The Unequal Geographic Burden of Federal Taxation

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Abstract

In the United States, workers in cities offering above-average 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, taxes lower long-run employment levels in high-wage areas by 17 percent and land and housing prices by 28 and 6 percent, causing locational inefficiencies costing 0.32 percent of income, or $39 billion in 2008. Employment is shifted from North to South and from urban to rural areas. Tax deductions index taxes partially to local cost-of-living, improving locational efficiency.

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

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1 Introduction

Wage and cost-of-living levels vary considerably across cities in the United States, yet the federal tax code does not take this variation into account. Since federal 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 (Dubay 2006) 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.

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.

For federal taxes to not distort the location choices of workers, the correct principle is that taxes be independent of where workers live, so that location-wise they are effectively lump sum. The current system taxes a worker more for taking a job in a higher-paying city, blunting the incentive to live in these cities, characterized by high firm-productivity and low quality of life. For example, in the New York metropolitan area, wage levels are 21 percent above the national average, which interacted with an effective marginal tax rate of 33 percent, creates a 7-percent federal surtax on labor income for locating there. Unlike local tax differences, federal tax differences of this kind are not compensated with higher levels of local spending, and may therefore affect location choices substantially.

Because federal taxes are not indexed to local wage levels, workers are induced to leave cities with high wages and move to cities with low wages. As a result, unequal federal taxes lower employment levels and property values in high-wage cities, while having the opposite effect on low-wage cities. In equilibrium, these price changes compensate workers for federal tax differences across cities, but the resulting geographic distribution of employment is inefficient, reducing overall welfare.

The unequal distribution of federal taxes that results from wage differences across cities does not depend on the progressivity of taxes, and cannot be eliminated with a flat tax. The view that workers with the same real incomes should pay the same nominal taxes holds true across cities that vary in the productivity of their firms, as nominal incomes merely track cost-of-living differences across these cities. However, this view is incorrect across cities that vary in quality-of-life as nicer cities have a higher cost-of-living but lower

nominal wage levels, and hence a lower federal tax burden. Indexing the tax code to local cost-of-living would eliminate federal tax differences across cities that vary in productivity, but exacerbate them across cities that vary in quality of life.

An empirical simulation for the United States below reveals that workers with the same skills can pay up to 30 percent more in federal taxes in high-wage cities than in low-wage cities. The federal government effectively taxes workers for living in large cities, while subsidizing them to live in rural areas. Taxes also fall more heavily on the Northeast, Pacific, and Great Lakes regions and less on the South. Controlling for socioeconomic disparities, approximately 300 billion dollars each year are transferred horizontally from high-wage areas to low-wage areas. These findings partly confirm Senator Patrick Moynihan's claims in 24 years of reports, entitled *The Federal Budget and the States*, that the "federal balance of payments" across areas is highly unequal, although these reports do not control for socioeconomic differences across regions, nor do they consider the effects on local employment or prices. Journalist Malcolm Gladwell (1996) writes that the inequality in the federal balance of payments "is according to urban experts and economists one of the best-kept secrets in American politics," and 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." Such a view is supported by the simulation: over the long run, federal taxes have lowered employment, house prices, and land values in high-wage areas by 17, 6, and 28 percent, respectfully. Opposite raises have occurred in low-wage areas. Overall, federal taxes have tilted the geographic distribution of employment away from the North towards South and from urban areas to rural areas, creating a welfare loss estimated at 0.32 percent of income, or $39 billion in 2008. Without federal tax deductions for mortgage interest and local taxes, this loss would be even larger.

Previous research about how federal taxes interact with local prices contains some important findings, but has been too narrow or informal to guide policy comprehensively. Wildasin (1980) finds that federal taxes on labor income cause mobile workers to locate inefficiently across cities offering different wages. He focuses on conditions characterizing efficiency, rather than the results of inefficiency. Without referring specifically to taxation, Glaeser (1997) argues that federal transfer levels should not be tied to local price levels, as this implicitly 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 arguments leave open the exact consequences of failing to index the tax code, raising the need for

more rigorous quantitative analysis.[1]

Section 2 introduces a model of mobile workers who live in cities with attributes that generate differences in costs-of-living, wages, and federal tax burdens. Section 3 describes the federal tax differences that arise in equilibrium, and how this affects local prices. Section 4 examines how taxes distort location decisions and how to calculate the resulting efficiency loss. Then, section 5 considers the effect of indexing taxes to local wages or costs-of-living and demonstrates how tax deductions for locally-produced goods, such as housing, produce a mild and slightly altered form of cost indexation. Section 6 calibrates the model and simulates how differential taxes affect the distribution of local prices, employment, and welfare, taking into account differential federal spending patterns. Considerable detail on theory, calibration, data, and extensions are left to the Appendix.

2 Theoretical Set-Up

To explain why prices and tax burdens differ across cities, I adapt the general-equilibrium model of Rosen (1979) and Roback (1980, 1982), incorporating federal taxes. 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. Cities differ in three types of exogenous attributes. Quality-of-life, Q^j, may be affected by amenities such as weather or safety. Productivity in the traded-good sector, A_X^j (or "trade-productivity"), may be due to natural advantages, like a harbor, or to agglomeration economies, such as input-sharing. Productivity in the home-good sector, A_Y^j, (or "home-productivity") may be affected by natural advantages or regulations affecting residential housing. The average value of each attribute is set to one. Although some city attributes 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,

[1] Kaplow's (1996a) analysis holds prices fixed and presents an index formula that does not equalize nominal tax payments across areas. 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.

Some work considers 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 disproportionately benefit high-cost areas, but neglects how these deductions may offset the unequal burden of federal taxes. Surveys of the possible benefits of tax deductions for mortgage interest (e.g. Glaeser and Shapiro 2003) or local taxes (e.g. Kaplow 1996b) do not consider their inter-urban locational effects.

K, is fully mobile and is paid the price $\bar{\imath}$ everywhere. 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. The total number of workers is fixed at N_{TOT}, so $\sum_j N^j = N_{TOT}$. Workers own identical diversified portfolios of land and capital, which pay an income $R = \frac{1}{N_{TOT}} \sum_j r^j L^j$, from land and $I = \bar{\imath}\frac{K_{TOT}}{N_{TOT}}$, from capital. Total income $m^j \equiv R + I + w^j$ varies across cities only as wages vary. Out of this income workers pay a federal income tax of $\tau\left(m^j\right)$. Deductions are introduced in Section 5.[2]

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 is $e(p, u, \tau(m); Q) \equiv \min_{x,y}\{x + py + \tau(m) : U(x, y; Q) \geq u\}$. Q is assumed to enter neutrally into the utility function and is normalized so that $e(p, u, \tau(m); Q) = [e(p, u) + \tau(m)]/Q$, where $e(p, u) \equiv e(p, u, 0; 1)$.[3] Since workers are fully mobile, their utility must be the same across all inhabited cities, so that higher prices, lower quality-of-life, or higher taxes must be compensated with greater income:

$$\left[e(p^j, \bar{u}) + \tau(m^j)\right]/Q^j = m^j \tag{1}$$

$\bar{u}$ is the level of utility attained by all workers, regardless of each worker's federal tax burden.

Operating under perfect competition, firms produce traded and home goods according to the functions $X = A_X F_X(L_X, N_X, K_X)$ and $Y = A_Y F_Y(L_Y, N_Y, K_Y)$, where F_X and F_Y are concave and exhibit constant returns to scale. Unit cost in the traded-good sector is $c_X(r, w, i; A_X) \equiv \min_{L,N,K}\{rL + wN + iK : A_X F(L, N, K) = 1\}$. For simplicity, let $c_X(r, w, i; A_X) = c_X(r, w, i)/A_X$ where $c(r, w, i) \equiv c(r, w, i; 1)$. A symmetric definition holds for unit cost in the home-good sector, c_Y. All factors are fully employed: $L_X^j + L_Y^j = L^j$, $N_X^j + N_Y^j = N^j$, and $K_X^j + K_Y^j = K^j$. As markets are competitive, firms make zero profits in equilibrium, so that for given output prices, more productive cities pay higher rents and

[2] Because markets are perfectly competitive, the economic incidence is unchanged if the nominal incidence of taxes is placed on firms' labor costs, rather than on workers' wage incomes. Also, consumption taxes in this model are equivalent to income taxes; taxes on production are largely equivalent, except for the portion that falls on capital and land.

[3] The model generalizes to a case with 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. More general types of worker heterogeneity are considered in Appendix D, including the case where some workers are immobile, or differ in their attachment to particular cities, simulating the effects of moving costs. The Appendix explains how federal tax changes can have redistributive effects across areas when tastes are heterogeneous or moving costs are substantial.

wages, so that following conditions hold in all cities j where production occurs.[4]:

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

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

This analysis models a single federal government that collects tax revenues, makes transfers, and uses the net balance to buy traded goods that are transformed into a federal public good, such as defense. This federal public good benefits workers everywhere equally, and its level is held fixed. Federal taxes are modeled net of federal transfers. Naturally, federal means-tested benefits increase the effective marginal tax rate for some workers.[5] Additionally, it matters if federal tax payments are tied to 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. Thus, the marginal benefit of paying these taxes should be subtracted from the effective marginal income tax rate.

The local public sector does not need to be modeled explicitly. If local government provides goods efficiently, as in the Tiebout (1956) model, these goods can be treated as consumption goods. Furthermore, efficiency differences across local public sectors may be subsumed into differences in Q^j or A_Y^j. Taxes levied at the subnational level can also be distributed unequally across areas when wages vary within a subnational jurisdiction, such as a state, but not usually a county or municipality. State taxes are incorporated into the simulation below, where their effects are small; for expositional ease, they are ignored here,

For workers, denote the expenditure shares of traded goods, home goods, and taxes as $s_X^j \quad x^j/m^j$, $s_Y^j \quad p^j y^j/m^j$, and $s_T^j = \tau(m^j)/m^j$; denote the shares of income received from land, labor, and capital income as $s_R^j \quad R/m^j$, $s_W^j \quad w^j/m^j$, and $s_I^j \quad I/m^j$. For firms, denote the cost shares of land, labor, and capital in the traded-good sector as $\theta_L^j \quad r^j L_X^j/X^j$, $\theta_N^j \quad w^j N_X^j/X^j$ and $\theta_K^j \quad \bar{\imath} K_X^j/X^j$; 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., $\phi_L/\phi_N > \theta_L/\theta_N$.

[4] Non-Hicks-neutral productivity differences have similar impacts on relative prices across cities, but not on relative quantities.

[5] This is complicated by eligibility requirements for programs which vary by state or county. Furthermore, some benefit levels are tied to local prices, such as housing programs, although these programs tend to be small. Insomuch as they are valued, local goods provided by the federal government may be treated as transfers, as can intergovernmental transfers that increase the supply of local government goods. 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, as in Section 6.4.

3 Price and Federal-Tax Differences across Cities

Federal taxes on labor income affect how prices vary cross-sectionally across cities with different attributes. To analyze this, assume that there are enough cities varying in the three city attributes, Q, A_{X}, and A_{Y} so we can treat these attributes as continuous variables. The equilibrium conditions (1), (2), and (3) implicitly define the prices w^{j},r^{j}, and p^{j} – and the federal tax, $\tau(m^{\mathsf{j}})$, which depends on them – as a function of $Q^{\mathsf{j}}, A_{\mathsf{X}}^{\mathsf{j}}$, and $A_{\mathsf{Y}}^{\mathsf{j}}$. These conditions may be log-linearized to express a particular city's price differentials in terms of its city-attribute differentials, each relative to the national average. These differentials are expressed in logarithms so that, for any variable z, $\hat{z}^{\mathsf{j}} = \ln z^{\mathsf{j}} \quad \ln \bar{z} = \left(z^{\mathsf{j}} \quad \bar{z}\right)/\bar{z}$, approximates the percent difference in city j of z relative to the geometric average $\bar{z}$. Values in the presence of income taxes are not subscripted; counterfactual values under a uniform, utility-equivalent lump-sum tax are subscripted by zero, e.g. $\hat{z}_0^{\mathsf{j}}$; The change in z due to income taxes is denoted with a "d," so $dz^{\mathsf{j}} = z^{\mathsf{j}} \quad z_0^{\mathsf{j}}$ and $d\hat{z}^{\mathsf{j}} = \hat{z}^{\mathsf{j}} \quad \hat{z}_0^{\mathsf{j}}$. In an average city $\hat{z}^{\mathsf{j}} = \hat{z}_0^{\mathsf{j}} = d\hat{z}^{\mathsf{j}} = 0$. Letting E be the expectations operator over cities, then $E[\hat{z}^{\mathsf{j}}] = 0$ for any z.

