	0.200	0.200	0.200	0.200
Home good labor share ϕ_N	0.650	0.650	0.650	0.650	0.650	0.650	0.650	0.650
Comp. demand elast for home goods $\varepsilon_{y,p}$	-0.667	-0.667	-0.667	-0.667	**-0.333**	-0.667	-0.667	-0.667
Elasticity of employment to tax/income $\varepsilon_{N,T/m}$	-6.000	-6.000	-6.000	**-9.970**	-6.000	-6.000	-6.000	-6.000
Tax Parameters								
Marginal tax rate τ'	0.346	0.346	0.346	0.346	0.346	0.346	0.346	0.346
Deduction level δ	0.421	0.421	0.421	0.421	0.421	0.421	0.000	0.421
Implied Parameters								
Share of income to land s_R	0.100	0.100	**0.050**	0.133	0.100	0.100	0.100	0.100
Share of income to labor s_w	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
Average Percent Effects (Mean Absolute Values)								
Tax differential: E|dτ/m|	**0.026**	0.026	0.023	0.026	**0.022**	**0.011**	**0.028**	**0.028**
Wage effect: E|dw|	**0.016**	**0.000**	0.016	0.016	0.014	0.107	0.018	0.017
Home-good price effect: E|dp|	**0.041**	**0.077**	0.041	0.041	0.035	0.028	0.045	0.044
Land rent effect: E|dr|	**0.257**	0.257	**0.514**	0.257	0.217	0.173	0.283	0.028
Employment effect: E|dN|	**0.154**	0.154	0.154	**0.256**	0.130	0.104	0.170	0.166
Deadweight Loss (from employment only)								
As a percent of income, E(DWL/Nm)	**0.278%**	0.278%	0.278%	**0.461%**	**0.198%**	**0.125%**	**0.337%**	**0.331%**
Total DWL (Billions per year, 2005$)	34.4	34.4	34.4	57.2	24.6	15.6	41.8	41.1
Per Capita (per year, 2005$)	118.8	118.8	118.8	197.2	84.7	53.6	144.0	141.7

Simulatons based off of data seen in Tables 2, 3 and 4, but for all cities. Tax differential calculated with equation (20). Effects determined by equations (5), (6), (7), and (14). DWL estimated off of equation (16). Total DWL measured by taking per DWL as a percent of income and multiplying it by $12.4 Trillion, U.S. GDP in 2005.

TABLE 6: DIFFERENTIAL FEDERAL SPENDING PATTERNS RELATIVE TO DIFFERENTIAL TAXATION PATTERNS

Dependent Variable	Raw Differentials				Adjusted Differentials			
Type of Federal Spending	All Spending	Wages & Contracts	Non-Worker Benefits	Other Spending	All Spending	Wages & Contracts	Non-Worker Benefits	Other Spending
Panel A: Year 2000								
Tax Differential	-0.068	0.187	-0.164	0.007	-0.146	-0.075	-0.018	-0.030
(standard error)	(0.159)	(0.102)	(0.063)	(0.036)	(0.125)	(0.057)	(0.017)	(0.024)
Panel B: Year 1990								
Tax Differential	0.228	0.332	-0.179	0.046	-0.101	-0.059	-0.027	0.013
(standard error)	(0.143)	(0.085)	(0.067)	(0.037)	(0.089)	(0.043)	(0.026)	(0.021)

Regressions weighted by MSA population for all 295 observations. Robust standard errors reported. Definitions of federal spending variables are discussed in the main text and in Appendix C.

TABLE 7: DIFFERENTIAL TAX EFFECTS AND DEADWEIGHT LOSS FROM LOCATIONAL INEFFICIENCY AND HOME-GOOD OVERCONSUMPTION WITH DIFFERENT TAX REFORMS, 2000

