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ABSTRACT

In the United States, workers in cities offering above-average nominal wages – cities with high productivity, low quality-of-life, or inefficient housing sectors – pay 30 percent more in federal taxes than otherwise identical workers in cities offering below-average wages. According to simulation results, federal taxes lower long-run employment levels in high-wage areas by 15 percent and land and housing prices by 25 and 4 percent, leading to locational inefficiencies costing 0.28 percent of income, or $34 billion in 2005. Indexing taxes to local wage-levels eliminates these locational inefficiencies. Tax deductions index taxes partially to local cost-of-living and improve locational efficiency.

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1 Introduction

Wage and cost-of-living differences across cities in the United States are large, yet economists do not understand clearly how federal taxes interact with these differences. Since federal income taxes are based on nominal incomes, workers with the same real income pay more taxes in high-cost areas than in low-cost areas, without receiving additional benefits. Recognizing 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) recommended cutting tax deductions for local taxes and home-mortgage interest, which would raise taxes disproportionately in high-cost areas. The Panel also suggested 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, analyzing how workers in different locations unequally bear federal taxes net of transfers, 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 with high worker productivity or inefficient housing sectors. In contrast, taxes may fall less on workers in cities which are expensive solely because they offer an exceptional quality-of-life: such workers are likely paid lower nominal wages, since they implicitly receive an untaxed "income" from living in a nicer area.

As 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 having the opposite effect on 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, however, be eliminated by indexing taxes to an "ideal" wage index, or to an "ideal" cost-of-living index which accounts for quality-of-life differences, such that a worker pays the same taxes regardless of where she lives. Cost-of-living indexation that disregards quality-of-life neutralizes tax differences across cities that differ in productivity, as wages track prices in these cities, but exacerbates tax differences across cities that differ in quality-of-life, since nicer cities have lower wages and higher costs. 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 "cost-indexation effect" from these deductions is only partial, but strong if demand for housing and local-government goods is highly inelastic.

I also present quantitative evidence on the impact of differential federal taxation across metropolitan areas in the United States from an empirical simulation. Workers with the same skills can pay up to 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, while subsidizing them to live in smaller cities in towns. Taxes also fall more heavily on the West and Northeast than on the South. These federal tax differences are enormous compared to local tax differences, particularly as federal tax differences are not compensated with federal spending differences. Approximately 300 billion dollars each year are transferred horizontally from workers in high-wage areas to similar workers in low-wage areas, independent of vertical redistribution. These findings partly confirm Senator Patrick Moynihan's claims in 24 years of reports, entitled *The Federal Budget and the States*, that "federal balance of payments" across areas is highly unequal, although Moynihan did not account for federal redistribution from the rich to the poor across regions.

This inequality in the federal balance of payments "is according to urban experts and economists, one of the best-kept secrets in American politics," according to journalist Malcolm Gladwell (1996), who reports that "the decline of many northeastern American cities may be due not just to mismanagement – as is now popularly imagined – but to the emptying of their coffers by the federal government." This view is supported by the simulation results: over the long run, federal taxes have lowered employment in high-wage areas by 15 percent, and housing and land values by 4 and 25 percent, respectfully. The opposite has occurred in low-wage areas. Distortions in the geographic distribution of employment create a welfare loss of 0.28 percent of GDP, or $34 billion a year.

This welfare loss is similar in size to the loss generated by the favorable tax treatment of housing and local public goods, a loss which has received far greater attention in the literature. Given the existing distortions, this favorable tax treatment helps workers to locate more efficiently, reducing the welfare loss by about $4 billion a year, although this is too small offset the costs of the this favorable tax treatment. Whether or not the tax treatment is 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.

Despite containing some important findings, previous research about how federal taxes interact with local price differences 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. However, he focuses mostly on the mathematical conditions characterizing efficiency, rather than describing the impact of unequal taxation. Without referring specifically to 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) also allow productivity differences to affect local wages and prices, 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 as it remains unclear what the implications are of failing to index the tax code.[1]

There has been less work on how tax deductions interact with local prices. 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. Studies considering the possible benefits 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.

This paper begins in Section 2 by proposing a model with different cities that share mobile workers in a trading equilibrium. City characteristics generate differences in costs-of-living, wages, and federal tax burdens. Section 3 uses this model to describe the federal tax differences across cities that arise in equilibrium, and how this affects local prices. Section 4 examines how workers are redistributed by taxes, and the deadweight loss which arises. Then, section 5 considers the effect of indexing taxes to local wages or costs-of-living; it also demonstrates how tax deductions for locally-produced goods, such as housing, produce a kind of cost indexation, albeit with a twist. Section 6 calibrates the model and simulates how differential taxes affect local prices, employment, and welfare, taking into account differential federal spending patterns. It also examines how changing deduction levels or indexing taxes would affect welfare. Section 7 considers various extensions to the model. Considerable detail on theory, calibration, data, and extensions are left to the Appendix.[2]

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

[2] Some attempts, seen in Albouy (2007), have been made to test this theory empirically using Census data from 1980 to 2000 using tax rate changes from different tax reforms. Unfortunately, changes in wage and price differentials over time are too noisy, and predicted changes by the model too small, to provide a convincing test of the model or a direct calibration. The results do seem to confirm the prediction that relative housing prices in high-wage cities should have risen in the 1980s with the fall in marginal tax rates, and fallen in the 1990s, with the subsequent rise in rates.

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 mobile 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 city characteristics. Quality-of-life, Q^j, may be affected by weather, crime, scenic beauty, or cultural opportunities. Productivity in the traded-good sector, A_X^j (or "trade-productivity"), may be due to natural advantages or to agglomeration economies. Productivity in the home-good sector, A_Y^j, (or "home-productivity") may be due to natural advantages, regulations in the housing market, or the efficiency of the local public sector. The average value of each characteristic is set to one. Although some city characteristics may indeed be endogenous, it is safe to consider them exogenous if federal taxes do not significantly affect their relative levels across cities.

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, and each supplies a single unit of labor. A model with 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. 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 $m^j \equiv R + I + w^j h^j$ varies across cities only as wages vary. Out of this income workers pay a federal income tax of $\tau(m)$. Deductions are introduced in Section 5.

Workers' preferences are modeled by a utility function $U(x, y; Q)$, that is 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 such that $e(p^j, u; Q^j) = e(p^j, u)/Q^j$, where $e(p^j, u) \equiv e(p^j, u; 1)$.[3] Since workers are fully mobile, their utility must be the same across all inhabited cities, so that higher prices or lower quality-of-life must be compensated with greater after-tax income:

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

$\bar{u}$ is the level of utility attained nationally. While full mobility is a strong assumption, it seems justified given that widespread income taxation has lasted several generations. The tax incentives modeled here 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 (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. All factors are fully employed: $L_X^j + L_Y^j = L^j$, $N_X^j + N_Y^j = N^j$, and $K_X^j + K_Y^j = K^j$. Unit cost in the traded-good sector is

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

[3]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 fixed amounts of labor if these workers are perfect substitutes in production, have identical homothetic preferences, and earn equal shares of income from labor.

For simplicity, let $c_X(r^j, w^j, \bar{\imath}; A_X^j) = c_X(r^j, w^j, \bar{\imath})/A_X^j$ where $c(r, w, i) \equiv c(r, w, i; 1)$. A symmetric definition holds for the unit costs 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.[4]

Instead of modeling the public sector at all levels, this analysis reduces the public sector to a single federal government. 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 as consumption goods, part traded and part non-traded. Efficiency differences in local public sectors may be captured by 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.[5]

The federal government does more than provide public goods: it also gives transfers to workers, sometimes in kind. In the model, it matters whether workers who pay higher federal taxes receive more federal transfers. In the United States, workers in high-wage areas pay more in 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. 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,

[4]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 prices across cities, but not on relative quantities.

[5]Since state tax levels are only partially tied to local government provision, especially in large states, state government may be considered part local and part federal.

some benefit levels are tied to local prices, such as housing programs, although these programs tend to be small. Insomuch as they are provided efficiently, goods provided by the federal government locally may be treated as transfers.[6]

The federal government collects tax revenues and makes transfers, and uses the net balance to buy traded goods, using them to produce a federal public good. Since this federal public good benefits workers everywhere equally, its benefits do not need modeling.

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 $s_T^j = \tau\left(m^j\right)/m^j$; 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 $s_I^j \equiv I/m^j$. For firms, denote the cost shares of land, labor, and capital in the traded-good sector 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-good sector as ϕ_L^j, ϕ_N^j, and ϕ_K^j. Assume, as is likely, that home goods are more cost intensive in land relative to labor than traded goods, i.e., $\phi_L/\phi_N > \theta_L/\theta_N$.

3 Federal Tax and Price Differences Across Cities

The following analysis considers how prices and federal-tax burdens vary cross-sectionally across cities with different city characteristics in the presence of an income tax. Assume that there are enough cities varying in the three city characteristics, Q, A_X, and A_Y so we can treat these characteristics as continuous variables. 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 may be log-linearized to express a particular city's price differentials in terms of its city-characteristic differentials, all relative to the national average. These 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

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

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 $d\hat{z}^j = \hat{z}^j - \hat{z}_0^j$. In an average city $\hat{z}^j = \hat{z}_0^j = d\hat{z}^j = 0$ for any variable z. Letting E be the expectations operator over cities, weighted by population, $E[\hat{Q}^j] = E[\hat{A}_X^j] = E[\hat{A}_Y^j] = 0$.

Log-linearizing (1), (2), and (3) produces equations describing how prices co-vary with city characteristics[7]

$$s_w\hat{w} - s_y\hat{p} = \tau' s_w\hat{w} - \hat{Q} \tag{4a}$$

$$\theta_L\hat{r} + \theta_N\hat{w} = \hat{A}_X \tag{4b}$$

$$\phi_L\hat{r} + \phi_N\hat{w} - \hat{p} = \hat{A}_Y \tag{4c}$$

The first equation states how before-tax real income, given by nominal wage differences $s_w\hat{w}$ net of cost-of-living differences $s_y\hat{p}$, must compensate for quality-of-life losses $-\hat{Q}$, and higher federal taxes, $\tau' s_w\hat{w}$. This last term expresses the income tax differential in terms of total income 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 a differential head tax being placed on workers in that city, except that it depends on an endogenous wage differential, $\hat{w}$, rather than being set arbitrarily. Equation (4a) reveals that additional federal taxes must be compensated for in the same way as a lower quality-of-life. The second and third equations (4b, 4c) demonstrate how high productivity in each sector results in high factor prices relative to the output price in equilibrium.

As the extra tax term depends on the wage differential, $\hat{w}$, this needs to be solved for first:[8]

[7]These equations are first-order approximations, evaluated at average values, so that the share values correspond to national averages. Note that for simplicity $\hat{Q}(1 - s_T)$ is reinterpreted as $\hat{Q}$.