Log-linearized versions of (1), (2), and (3) describe how prices co-vary with city attributes.

$$s_{\mathsf{W}}\hat{w}^{\mathsf{j}} \quad s_{\mathsf{Y}}\hat{p}^{\mathsf{j}} = \tau' s_{\mathsf{W}}\hat{w}^{\mathsf{j}} \quad \hat{Q}^{\mathsf{j}} \tag{4a}$$

$$\theta_{\mathsf{L}}\hat{r}^{\mathsf{j}} + \theta_{\mathsf{N}}\hat{w}^{\mathsf{j}} = \hat{A}_{\mathsf{X}}^{\mathsf{j}} \tag{4b}$$

$$\phi_{\mathsf{L}}\hat{r}^{\mathsf{j}} + \phi_{\mathsf{N}}\hat{w}^{\mathsf{j}} \quad \hat{p}^{\mathsf{j}} = \hat{A}_{\mathsf{Y}}^{\mathsf{j}} \tag{4c}$$

These equations are first-order approximations around a nationally-representative city and so the share values are national averages. Equation (4a) states how before-tax real income, given by nominal wage differences $s_{\mathsf{W}}\hat{w}^{\mathsf{j}}$ net of cost-of-living differences $s_{\mathsf{Y}}\hat{p}^{\mathsf{j}}$, compensates for lower quality of life, $\hat{Q}^{\mathsf{j}}$, and higher federal taxes, $\tau' s_{\mathsf{W}}\hat{w}^{\mathsf{j}}$. This last term is the income tax differential as a fraction of total income, $\tau' s_{\mathsf{W}}\hat{w}^{\mathsf{j}} = \tau'\hat{m}^{\mathsf{j}} \quad d\tau^{\mathsf{j}}/m$, due to the wage differential $\hat{w}^{\mathsf{j}}$. 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. The effects of a federal tax differential are similar to that of a head tax being on workers in city j, except that the federal tax differential depends on an endogenous wage differential, $\hat{w}^{\mathsf{j}}$, rather than being set exogenously. Equations (4b, 4c) demonstrate how high productivity in each sector results in high factor prices relative to the output price in equilibrium.

The tax differentials depend on the wage differentials, which may be written[6]

$$\hat{w}^{\mathsf{j}} = \hat{w}_0^{\mathsf{j}} + \underbrace{\frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\frac{1}{s_{\mathsf{R}}}\overbrace{\tau' s_{\mathsf{W}}\hat{w}^{\mathsf{j}}}^{\mathsf{d}\ ^{j}=\mathsf{m}}}_{\mathsf{d}\hat{\mathsf{w}}^{j}} = \frac{1}{1 \quad \frac{L}{N}\frac{\mathsf{s}_w}{\mathsf{s}_R}\tau'}\hat{w}_0^{\mathsf{j}} \tag{5}$$

where the wage differential under a neutral, utility-equivalent, lump-sum tax

$$\hat{w}_0^{\mathsf{j}} = \frac{1}{\theta_{\mathsf{N}}\, s_{\mathsf{R}}}\left(s_{\mathsf{y}}\phi_{\mathsf{L}}\hat{A}_{\mathsf{X}}^{\mathsf{j}} \quad \theta_{\mathsf{L}}\hat{Q}^{\mathsf{j}} \quad s_{\mathsf{y}}\theta_{\mathsf{L}}\hat{A}_{\mathsf{Y}}^{\mathsf{j}}\right) \tag{6}$$

relates how wages rise with trade-productivity and fall with quality-of-life or home-productivity.[7] The first equality of (5) demonstrates that firms paying a positive wage differential without income taxes, $\hat{w}_0^{\mathsf{j}}$, pay an additional wage differential, $d\hat{w}^{\mathsf{j}}$, to help compensate for higher income taxes. The term multiplying $\hat{w}_0^{\mathsf{j}}$ after the second equality exceeds one, meaning that income taxes increase wage differences across cities.

Combining equations $d\tau^{\mathsf{j}}/m = \tau' s_{\mathsf{W}}\hat{w}^{\mathsf{j}}$, (5), and (6), the tax differential in terms of city attributes is

$$\frac{d\tau^{\mathsf{j}}}{m} = \tau' \frac{1}{1 \quad \frac{L}{N}\frac{\mathsf{s}_w}{\mathsf{s}_R}\tau'}\frac{s_{\mathsf{W}}}{\theta_{\mathsf{N}}\, s_{\mathsf{R}}}\left(s_{\mathsf{y}}\phi_{\mathsf{L}}\hat{A}_{\mathsf{X}}^{\mathsf{j}} \quad \theta_{\mathsf{L}}\hat{Q}^{\mathsf{j}} \quad s_{\mathsf{y}}\theta_{\mathsf{L}}\hat{A}_{\mathsf{Y}}^{\mathsf{j}}\right) \tag{7}$$

As do wages, federal taxes rise with trade-productivity and fall with quality of life or home-productivity. Spatially, the income tax operates as if the federal government supplemented a uniform lump-sum tax with a revenue-neutral system of head taxes, which vary across cities according to (7).

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

$$\hat{r}^{\mathsf{j}} = \hat{r}_0^{\mathsf{j}} \quad \underbrace{\frac{1}{s_{\mathsf{R}}}\frac{d\tau^{\mathsf{j}}}{m}}_{\mathsf{d}\hat{\mathsf{r}}^{j}} \tag{8a}$$

$$\hat{p}^{\mathsf{j}} = \hat{p}_0^{\mathsf{j}} \quad \underbrace{\left(\phi_{\mathsf{L}} \quad \frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\phi_{\mathsf{N}}\right)\frac{1}{s_{\mathsf{R}}}\frac{d\tau^{\mathsf{j}}}{m}}_{\mathsf{d}\hat{\mathsf{p}}^{j}} \tag{8b}$$

[6]The solution requires the identities $s_R = (s_x + s_T)\theta_L + s_y\phi_L$ and $s_w = (s_x + s_T)\theta_N + s_y\phi_N$.

[7]Expressions for price differentials without taxation equivalent to (6), (9a), and (9b) are found in Roback (1980). Those expressions are not log-linearized, and ignore non-labor income and the accounting identities mentioned previously. 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 $\phi_L = 1$. 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.

where the rent and price differentials under a uniform lump-sum tax are

$$\hat{r}_0^{\mathsf{j}} = \frac{1}{s_{\mathsf{R}}} \left(\hat{Q}^{\mathsf{j}} + s_{\mathsf{X}} \hat{A}_{\mathsf{X}}^{\mathsf{j}} + s_{\mathsf{Y}} \hat{A}_{\mathsf{Y}}^{\mathsf{j}} \right) \tag{9a}$$

$$\hat{p}_0^{\mathsf{j}} = \frac{1}{\theta_{\mathsf{N}} s_{\mathsf{R}}} \left[(\theta_{\mathsf{N}} \phi_{\mathsf{L}} \quad \theta_{\mathsf{L}} \phi_{\mathsf{N}}) \hat{Q}^{\mathsf{j}} + \phi_{\mathsf{L}} s_{\mathsf{W}} \hat{A}_{\mathsf{X}}^{\mathsf{j}} \quad \theta_{\mathsf{L}} s_{\mathsf{W}} \hat{A}_{\mathsf{Y}}^{\mathsf{j}} \right] \tag{9b}$$

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 rents as $s_{\mathsf{R}} \quad m \quad d\hat{r}^{\mathsf{j}} = \quad d\tau^{\mathsf{j}}$, which implies $dr^{\mathsf{j}} \quad L^{\mathsf{j}} = \quad N^{\mathsf{j}} \quad d\tau^{\mathsf{j}}$.[8] (8b) reveals how taxes are capitalized into the price of home goods, depending on their land intensity. Overall, taxes lower relative land and home-good prices in cities with higher trade-productivity, lower quality-of-life, or lower home-productivity.[9]

Workers are compensated for higher taxes through a combination of higher wages and lower home-good prices. Using the expression for $d\hat{w}^{\mathsf{j}}$ in (5) it is possible to show that that the fraction of taxes compensated through wages, $dw^{\mathsf{j}}/d\tau^{\mathsf{j}}$, equals $\lambda_{\mathsf{L}}^{\mathsf{X}}/\lambda_{\mathsf{N}}^{\mathsf{X}}$, which is the ratio of the fraction of land in the traded goods sector, $\lambda_{\mathsf{L}}^{\mathsf{X}} \quad (1 \quad s_{\mathsf{Y}}) \theta_{\mathsf{L}}/s_{\mathsf{R}}$, to the fraction of labor in the traded sector, $\lambda_{\mathsf{N}}^{\mathsf{X}} = (1 \quad s_{\mathsf{Y}}) \theta_{\mathsf{N}}/s_{\mathsf{W}}$. The less land is used in traded-good production, the less total costs fall with land rents, the less wages increase, and the more lower land rents are passed to workers through lower home-good prices. This ratio also determines how much quality-of-life advantages are reflected in lower wages rather than higher prices.

The effect of federal taxes on local prices can be shown graphically by assuming that home goods are just land ($\phi_{\mathsf{L}} = 1$, $A_{\mathsf{Y}} = 1$), so that $p = r$, and that initially workers everywhere pay a uniform lump-sum tax of T. Figure 1 illustrates the case of a highly trade-productive city, say Chicago (labeled with "C"), and an average city, say Nashville, with productivities $A_{\mathsf{X}}^{\mathsf{C}} > 1$ and $\bar{A}_{\mathsf{X}} = 1$. The zero-profit conditions slope downward as wages must fall as rents rise to keep profits at zero. More productive firms

[8]If land is not shared equally across the population, increases in the marginal (but not average) tax rate benefits land owners in low-wage cities and hurts those in high-wage cities. Utilities cease to be equal across workers, but this does not change the resulting equilibrium if preferences are homothetic.

As home goods consist mainly of durable housing, supply of home goods 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.

[9]The effect of taxes on prices is sensitive to the assumption that attributes are exogenous. This is most conspicuous with respect to trade-productivity, which increases with overall employment becaue of agglomeration. Higher federal taxes cause employment to fall, lowering trade-productivity. This in turn lowers wages, home-good prices, and land rents, magnifying the effects for the latter two, while dampening (or possibly reversing) the effect on wages. A simplified example is shown in Appendix D.5. If quality-of-life falls (rises) with employment, wages, rent, and price changes will be magnified (dampened). If home-productivity falls (rises) with employment, wage and price effects are dampened (magnified), while rent effects are magnified (dampened).

in Chicago pay higher wages or 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 the tax-free equilibrium, shown at $\bar{E}$ and E_0^{C}, Chicago is more crowded than Nashville and pays workers a differential, $w_0^{\mathsf{C}} - \bar{w}$, to compensate them for the higher cost-of-living reflected in $r_0^{\mathsf{C}} - \bar{r}$.

Now replace the lump-sum tax with an income tax set so that workers with an average wage $\bar{w}$, pay the same amount of taxes, $\tau(\bar{w} + R + I) = T$, leaving utility unchanged, although now these workers face a positive marginal tax rate, $\tau' > 0$. With this positive marginal tax rate, workers in costlier cities must be paid more before taxes to receive the same compensation after taxes, rotating the mobility condition counter-clockwise around its intersection with the horizontal line at $\bar{w}$, to its slope of $y/(1 - \tau')$. Workers in Chicago at the old equilibrium E_0^{C} are now worse off than in Nashville, as the old compensating differential does not make up for the higher costs and higher taxes. Workers will leave ($dN^{\mathsf{C}} < 0$), lowering the demand for land for both production and consumption, causing rents to fall by dr^{C}, and raising the labor-to-land ratio, causing wages to rise by dw^{C}. At the new equilibrium, E^{C}, workers are no worse off in Chicago. Firms are no better off, since their cost savings in land are passed off to workers in higher wages. 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.