	Existing System (1)	Eliminating Deduction (2)	Full Deduction (3)	No Ded, Index Tax to COL (4)	No Ded, Index Tax to Wages (5)	W/ Ded, Index Tax to Wages (6)	W/ Ded, Index Tax to COL (7)
Reformed Tax Parameters							
Marginal tax rate τ'	0.346	0.000	0.346	0.346	0.346	0.346	0.346
Deduction level δ	0.421	0.421	1.000	0.000	0.000	0.421	0.421
Average Outcomes (Mean Absolute Values)							
Tax differential: $E\|d\tau/m\|$	0.026	0.029	0.021	0.023	0.000	0.004	0.014
Wage effect: $E\|dw\|$	0.016	0.018	0.012	0.014	0.000	0.002	0.009
Home-good price effect: $E\|dp\|$	0.041	0.046	0.034	0.036	0.000	0.006	0.023
Land rent effect: $E\|dr\|$	0.257	0.288	0.211	0.229	0.000	0.037	0.144
Employment effect: $E\|dN\|$	0.154	0.173	0.126	0.137	0.000	0.022	0.086
DWL from Locational Ineffciency							
Percent of GDP	0.278%	0.311%	0.228%	0.195%	0.000%	0.040%	0.137%
DWL (Billions \$2005)	34.4	38.6	28.3	24.2	0.0	4.9	17.0
DWL from Home-Good Overconsumption							
Percent of GDP	0.212%	0.000%	1.194%	0.000%	0.000%	0.212%	0.212%
DWL (Billions \$2005)	26.2	0.0	148.0	0.0	0.0	26.2	26.2
Total DWL							
Total DWL	0.489%	0.311%	1.422%	0.195%	0.000%	0.251%	0.349%
DWL (Billions \$2005)	60.7	38.6	176.3	24.2	0.0	31.2	43.2

Reforms are based on the economic parameters used in the main calibration. DWL from home goods overconsumption given by equation (22) in the text, adjusted down by 10 percent because of supply considerations. Baseline price and amenity differentials are estimated using the base calibration, with the original tax parameters; these differentials are then recalculated to account for the tax reform.

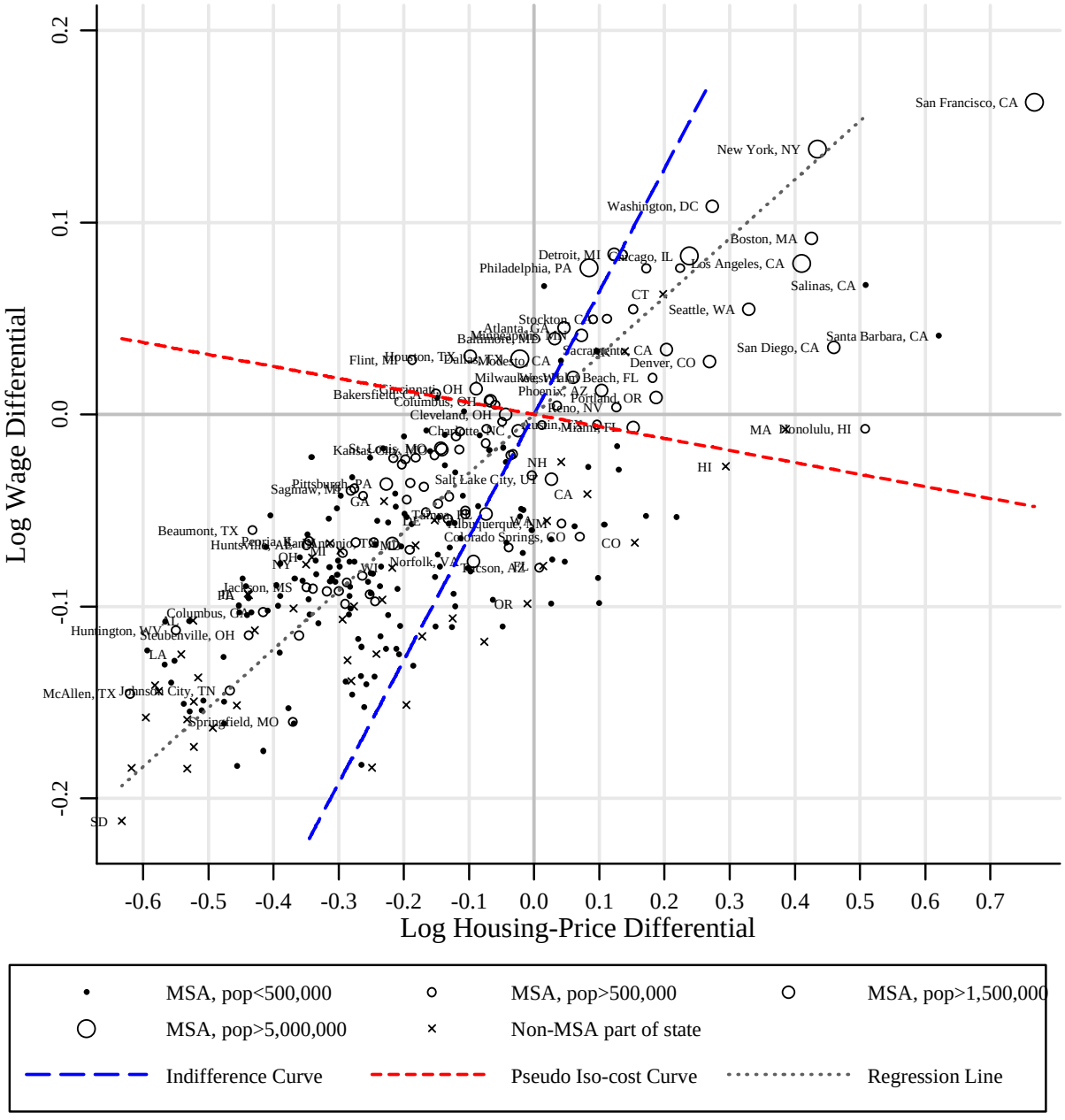
TABLE 8: PREDICTED VERSUS ACTUAL CHANGES IN WAGES AND PRICES DUE TO FEDERAL TAX CHANGES: 1980-1990 AND 1990-2000