[8]Solving the system requires using the identities $s_R = (s_x + s_T)\theta_L + s_y\phi_L$ and $s_w = (s_x + s_T)\theta_N + s_y\phi_N$.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. These identities should be treated as approximations, which only hold exactly in an average city. 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.

$$\hat{w} = \underbrace{\hat{w}_0 + \frac{\theta_L}{\theta_N}\frac{1}{s_R}\overbrace{\tau' s_w \hat{w}}^{d\tau/m}}_{d\hat{w}} = \frac{1}{1 - \frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\tau'}\hat{w}_0 \tag{5}$$

where

$$\hat{w}_0 = \frac{1}{\theta_N s_R}\left(s_y \phi_L \hat{A}_X - \theta_L \hat{Q} - s_y \theta_L \hat{A}_Y\right) \tag{6}$$

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 (5) expresses the wage differential as the sum of the pre-tax differential and the federal-tax effect. This demonstrates that cities paying a positive wage differential without income taxes, $\hat{w}_0$, pay an additional wage differential, $d\hat{w}$, to help compensate for the higher taxes. 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.

Combining $d\tau/m = \tau' s_w \hat{w}$, (5), and (6), the amount of additional income taxes paid in a city in terms of local city characteristics is

$$\frac{d\tau}{m} = \tau' \frac{1}{1 - \frac{\theta_L}{\theta_N}\frac{s_w}{s_R}\tau'}\frac{s_w}{\theta_N s_R}\left(s_y \phi_L \hat{A}_X - \theta_L \hat{Q} - s_y \theta_L \hat{A}_Y\right) \tag{7}$$

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 (7) based on city characteristics.

[9] Expressions for price differentials without taxation functionally equivalent to (6), (9a), and (9b) 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 (4a) 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 (5) and (8a) 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. These analyses do not refer to federal taxes or deductions.

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

$$\hat{r} = \hat{r}_0 - \underbrace{\frac{1}{s_R}\frac{d\tau}{m}}_{d\hat{r}} \tag{8a}$$

$$\hat{p} = \hat{p}_0 - \underbrace{\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right)\frac{1}{s_R}\frac{d\tau}{m}}_{d\hat{p}} \tag{8b}$$

where

$$\hat{r}_0 = \frac{1}{s_R}\left(\hat{Q} + s_x\hat{A}_X + s_y\hat{A}_Y\right) \tag{9a}$$

$$\hat{p}_0 = \frac{1}{\theta_N s_R}\left[\left(\theta_N\phi_L - \theta_L\phi_N\right)\hat{Q} + \phi_L s_w\hat{A}_X - \theta_L s_w\hat{A}_Y\right] \tag{9b}$$

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. (8a) reveals how additional federal taxes are fully capitalized into land rends as $s_R \cdot m \cdot d\hat{r} = -d\tau$ which implies $drL = -Nd\tau$. (8b) reveal how taxes are capitalized into the price of home goods, depending on their land intensity. Overall, taxes lower relative land and home-good 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 assuming that home goods are just land $(\phi_L = 1,\ A_Y = 1)$, so that $p = r$. Figure 1 illustrates how taxes affect price differentials between a city with higher trade-productivity, say Chicago (labeled with "C"), and an "average" city, say Nashville,[10] with productivities $A_X^C > 1$ and $\bar{A}_X = 1$. The zero-profit conditions 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, placing its zero-profit condition to the upper-right of the Nashville's. The worker-mobility condition 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,

[10] 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.

Chicago is more crowded than Nashville and pays workers a compensating differential, $w_0^C - \bar{w}$, to compensate them 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 salary 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, $\tau' > 0$.[11] The mobility condition for workers is now in terms of the after-tax wage, $w - \tau(w)$, so that the gross wage, w, must rise more quickly to compensate for higher rents.[12] 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. Only after workers leave ($dN^C < 0$), 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 $w_0^M - \bar{w}$.

[11] 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.

[12] The slope of the indifference curve is equal to $y/(1-\tau')$.

Introducing an income tax as before, residents of Miami receive a subsidy as the earn below average wages. A worker is 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 made better off. Workers are then 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.[13]

Although the federal income tax may have many desirable properties when spatial concerns are ignored, it is curiously distributed across cities with different city characteristics. 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 because workers will be artificially attracted to cities that are nice and efficient in the home-good sector, but inefficient in the traded-good sector. There is no obvious economic rationale for why the federal government should provide these incentives.

4 Employment and Efficiency

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.

[13] The third case of a city that is more home-productive, 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.

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 as

$$d\hat{N} = \varepsilon \cdot \frac{d\tau}{m} \tag{10}$$

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, which is given and derived in Appendix A. Although a function of many parameters, this elasticity is unambiguously negative if $\phi_L/\phi_N > \theta_L/\theta_N$, and depends on three components, each with a different elasticity of substitution.

4.2 Locational Inefficiency and Deadweight Loss

Because workers move in response to federal income taxes, the resulting spatial distribution of employment becomes inefficient, or "locationally inefficient" (Wildasin 1980). In Appendix A, I derive 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.

Whatever the distribution of city characteristics, this formula conveniently captures all of the distortions in production and consumption created by unequal geographic taxation. Furthermore, as $d\hat{N}^j = \varepsilon \cdot d\tau^j/m$ the deadweight loss can be calculated using only data on the variance of income tax differentials and ε.

$$\frac{DWL}{\bar{m} \cdot N_{TOT}} = \frac{1}{2}\text{Var}\left(\frac{d\tau^j}{m}\right) \cdot \varepsilon \tag{11}$$

Since $d\tau^j/m = \tau' s_w \hat{w}^j$ the deadweight loss increases with the variance of wage differences across cities.

5 Indexation and Deductions

Since federal taxes make workers locate inefficiently, it is worth considering policies to remedy this problem. Taxes can be indexed to either local wages or local costs. In theory, indexing taxes to wages is better, but may be more difficult to implement. [14] If demand for home goods is inelastic, tax deductions for home-good expenditures will effectively index taxes partially to local costs, but at the cost of creating inefficiencies in consumption.[15]

5.1 Wage Indexation

Income taxes may be indexed to wages by dividing taxable labor income by the "pay relative" $1 + \hat{w}^j = w^j/\bar{w}$. With this indexation, a worker's federal taxes do not depend on where she lives, effectively turning the income tax into a neutral lump-sum tax.

[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).

Because workers with greater skills earn higher wages, it is important that such a wage index control for skills. Using raw wage differences across cities to index taxes could create undesirable transfers of wealth from cities with a low-skilled labor force, to cities with a high-skilled labor force. Measures of $\hat{w}^j$ must represent the causal effect of a city's characteristics on the workers wages, which face standard estimation problems as workers may sort across cities according to unobserved skills.[16] Measured wage differentials may need to account for how skills are compensated differently across cities, creating heterogeneity in wage premia across cities. (Roback 1988; Moretti 2004; Bacolod, Blum, and Strange 2007). However, as shown in Appendix D, if tastes of workers are sufficiently similar than the wage premia of different workers should be highly correlated across cities Measures of wage differentials across cities by the Bureau of Labor Statistics indicate that these do not vary tremendously by occupation (Gittleman 2005).

The BLS measures of wage differentials could easily be used to index federal taxes. These measures have advantages as they control for occupation, although they suffer from certain drawbacks: workers may still differ in unobserved skills within occupations, and may choose to work in different occupations in different cities. Workers may also gain skills, some unobserved, as a consequence of working in certain cities (Glaeser and Maré 2001) - these skills could lead to higher paying jobs and should not be controlled for.

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 should be easier to measure than the prices of homogenous units of labor. Presumably, taxes would be indexed to local costs by dividing income by an index $\kappa(p)$, resulting in taxes $\tau = \tau\left(m/\kappa\left(p\right)\right)$. Ideally the cost-of-living index would be defined as $\kappa\left(p\right) = e\left(p, \bar{u}\right)/e\left(\bar{p}, \bar{u}\right)$, where $\bar{p}$ is the average home-good price.[17]

With this indexation, the tax differential in a city increases with wages and decreases with

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

[17] If taxes are not flat, then $e(p, u)$ should change to refer to before-tax expenditures, rather than after-tax expenditures.

home-good prices according to the formula $d\tau/m = \tau'\left(s_w\hat{w} - s_y\hat{p}\right)$. The equations determining price differentials are unaffected except for the mobility condition (4a), which becomes

$$s_y\hat{p} - s_w\hat{w} = \hat{Q}/\left(1-\tau'\right) \tag{12}$$

With cost-indexed taxes workers are willing to take a larger fall in pre-tax real income to improve their quality-of-life. Substituting in $d\tau/m = \tau'\left(s_w\hat{w} - s_y\hat{p}\right)$ reveals that cost indexation causes taxes to fall sharply with quality-of-life.

$$\frac{d\tau}{m} = -\frac{\tau'}{1-\tau'}\hat{Q} \tag{13}$$

Compared with the effect of income taxation with no indexation, seen in (7), 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, $\hat{w} = \left(s_y/s_w\right)\hat{p}$. Thus, 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 declines as taxes induce workers to overcrowd nice cities.[18]

Tax differentials with cost indexation affect prices, employment, and welfare like tax differentials without indexation, except that they given by the formula (13). Equilibrium price differentials with cost-indexation are the same as the pre-tax differentials ($\hat{w}_0, \hat{r}_0, \hat{p}_0$) given in equations (6), (9a), and (9b), with $\hat{Q}$, replaced with $\hat{Q}/\left(1-\tau'\right)$. Nicer cities have even lower wages and higher land and home-good prices than before. Since, relative to un-indexed 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: this is an empirical question to be answered in Section 6.

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

Because of the problems associated with cost-of-living indexation ignoring quality-of-life differences, consider an ideal price index that 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 federal tax code confers a number of advantages to housing and goods provided by local government. Home-owners 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). Goods provided by local governments are also subsidized by the federal government, as local and state taxes can be deducted from federal taxes. Since housing and 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. Together, these advantages may be modeled 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 $\tau(m - \delta py)$. δ should be less than 1 as deductions do not apply to certain taxes (e.g. payroll), and as some 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:

$$\frac{d\tau}{m} = \tau' \cdot \left[s_w \hat{w} - \delta s_y \left(\hat{p} + \hat{y} \right) \right] \tag{14}$$

Because worker utility is constant across cities 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 $\hat{y} = \eta^c \hat{p} - \hat{Q}$. 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 $|\eta^c| < 1$. Thus the tax differential with deductions is

$$\frac{d\tau}{m} = \tau' s_w \hat{w} - \delta\tau'(1 - |\eta^c|) s_y \hat{p} + \delta\tau' s_y \hat{Q} \tag{15}$$

The full dependence on this tax differential on $\hat{A}_X$, $\hat{A}_Y$ and $\hat{Q}$ is given in Appendix A.