The case of a city offering a higher quality-of-life, say Miami, is illustrated in Figure 2. Like Chicago, Miami is also relatively crowded, 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 $Q^{\mathsf{M}} > 1$. 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 $r_0^{\mathsf{M}} - \bar{r}$, and receive the negative wage differential $w_0^{\mathsf{M}} - \bar{w}$.

Replacing the lump-sum tax with an income tax, workers in Miami pay less tax as they 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 ($dN^{\mathsf{M}} > 0$)

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 pre-tax wages, rather than higher post-tax home-good prices, its tax treatment is similar to untaxed fringe benefits: firms located in a city by the beach share tax advantages similar to firms that offer a tax-deductible company car.

The third case is of a more home-productive city, say Dallas, where home-good prices are lower than land rents: $p = r/A_{\mathsf{Y}}^{\mathsf{D}} < r$, as $A_{\mathsf{Y}}^{\mathsf{D}} > \bar{A}_{\mathsf{Y}} = 1$. Lower prices make Dallas workers better off for a given wages and rents, shifting the mobility condition to the lower right, as in Figure 2. In equilibrium, wages are and home-good prices are lower, although rents are higher. Because Dallas workers are paid less, they have lower tax burdens, creating the same tax effects as in Miami.

Although federal taxes on labor income may have desirable properties, the tax burden is curiously distributed across cities with different attributes. By falling more heavily on cities offering higher wages, federal taxes act like an arbitrary head tax for deciding to live in a city with wage-improving attributes, whatever those attributes may be. The tax is distortionary because workers are artificially attracted to cities that are nicer to live in, more home-productive, or less trade-productive. At a minimum, it would be preferable to charge an equivalent tax directly on land according to its wage-improving attributes: this would affect land rents in the same way, but would not distort location behavior or other prices.[10]

4 Employment Effects and Locational Efficiency

Federal taxes not only influence prices, but also cause factors such as labor to move across cities. By making high-wage cities more expensive to live in – or equivalently, more expensive to hire in – federal taxes induce workers to move away from high-wage areas towards low-wage areas, leading to an efficiency loss from misallocating workers across areas.

The employment effect of a differential tax can be written as

$$d\hat{N}^{\mathsf{j}} = \varepsilon \; \frac{d\tau^{\mathsf{j}}}{m} \tag{10}$$

where ε is the elasticity of local employment with respect to a local, uncompensated tax, written as a percent

[10] If labor supply is elastic the effect of federal tax differentials cannot be equated directly with head taxes. Real wages fall with quality of life, and so if labor supply increases with real wages, labor supply is lower in nicer cities, assuming quality of life and leisure are not substitutes. Thus, in nicer cities workers will work less, and thus avoid taxes even more, increasing the tax advantage that nicer cities have.

of total income. In principle, reduced-form estimates of this elasticity can be obtained. Furthermore, tax differentials can be obtained directly from data on wages and federal taxes. Thus, employment effects in (10) can be calculated without referring to a richer theoretical apparatus. Nevertheless, the theoretical model does imply a structural value for ε, which is given and derived in Appendix A. This elasticity is the sum of three long terms, each dependent on a different elasticity of substitution, and is unambiguously negative if $\phi_L/\phi_N > \theta_L/\theta_N$.

Because workers locate 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. Consistent with Harberger (1964), this deadweight loss, expressed as a fraction of national income, is proportional to half the size of the tax differential times the induced change in migration, averaged across cities.

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

Whatever the distribution of city attributes, this formula captures the entire efficiency loss from all of the distortions created by unequal geographic taxation, including the indirect distortion on the location of capital. This does assume that city attributes are unaffected by employment levels. Furthermore, as $d\hat{N}^j = \varepsilon \, d\tau^j/m$, the deadweight loss can be calculated using only data on ε and the variance of income tax differentials:

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

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

5 Tax 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: the former is better in theory, but arguably harder to implement, while the latter over-subsidizes life in nicer locations. If demand for home goods is inelastic, tax deductions for home-good expenditures effectively index taxes partially to local costs.

5.1 Wage-Level and Cost-of-Living Indexation

Income taxes may be indexed to wages by dividing taxable labor income by the "pay relative" $1 + \hat{w}^{\mathsf{j}} = w^{\mathsf{j}}/\bar{w}$, assuming those pay relatives can be correctly measured. 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.

Indexing taxes to local cost-of-living may be easier than indexing taxes to wages as the prices of homogenous goods across cities could 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 $\kappa(p^{\mathsf{j}})$ – one that ignores quality of life – resulting in taxes $\tau = \tau\left(m^{\mathsf{j}}/\kappa\left(p^{\mathsf{j}}\right)\right)$. An ideal cost-of-living index of this kind is defined in terms of gross expenditures: $\kappa\left(p^{\mathsf{j}}\right) = \left[e\left(p^{\mathsf{j}}, \bar{u}\right) + \bar{\tau}\right] / \left[e\left(\bar{p}, \bar{u}\right) + \bar{\tau}\right]$, where $\bar{p}$ and $\bar{\tau}$ are the average home-good price and tax burden.

With this indexation, the tax differential in a city increases with wages and decreases with home-good prices according to the formula $d\tau^{\mathsf{j}}/m = \tau'\left(s_{\mathsf{W}}\hat{w}^{\mathsf{j}} \quad s_{\mathsf{Y}}\hat{p}^{\mathsf{j}}\right)$. This changes the mobility condition (4a) to

$$s_{\mathsf{Y}}\hat{p}^{\mathsf{j}} \quad s_{\mathsf{W}}\hat{w}^{\mathsf{j}} = \hat{Q}^{\mathsf{j}} / \left(1 \quad \tau'\right) \tag{12}$$

With cost-indexed taxes workers are willing to take a larger fall in pre-tax real income to improve their quality-of-life. Substituting (12) into $d\tau^{\mathsf{j}}/m = \tau'\left(s_{\mathsf{W}}\hat{w}^{\mathsf{j}} \quad s_{\mathsf{Y}}\hat{p}^{\mathsf{j}}\right)$ reveals that cost-indexed taxes depend only on local quality-of-life.

$$\frac{d\tau^{\mathsf{j}}}{m} = \quad \frac{\tau'}{1 \quad \tau'}\hat{Q}^{\mathsf{j}} \tag{13}$$

Relative to taxation without indexation, cost indexation eliminates tax differences across cities differing in either type of productivity (A_{X} or A_{Y}); across these cities, wages rise in step with costs. 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 then massively subsidizes life in nicer cities. While this may sound like a welfare improving policy, it would actually reduce welfare as nicer cities would become overcrowded.[11]

[11] 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 use local metropolitan area income levels to determine eligibility, in combination with a local index of "Fair Market Rents" to determine benefits. U.S. members of Congress have proposed, but not passed, 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.

5.2 Tax Deductions for Housing and Local Taxes

Thus far, I 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 $\tau\left(m^j - \delta p^j y\right)$. 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 the home-good price and consumption:

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

Because 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 $\hat{y}^j = \eta^c \hat{p}^j - \hat{Q}^j$. With a price increase of $\hat{p}^j$, the home-good expenditure share increases by $s_y\left(1 - |\eta^c|\right)\hat{p}^j$. Thus, the tax differential with deductions is

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

With the deduction, the tax differential in (15) depends on two other effects:

Partial-Indexation Effect The term $-\delta\tau' s_y\left(1 - |\eta^c|\right)\hat{p}^j$ 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.

Quality-of-Life Income Effect The term, $\delta\tau' s_y \hat{Q}^j$, 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.[12]

The full dependence of this tax differential on $\hat{A}_X^j$, $\hat{A}_Y^j$, and $\hat{Q}^j$ is in Appendix equation (A.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 below suggests that taxes still fall with quality-of-life.[13]

6 Simulation of Tax Differences across the United States

The theoretical model above may be used to simulate the effects of differential federal taxation across the United States. This requires calibrating the economic parameters of the model and estimating wage, housing-cost, federal spending, and quality-of-life differentials across metropolitan areas. The simulation then reveals how unequal federal taxes affects prices, employment, and welfare nationwide.

6.1 Calibrating the Model

An overview of the calibration is presented here, with greater detail left to the Appendix B. Alternative calibrations are considered in several sensitivity checks. Given that parameters are known with limited certainty, I use round fractions for ease.

Looking first at factor income shares, labor, s_W, receives 75 percent of income (Krueger 1999); capital, s_I, 15 percent (Poterba 1998); and land, s_R, 10 percent (Keiper et al. 1961). Housing cost differences are used to measure home-good price differences. Using this measure requires that the expenditure share for home goods equals the expenditure share on housing of 22 percent *plus* the estimated expenditure share on non-housing home goods of 14 percent, to produce $s_Y = 0.36$ – see Albouy (2008a), Moretti (2008) and Shaprio (2006). From national accounts, the government expenditure share, s_T, is 15 percent. The cost

[12]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.

[13]The effect of federal taxes on prices or employment with cost-of-living indexation or deductions is determined by substituting $d\tau^j/m$ from (13) or (15) into equations (5),(8a), (8b), and (10).

shares depend on a number of sources discussed in the Appendix. For traded goods, the cost-share of land, θ_L, is 2.5 percent, the cost share of capital, θ_K, is 15 percent, and the cost share of labor, θ_N, is 82.5 percent. For home goods, the cost-share of land, ϕ_L, is 23 percent, the cost share of capital, ϕ_K, is 15 percent, and the cost share of labor, ϕ_N, is 62 percent. The cost and expenditure shares are consistent with the income shares, and imply that the ratio $\lambda_L^X / \lambda_N^X$, which determines the fraction of taxes capitalized into wages, is equal to 23 percent.

The compensated own-price elasticity of demand for home-goods, η^c, is taken from studies detailed in the Appendix, with estimates that center around 0.5. The elasticity of employment with respect to local taxes, ε, is taken at 6.0 based on two methods, each yielding similar estimates. The first is to use direct reduced-form estimates of ε from Bartik's (1991) meta-analysis of the effect of local taxes on local levels of output and employment, controlling for local public spending. The second is to infer ε by directly calibrating a derived theoretical equation for employment changes, shown in Appendix B.2, using the above parameters, as well elasticity of substitution parameters in production taken from the literature.

The marginal federal income tax rate on gross wages, τ', of 33.3 percent is equal to the average marginal tax rate from TAXSIM (Feenberg and Coutts 1993) of 25.1 percent plus the marginal payroll tax rate on both the employer and employee sides, net of additional Social Security benefits (Boskin et al. 1987) of 8.2 percent. The federal deduction level, δ, is set at 0.257, which is far less than one because of non-housing home goods, renters, non-itemizing owners, and the inability to deduct from payroll taxes.[14]

Furthermore, I also include state-tax differentials due to the fact that wages, and hence state tax burdens, vary within state, even though state services do not. Taking into account federal deductions, state taxes (including income and sales taxes) increase the effective marginal tax rate on wages by 6.2 percentage points, on average, ranging from 0 points in Alaska to 8.8 percent in Minnesota. However, wage differences within state are only 44 percent as large, on average, as wage differences within the United States. Thus, total tax differences may be approximated by increasing the federal marginal tax rate by $6.2 \quad 0.44 = 2.7$ points to 36.0 percent. Exact state tax differentials are calculated by multiplying the within-state wage differential by the corresponding state tax rate, and also account for state deductions for housing. Formulas with state taxes are too long to be presented here, but are available from the author.

[14]Effects of a progressive tax system were also explored. A progressive tax schedule increases the variance of tax differentials, increasing the associated deadweight loss in (11). Because wage differentials are small relative to the tax schedule, they lead to only moderate changes in tax rates. A generous calculation produced at most a 5 percent increase in the deadweight burden calculation.

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 2000 Integrated Public Use Microdata Series (IPUMS). Home-good price differentials are based on housing costs, as they are a prime determinant and predictor of cost-of-living differences. Cities are defined at the Metropolitan Statistical Area (MSA) level using 1999 OMB definitions. Consolidated MSAs are treated as a single city (e.g. San Francisco includes Oakland and San Jose), as are the non-metropolitan areas of each state. This classification produces a total of 241 cities, and 49 state-level collections of non-metropolitan areas. More details are given in Appendix C.