Year	1990		2000	
Dependent Variable	Change in Wage Diff.	Change in Price Diff.	Change in Wage Diff.	Change in Price Diff.
Predicted Slope: (Long-run)	-0.002	0.059	0.001	-0.038
(Short-run)	-0.002	0.129	0.001	-0.084
Std dev of prediction: (Long-run)	0.0002	0.0064	0.0002	0.0053
(Short-run)		0.0105		0.0088
Standard Deviation of Data	0.0728	0.2017	0.0341	0.1249
Model 1: No Controls				
Lagged Wage Differential	0.083	0.673	-0.081	-0.473
(standard error)	(0.115)	(0.266)	(0.009)	(0.126)
Test: Actual = Predicted (*p-val*)				
Long-run	0.513	0.104	0.003	0.041
Short-run		0.133		0.057
Model 2: Region Controls				
Lagged Wage Differential	0.093	0.671	-0.057	-0.402
(standard error)	(0.096)	(0.253)	(0.027)	(0.205)
Test: Actual = Predicted (*p-val*)				
Long-run	0.395	0.094	0.119	0.174
Short-run		0.122		0.219

Sample includes 294 metropolitan areas. Robust standard errors clustered by region. Long-run predictions due to federal tax rate changes given by the theoretical model using the baseline calibration; the short-run predictions use a similar calibration but with φ_L=1. The assumption is that otherwise differentials would not have changed, so that with no tax change the prediction would be zero. Region controls are for Northeast, Midwest, South, and West. See Figure 7 and text for more detail.