Besides the primary wage-tax effect already discussed, the tax differential in (15) depends on two additional effects:

Partial-Indexation Effect The 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 high-cost areas claim larger deductions, producing an implicit form of price indexation. If $\delta = 1$ and $\eta^c = 0$ this term equals $-s_y \hat{p}$, leading to 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 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]

With deductions, workers in cities with high trade-productivity or low home-productivity 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. The calibration used below suggests that taxes still fall with quality-of-life.

[19] For the reduction in home-goods consumption to be proportional to s_y, I assume no complementarities between y and Q, and that the elasticity of y to income, $\eta_{y,m}$ is equal to one. If $\eta_{y,m} \neq 1$ then the quality-of-life income effect is $Ds_y \eta_{y,m} \hat{Q}$. With complementarities between y and Q the effect is smaller.

The effect of the income tax with deductions on prices and employment in cities can be found by substituting $d\tau/m$ from (15) into the associated the associated formulas from Section 3. However, the deadweight loss formula (11) 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 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

$$\frac{1}{2}s_y\eta^c\left(\delta\tau'\right)^2 \tag{16}$$

While many have tried to justify tax subsidies for housing or local public goods, none have previously considered that these tax subsidies may help workers locate more efficiently. While it may be desirable to eliminate deductions to prevent the overconsumption of housing or local government goods, changes in locational efficiency should be taken into account when considering such a reform.

If home-mortgage deductions are capped according to local-housing prices, as proposed by the President's Advisory Panel, one of two outcomes will occur. If home-owners purchase below the cap, the effect of the deductions will not change. If home-owners purchase above the cap, the deduction will have effects more similar to direct cost-indexation. 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. They also lose 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 $k\delta$. To deal with income heterogeneity, the cap could also change with income as well as location. 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 of the model and estimating wage, price, spending, and quality-of-life differentials across metropolitan areas. The simulation can then reveal how the unequal distribution of federal taxes affects prices, employment, and welfare nationwide, and assess the benefits of indexing the tax code or eliminating tax subsidies for 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 known with some certainty; for ease round fractions are used. 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 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 at most 5 percent, while capital, θ_K, accounts for 15 percent of costs and the remaining 80 percent goes 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 15 percent, with the remaining 65 percent going to labor, ϕ_N. These cost-shares are consistent with the income and expenditure shares. Furthermore, the results are not usually sensitive to altering the shares by reasonable amounts.[21] Alternative calibrations are presented in the most sensitive

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

[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

cases .

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 more recent studies of housing demand (e.g. Goodman and Kawai 1986), the value for η^c is taken at -0.67, although it may differ slightly.

The value for ε taken is -6 based on two methods, each yielding similar estimates. The first is from direct reduced-form estimates from Bartik's (1991) meta-analysis of the effect of local taxes on local levels of output and employment, controlling for local public spending. Second, ε is inferable by directly calibrating the derived equation for employment changes, shown in Appendix B, using other parameters from the literature. Although large in an economic sense, the value of -6 is in the conservative range using 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 dividing 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 produces conservative estimates.

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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 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 on housing-price differentials, as these are the prime determinant of cost-of-living differences (Shapiro 2006). Cities are defined at the Metropolitan Statistical Area (MSA) level using 1990 OMB definitions, extended using constant-geography definitions by Deaton and Lubotsky (2003), and 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.

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, 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, and are interpreted as the causal effect of city characteristics on a worker's wage. Identifying these differentials correctly raises the same problems mentioned in Section 5.1. It is important that workers do not sort across cities according to their unobserved skills. This assumption may not hold completely: Glaeser and Maré (2001) argue that up to one third of the urban-rural wage gap could be due to selection, suggesting that at least two thirds of wage differentials 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.[22]

[22] There are 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 complications, so long as each is weighted by their share of income (which is done, although it has little impact on the estimates). Furthermore, many workers report receiving little income other than labor income. However, given the static nature of the model, a worker's choices should be

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 acquired 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 - interacted with tenure - for size, rooms, acreage, commercial use, kitchen and plumbing facilities, type and age of building, and the number of residents per room. Proper identification of housing rent differences requires that average unobserved housing quality does not vary systematically across cities.[23]

As seen in equations (14) and (15), 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 (4a) given in Appendix equation (A.18).

Table 1 presents the wage, housing-price, quality-of-life, and federal-spending differentials for selected MSAs, Census regions, and MSA sizes in 2000. Figure 3 graphs wage differentials against housing-price differentials, marking cities with circles, increasing in population size, and non-metro parts of states 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 the West. Overall, wages and housing prices exhibit a strong positive correlation, with a regression line, weighted by employment, having a positive slope near one-half. The quality-of-life calculation can be seen using the marked indifference curve, calculated for an average quality-of-life city. $\hat{Q}$ in a particular city depends on how far its marker is to the lower-right perpendicularly of this curve; cities to the upper-left have below-average quality-of-life. Also shown is an iso-cost curve through an average city, where $\hat{A}_X^j = \hat{A}_Y^j = 0$.[24]

In order to investigate federal spending differentials, spending amounts across MSAs are calculated using data from the Consolidated Federal Funds Report (CFFR), available from the U.S.

modeled to account for a worker's permanent income, which includes a large non-labor component, particularly if implicit rental earnings from one's own home are included.

[23]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 simulation is not affected significantly if wage and price differentials are estimated using only home-owners or only renters.

[24]The slopes of an indifference curve, holding quality-of-life constant, and an isocost curve, holding productivity

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, they should not be considered transfers.[25] The second category includes spending, such as Social Security and Medicare, which benefits individuals who are typically inactive in the labor market, including retirees and full-time students. The remaining category of "other" spending reflects spending which is likely to be location-specific and which may 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 minority, to provide a spending differential applicable to a representative worker.

6.3 The Effect of Federal Taxes Across Cities

Using the base calibration and estimates of $\hat{w}$, $\hat{p}$, and $\hat{Q}$ for 2000, Table 2 reports estimates of tax differentials and its effects across twenty notable cities with very large and small burdens. Average estimates are also given according to region and to city size. The three components of the tax differentials from (15) are shown in the first three columns, with the total in the fourth column. A kernel density of the total tax differentials is shown in Figure 4. The fifth column displays tax differentials net of federal-spending differences.

The total amount of differential taxation is substantial: the mean absolute deviation of tax differentials equals 2.6 percent of all income. Using an average federal tax rate of 17 percent, this implies that a worker moving from a low-wage city to a high-wage city will pay 30 percent more

constant, are given by

$$\left(\frac{\hat{w}}{\hat{p}}\right)_{\hat{Q}=0} = \frac{s_y}{s_w}\frac{1-\delta\tau'\left(1-|\eta^c|\right)}{1-\tau'}$$

$$\left(\frac{\hat{w}}{\hat{p}}\right)_{\hat{A}^X=\hat{A}_Y=0} = -\frac{\theta_L}{\theta_N\phi_L-\theta_L\phi_N}$$

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

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.[26] Federal tax burdens are greatest 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.

Deductions plays an interesting role in changing the tax differentials. The partial-indexation effect tends to lower taxes in high wage areas, while the quality-of-life effect tends to diminish the partial indexation effect. Figure 4 shows how eliminating the deduction would change the distribution of federal taxes across cities, increasing the tax differential gradient by 12 percent. Thus, without the deduction, the average tax differential would be 0.3 percent wider, making the distribution of federal taxes even more unequal.[27]

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 calamity. Yet, the federal government is imposing this situation on cities like Chicago, New York and San Francisco. On the other hand, an unconditional grant of two percent of income would dwarf any pork-barrel project: in relative terms this is what workers in cities like Little Rock and San Antonio, as well as most non-metropolitan areas, effectively receive from the federal government.

Because the tax differentials are large, the effect of taxes on prices and employment, seen in the last four columns Table 2, are considerable. Taking New York as an example, federal taxes 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 than in an undistorted equilibrium. This effect may seem too large, but it may be reasonable in the long run, as sizable federal taxes first affected average workers in World War II. The rise of the income tax is certainly consistent with the migration of people and jobs over the last sixty years from the

[26] The average federal tax rate of 17 percent takes into account federal income taxes and payroll taxes, appropriately adjusted (Congressional Budget Office 2003). The $300 billion transfer 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 of about $200 billion.

[27] Since the existing tax system 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.

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 3. The economic and tax parameters of these calibrations are displayed in the first panel, followed by the mean absolute deviations in outcomes, and the deadweight loss of taxation throughout the economy. All effects are averaged using the total population size 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 city differences. These taxes affect relative land rents by 26 percent and housing prices by 4.1 percent. The average wage effect is only 1.6 percent, although the employment effect is quite large at 15 percent. This creates a substantial deadweight loss of about 0.28 percent of GDP a year, or $34 billion in 2005. As these numbers are based on a calibrated model, they should not be taken as absolute truth, but they do provide a sense of the magnitude of the impacts and costs caused by the uneven distribution of federal taxes. It should be kept in mind that parameters in the model are chosen to make these estimated effects relatively conservative.[28]

Alternative calibrations in Table 3 are shown in columns to the right. In column 2, all land is devoted 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 affected more. In column 3, the cost shares of land in both sectors are reduced by one-half, with mobile capital taking up the remaining costs; here the impact on land prices double, while no other quantities change.

Column 4 shows that if ε is -9.97, which corresponds to when production and utility are Cobb-Douglas, the employment effects and deadweight loss are increased proportionally. Column 5 shows that if η^c is only -0.33, then tax differentials are reduced, as the partial-indexation effect from the home-good deduction is stronger. Column 6 cuts wage differentials down to two-thirds their original size, in case unobserved selection makes the estimated differentials too large: this

[28] 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 ε and the most basic of economic incidence models.

lowers the differential taxes, price and employment effects by a third and deadweight-loss by five-ninths. Column 7 reveals that if the deduction is ignored, measured tax differentials are larger.

6.4 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 4 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. Figure 5, which graphs "other spending" differentials against tax differentials, makes it clear that federal spending does not offset differences in federal taxation. Although the federal government makes greater purchases in areas with higher wages, this arises from its need to purchase skilled labor. Column 8 of Table 3 simulates the effects of tax differentials net of spending: these differentials have slightly larger variance.

6.5 Simulating Tax Reform

Although simple, this model provides some insight into the 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 5. 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 (11), and consumption inefficiency from the overconsumption of home goods from (16).[29] All reforms are based on the benchmark calibration. Column 1 shows the existing situation, modeled in Column 1 of Table 3. 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. 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 leads to a net welfare gain of $22 billion. Raising the deduction in column 3 has opposite effects.