Inter-urban wage differentials, w^j, are calculated from the logarithm of hourly wages for full-time workers, ages 25 to 55. These differentials control for skill differences across workers to provide an analogue to the representative worker in the model. Thus, 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 requires 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 control variables, such as occupation or industry, could depend on where the worker locates.[15]

Housing values and gross rents reported in the Census are used to calculate home-good price differentials, $\hat{p}^j$. To reduce 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-cost differences requires that average unobserved

[15] Obviously workers do not all have the same endowments and tastes or pay the same marginal tax rate, nor are they 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 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.

housing quality does not vary systematically across cities.[16]

Table 1 presents wage, housing-cost, quality-of-life, and federal-spending differentials in 2000 for selected metro areas, and by Census division and metropolitan size. Figure 3 graphs wage differentials against housing-cost differentials for all metro areas and non-metro areas. Most large cities have above-average wages and housing costs; and, across cities of the same size, wages and costs tend to be higher in the Northeast and the Pacific. Overall, wages and housing costs are positively correlated, as reflected in the regression line.

As seen in equation (15), the calculation of tax differentials with deductions requires estimates of the quality-of-life differential, $\hat{Q}^j$, which is inferred from an amended mobility condition in Appendix A.4. This calculation can be seen using the drawn mobility condition across cities with average quality of life. $\hat{Q}^j$ in a particular city depends on how far its marker is to the right of this curve. Also shown is a zero-profit condition for firms for an average city where $\hat{A}_X^j = \hat{A}_Y^j = 0$. Note that without data on land rents, trade and home-productivity differences are not separately identified.[17]

To investigate federal spending differentials, data is taken from the Consolidated Federal Funds Report (CFFR), available from the U.S. Census of Governments. Spending is 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.[18] The second category includes spending that benefits individuals who are typically inactive in the labor market, such as retirees and full-time students, including Social Security and Medicare. The remaining category of "other" spending is more likely to benefit workers according to their location. Other spending 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. The adjusted differentials for other spending are reported as a fraction of household income in Table 1.

[16] Malpezzi et. al. (1998) determine that similar housing-cost indices derived from the Census perform as well or better than most other indices. Because home-good prices have only a minor effect on tax differentials, and as rent and housing-price differentials are highly correlated, the simulation is not very sensitive to how housing-cost differentials are estimated.

[17] The slope of the mobility condition is $s_y\left[1-\delta\tau^{\theta}\left(1-\left|\eta^c\right|\right)\right]/\left[s_w\left(1-\tau^{\theta}\right)\right]$ and the slope of the zero-profit condition is $-\theta_L/\left(\theta_N\phi_L-\theta_L\phi_N\right)$. The capitalization of a quality-of-life improvement or a federal tax reduction (modeled as a head tax) on wages and housing prices is illustrated by shifting the mobility condition to the right. The capitalization of an increase in firm-productivity or a decrease in home-productivity is modeled by shifting the zero-profit condition to the right. Quality-of-life and productivity estimates are presented and explained in Albouy (2008a) and Albouy (2008c).

[18] Weingast et al. (1981) explains when localized spending should be treated as a transfer.

6.3 Tax Differences and Their Effects

Using the base calibration and estimates of $\hat{w}^j$, $\hat{p}^j$, and $\hat{Q}^j$ for 2000, Table 2 reports estimates of tax differentials and its effects across fifteen larger cities with relatively large or small tax burdens. Estimates are also reported by Census division and city size. The three components of the federal t

while most small towns and non-metropolitan areas, particularly in the South, receive a large tax break. Empirically, this appears to have more to do with productivity differences than quality-of-life differences. The average tax differential from quality-of-life differences alone would be only 0.4 percent, while the average from productivity differences alone would be 3.0 percent.

The total tax differentials are considerable relative to typical differences in local taxes. Any local official would consider a permanent three-percent tax, without any compensating services, on local residents to be a fiscal calamity. Yet, central governments are imposing this situation on cities like Chicago, New York and San Francisco. On the other hand, an unconditional grant of two percent of income in perpetuity dwarfs almost any pork-barrel project. Relative to the national average, this is what workers in cities like Norfolk and San Antonio, as well as most non-metropolitan areas, effectively receive from the federal government.

These large tax differentials have considerable effects on prices and employment, seen in the last four columns Table 2. For example, the additional taxes paid to Washington and Albany by New York City raise wages by 1.6 percent, lower long-run housing prices by 11 percent, and lower land values by 41 percent. The employment effect is especially striking, stating that employment is 27 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 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. In a typical high-wage city, workers pay 2.8 percent more of their income in taxes, which causes land values to be 28 percent lower. Workers are compensated for the tax differential through a 0.9 percent increase in wages, increasing their pre-tax incomes by 0.6 percent, and a 6.0 percent reduction in the housing prices, reflecting a cost-of-living reduction of 2.2 percent. Thus, workers are compensated more through a lower cost-of-living than through higher wages.

The employment effect is quite large at 17 percent. Taken together, the employment effects create a substantial deadweight loss of about 0.32 percent of income a year, or $39.2 billion in 2008. 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.[21]

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; this doubles the impact on land rents, without changing any of the other quantities.

Column 4 shows that if ε is -9.37, 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 zero then tax differentials are reduced substantially, 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 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. Finally, column 8 looks at the effect of federal taxes only, ignoring state taxes. Since federal taxes account for 92 percent of tax differences, the effects are only slightly smaller.

6.4 The Distribution of Federal Spending

The unequal burden of federal taxation would not be much of an issue if it was compensated for by federal spending differences. To explore this possibility, Table 4 reports coefficients from regressions of spending differentials, both raw and adjusted, on tax differentials in 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 wages and contracts and non-worker benefits become negative and insignificant, while remaining spending, as well as aggregate spending, becomes negatively correlated with federal tax differentials. 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

[21] In the base calibration, agglomeration effects could dampen the positive effect of taxes on wages. According to Rosenthal and Strange (2004), the elasticity of wages with respect to population size due to agglomeration is not likely to be more than 5 percent. A 17 percent reduction in employment from taxes reduce wages by 0.9 percent, which would offset the 0.9 percent predicted increase in wages due to higher land-to-labor ratios.

government makes greater purchases in areas with higher wages, this arises from its need to purchase skilled labor. Column 9 of Table 3 simulates the effects of tax differentials net of spending: these differentials have slightly larger variance, increasing the deadweight loss by a small amount. Overall, these results establish that federal spending patterns do not offset the pattern of differential taxation.

7 Conclusion

Any tax on labor income creates an incentive for workers to leave high-wage areas in favor of low-wage areas. Even though mobile workers should be compensated for the resulting tax differences through adjustments in local prices and wages, the resulting geographic distribution of employment will be distorted, causing a substantial welfare loss. The simulated effects of federal taxes on prices, employment and welfare are based on the assumption that city attributes are unaffected by population movements. When city attributes are affected by population size, these effects could be smaller or larger than predicted. Furthermore, the distribution of city sizes may no longer be optimal even in the absence of federal taxes, which could ameliorate or aggravate pre-existing distortions. Given the complexities of dealing with endogenous attributes, these issues are left for further work.

Politicians who represent larger cities may legitimately complain that their districts pay a disproportionate share of federal taxes. However, in most countries, reforms to equalize the federal tax burden across areas would likely meet fierce opposition. In the United States, highly-taxed areas tend to be in large cities inside of populous states, which have low Congressional representation per capita, making the prospect of reform daunting. In other countries, such as Canada, rural areas also receive disproportionate representation in national legislatures. Nevertheless, when considering federal tax reforms, policy-makers should be aware of their spatial consequences on local prices, employment, and welfare.

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TABLE 1: WAGE, HOUSING-COST, QUALITY-OF-LIFE, AND FEDERAL-SPENDING DIFFERENCES ACROSS METROPOLITAN AREAS, 2000

		Adjusted Differentials			
	Population Size	Wages	Housing Costs	Quality-of Life	Federal Spending
Main city in MSA/CMSA					
San Francisco, CA	7,039,362	0.26	0.75	0.13	0.009
New York, NY	21,199,865	0.21	0.42	0.04	-0.002
Detroit, MI	5,456,428	0.13	0.09	-0.03	-0.005
Chicago, IL	9,157,540	0.13	0.22	0.01	0.002
Boston, MA	5,819,100	0.14	0.35	0.05	-0.002
Washington, DC	7,608,070	0.13	0.17	-0.01	0.004
Los Angeles, CA	16,373,645	0.13	0.40	0.07	-0.003
Philadelphia, PA	6,188,463	0.12	0.07	-0.04	0.001
Minneapolis, MN	2,968,806	0.09	0.06	-0.02	-0.017
Atlanta, GA	4,112,198	0.08	0.02	-0.03	-0.016
New Orleans, LA	1,337,726	-0.07	-0.07	0.02	-0.008
Jacksonville, FL	1,100,491	-0.07	-0.09	0.01	0.004
San Antonio, TX	1,592,383	-0.09	-0.19	-0.02	-0.003
Oklahoma City, OK	1,083,346	-0.12	-0.21	-0.01	-0.004
Norfolk, VA	1,569,541	-0.11	-0.07	0.03	-0.010
Census Division					
Pacific	45,042,272	0.10	0.36	0.08	0.001
Middle Atlantic	39,668,438	0.08	0.11	0.00	0.000
New England	13,928,540	0.07	0.18	0.03	-0.003
East North Central	45,145,135	0.00	-0.09	-0.03	-0.002
South Atlantic	51,778,682	-0.03	-0.06	0.00	-0.002
Mountain	18,174,904	-0.05	0.02	0.03	0.002
West South Central	31,440,101	-0.07	-0.21	-0.03	0.001
West North Central	19,224,096	-0.11	-0.25	-0.03	0.005
East South Central	17,019,738	-0.12	-0.30	-0.04	0.001
MSA Population					
MSA, Pop > 5 Million	81,606,427	0.16	0.32	0.03	0.000
MSA, Pop 1.5-4.9 Million	55,543,090	0.03	0.05	0.00	-0.005
MSA, Pop 0.5-1.4 Million	40,499,870	-0.03	-0.07	-0.01	0.000
MSA, Pop < 0.5 Million	36,417,747	-0.09	-0.15	-0.01	-0.002
Non-MSA areas	67,354,772	-0.14	-0.28	-0.03	0.005
United States (std dev)	281,421,906	0.13	0.29	0.05	0.009
United States (mean abs dev)	total	0.11	0.24	0.04	0.007

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. Adjusted differentials are residual differences from city-level regressions on a limited set of population covariates.