Figure 3: Wages versus Housing Prices, 2000

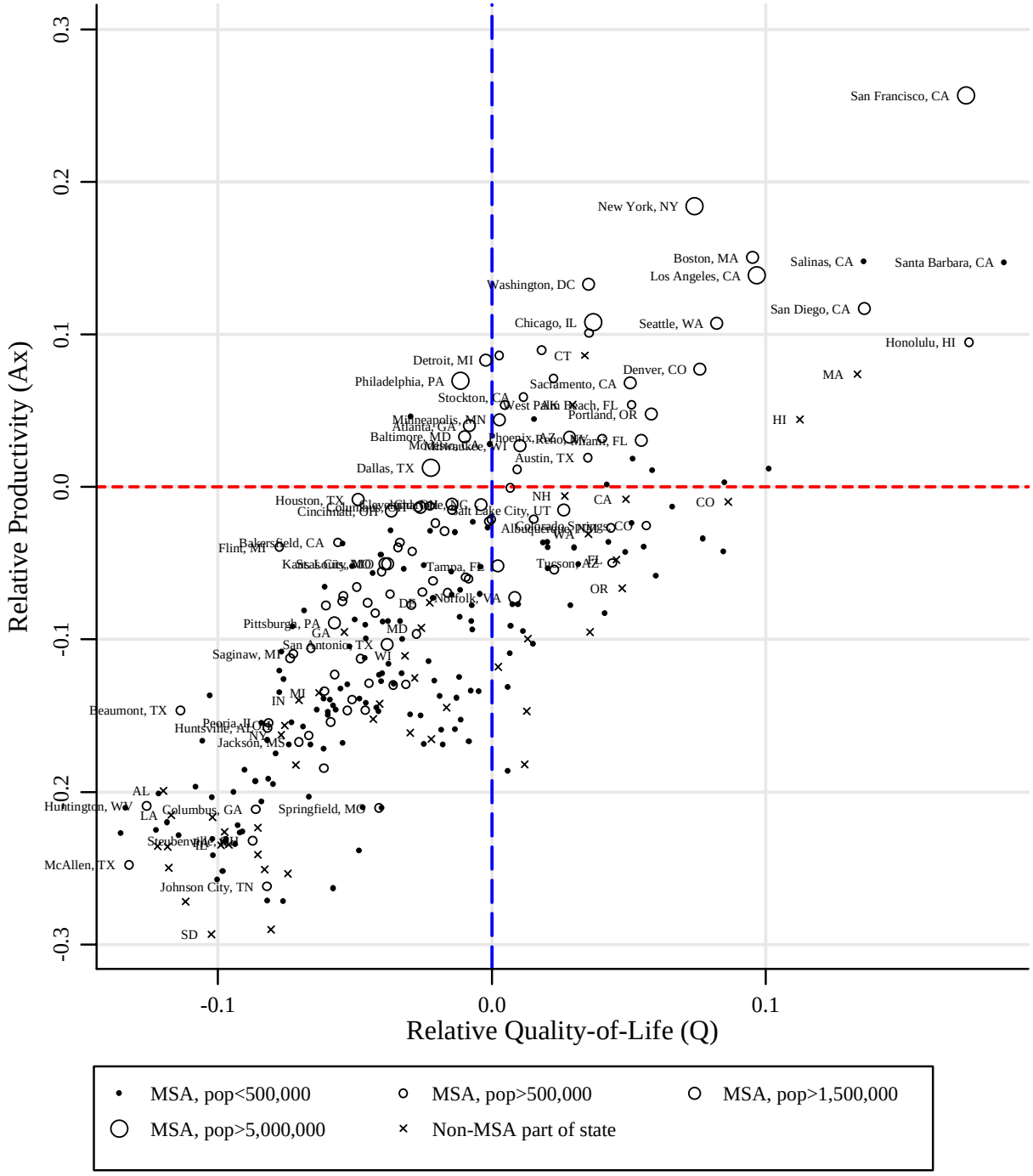
Metropolitan Statistical Areas (MSAs) and Non-Metro States



Log wage (for full-time workers) and housing-price (for home-owners and renters) differentials from regressions described in Appendix C. According to the model, cities to the right of the indifference curve (for an average city) have above average quality-of-life, while cities above the pseudo-iso-cost curve (for an average city) tend to have above average productivity, as seen in Figure 4. These curves are derived from a simplified model (see footnote 28) using the following calibration: sy=.33, sT=.1, thetaL=.05, phiL=1, phiN=0, thetaN=.8, elast_y,p=-.67, tax rate=.3455, deduction=.421.
At zero, slope of indifference curve = .64, slope of iso-cost curve = -.06.
Regression line from regression of rent residual on wage residual, slope = .31 (s.e. 0.01)