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.[30] 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.

The best reform would eliminate both consumption and locational inefficiencies. This would eliminate the tax advantages for housing and local public goods, unless some other reason is found for preserving them, while indexing taxes to wages or local quality-of-life adjusted costs. The President's Advisory Panel recommendation of including some kind of cost-indexation through deduction caps is a move in this direction. However it falls short as most renters and many home-

[29]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, which is a plausible value (Green, Malpezzi, Mayo 2005).

[30]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.

owners do not benefit from these deductions, and the cap does not adjust for quality-of-life.

7 Extensions

Since the model makes strong assumptions for analytical tractability, it is worth considering how its predictions are altered when its assumptions are changed. One assumption is that people own a diversified portfolio of land and capital, when actually people typically own land and housing where they live. Without this assumption, increases in the federal income tax rate will benefit property owners in low-wage cities and hurt those in high-wage cities. Utilities will cease to be equal across workers, but this will not change the resulting equilibrium if preferences are homothetic.

Property owners are assumed to supply a fixed amount of land; workers, a fixed amount of labor. Relaxing these assumptions has no effect on equations (4a), (4b), and (4c), determining price differentials across cities – a result of duality theory. These assumptions do affect quantities in the model: variable supply of either land or labor increases the responsiveness of employment to taxes given in ε, as seen in Appendix equation (D.1). Since the calibration already relies on a direct estimate of ε, these types of deviations are accounted for in the simulation.

In equilibrium, the supply of home goods should adjust so that its price equals its unit cost. As home goods consist mainly of durable housing, supply could take time to adjust to this equilibrium in response to a tax change. In the short-run, the housing supply is relatively fixed. A way to model this is to augment the definition of "land" to include the housing stock, and to increase the effective cost shares ϕ_L and θ_L. In this short-run, housing-price changes are larger and employment changes smaller than in the long run.

Another challengeable assumption is that workers are fully mobile. Appendix D.2 considers the case when otherwise identical workers have heterogeneous tastes for living in their city - which can be related to moving costs - with greater heterogeneity resulting in lower mobility. When taxes are raised on workers in a city, "marginal" workers, with weaker tastes leave, while "inframarginal" workers, with stronger tastes, stay. In equilibrium, taxes are only partially capitalized into land rents, wages and home-good prices, with the fraction of capitalization decreasing in the amount of heterogeneity in tastes. In high-wage cities, high federal taxes fall partly on land and partly on the workers who stay, as their real after-tax incomes fall, diminishing their relative welfare. Similarly, workers who prefer low-wage cities see their after-tax incomes rise, and are made better off.

Workers can differ substantially in skills, endowments, and tastes for consumption. A model with two mobile worker types is considered in Appendix D.3. Aggregating multiple worker types does not substantially alter overall price effects, but it does change some quantity effects. Some qualitative conclusions also be drawn about welfare effects. First, workers who are more sensitive to quality-of-life differences will sort disproportionately into nicer cities: by sorting into these areas and taking low wages, these types pay relatively few taxes. Workers who receive a large share of income from non-labor sources also tend to pay fewer taxes as they are prone to live in low-wage cities that are nicer or home-productive. The relative tax burden of workers with a strong taste for home goods is not well determined as these workers tend to avoid both nicer and trade-productive cities in favor of home-productive cities; their relative burden depends on the distribution of city characteristics.

The spatial decisions of heterogenous workers cause them to be taxed differently according to their tastes and endowments. Efficiency or equity considerations might justify these tax differences if living in nicer or less trade-productive areas is complementary to work, or is associated with having low skills (Atkinson and Stiglitz, 1976; Saez 2003), however neither case is obvious. Nor is it apparent that individuals who receive a larger share of income from non-labor sources should be taxed less.

Workers with different skills and incomes often face different marginal tax rates. Although income tax rates rise with income, unskilled workers with families may face effective marginal tax rates as high as 90 percent because of the earned income tax credit and means-tested welfare programs, such as Medicaid (Blundell and MaCurdy 1999). As a result unskilled workers may have a greater incentive to leave high-wage areas than skilled workers, which could cause a shortage of low-skilled workers in high-wage cities.

Unskilled workers are also generally less mobile than skilled workers (Bound and Holzer 2000). As seen in Appendix D.4, in cities where high-wage workers are highly taxed, immobile workers are likely to be made worse off. When mobile workers leave, immobile workers' wages typically fall, although so do home-good prices. It is possible for the real incomes of immobile workers to rise if mobile and immobile workers are sufficiently substitutable in production. However, if these workers are highly substitutable, immobile workers' wages will be high where mobile workers' wages are high, meaning that they too will pay higher federal taxes. Since these taxes are only partly capitalized into home-good prices, immobile workers are likely worse off in high-wage areas.

Another simplification 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.[31] For example, if firms in Detroit exclusively provide cars to the rest of the country, they may be able to raise the price of cars 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, city characteristic may not be fully exogenous to federal taxes. Because of agglomeration economies, productivity in goods, especially traded goods, may increase with city size, a case explored in Appendix D.5. As federal taxes induce workers to leave high wage cities in large numbers, this exodus could decrease productivity. If productivity falls sufficiently in response to lost workers, then high federal taxes may cause wages in high-wage cities to fall, rather than rise, although they cause land rents and housing prices to decrease by even more than predicted.[32]

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

[32] 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 hinder cities from attaining their optimal size.

8 Conclusion

Federal taxes are distributed unequally across similar workers who work in different cities: because wages depend on where worker lives, so do federal tax burdens. This unequal geographic tax burden appears to have serious consequences for local prices, employment, and welfare. Politicians from cities offering higher nominal wages have reason to complain that their constituents pay a disproportionate share of federal taxes, and to endorse a tax-indexation scheme to equalize geographic tax burdens, 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, does justify additional research and data-collection to better understand and possibly 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 justification, although it suffers from many of the same shortcomings that cost-of-living indexation does. Furthermore, it does little to help those who do not itemize their deductions.

In most countries, reforms to make the federal tax more efficient and equitable across areas would likely meet fierce opposition. In the United States, highly taxed areas tend to be in large cities inside of large states, which have relatively low Senate representation and later presidential primaries, making the prospect of reform daunting. Nevertheless, even when considering smaller federal tax reforms, policy-makers should be aware of the spatial consequences of these reforms on local prices, employment, and welfare.

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TABLE 1: WAGE, HOUSING PRICE AND FEDERAL SPENDING DIFFERENTIALS,

		Adjusted Differentials			
	Population Size	Wages	Housing Prices	Quality-of Life	Federal Spending
Main city in MSA/CMSA					
San Francisco, CA	7,051,730	0.25	0.15	0.83	-0.002
New York, NY	19,875,235	0.21	0.05	0.47	-0.004
Washington, DC	4,896,958	0.16	0.00	0.26	0.014
Boston, MA	3,250,846	0.14	0.09	0.47	0.005
Detroit, MI	4,910,231	0.13	-0.02	0.14	-0.004
Chicago, IL	9,080,658	0.13	0.02	0.26	-0.003
Los Angeles, CA	16,517,899	0.12	0.09	0.45	0.003
Philadelphia, PA	6,181,697	0.11	-0.03	0.08	0.006
Seattle, WA	3,038,785	0.08	0.08	0.36	-0.012
Atlanta, GA	3,258,673	0.07	-0.03	0.03	-0.013
Tulsa, OK	1,121,973	-0.14	-0.03	-0.31	-0.026
Oklahoma City, OK	1,157,773	-0.15	-0.03	-0.30	-0.002
Knoxville, TN	804,491	-0.15	0.00	-0.24	-0.007
Columbus, GA	875,236	-0.15	-0.06	-0.41	-0.007
Huntington, WV	520,250	-0.17	-0.10	-0.56	0.004
Steubenville, OH	575,016	-0.17	-0.06	-0.44	0.001
El Paso, TX	676,220	-0.18	-0.03	-0.37	-0.001
Johnson City, TN	985,334	-0.22	-0.04	-0.47	-0.010
McAllen, TX	565,800	-0.23	-0.10	-0.63	-0.008
Springfield, MO	659,672	-0.24	0.00	-0.37	-0.005
Region					
Northeast	54,096,432	0.07	0.13	0.01	0.000
Midwest	64,356,624	-0.04	-0.14	-0.03	-0.001
South	99,751,674	-0.07	-0.17	-0.02	-0.001
West	63,217,176	0.04	0.30	0.08	0.001
MSA Population					
Non-MSA	47,660,820	-0.15	-0.31	-0.03	0.005
MSA, pop<500,000	37,714,735	-0.11	-0.21	-0.01	-0.001
MSA, pop>500,000	60,462,698	-0.05	-0.12	-0.02	-0.002
MSA, pop>1,500,000	71,540,847	0.04	0.09	0.01	-0.001
MSA, pop>5,000,000	64,042,806	0.16	0.40	0.05	-0.002
United States	281,421,906	0.13	0.33	0.06	0.011
	total	*standard deviations*			

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. Quality-of-life calculated according to equation (A.18) from price and wage differentials. 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.