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

Tax Pay-ment Rank		Federal Tax Differential				State Tax Differ-ential	Total Tax Differ-ential	Total Tax Differential Effects			
			Deduction Effects								
		Wage Effect	Partial Index	QOL Income	Total Federal			Wages	Housing Price	Land Rent	Employ-ment
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Main city in MSA/CMSA										
1	San Francisco, CA	0.067	-0.012	0.005	0.061	0.007	0.068	0.020	-0.145	-0.675	-0.405
2	New York, NY	0.054	-0.007	0.002	0.049	0.004	0.052	0.016	-0.113	-0.524	-0.315
3	Detroit, MI	0.034	-0.001	-0.001	0.032	0.004	0.036	0.011	-0.077	-0.358	-0.215
4	Chicago, IL	0.035	-0.003	0.000	0.032	0.004	0.035	0.011	-0.076	-0.354	-0.213
6	Boston, MA	0.035	-0.005	0.002	0.032	0.002	0.033	0.010	-0.071	-0.332	-0.199
7	Washington, DC	0.034	-0.003	0.000	0.031	0.002	0.033	0.010	-0.071	-0.331	-0.199
8	Los Angeles, CA	0.033	-0.006	0.003	0.030	0.000	0.029	0.009	-0.063	-0.294	-0.177
9	Philadelphia, PA	0.030	-0.001	-0.001	0.027	0.002	0.029	0.009	-0.063	-0.294	-0.176
10	Minneapolis, MN	0.022	-0.001	-0.001	0.021	0.006	0.027	0.008	-0.058	-0.270	-0.162
11	Atlanta, GA	0.020	0.000	-0.001	0.019	0.004	0.023	0.007	-0.049	-0.227	-0.136
108	New Orleans, LA	-0.019	0.001	0.001	-0.017	0.001	-0.016	-0.005	0.035	0.163	0.098
110	Jacksonville, FL	-0.018	0.001	0.000	-0.017	0.000	-0.017	-0.005	0.036	0.168	0.101
132	San Antonio, TX	-0.024	0.003	-0.001	-0.021	-0.001	-0.023	-0.007	0.048	0.225	0.135
148	Oklahoma City, OK	-0.032	0.003	0.000	-0.029	0.003	-0.026	-0.008	0.056	0.262	0.157
173	Norfolk, VA	-0.028	0.001	0.001	-0.026	-0.004	-0.030	-0.009	0.065	0.301	0.180
	Census Divison										
1	Pacific	0.026	-0.006	0.003	0.023	0.000	0.023	0.007	-0.049	-0.230	-0.138
2	Middle Atlantic	0.020	-0.002	0.000	0.019	0.000	0.019	0.006	-0.040	-0.186	-0.112
3	New England	0.017	-0.003	0.001	0.016	0.000	0.016	0.005	-0.034	-0.156	-0.094
4	East North Central	0.000	0.001	-0.001	0.001	0.000	0.001	0.000	-0.001	-0.006	-0.004
5	South Atlantic	-0.008	0.001	0.000	-0.008	0.000	-0.008	-0.002	0.016	0.075	0.045
6	Mountain	-0.013	0.000	0.001	-0.012	0.000	-0.012	-0.004	0.025	0.117	0.070
7	West South Central	-0.019	0.003	-0.001	-0.017	0.000	-0.017	-0.005	0.036	0.168	0.101
8	West North Central	-0.029	0.004	-0.001	-0.026	0.000	-0.026	-0.008	0.055	0.257	0.154
9	East South Central	-0.030	0.005	-0.002	-0.027	0.000	-0.027	-0.008	0.058	0.269	0.161
	MSA/CMSA Population										
1	MSA, Pop > 5 Million	0.041	-0.005	0.001	0.037	0.003	0.040	0.012	-0.085	-0.398	-0.239
2	MSA, Pop 1.5-4.9 Million	0.007	-0.001	0.000	0.006	0.002	0.008	0.002	-0.017	-0.080	-0.048
3	MSA, Pop 0.5-1.4 Million	-0.008	0.001	0.000	-0.007	0.000	-0.007	-0.002	0.015	0.070	0.042
4	MSA, Pop < 0.5 Million	-0.022	0.002	0.000	-0.020	-0.002	-0.022	-0.007	0.048	0.223	0.134
5	Non-MSA areas	-0.035	0.004	-0.001	-0.032	-0.003	-0.035	-0.011	0.076	0.354	0.212
	United States (std dev)	0.034	0.004	0.002	0.030	0.003	0.033	0.010	0.071	0.329	0.197
	United States (mean abs dev)	0.028	0.004	0.002	0.026	0.003	0.028	0.009	0.060	0.281	0.169

Tax differentials calculated using equation (15) with and without the 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 (1)	All land in home goods (2)	Smaller land share (3)	Larger employment response: Cobb-Doug (4)	Inelastic home-good demand (5)	Wage diffs two-thirds estimated size (6)	Housing deductions ignored (7)	Federal taxes only, no state taxes (8)	Adding Federal spending differences (9)
Economic Parameters									
Home goods share s_y	**0.360**	0.360	0.360	0.360	0.333	0.333	0.360	0.360	0.360
Traded good land share θ_L	**0.025**	**0.000**	**0.013**	0.025	0.050	0.050	0.025	0.025	0.025
Traded good labor share θ_N	**0.825**	0.850	0.825	0.825	0.800	0.800	0.825	0.825	0.825
Home good land share ϕ_L	**0.233**	**0.278**	**0.117**	0.233	0.200	0.200	0.233	0.233	0.233
Home good labor share ϕ_N	**0.617**	0.572	0.617	0.617	0.650	0.650	0.617	0.617	0.617
Comp. demand elast for home goods $\varepsilon_{y,p}$	**-0.500**	-0.500	-0.500	-0.500	**0.000**	-0.667	-0.500	-0.500	-0.500
Elasticity of employment to tax/income $\varepsilon_{N,T/m}$	**-6.000**	-6.000	-6.000	**-9.370**	-6.000	-6.000	-6.000	-6.000	-6.000
Tax Parameters									
Marginal tax rate τ'	**0.360**	0.360	0.360	0.360	0.360	0.360	0.360	**0.333**	0.360
Deduction level δ	**0.292**	0.292	0.292	0.292	0.292	0.292	**0.000**	**0.257**	0.292
Implied Parameters									
Share of income to land s_R	**0.100**	0.100	**0.050**	0.100	0.100	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	0.750
Average Percent Effects (Mean Absolute Values)									
Tax differential: $E\|d\tau/m\|$	**0.028**	0.028	0.028	0.028	**0.024**	**0.019**	**0.031**	**0.026**	0.031
Wage effect: $E\|dw\|$	**0.009**	**0.000**	0.009	0.009	0.007	0.006	0.009	0.008	0.009
Home-good price effect: $E\|dp\|$	**0.060**	**0.078**	0.060	0.060	0.052	0.040	0.067	0.055	0.066
Land rent effect: $E\|dr\|$	**0.281**	0.281	**0.562**	0.281	0.242	0.185	0.311	0.258	0.308
Employment effect: $E\|dN\|$	**0.168**	0.168	0.168	0.263	0.145	0.111	0.187	0.155	0.185
Deadweight Loss from Locational Inefficiency									
As a percent of income, E(DWL/Nm)	**0.324%**	0.324%	0.324%	**0.505%**	**0.237%**	**0.140%**	**0.398%**	**0.277%**	**0.390%**
Total DWL (Billions per year, 2008$)	**39.2**	39.2	39.2	61.2	28.6	17.0	48.1	33.5	47.2
Per Capita (per year, 2008$)	**130.6**	130.6	130.6	203.9	95.5	56.7	160.4	111.7	157.3

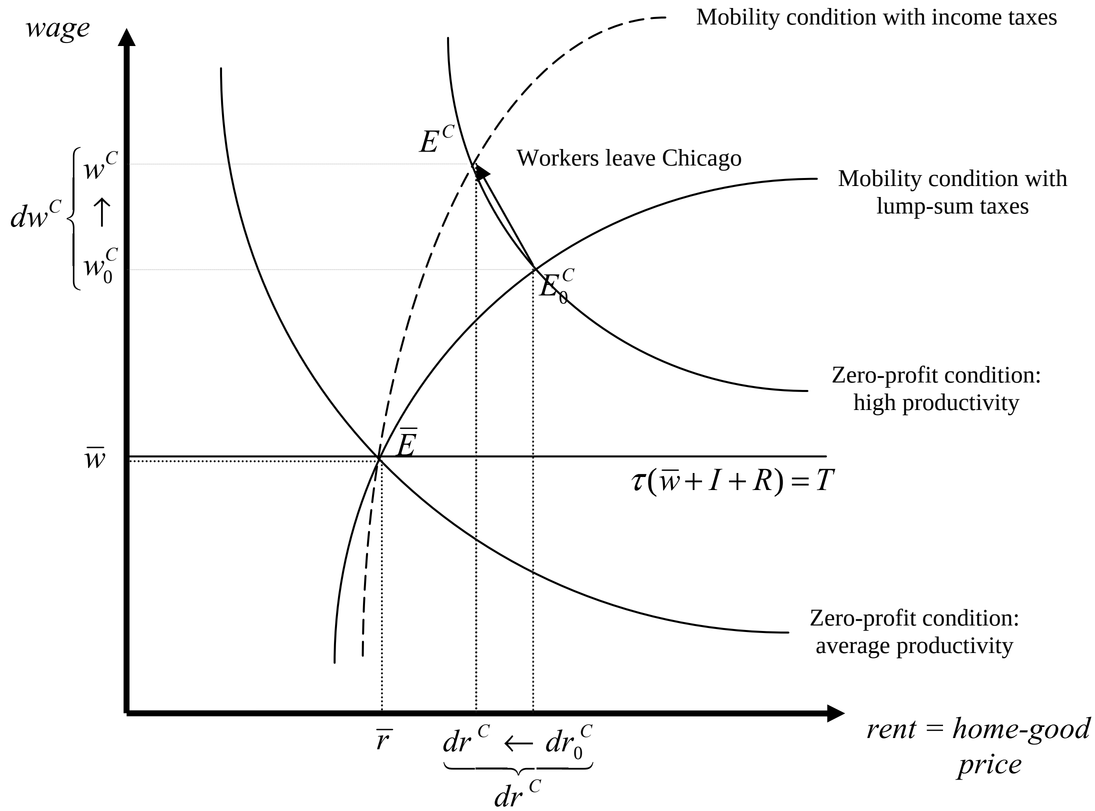
Total DWL measured by taking per DWL as a percent of income and multiplying it by $12.11 trillion, U.S. Personal income in 2008.

TABLE 4: DIFFERENTIAL FEDERAL SPENDING PATTERNS RELATIVE TO DIFFERENTIAL TAXATION PATTERNS

Type of Federal Spending	All Spending	Wages & Contracts	Non-Worker Benefits	All Other Spending
Panel A: Raw Differentials				
Federal Tax Differential	-0.081	0.242	-0.194	-0.014
(standard error)	(0.114)	(0.086)	(0.053)	(0.039)
Panel B: Adjusted Differentials				
Federal Tax Differential	-0.231	-0.087	-0.028	-0.072
(standard error)	(0.084)	(0.055)	(0.015)	(0.028)

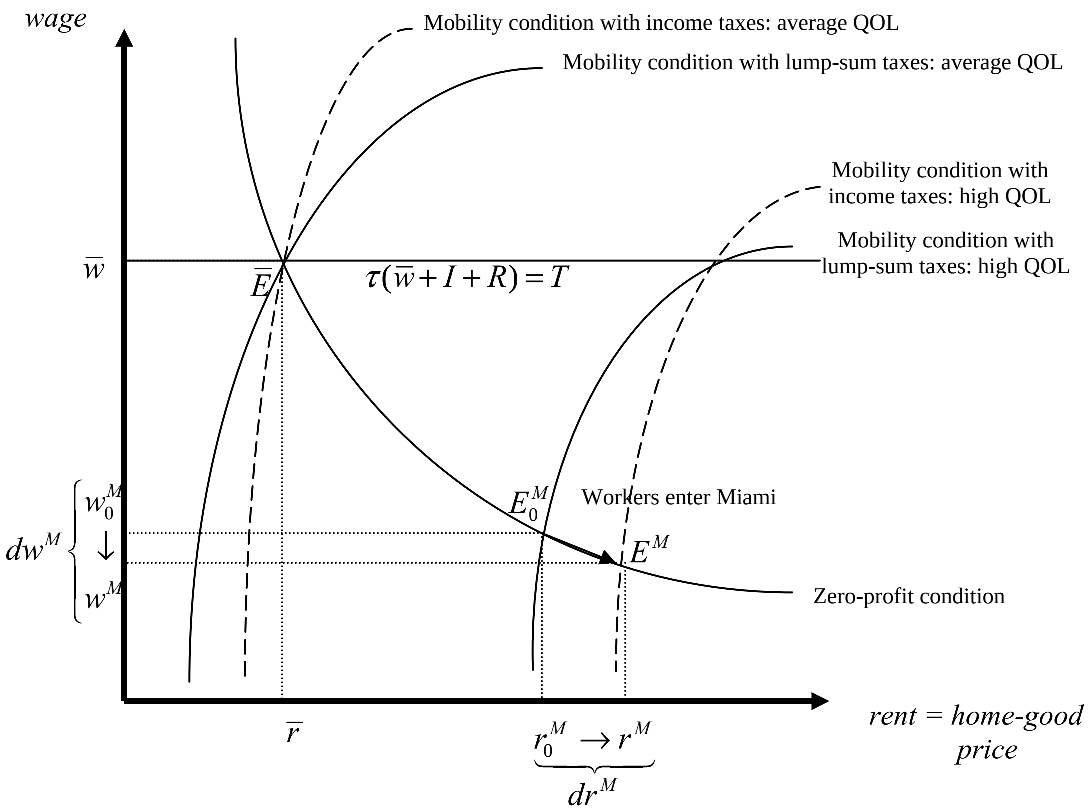
Regressions weighted by MSA population for all 290 observations. Robust standard errors reported. Definitions of federal spending variables are discussed in the main text and in Appendix C.