Figure 4: Estimated Productivity and Quality-of-Life, 2000

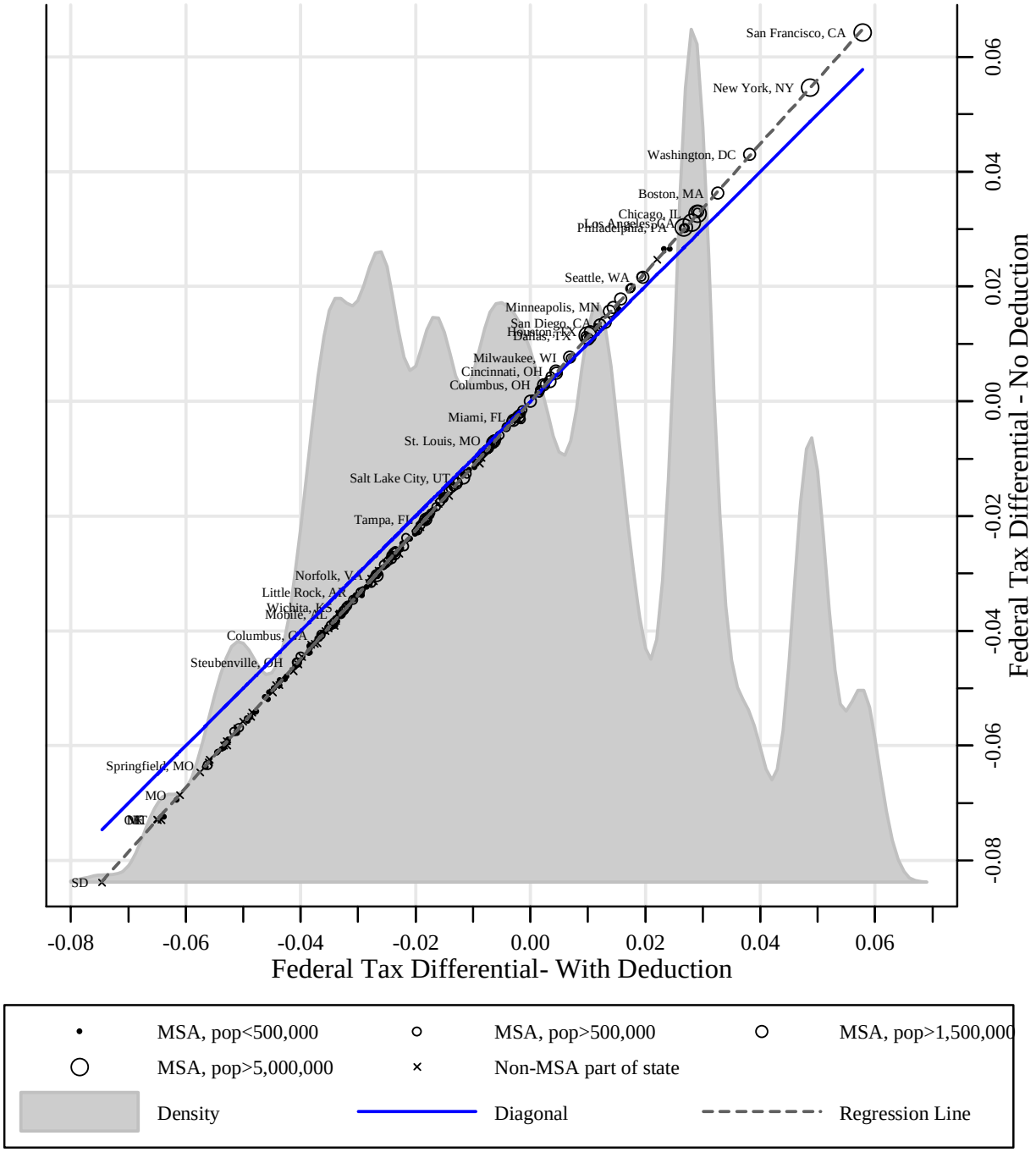
Metropolitan Statistical Areas (MSAs) and Non-Metro States



Relative productivity and quality-of-life estimated using equations (8b) and (A.13) with wage, housing price, and inferred land rents from equation (23).
Calibration: sy=.33, sT=.1, thetaL=.05, thetaN=.8, phiL=.2. phiN=.65, elast_y,p=-.67, tax rate=.3455, deduction=.421