TABLE 2: TAX DIFFERENTIALS ACROSS CITIES AND THEIR EFFECTS ON PRICES AND EMPLOYMENT, 2000

Tax Pay-ment Rank			Deduction Effects				Tax Differential Effects			
		Wage Effect	Partial Indexation	QOL Income	Total Tax Differential	Tax Diff, Net of Spending	Wages	Housing Price	Land Rent	Employ-ment
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Main city in MSA/CMSA									
1	San Francisco, CA	0.064	-0.013	0.008	0.058	0.060	0.036	-0.093	-0.582	-0.349
2	New York, NY	0.053	-0.008	0.003	0.048	0.052	0.030	-0.077	-0.483	-0.290
3	Washington, DC	0.042	-0.004	0.000	0.038	0.023	0.023	-0.060	-0.375	-0.225
4	Boston, MA	0.035	-0.008	0.005	0.032	0.028	0.020	-0.051	-0.323	-0.194
5	Detroit, MI	0.033	-0.002	-0.001	0.030	0.034	0.019	-0.047	-0.296	-0.178
6	Chicago, IL	0.032	-0.004	0.001	0.029	0.032	0.018	-0.047	-0.293	-0.176
7	Los Angeles, CA	0.030	-0.007	0.005	0.028	0.025	0.017	-0.044	-0.278	-0.167
8	Philadelphia, PA	0.029	-0.001	-0.002	0.026	0.021	0.016	-0.042	-0.264	-0.158
9	Seattle, WA	0.021	-0.006	0.004	0.020	0.032	0.012	-0.032	-0.198	-0.119
10	Atlanta, GA	0.018	0.000	-0.001	0.016	0.029	0.010	-0.026	-0.162	-0.097
197	Tulsa, OK	-0.035	0.005	-0.002	-0.032	-0.006	-0.020	0.051	0.320	0.192
213	Oklahoma City, OK	-0.038	0.005	-0.001	-0.034	-0.033	-0.022	0.055	0.345	0.207
214	Knoxville, TN	-0.038	0.004	0.000	-0.035	-0.028	-0.022	0.055	0.345	0.207
223	Columbus, GA	-0.040	0.007	-0.003	-0.036	-0.030	-0.023	0.058	0.363	0.218
239	Huntington, WV	-0.043	0.009	-0.005	-0.039	-0.043	-0.025	0.063	0.395	0.237
242	Steubenville, OH	-0.044	0.007	-0.003	-0.040	-0.041	-0.025	0.063	0.398	0.239
244	El Paso, TX	-0.045	0.006	-0.002	-0.041	-0.040	-0.026	0.066	0.411	0.247
270	Johnson City, TN	-0.056	0.008	-0.002	-0.051	-0.041	-0.032	0.081	0.511	0.307
274	McAllen, TX	-0.058	0.010	-0.005	-0.053	-0.045	-0.033	0.085	0.531	0.319
283	Springfield, MO	-0.063	0.006	0.000	-0.057	-0.052	-0.035	0.090	0.566	0.340
	Region									
1	Northeast	0.018	-0.002	0.000	0.016	0.016	0.010	-0.025	-0.159	-0.096
3	Midwest	-0.010	0.002	-0.001	-0.009	-0.009	-0.006	0.015	0.093	0.056
4	South	-0.017	0.003	-0.001	-0.015	-0.014	-0.010	0.025	0.155	0.093
2	West	0.011	-0.005	0.004	0.011	0.010	0.007	-0.017	-0.108	-0.065
	MSA Population									
5	Non-MSA	-0.039	0.005	-0.001	-0.035	-0.040	-0.022	0.056	0.353	0.212
4	MSA, pop<500,000	-0.029	0.003	-0.001	-0.027	-0.025	-0.017	0.042	0.266	0.159
3	MSA, pop>500,000	-0.012	0.002	-0.001	-0.011	-0.009	-0.007	0.018	0.113	0.068
2	MSA, pop>1,500,000	0.010	-0.001	0.001	0.009	0.010	0.006	-0.014	-0.090	-0.054
1	MSA, pop>5,000,000	0.040	-0.006	0.003	0.037	0.039	0.023	-0.058	-0.366	-0.220
	United States (std dev)	0.033	0.005	0.003	0.030	0.033	0.019	0.048	0.303	0.182
	United States (mean abs dev)	0.282	0.004	0.003	0.026	0.028	0.016	0.041	0.256	0.154

Tax differentials calculated using equation (16) with and without deduction. Tax effects calculated using tax differential with deduction and equations (5), (8a), (8b), and (10).Calibrated effects from benchmark calibration in column 1 of Table 3.

TABLE 3: ESTIMATED EFFECTS OF TAX DIFFERENTIALS ACROSS ALL CITIES FOR DIFFERENT CALIBRATIONS, 2000

	Benchmark case	Smaller θ_L Larger ϕ_L	Smaller s_R	Larger ε (Cobb-Douglas)	Smaller η^c	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: $E\|d\tau/m\|$	**0.026**	0.026	0.026	0.026	**0.021**	**0.017**	**0.028**	**0.027**
Wage effect: $E\|dw\|$	**0.016**	**0.000**	0.016	0.016	0.013	0.106	0.018	0.017
Home-good price effect: $E\|dp\|$	**0.041**	**0.077**	0.041	0.041	0.341	0.027	0.045	0.044
Land rent effect: $E\|dr\|$	**0.255**	0.255	**0.510**	0.255	0.214	0.170	0.282	0.275
Employment effect: $E\|dN\|$	**0.153**	0.153	0.153	**0.254**	0.129	0.102	0.170	0.165
Deadweight Loss (from employment only)								
As a percent of income, E(DWL/Nm)	**0.276%**	0.276%	0.276%	**0.455%**	**0.193%**	**0.122%**	**0.335%**	**0.328%**
Total DWL (Billions per year, 2005\$)	34.3	34.3	34.3	56.4	23.9	15.1	41.5	40.6
Per Capita (per year, 2005\$)	118.2	118.2	118.2	194.3	82.5	52.1	143.1	140.2

DWL estimated from equation (11). 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 4: 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)

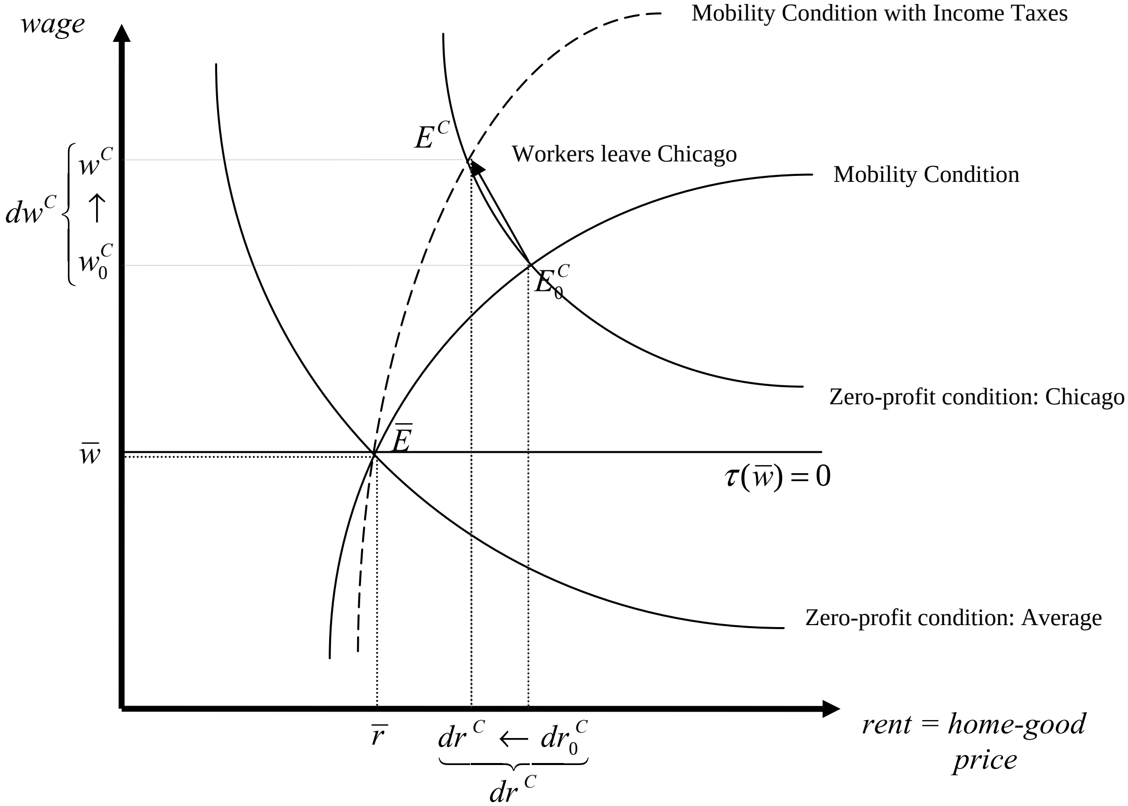
Regressions weighted by MSA population for all 295 observations. Robust standard errors reported. Definitions of federal spending variables are discussed in the main text and in Appendix C.

TABLE 5: 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	0.025	0.000	0.004	0.154
Wage effect: $E\|dw\|$	0.016	0.018	0.012	0.016	0.000	0.002	0.010
Home-good price effect: $E\|dp\|$	0.041	0.046	0.034	0.040	0.000	0.006	0.025
Land rent effect: $E\|dr\|$	0.256	0.287	0.211	0.251	0.000	0.037	0.155
Employment effect: $E\|dN\|$	0.154	0.172	0.126	0.150	0.000	0.022	0.093
DWL from Locational Ineffciency							
Percent of GDP	0.276%	0.310%	0.227%	0.217%	0.000%	0.040%	0.147%
DWL (Billions $2005)	34.3	38.4	28.2	26.9	0.0	4.9	18.3
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	0.488%	0.310%	1.421%	0.217%	0.000%	0.251%	0.359%
DWL (Billions $2005)	60.5	38.4	176.2	26.9	0.0	31.2	44.5

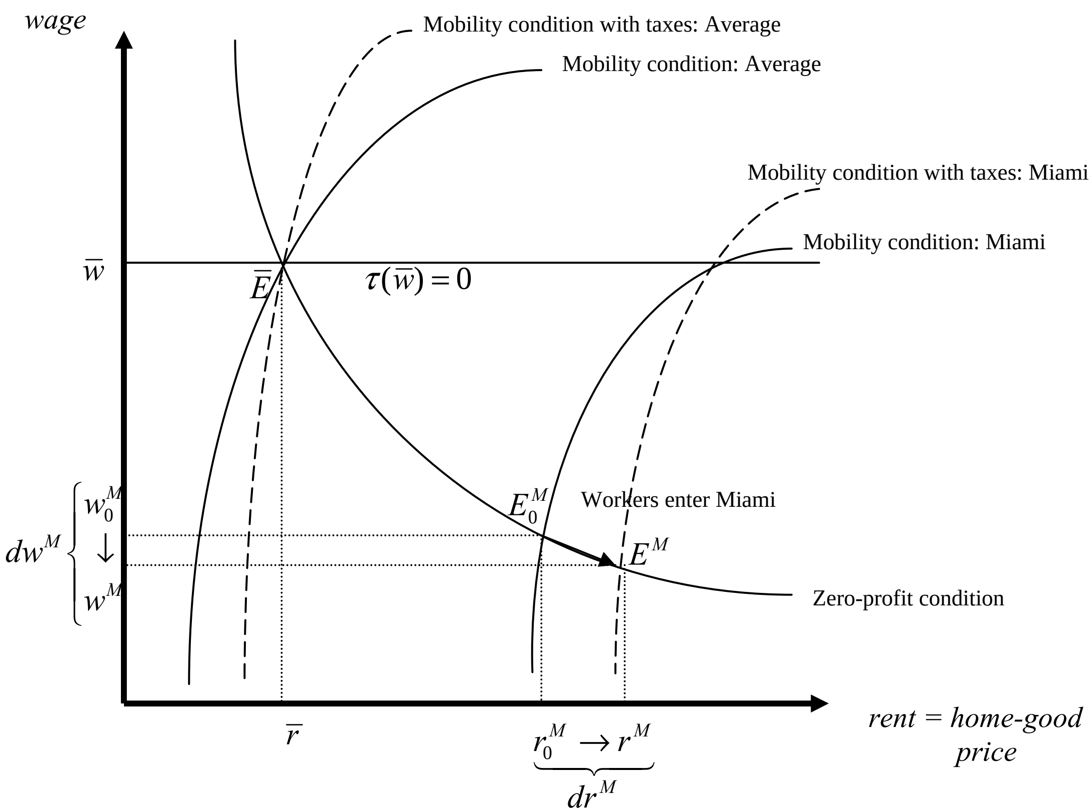
Reforms are based on the economic parameters used in the main calibration. DWL from home-good overconsumption given by equation (16) in the text, adjusted down by 10 percent because of supply considerations. Baseline price and amenity differentials are estimated using the base calibration, with the original tax parameters; these differentials are then recalculated to account for the tax reform.