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



In a simplified model ($r = p$, $Q = 1$, $A_Y = 1$), replacing a lump-sum tax, T, with a utility-equivalent federal income tax, τ, raises wages, w, and lowers rents, r, and employment, N, in Chicago, labeled "C," a city with high trade-productivity ($A_X^C > 1$), changing the equilibrium from E_0^C to E^C.

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



In a simplified model ($r = p$, $A_X = 1$, $A_Y = 1$), replacing a lump-sum tax, T, with a utility-equivalent federal income tax, τ, lowers wages, w, rents, r, and employment in Miami, labeled "M", a city with high quality of life, QOL, ($Q^M > 1$), changing the equilibrium from E_0^M to E^M .

Figure 3: Wage Levels versus Housing Costs across Metro Areas, 2000

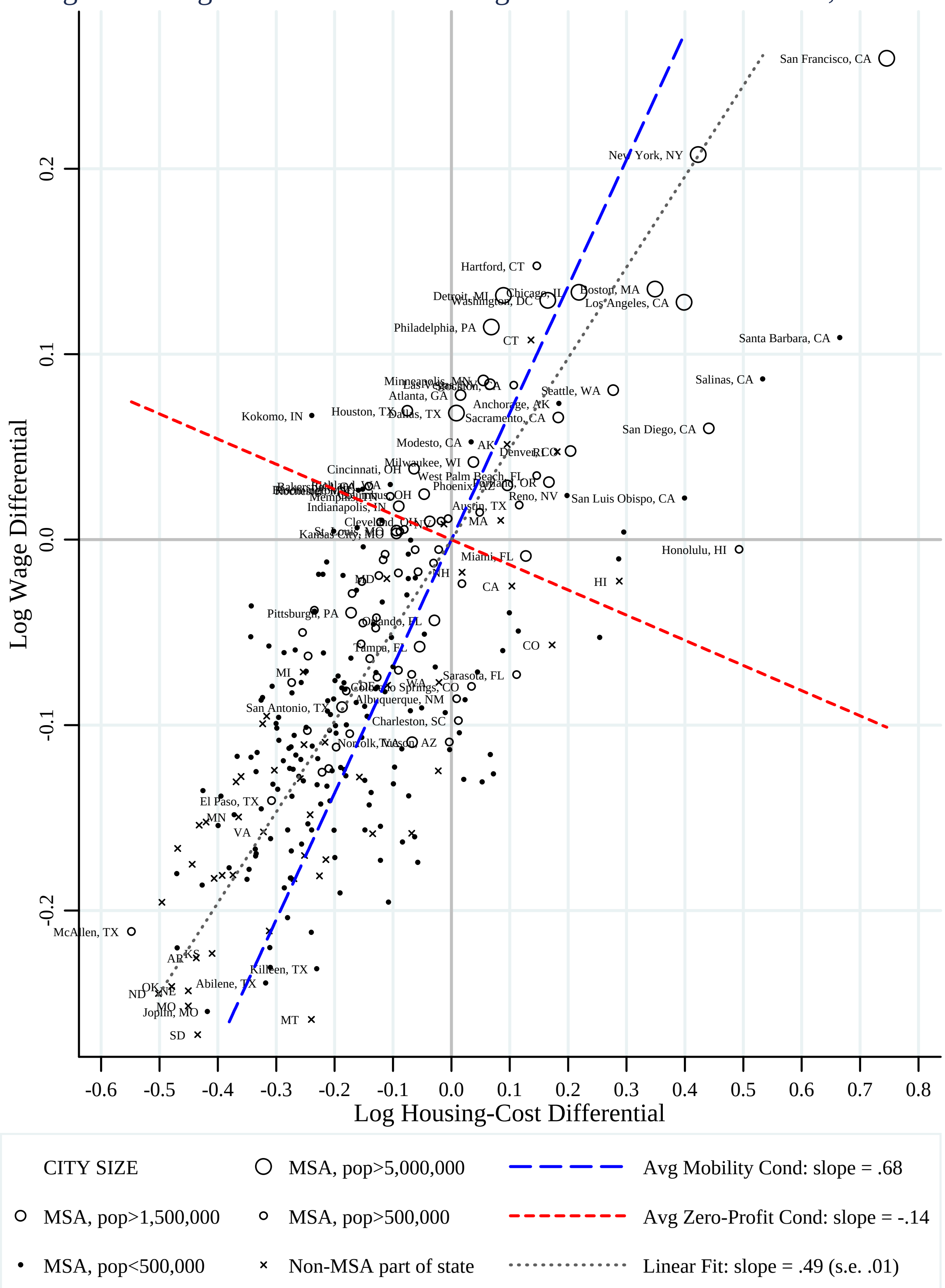
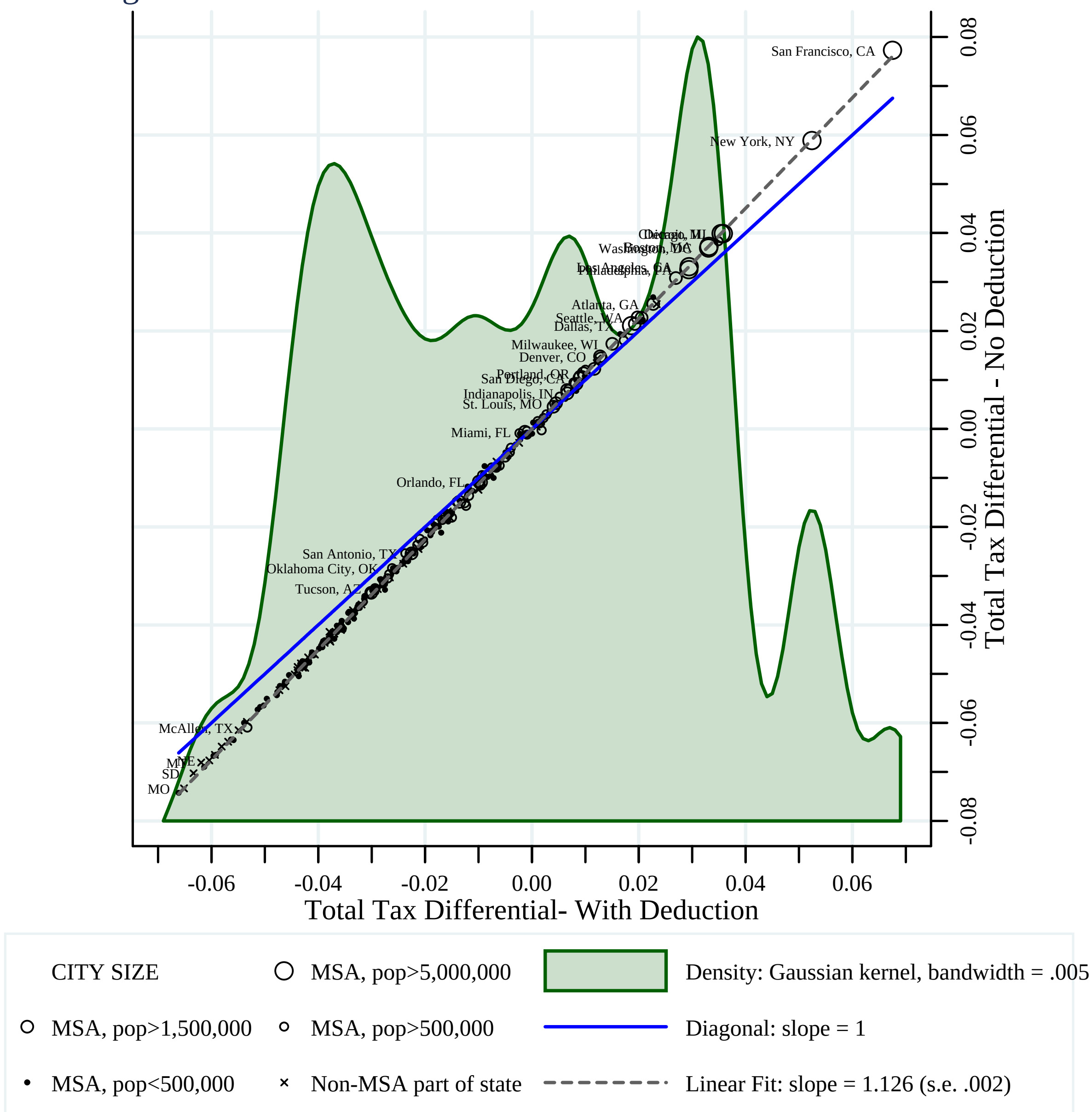


Figure 4: Differential Tax Burden With and Without Deduction



Springfield, IL
ND
Anchorage, AK
Tallahassee, FL
NE
Albany, NY
SD
Raleigh, NC
MT
OK
Miami, FL
Pittsburgh, PA
San Francisco, CA
McAllen, TX
Tucson, AZ
San Diego, CA
MO
El Paso, TX
Washington, DC
Mobile, AL
Columbus, OH
Joplin, MO
Kansas City, MO
Houston, TX
Los Angeles, CA
Boston, MA
New York, NY
San Antonio, TX
Portland, OR
Detroit, MI
Phoenix, AZ
Norfolk, VA
Denver, CO
Orlando, FL
Tampa, FL
Atlanta, GA
Minneapolis, MN
Colorado Springs, CO
Sarasota, FL
Odessa, TX

Appendix

A Additional Theoretical Details

A.1 System of Equations

The entire system consists of fourteen equations in fourteen unknowns, with four exogenous parameters: $Q, A^{\mathsf{X}}, A^{\mathsf{Y}}$, and T, where T is a city-specific head-tax (superscripts j supressed). 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,

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

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

R, I, and T are given. Changes in output (X, Y), employment $(N_{\mathsf{X}}, N_{\mathsf{Y}}, N)$, capital $(K_{\mathsf{X}}, K_{\mathsf{Y}})$, and land use $(L_{\mathsf{X}}, L_{\mathsf{Y}})$ are determined by nine equations in the production sector: six statements of Shepard's Lemma

$$\partial c_{\mathsf{X}}/\partial w = N_{\mathsf{X}}/X, \; \partial c_{\mathsf{X}}/\partial r = L_{\mathsf{X}}/X, \; \partial c_{\mathsf{X}}/\partial i = K_{\mathsf{X}}/X \tag{A.3}$$

$$\partial N_{\mathsf{Y}}/\partial w = N_{\mathsf{Y}}/Y, \; \partial c_{\mathsf{Y}}/\partial r = L_{\mathsf{Y}}/Y, \; \partial c_{\mathsf{Y}}/\partial i = K_{\mathsf{Y}}/Y \tag{A.4}$$

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

$$N_{\mathsf{X}} + N_{\mathsf{Y}} = N \tag{A.5}$$

$$L_{\mathsf{X}} + L_{\mathsf{Y}} = L \tag{A.6}$$

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

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 expositional brevity.

A.2.1 Prices

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 $d\hat{z} = dz/z$:

$$s_{\mathsf{w}} d\hat{w} \quad s_{\mathsf{y}} d\hat{p} = dT/m \tag{A.8a}$$

$$\theta_{\mathsf{L}} d\hat{r} + \theta_{\mathsf{N}} d\hat{w} = 0 \tag{A.8b}$$

$$\phi_{\mathsf{L}} d\hat{r} + \phi_{\mathsf{N}} d\hat{w} \quad d\hat{p} = 0 \tag{A.8c}$$

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, after-tax real incomes do not change because of head taxes. Equations (A.8b) and (A.8c) demonstrate how wage and rent changes must offset one another to keep unit costs equal to prices.[i]

The percent price changes are solved with Cramer's Rule and the accounting identities. Land rents decrease in proportion to taxes according to:

$$d\hat{r} = \quad \frac{1}{s_{\mathsf{R}}}\frac{dT}{m} \tag{A.9}$$

As $s_{\mathsf{R}} = rL/Nm$, (A.9) can be re-expressed in level terms as $dr \quad L = \quad N \quad dT$, 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

$$d\hat{w} = \frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\frac{1}{s_{\mathsf{R}}}\frac{dT}{m} \tag{A.10}$$

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 $\quad d\hat{w}/d\hat{r} = \theta_{\mathsf{L}}/\theta_{\mathsf{N}}$, a cost ratio which should be well below one. The price change

$$d\hat{p} = \quad \left(\phi_{\mathsf{L}} \quad \phi_{\mathsf{N}}\frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\right)\frac{1}{s_{\mathsf{R}}}\frac{dT}{m} \tag{A.11}$$

is negative if home goods are more cost intensive in land relative to labor than traded goods ($\phi_{\mathsf{L}}/\phi_{\mathsf{N}} > \theta_{\mathsf{L}}/\theta_{\mathsf{N}}$) 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, ($\phi_{\mathsf{L}} < 1$) 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 ($\quad d\hat{p}/d\hat{w} > 1$).