Figure 5: Differential Tax Burden With and Without Deduction

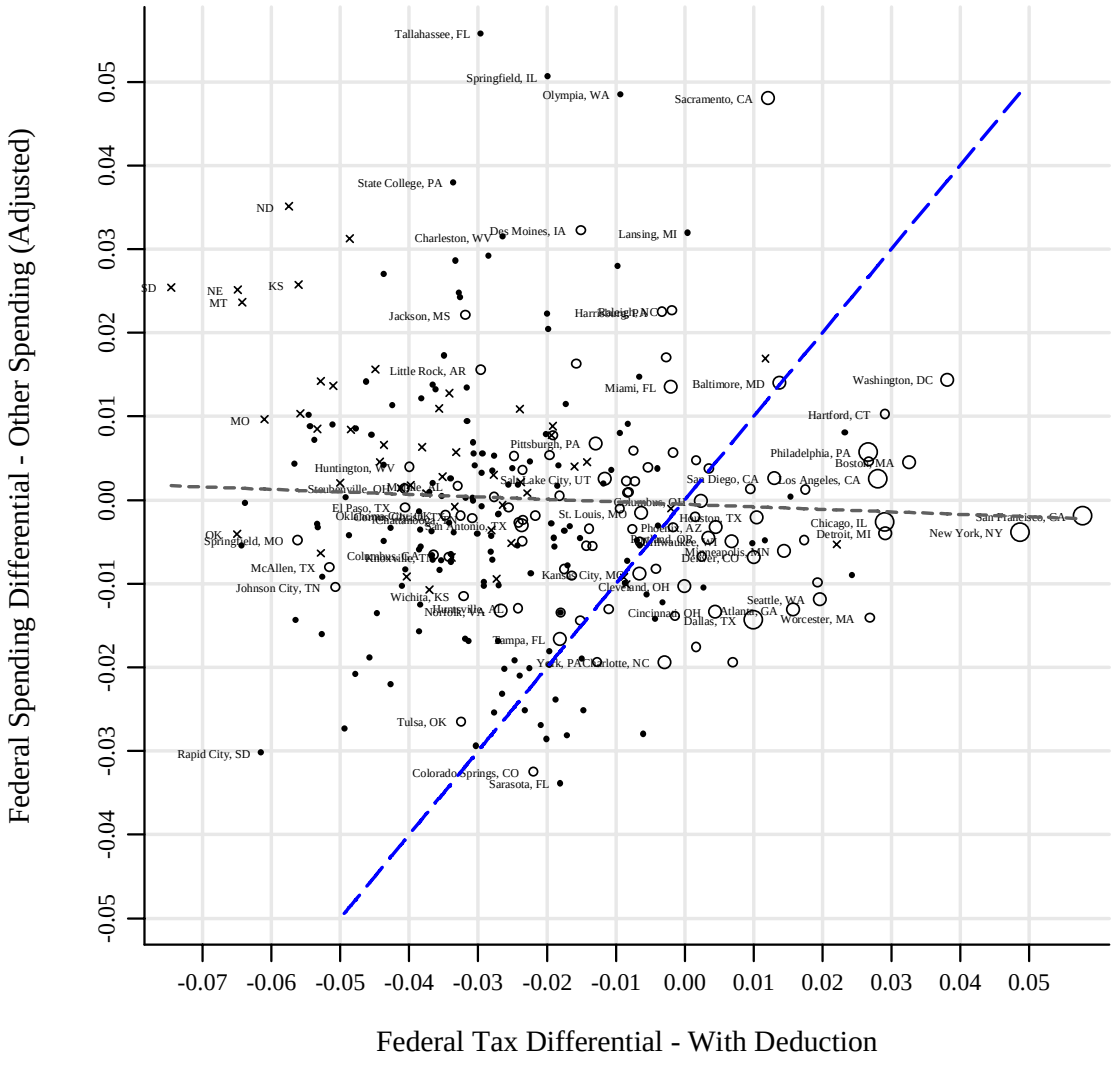
Metropolitan Statistical Areas (MSAs) and Non-Metro States



Differential federal tax with deduction estimated directly off data using equation (20) while tax deduction with no deduction estimated off of inferred counterfactual wage using equation (10). Each is expressed as a fraction of total income. Values for selected cities shown in Table 4. Diagonal shows where differential taxes are equal. Regression line has slope 1.121 (s.e. .001). Density plot uses a Gaussian kernel with a bandwidth of .003