Figure 1: Effect of Income Taxes on a Productive City (Chicago)



In a simplified model ($r = p$, $Q = 1$, $A_Y = 1$), Federal income taxes (τ) raise wages (w) and lower rents (r) and employment (N) in Chicago, (labeled "C") with high trade-productivity (A_X), as taxes change the equilibrium from E_0^C to E^C.

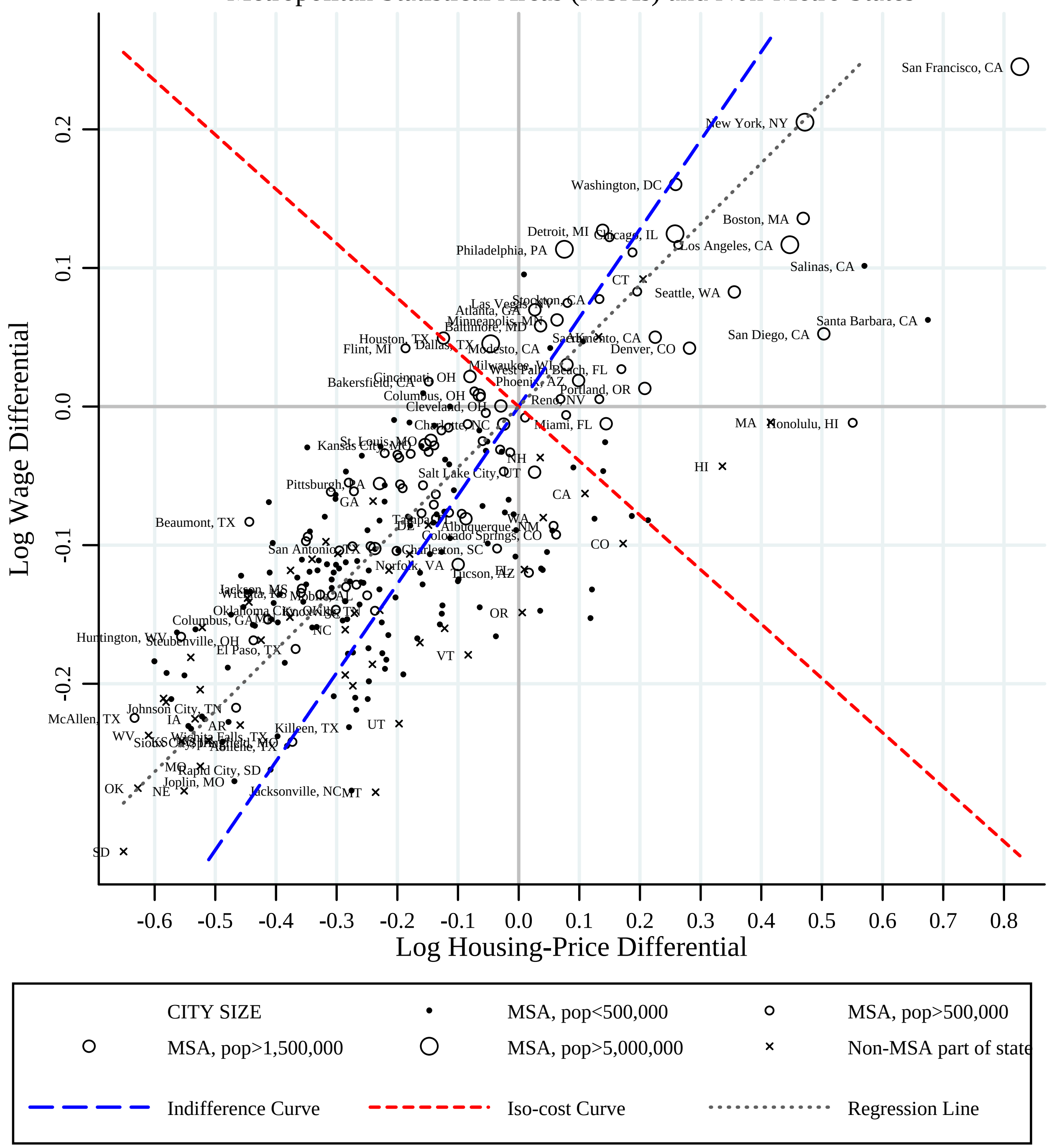
Figure 2: Effect of Income Taxes on a Nicer City (Miami)



In a simplified model ($r = p$, $A_X = 1$, $A_Y = 1$), Federal income taxes (τ) raise wages (w), rents (r), and employment (N) in Miami, a nice city (labeled "M"), as taxes change the equilibrium from E_0^M to E^M.

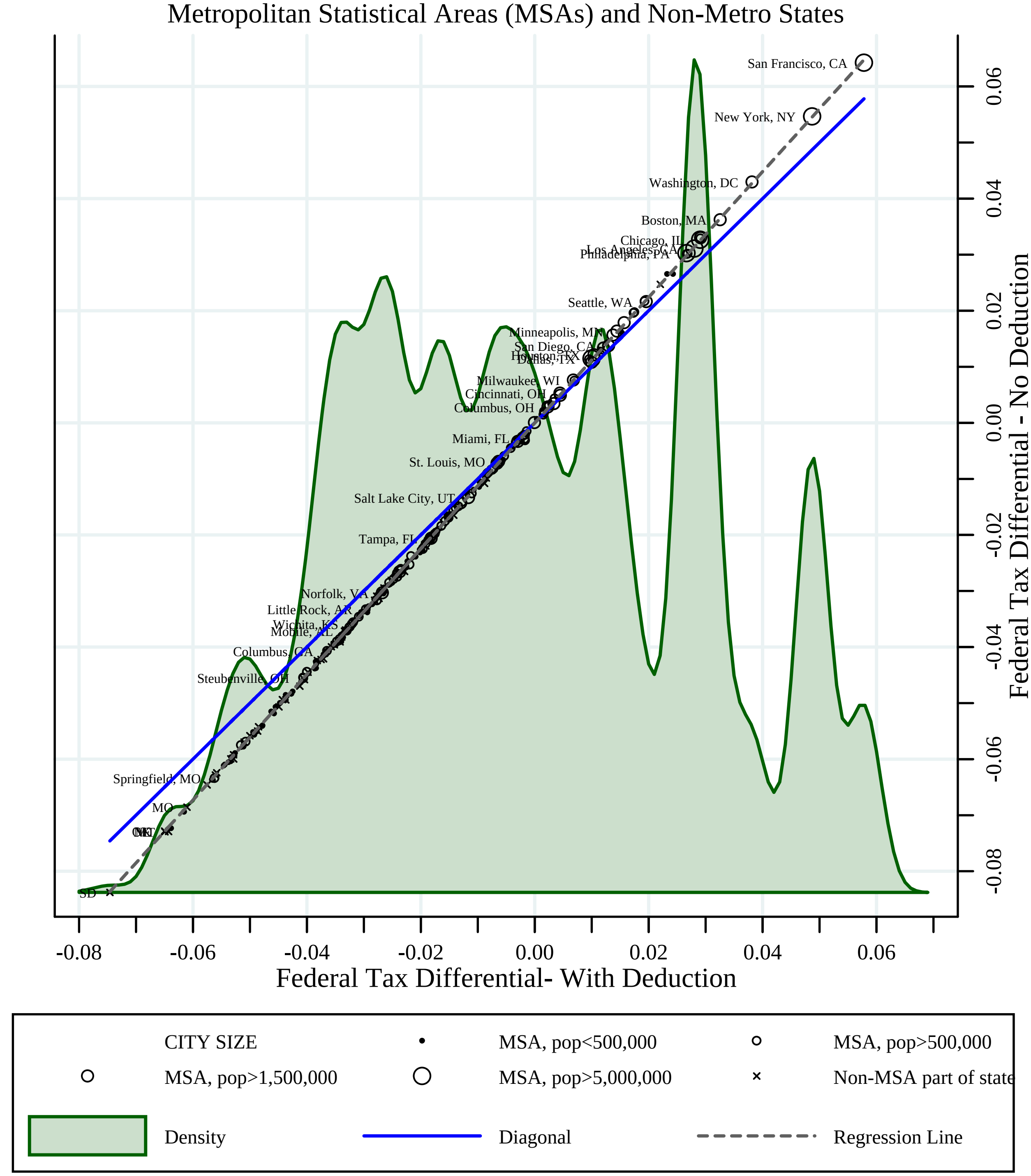
Figure 3: Wages versus Housing Prices, 2000