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.

A.2.2 Consumption

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

$$s_{\mathsf{x}}d\hat{x} + s_{\mathsf{y}}\left(d\hat{p} + d\hat{y}\right) = s_{\mathsf{w}}d\hat{w} \quad \frac{dT}{m} \tag{A.12}$$

$$d\hat{x} \quad d\hat{y} = \sigma_{\mathsf{D}}d\hat{p} \tag{A.13}$$

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

$$d\hat{y} = \quad s_{\mathsf{x}}^{*}\sigma_{\mathsf{D}}d\hat{p} = \quad s_{\mathsf{x}}^{*}\sigma_{\mathsf{D}}\frac{1}{s_{\mathsf{R}}}\left(\phi_{\mathsf{L}} \quad \phi_{\mathsf{N}}\frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\right)\frac{dT}{m} \tag{A.14}$$

[i] 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.

where $s_X^* = s_X/(s_X + s_Y) = s_X/(1 \quad s_T)$ 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.2.3 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

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

These expressions make use of partial (Allen-Uzawa) elasticities of substitution. Each sector has three partial (Allen-Uzawa) elasticities of substitution in production for each combination of two factors, where $\sigma_X^{LN} \quad \left(\partial^2 c/\partial w \partial r\right) / \left(\partial c/\partial w \quad \partial c/\partial r\right)$ 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. 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

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

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

$$\begin{aligned} \varepsilon = \; & \frac{1}{(\theta_N s_R)^2} \mathsf{f} (s_X + s_T)\theta_L\theta_N \left(\theta_L + \theta_N\right)\sigma_X + \frac{s_X s_Y}{s_X + s_Y}\left(\theta_N \phi_L \quad \theta_L \phi_N\right)^2 \sigma_D \\ & + s_Y[\phi_L \phi_N \left(\theta_L + \theta_N\right)^2 + \phi_K \left(\phi_N \theta_L^2 + \theta_N^2 \phi_L\right)]\sigma_Y \, \mathsf{g} \end{aligned} \tag{A.16}$$

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 due to locational inefficiency from federal income taxation 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. $\tau \bar{m} = \quad T$. The net revenue collected from city j is then $G^{\mathsf{j}} = \left(\tau m^{\mathsf{j}} + T\right) N^{\mathsf{j}} = \tau \left(w^{\mathsf{j}} \quad \bar{w}\right) N^{\mathsf{j}}$, positive in cities with above-average wages. Differentiating totally with respect to τ^{j}

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

Equations (5) and (10) give the derivatives $dw^{\mathsf{j}}/d\tau = m^{\mathsf{j}} \left(\theta_{\mathsf{L}}/\theta_{\mathsf{N}}\right)\left(s_{\mathsf{W}}/s_{\mathsf{R}}\right)\hat{w}^{\mathsf{j}}$ and $dN^{\mathsf{j}}/d\tau = \varepsilon N^{\mathsf{j}} s_{\mathsf{W}} \hat{w}^{\mathsf{j}}$. Using these together with the first-order approximation $w^{\mathsf{j}} \quad \bar{w} = \hat{w}^{\mathsf{j}} w^{\mathsf{j}} = \hat{w}^{\mathsf{j}} s_{\mathsf{W}} m^{\mathsf{j}}$,

$$dG^{\mathsf{j}} = N^{\mathsf{j}} m^{\mathsf{j}} \left[s_{\mathsf{W}} \hat{w}^{\mathsf{j}} + \tau^{\mathsf{j}} \frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}} \frac{1}{s_{\mathsf{R}}} \hat{w}^{\mathsf{j}} + \tau^{\mathsf{j}} \left(s_{\mathsf{W}} \hat{w}^{\mathsf{j}}\right)^2 \varepsilon\right] d\tau^{\mathsf{j}}$$

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

$$E\left[dG^{\mathsf{j}}\right] = Nm \quad E\left[\left(s_{\mathsf{W}} \hat{w}^{\mathsf{j}}\right)^2 \tau^{\mathsf{j}} d\tau^{\mathsf{j}}\right] \varepsilon$$

which is negative since $\varepsilon < 0$. Integrating over $d\tau^{\mathsf{j}}$ and substituting in $\tau^{\mathsf{j}} s_{\mathsf{W}} \hat{w}^{\mathsf{j}} = d\tau^{\mathsf{j}}/m$ 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 $\tau = \tau\left(m \quad \delta p y\right)$, the mobility condition (4a) and the log-linearized budget constraint (A.12) change to

$$\begin{aligned} \hat{Q} &= \left(1 \quad \delta\tau'\right) s_{\mathsf{y}} \hat{p} \quad \delta\tau' s_{\mathsf{y}} \hat{y} \quad \left(1 \quad \tau'\right) s_{\mathsf{W}} \hat{w} \\ s_{\mathsf{x}} \hat{x} &= \quad \left(1 \quad \delta\tau'\right) s_{\mathsf{y}} \hat{p} \quad \left(1 \quad \delta\tau'\right) s_{\mathsf{y}} \hat{y} + \left(1 \quad \tau'\right) s_{\mathsf{W}} \hat{w} \end{aligned} \tag{A.17}$$

Adding these expressions gives

$$\hat{Q} + s_{\mathsf{x}} \hat{x} = \quad s_{\mathsf{y}} \hat{y}$$

Substituting in $\hat{x} = \hat{y} + \sigma_{\mathsf{D}} \hat{p}$, and using $\eta^{\mathsf{c}} = \quad s_{\mathsf{x}}^{*} \sigma_{\mathsf{D}} < 0$, we have

$$\hat{y} = \quad (\hat{Q} + s_{\mathsf{x}} \sigma_{\mathsf{D}} \hat{p})/(s_{\mathsf{x}} + s_{\mathsf{y}}) = \eta^{\mathsf{c}} \hat{p} \quad \hat{Q}/(s_{\mathsf{x}} + s_{\mathsf{y}})$$

This expression is used in (15), although s_{T} is set to zero there for expositional ease. Substituting back into (A.17) and using $s_{\mathsf{y}}^{*} \quad s_{\mathsf{y}}/(s_{\mathsf{x}} + s_{\mathsf{y}})$

$$\hat{Q} = \left\{\left[1 \quad \delta\tau'\left(1 \quad |\eta^{\mathsf{c}}|\right)\right] s_{\mathsf{y}} \hat{p} \quad \left(1 \quad \tau'\right) s_{\mathsf{W}} \hat{w}\right\} / \left(1 \quad \delta\tau' s_{\mathsf{y}}^{*}\right) \tag{A.18}$$

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

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

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)

$$\frac{d\tau}{m} = \frac{\tau' s_{\mathsf{w}} \hat{w}_0 \quad \delta\tau' \left(1 \quad |\eta^{\mathsf{c}}|\right) s_{\mathsf{y}} \hat{p}_0 + \delta\tau' s_{\mathsf{y}} \hat{Q}}{1 \quad \tau' \frac{L}{N} \frac{\mathsf{s}_w}{\mathsf{s}_R} \quad \delta\tau' \left(1 \quad |\eta^{\mathsf{c}}|\right) \frac{\mathsf{s}_y}{\mathsf{s}_R} \left(\phi_{\mathsf{L}} \quad \phi_{\mathsf{N}} \frac{L}{N}\right)} \tag{A.20}$$

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. Here, I explain my choices of tax parameters, elasticities, and cost, income, and consumption shares for the United States. The calibration draws from similar calibrations in Rappaport (2008) and Shapiro (2006), although the models, as well as the choices made here, are different.

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}, θ_{L}, ϕ_{L}, s_{y}, and s_{T} gives values of θ_{N}, θ_{K}, ϕ_{L}, ϕ_{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},

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 (2008), 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 $\phi_{\mathsf{L}} = 0.20$ seems reasonable.

The cost-share of land in traded goods, θ_{L}, appears to be small: Beeson and Eberts (1986) use a value of 0.027, while Rappaport (2008) uses a smaller value of 0.016. Valentinyi and Herrendorff (2008) estimate the land share of tradeables at 4 percent, although their definition of tradeables differs from the definition here. A value of $\theta_{\mathsf{L}} = 0.025$ is used here. The cost-share of land in home-goods, taken as housing costs, ϕ_{L}, is taken at 23 percent: this is slightly above values reported in McDonald (1981), Roback (1982), and Thorsnes (1997) to take into account an increase in land-cost shares over time seen in Davis and Palumbo (2007). Together with the expenditure shares, these cost shares imply that income-share of land, s_{R}, is 10 percent, with 83 percent of land in cities going to the production of home goods. This is roughly consistent with patterns in Keiper et al. (1961).[iii]

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.

Because there is only one remaining free parameter, the next choice simultaneously determines the cost shares of labor and capital in the two production sectors. As information on the cost-share of capital in the housing sector, ϕ_{K}, or the traded sector, θ_{N}, is unavailable, the capital shares in both sectors are set equal to 15 percent. The remaining cost shares for labor are then determined by the identities, with the share in traded goods, θ_{N}, equal to 82.5 percent and the share in home goods, ϕ_{N}, equal to 62 percent.[iv]

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 price elasticity of home goods, η^{c}, is approximated with the compensated price elasticity for housing services, $\eta^{\mathsf{c}}_{\mathsf{hous}}$. The Slutsky equation for the compensated price elasticity is $\eta^{\mathsf{c}}_{\mathsf{hous}} = \eta_{\mathsf{hous}} + s_{\mathsf{hous}}\varepsilon_{\mathsf{hous;m}}$, where η_{hous} is the uncompensated price elasticity and $\varepsilon_{\mathsf{hous;m}}$ is the income elasticity. There is a large literature devoted to trying to estimate these parameters, including Rosen (1985), Goodman and Kawai (1986), Goodman (1988) Ermisch et al. (1996), Goodman (2002), and Ionnides and Zabel (2003). The range of plausible estimates in this literature is large, with uncompensated price elasticities ranging from 1 to 0.3, and income elasticities from 1 to 0.4. This implies that the homothetic assumption is a sensible approximation, and that the compensated elasticities lie in the range of

[iii] 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. In the base calibration of the model, 51 percent of land is devoted to actual housing, 32 percent is for non-housing home goods, and 17 percent is for traded goods, including those purchased by the federal government.

[iv] 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.

0.08 to 0.91. A midrange value of $\eta^{c} = \quad 0.5$ is used for the base calibration. η^{c} provides the elasticity of substitution value of $\sigma_{D} = \quad \eta^{c}/s_{X}^{*}$, which under the current calibration is $\sigma_{D} = 0.67$.

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 $\varepsilon_{N\ T=m}$ 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

$$\varepsilon = \quad 1,65\sigma_{X} \quad 6.76\sigma_{Y} \quad 0.96\sigma_{D} \tag{A.21}$$

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 is $\quad 9.37$. This case seems unlikely, as the value of σ_{D} appears to be less than one, as do the elasticities of substitution in production σ_{X} and σ_{Y}..