Figure 6: Differential Federal Taxes and Transfers, 2000

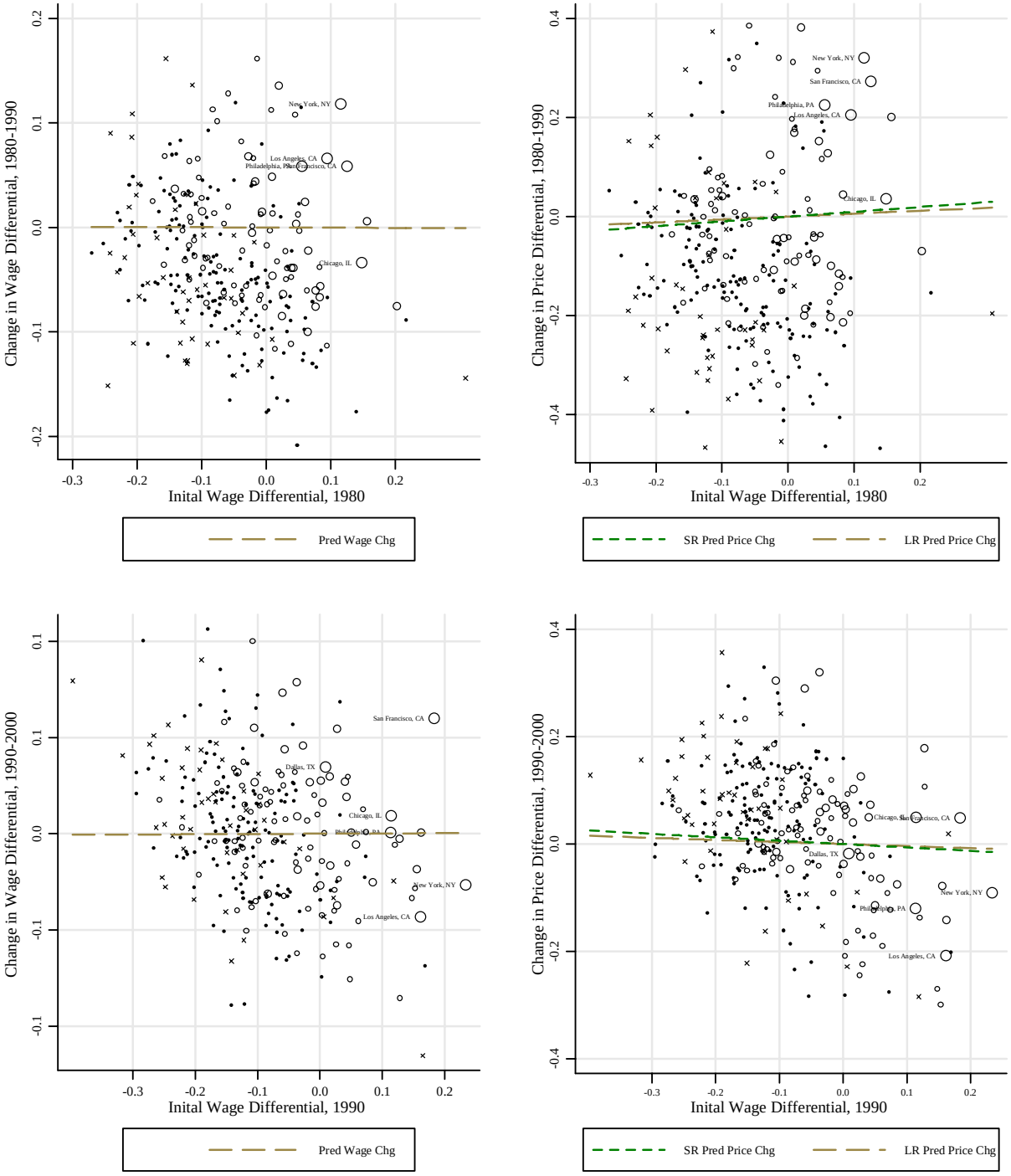
Metropolitan Statistical Areas (MSAs) and non-Metro states



Federal tax differential calculated as before. Federal sepnding differential (Other Spending) includes all spending not for federal wages & contracts, or transfers to non-workers in the CFFR database as described in Appendix C, which also explains how the differential is adjusted for city characteristics. Tax=Spending line repsresents where spending differential compensates for tax differential. Spending differentials for MSA's containing state capitals may be over-estimates. Regression line has slope -.03 (s.e. .021).

Figure 7: Actual versus Predicted Wage and Price Differential Changes

Using Federal Tax Changes over the 1980s and 1990s



Predicted price and wage changes are from federal tax rate changes according to the model assuming that the differentials would not have changed otherwise. See Table 8 and text for more detail.