Metropolitan Statistical Areas (MSAs) and Non-Metro States



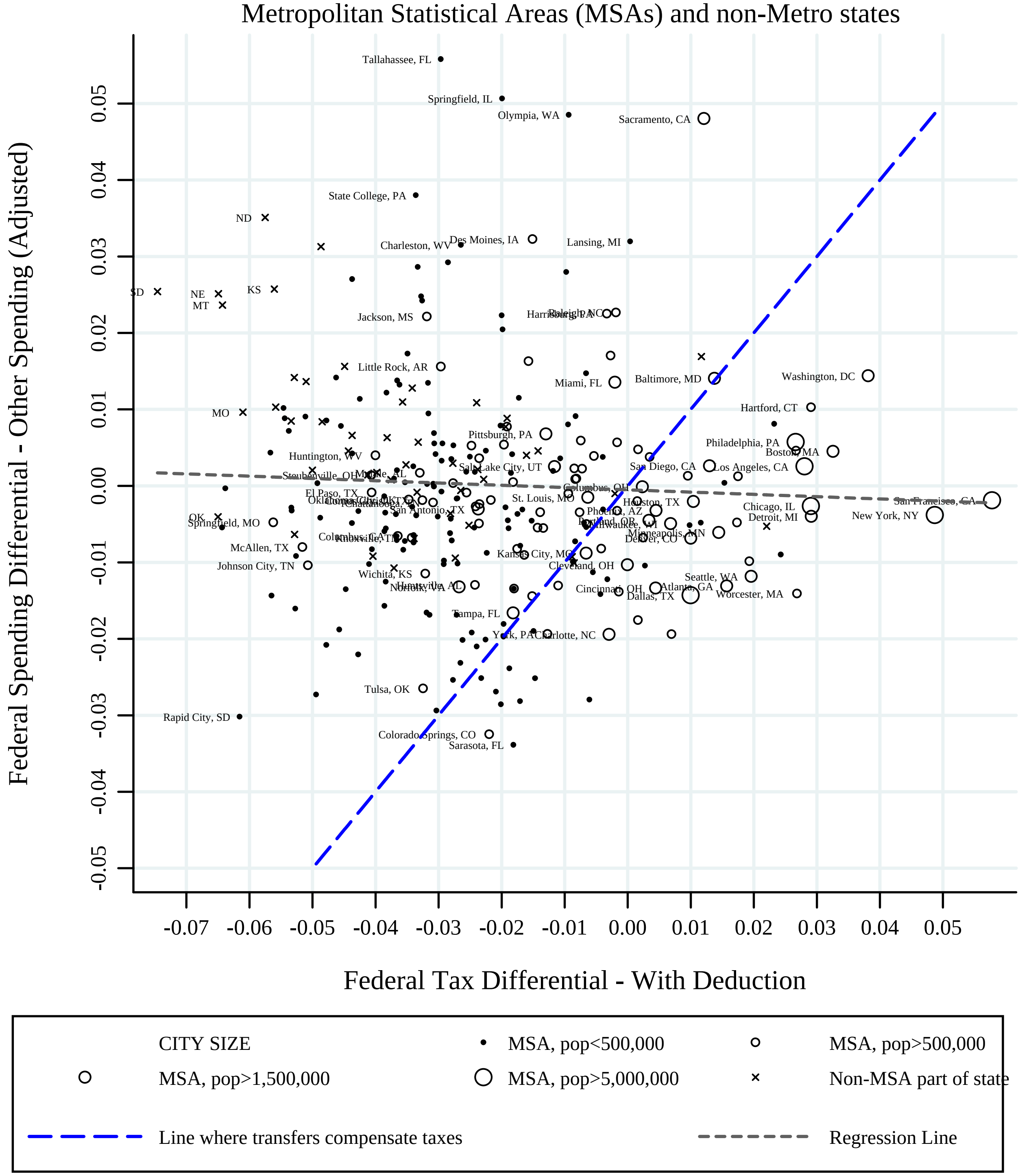
Mean log wage (for full-time workers) and housing-price (for home-owners and renters) residuals from regressions described in Appendix C.
According to the model, cities above the iso-cost curve (for an average city) have above-average trade productivity, or below-average home-productivity.
Cities to the right of the indifference curve (for an average city) have above average quality-of-life The indifference and iso-cost curves are derived from the main calibration, seen in column 1 of Table 3
At zero, slope of indifference curve = 0.64 slope of iso-cost curve = -0-.39
Regression line from regression of rent residual on wage residual, slope = 0.44 (s.e. 0.01)

Figure 4: Differential Tax Burden With and Without Deduction



Differential federal tax with deduction estimated directly off data using equation (16) while tax deduction with no deduction estimated off of inferred counterfactual wage using equation (5). Each is expressed as a fraction of total income. 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 5: Differential Federal Taxes and Transfers, 2000



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 population characteristics. Taxes compenate transfers line shows where spending differential equals tax differential. Spending differentials for MSA's containing state capitals may be over-estimates. Regression line has slope -.03 (s.e. .021).

Appendix

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, where T is a city-specific head-tax. The first three equations (1), with an added T on the right-hand side, (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 simple head-taxes are modeled for brevity.

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, and the notation

$d\hat{w} = dw/w$:

$$s_w d\hat{w} - s_y d\hat{p} = dT/m \tag{A.8a}$$
$$\theta_L d\hat{r} + \theta_N d\hat{w} = 0 \tag{A.8b}$$
$$\phi_L d\hat{r} + \phi_N d\hat{w} - d\hat{p} = 0 \tag{A.8c}$$

omitting superscript j. According to (A.8a), 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 (A.8b) and (A.8c) demonstrate how wage and rent changes must offset to keep unit costs equal to prices.[33]

The percent price changes may be solved for using Cramer's Rule and the accounting identities. Land rents decrease in proportion to taxes according to:

$$d\hat{r} = -\frac{1}{s_R}\frac{dT}{m} \tag{A.9}$$

As $s_R = rL/Nm$, (A.9) 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

$$d\hat{w} = \frac{\theta_L}{\theta_N}\frac{1}{s_R}\frac{dT}{m} \tag{A.10}$$

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

$$d\hat{p} = -\left(\phi_L - \phi_N\frac{\theta_L}{\theta_N}\right)\frac{1}{s_R}\frac{dT}{m} \tag{A.11}$$

is negative if home goods are more cost intensive in land relative to labor than traded goods ($\phi_L/\phi_N > \theta_L/\theta_N$) 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, ($\phi_L < 1$) then the home-good price falls by less than the rent for land ($d\hat{p}/d\hat{r} < 1$). It is also straightforward to show that housing prices fall more than wages rise ($-d\hat{p}/d\hat{w} > 1$).

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

[33] 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.

A.2.1 Consumption

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

$$s_x d\hat{x} + s_y \left(d\hat{p} + d\hat{y}\right) = s_w d\hat{w} - \frac{dT}{m} \tag{A.12}$$

$$d\hat{x} - d\hat{y} = \sigma_D d\hat{p} \tag{A.13}$$

Subtracting (A.8a) from (A.12) and substituting in (A.13) and (A.11) yields

$$d\hat{y} = -s_x^* \sigma_D d\hat{p} = -s_x^* \sigma_D \frac{1}{s_R}\left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right)\frac{dT}{m} \tag{A.14}$$

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

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

$$d\hat{N}_X = d\hat{X} + \theta_L \sigma_X^{LN}\left(d\hat{r} - d\hat{w}\right) + \theta_K \sigma_X^{NK}\left(d\hat{\imath} - d\hat{w}\right) \tag{A.15}$$

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 (A.9), (A.10), (A.14) 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. If partial elasticities within sectors are equal, $\sigma_Y^{NL} = \sigma_Y^{LK} = \sigma_Y^{NK} = \sigma_Y$, as in CES production, the solution for $d\hat{N}/dT$ gives the elasticity of employment to local taxes

$$\varepsilon = -\frac{1}{(\theta_N s_R)^2}\{(s_x + s_T)\theta_L\theta_N\left(\theta_L + \theta_N\right)\sigma_X + \frac{s_x s_y}{s_x + s_y}\left(\theta_N\phi_L - \theta_L\phi_N\right)^2\sigma_D + s_y[\phi_L\phi_N\left(\theta_L + \theta_N\right)^2 + \phi_K\left(\phi_N\theta_L^2 + \theta_N^2\phi_L\right)]\sigma_Y\} \tag{A.16}$$

Because of free mobility, workers require a higher wage or a lower home-good price 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 as land rents fall through supply.

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 $G^j = \left(\tau m^j + T\right)N^j = \tau\left(w^j - \bar{w}\right)N^j$, 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 (5) and (10) 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 an approximation around the average share values, ε, and m^j, and using $E\left[\hat{w}^j\right] = 0$,

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

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 (11).

A.4 Housing Deduction

Incorporating the home goods deduction requires amending some of the results above. As the income tax is now $\tau = \tau\left(m - \delta py\right)$, the mobility condition (4a) and the log-linearized budget constraint (A.12) change to

$$\hat{Q} = (1 + \delta\tau')\, s_y \hat{p} - \delta\tau' s_y \hat{y} - (1 - \tau')\, s_w \hat{w} \tag{A.17}$$
$$s_x \hat{x} = -\,(1 - \delta\tau')\, s_y \hat{p} - (1 - \delta\tau')\, s_y \hat{y} + (1 - \tau')\, s_w \hat{w}$$

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 $\eta^c = -s_x^* \sigma_D$, we have

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

This expression is used in (15), although s_T is set to zero there for expositional ease. Substituting back into (A.17) and using $s_y^* \equiv s_y/(s_x + s_y)$

$$\left(1 - \delta\tau' s_y^*\right) \hat{Q} = \left[1 - \delta\tau' \left(1 + \eta^c\right)\right] s_y \hat{p} - (1 - \tau')\, s_w \hat{w} \tag{A.18}$$

Solving completely with (4b) and (4c)

$$\frac{d\tau}{m} = \tau' \frac{\left[1 - \delta(1+\eta^c)\right] \frac{s_y}{s_R} \left(\frac{s_w \phi_L}{\theta_N} \hat{A}^X - \frac{s_w \theta_L}{\theta_N} \hat{A}^Y\right) + \left\{ s_y \delta \left[1 - (1+\eta^c) \frac{1}{s_R} \left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right)\right] - \frac{\theta_L}{\theta_N} \frac{s_w}{s_R} \right\} \hat{Q}}{1 - \tau' \frac{\theta_L}{\theta_N} \frac{s_w}{s_R} - \delta\tau' (1 - |\eta^c|) \frac{s_y}{s_R} \left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right)} \tag{A.19}$$

which can also be re-expressed in terms of the the pre-tax differentials, $\hat{w}_0$, and $\hat{p}_0$, seen in (6) and (9b)

$$\frac{d\tau}{m} = \frac{\tau' s_w \hat{w}_0 - \delta\tau' \left(1 - |\eta^c|\right) s_y \hat{p}_0 + \delta\tau' s_y \hat{Q}}{1 - \tau' \frac{\theta_L}{\theta_N} \frac{s_w}{s_R} - \delta\tau' \left(1 - |\eta^c|\right) \frac{s_y}{s_R} \left(\phi_L - \phi_N \frac{\theta_L}{\theta_N}\right)} \tag{A.20}$$

The term in the denominator of (A.20) 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.

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 for the income derived from land. This is consistent with Keiper et al., (1961) who find that the share of income from land in 1956 was between 0.04 and 0.12, depending on the rate of return used.[34]

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 equal 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 numbers make it difficult to determine which 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 value of around 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 have been studied, few have determined cost shares of labor, land, and capital separately for 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.

Work by Beeson and Eberts (1989), Ciccone (2002) and Rappaport (2006) suggests that the cost-share of land in traded goods, θ_L, is 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

[34] 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.

with existing evidence.[35]

The last free parameter needed is capital's share in traded or home goods, θ_K or ϕ_K. These are both taken to be 15 percent given the lack of information; the parametrization is not highly sensitive to changes in these shares.[36]

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 $\eta^c = \eta + s_y^* \eta_{y,m}$, where η is the uncompensated price elasticity and $\eta_{y,m}$ 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 $\eta_{y,m} = 1$ (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. There are two ways to determine ε: first, through direct estimates; second, to infer $\varepsilon_{NT/m}$ theoretically through equation (A.16), although this requires all share and substitution parameters, and the assumption that the model is exactly 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

$$\varepsilon = -3.54\sigma_X - 5.90\sigma_Y - 0.53\sigma_D \tag{A.21}$$

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

[35] 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.

[36] 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.

unlikely: a value 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 of value.

Because the model is not exactly true, and because it is sensitive to σ_Y, looking for direct estimates of ε seems preferable to inferring through equation (A.16). 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 by 20, the ratio of total costs to local taxes' cost share (5 percent), gives an elasticity of output to local taxes as a percent of total costs (or income) of $\varepsilon_{Out} = -6.67$. 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

$$\varepsilon_{Out} = \left[(s_x + s_T) \hat{X} + s_y \hat{Y} \right] / (dT/m) = -3.25\sigma_X - 5.52\sigma_Y - 0.84\sigma_D \tag{A.22}$$

Combining (A.22) with (A.21) it is possible to eliminate σ_Y

$$\varepsilon = 1.07\varepsilon_{Out} - 0.07\sigma_X + 0.37\sigma_D$$

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 $\varepsilon = -6$ is taken in the main calibration for the sake of being conservative, although it could be larger.[37]

[37] 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 $\varepsilon_{N\,T/m} = -3.25$. 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.

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 of 25.1 percent in 2000. 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 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 2000, 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

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

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 is found by regressing log hourly wages on individual covariates and indicators for which MSA a worker lives in, and using the coefficients on these indicators. 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 English proficiency (none or poor).

All of covariates are interacted with gender. The regressions is run using census-person weights. From the regressions 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) workers need to be weighted by their income share. The regression is run again using these income-adjusted weights. The city-wage differentials used are taken from this second regression. 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).

A first regression is run using only owned units using census-housing weights. An adjusted weight is calculated by multiplying the census-housing weights times the predicted value from this first regression. A second regression is run using these adjusted weights for all units, rented and owned, on the covariates fully interacted with tenure. The house-price differentials are taken from the indicator variables for MSA for this second regression. Weighting has only a minute impact on these differentials, but is used since it is methodologically 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 include

- 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;
- percent 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

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

where ε is the elasticity from the previous formula (A.16). 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. 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

$$e(p, \bar{u})/(Q\xi_k) = m - T \tag{A.23}$$

where k indexes the marginal individual, and $\bar{u}$ is the reservation utility, which is equal across workers. Fully differentiating (A.23),

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

Assume that ξ_i follows a Pareto distribution 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

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

Totally differentiating, $\hat{N} = -\hat{\xi}_k/\psi$, so that the worker-mobility condition in (A.23) can be rewritten as

$$s_w \hat{w} - s_y \hat{p} = \frac{dT}{m} + \psi \hat{N} \tag{A.24}$$

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. This is indicative of a downward sloping demand curve to live in Chicago. Equation (A.24) also produces an upward sloping supply curve of workers to Chicago.

Using this condition to replace (A.8a) and solving as before, the elasticity of workers with respect to taxes is now a function of ψ, with

$$\varepsilon(\psi) = \frac{\varepsilon(0)}{1 + \psi\left[\frac{s_y}{s_R}\left(\phi_L - \frac{\theta_L}{\theta_N}\phi_N\right) - \varepsilon(0)\right]} \tag{A.25}$$

where $\varepsilon(0)$ is the elasticity given in (A.16), which assumed homogenous tastes, i.e. $\psi = 0$. As seen in the formula, a higher ψ implies 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 $\varepsilon(\psi)$

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

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

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

is strictly greater than -1. Because $\varepsilon(0)<\varepsilon(\psi)$, equation (A.25) 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 (A.9) to (A.11). 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

$$e^a(r/A_Y,\bar{u}^a)/Q^a=w^a+R^a-\tau^a \tag{A.26a}$$

$$e^b(r/A_Y,\bar{u}^b)/Q^b=w^b+R^b-\tau^b \tag{A.26b}$$

$$c_X(w^a,w^b,r)=A_X \tag{A.26c}$$

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

a-worker be $\mu^a = N^a m^a / \left(N^a m^a + N^b m^b\right)$, with $\mu^b = 1 - \mu^a$. Log-linearizing and solving the system reveals the wage differential for a type a worker

$$\hat{w}^a = \frac{1}{s_R s_w^a}\left\{s_y^a s_x \hat{A}_X + s_x \theta_L \left(\frac{d\tau^a}{m^a} - \hat{Q}^a - s_y^a \hat{A}_Y\right)\right\} + \frac{\mu^b}{s_R s_w^a}\left\{\left[s_y^b\left(\frac{d\tau^a}{m^a} - \hat{Q}^a\right) - s_y^a\left(\frac{d\tau^b}{m^b} - \hat{Q}^b\right)\right]\right\} \tag{A.27}$$

where an analogous expression holds for $\hat{w}^b$. Comparing this equation with (6), a new effect 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

$$\hat{r} = \frac{1}{s_R}\left(\hat{Q} + s_x \hat{A}_X + s_y \hat{A}_Y - \frac{d\tau}{m}\right) \tag{A.28}$$

$$\hat{w} \equiv \frac{1}{s_w}\left(s_w^a \mu^a \hat{w}^a + s_w^b \mu^b \hat{w}^b\right) = \frac{1}{\theta_N s_R}\left[s_y \hat{A}_X - s_y \theta_L \hat{A}_Y + \theta_L\left(\frac{d\tau}{m} - \hat{Q}\right)\right] \tag{A.29}$$

which are analogous to the previous expressions given in (9a) and (6) with homogenous types, except that now the quantities in the model refer to income-weighted averages. The relative wage difference

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

also determines the relative levels of employment. In the CES case, workers paid higher wages are employed in fewer numbers, with the amount determined by the elasticity of substitution.

$$\hat{N}^a - \hat{N}^b = -\sigma_X\left(\hat{w}^a - \hat{w}^a\right) \tag{A.30}$$

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.

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

It is unclear whether workers receiving a higher relative wage in a city pay a higher relative tax burden, as fewer 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.

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 ($\hat{Q}^a > \hat{Q}^b$, $s_y^a = s_y^b$, and $s_w^a = s_w^b$) will take relatively lower wages and be more populous in nice cities; because they are 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 ($s_w^a < s_w^b$, $s_y^a = s_y^b$, and $\hat{Q}^a = \hat{Q}^b$) find it advantageous to live in nice cities and to avoid productive cities. Although within a given city, these workers pay the same tax differentials as other types ($s_w^a \hat{w}^a = s_w^b \hat{w}^b$), as they sort disproportionately into low-tax cities they pay less total taxes. Workers with a strong taste for the home good ($s_y^a > s_y^b$, $s_w^a = s_w^b$, $\hat{Q}^a = \hat{Q}^b$) are paid higher wages and are less populous in nice or productive cities: the overall effect on their tax burdens is indeterminate. Finally, workers facing 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.26c) 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.28) and (A.29) 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.30) 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 where a-types are mobile and b-types are 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

$$s_w^a \hat{w}^a - s_y^a \hat{r} = -\hat{Q}^a + dT^a/m^a \tag{A.31a}$$

$$\theta_N^a \hat{w}^a + \theta_N^b \hat{w}^b = \theta_N^a \hat{A}_X^a + \theta_N^b \hat{A}_X^b \tag{A.31b}$$

$$\hat{N}^a + \sigma_X \left(\hat{w}^a - \hat{w}^b\right) = (\sigma_X - 1)\left(\hat{A}^a - \hat{A}^b\right) \tag{A.31c}$$

$$\mu^a \hat{N}^a + \mu^b s_w^b \hat{w}^b - \left[\mu^a s_x^a \sigma_D^a + \mu^b \left(s_y^b + s_x^b \sigma_D^b\right)\right]\hat{r} = \mu^a \hat{Q}^a + \mu^b dT^b/m^b \tag{A.31d}$$

The left-hand side of the (A.31d) 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

$$\hat{w}^a = \frac{-|\eta^u|\hat{Q}^a + s_y\left(\frac{\theta_N^a}{\theta_N^b}\sigma_X + s_x\right)\hat{A}_X + \left(|\eta^c| + s_y\theta_N^b\right)\frac{dT^a}{m^a} - s_y\theta_N^b\frac{dT^b}{m^b}}{s_x|\eta^u| + s_y\frac{\theta_N^a}{\theta_N^b}\sigma_X} \tag{A.32a}$$

$$\hat{w}^b = \frac{|\eta^u|\hat{Q}^a + \left(\frac{s_x|\eta^u|}{\theta_N^a} + s_y(\sigma_X - 1)\right)\hat{A}_X - \left(|\eta^c| + s_y\theta_N^b\right)\frac{dT^a}{m^a} + s_y\theta_N^b\frac{dT^b}{m^b}}{s_x\frac{\theta_N^b}{\theta_N^a}|\eta^u| + s_y\sigma_X} \tag{A.32b}$$

$$\hat{r} = \frac{\theta_N^a\sigma_X\hat{Q}^a + s_x\left(\theta_N^a\sigma_X + \theta_N^b\right)\hat{A}_X - \theta_N^a\left(\theta_N^b + \sigma_X\right)\frac{dT^a}{m^a} - s_x\left(\theta_N^b\right)^2\frac{dT^b}{m^b}}{s_x\theta_N^b|\eta^u| + s_y\theta_N^a\sigma_X} \tag{A.32c}$$

$$\hat{N}^a = \sigma_X\frac{|\eta^u|\hat{Q}^a + s_x|\eta^c|\hat{A}_X - \left(|\eta^c| + s_y\theta_N^b\right)\frac{dT^a}{m^a} + s_y\theta_N^b\frac{dT^b}{m^b}}{s_x\theta_N^b|\eta^u| + s_y\theta_N^a\sigma_X} \tag{A.32d}$$

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 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:

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

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 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 fraction of these taxes being passed on to land. Higher taxes on mobile workers, will lower the welfare of immobile workers if $s_x |\eta^c| > s_y \sigma_X$ in which case wage losses dominate the reduction in local prices.

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. As pointed out on page 6, the main results in the text hold if workers are identical ($\sigma_X \to \infty$) but only a subset of workers are fully mobile. This case yields $\hat{w}^a = \hat{w}^b = \hat{A}_X$, with $\hat{r} = (\hat{Q}^a + s_x \hat{A}_X - \frac{dT^a}{m^a})/s_y$, the appropriate simplifications of the formulas in (5) and (8a).

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: $A_X^j = A_X^{0j} (N^j)^\gamma$, where γ measures the percent increase in productivity from a percent increase in a city's population. Amending condition (4b) 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 (4) 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.