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 $\quad 0.25$. Studies more fitting to the model exhibit somewhat larger elasticities: 30 studies with public service controls have an average elasticity of $\quad 0.33$; the 12 studies with fixed-effect controls have an average elasticity of $\quad 0.44$. Taking the $\quad 0.33$ 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 $\varepsilon_{Out} = \quad 6.67$. 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

$$\varepsilon_{Out} = \left[(s_{x} + s_{T})\,\hat{X} + s_{y}\hat{Y} \right] / \,(dT/m) = \quad 2.58\sigma_{X} \quad 7.47\sigma_{Y} \quad 1.08\sigma_{D} \tag{A.22}$$

Combining (A.22) with (A.21) it is possible to eliminate σ_{Y}

$$\varepsilon = 0.91\varepsilon_{Out} \quad 0.69\sigma_{X} \quad 0.03\sigma_{D}$$

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 $\varepsilon_{Out;T=m} = \quad 6.67$, $\sigma_{X} = 0.67$, and $\sigma_{D} = 0.67$, yields a value of $\varepsilon = \quad 5.56$. This is consistent with a value of $\sigma_{Y} = \quad 0.57$. A value of $\varepsilon = \quad 6.0$ is taken in the main calibration.[v]

[v] 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

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, although only 85 percent of wage earnings are subject to the OASDI cap. HI taxes emulate a pure tax (Congressional Budget Office 2005). These facts suggest adding 37.5 percent of the Social Security tax and all of the Medicare tax to the federal income tax rate, adding 8.2 percent. The employer half of the payroll tax (4.1 percent) has to be added to wage observed wage levels, to produce the gross wage level. Overall, this puts an overall federal tax rate of 33.3 percent tax rate on gross wages (used to calculate the federal tax differential), although only a 29.2 percent rate on observed wages (used to calculate quality-of-life differentials).

Determining the federal 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 of 21.6 percent. Thus, on average these deductions reduce the effective price of eligible goods by 14.5 percent. Since eligible goods only include housing, this deduction applies to only 59 percent of home goods. Multiplying 14.5 percent times 59 percent gives an effective price reduction of 8.6 percent for home goods. Divided by a federal tax rate of 33.3 percent, this produces a federal deduction level of 25.7 percent.

State income tax rates from 2000 are taken from TAXSIM, which, per dollar, fall at an average marginal rate of 4.5 percent. State sales tax data in 2000 is taken from the Tax Policy Center, originally supplied by the Federation of Tax Administrators. The average state sales tax rate is 5.2 percent. Sales tax rates are reduced by 10 percent to accomodate untaxed goods and services other than food or housing (Feenberg et al. 1997), and by another 8 percent in states that exempt food. Putting these taxes, raises the marginal tax rate on wage differences within state by an average of 5.9 percentage points, ranging from zero points in Alaska to 8.8 points in Minnesota.

State-level deductions for housing expenditures, explicit in income taxes, and implicit in sales taxes, should also be included. At the state level, deductions for income taxes are calculated in an equivalent way using TAXSIM data. Furthermore, all housing expenditures are deducted from the sales tax. Overall this produces an effective deduction level of $\delta = 0.293$.

In summary, the following values are taken for the calibration

$$\begin{array}{llllll}
s_{\mathsf{x}} = 0.49 & \theta_{\mathsf{L}} = 0.025 & \phi_{\mathsf{L}} = 0.233 & s_{\mathsf{R}} = 0.10 & \eta^{\mathsf{c}} = 0.50 & \tau' = 0.346 \\
s_{\mathsf{y}} = 0.36 & \theta_{\mathsf{N}} = 0.825 & \phi_{\mathsf{N}} = 0.617 & s_{\mathsf{w}} = 0.75 & \varepsilon = 6.0 & \delta = 0.421 \\
s_{\mathsf{T}} = 0.15 & \theta_{\mathsf{K}} = 0.15 & \phi_{\mathsf{K}} = 0.15 & s_{\mathsf{I}} = 0.15 & &
\end{array}$$

C Data and Estimation

I use United States Census data from the 2000 Integrated Public-Use Microdata Series (IPUMS), from Ruggles et al. (2004), to calculate wage and housing price differentials. The wage differentials are calculated for workers ages 25 to 55, who report working at least 30 hours a week, 26 weeks a year. The MSA assigned

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.

to a worker is determined by their place of residence, rather than their place of work. The wage differential of an MSA is found by regressing log hourly wages on individual covariates and indicators for a worker's MSA of residence, using the coefficients on these MSA indicators. The covariates consist of

12 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 covariates are interacted with gender.

I first run the regression using census-person weights. From the regressions a predicted wage is calculated using individual characteristics alone, controlling for MSA, to form a new weight equal to the predicted wage times the census-person weight. These new income-adjusted weights are needed since workers need to be weighted by their income share (see Appendix D.3). The new weights are then used in a second regression, which is used to calculate the city-wage differentials from the MSA indicator variables. In practice, this weighting procedure has only a small effect on the estimated wage differentials.

Housing-cost differentials are calculated using the logarithm of rents, whether they are reported gross rents or imputed rents derived from 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 cost of an MSA is calculated in a manner similar to wages, except using a regression of the actual or imputed 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).

I first run a regression of housing values on housing characteristics and MSA indicator variables using only owner-occupied units, weighting by census-housing weights. A new value-adjusted weight is calculated by multiplying the census-housing weights by the predicted value from this first regression using housing characteristics alone, controlling for MSA. A second regression is run using these new weights for all units, rented and owner-occupied, on the housing characteristics fully interacted with tenure, along with the MSA indicators, which are not interacted. The house-price differentials are taken from the MSA indicator variables in this second regression. As with the wage differentials, this adjusted weighting method has only a small impact on the measured price differentials.

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

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. 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

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

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. Since the calibration already relies on a direct estimate of ε, these types of deviations are accounted for in the simulation.

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

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

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

$$s_{\mathsf{w}}\hat{w} \quad s_{\mathsf{y}}\hat{p} = \frac{dT}{m} \quad \hat{\xi}_{\mathsf{k}}$$

Assume that ξ_{i} follows a Pareto distribution with parameter $1/\psi$

$$F\left(\xi_{\mathsf{i}^{\theta}}\right) = 1 \quad \left(\frac{\underline{\xi}}{\xi_{\mathsf{i}}}\right)^{1=} \; , \; \xi_{\mathsf{i}} \quad \underline{\xi}$$

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 $N = \mu \Pr(\xi_{\mathsf{i}} \quad \xi_{\mathsf{k}}) = \mu[1 \quad F(\xi_{\mathsf{k}})] = \mu\left(\underline{\xi}/\xi_{\mathsf{k}}\right)^{1=}$, thus

$$\log N = \log\mu + \frac{1}{\psi}[\log\underline{\xi} \quad \log\xi_{\mathsf{k}}]$$

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

$$s_{\mathsf{w}}\hat{w} \quad s_{\mathsf{y}}\hat{p} = \frac{dT}{m} + \psi\hat{N} \tag{A.24}$$

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

$$\varepsilon(\psi) = \frac{\varepsilon(0)}{1 + \psi\left[\frac{\mathsf{s}_y}{\mathsf{s}_R}\left(\phi_{\mathsf{L}} \quad \frac{L}{N}\phi_{\mathsf{N}}\right) \quad \varepsilon(0)\right]} \tag{A.25}$$

where $\varepsilon(0)$ is the elasticity given in (A.16), which assumed homogenous tastes, i.e. $\psi = 0$. Thus, $1/\psi$ may be interpreted as a mobility parameter, as a higher ψ represents lower mobility, from $\psi = 0$ for perfect mobility, to $\psi = \mathbf{1}$ for perfect immobility, as $\varepsilon(\mathbf{1}) = 0$.

The effects of taxes on prices depends on the product of ψ and the elasticity $\varepsilon(\psi)$

$$\begin{aligned}
d\hat{r} &= \quad \frac{1+\psi\varepsilon(\psi)}{s_{\mathsf{R}}}\frac{dT}{m} \\
d\hat{w} &= \frac{1+\psi\varepsilon(\psi)}{s_{\mathsf{R}}}\frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\frac{dT}{m} \\
d\hat{p} &= \quad \frac{1+\psi\varepsilon(\psi)}{s_{\mathsf{R}}}\left(\phi_{\mathsf{L}} \quad \frac{\theta_{\mathsf{L}}}{\theta_{\mathsf{N}}}\phi_{\mathsf{N}}\right)\frac{dT}{m}
\end{aligned}$$

It is straightforward to show that the product $\psi\varepsilon(\psi)$ must fall between $\quad 1$ 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

$$\lim_{\to\infty} \psi\varepsilon(\psi) = \frac{\varepsilon(0)}{\frac{\mathsf{s}_y}{\mathsf{s}_R}\left(\phi_{\mathsf{L}} \quad \frac{L}{N}\phi_{\mathsf{N}}\right) \quad \varepsilon(0)}$$

is strictly greater than $\quad 1$. Because $\varepsilon(0) < \varepsilon(\psi)$, equation (A.25) implies an upper bound for ψ of $\left[\frac{\mathsf{s}_y}{\mathsf{s}_R}\left(\phi_{\mathsf{L}} \quad \frac{L}{N}\phi_{\mathsf{N}}\right) \quad \varepsilon(\psi)\right]^{-1}$, which according to the main calibration is $[17/32 + 6]^{-1} = 32/209 = 0.15$. The product $\psi\varepsilon(\psi)$ is then bounded above by $(32/209) \quad 6 = 192/209 = 0.92$, 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

$$\begin{aligned}\frac{1}{m}d\left[w \quad e(p,u)\right] &= s_{\mathsf{w}}d\hat{w} \quad s_{\mathsf{y}}d\hat{p} \quad \frac{dT}{m}\\ &= \psi\varepsilon\left(\psi\right)\frac{dT}{m}\end{aligned}$$

The effect on local land prices and welfare together add up to the local burden of the tax, i.e. $\frac{1}{\mathsf{m}}d\left[w \quad e(p,u)\right] + s_{\mathsf{R}}d\hat{r} = dT/m$. Thus, if local prices do not fully capitalize federal tax differences, the remainder is borne by local "infra-marginal" workers, who are more attached to their city. Thus the differential tax burden is split between local labor and land, with the ratio given by

$$\frac{\frac{1}{\mathsf{m}}d\left[w \quad e(p,u)\right]}{s_{\mathsf{R}}d\hat{r}} = \frac{\psi\varepsilon(0)}{1 + \psi\frac{\mathsf{s}_y}{\mathsf{s}_R}\left(\phi_{\mathsf{L}} \quad \frac{L}{N}\phi_{\mathsf{N}}\right)}$$

which increases with ψ and lies between 0 and $\varepsilon(0)/\frac{\mathsf{s}_y}{\mathsf{s}_R}\left(\phi_{\mathsf{L}} \quad \frac{L}{N}\phi_{\mathsf{N}}\right)$.

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 $\phi_{\mathsf{L}} = 1$ so that $p = r/A_{\mathsf{Y}}$. The three equations defining the system are

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

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

$$c_{\mathsf{X}}\left(w^{\mathsf{a}}, w^{\mathsf{b}}, r\right) = A_{\mathsf{X}} \tag{A.26c}$$

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

differential for a type a worker

$$\hat{w}^{\mathsf{a}} = \frac{1}{s_{\mathsf{R}} s^{\mathsf{a}}_{\mathsf{w}}} \left\{ s^{\mathsf{a}}_{\mathsf{y}} s_{\mathsf{x}} \hat{A}_{\mathsf{X}} + s_{\mathsf{x}} \theta_{\mathsf{L}} \left(\frac{d\tau^{\mathsf{a}}}{m^{\mathsf{a}}} \quad \hat{Q}^{\mathsf{a}} \quad s^{\mathsf{a}}_{\mathsf{y}} \hat{A}_{\mathsf{Y}} \right) \right\} + \tag{A.27}$$
$$\frac{\mu^{\mathsf{b}}}{s_{\mathsf{R}} s^{\mathsf{a}}_{\mathsf{w}}} \left\{ \left[s^{\mathsf{b}}_{\mathsf{y}} \left(\frac{d\tau^{\mathsf{a}}}{m^{\mathsf{a}}} \quad \hat{Q}^{\mathsf{a}} \right) \quad s^{\mathsf{a}}_{\mathsf{y}} \left(\frac{d\tau^{\mathsf{b}}}{m^{\mathsf{b}}} \quad \hat{Q}^{\mathsf{b}} \right) \right] \right\}$$

where an analogous expression holds for $\hat{w}^{\mathsf{b}}$. 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

$$s_{\mathsf{x}} = \mu^{\mathsf{a}} s^{\mathsf{a}}_{\mathsf{x}} + \mu^{\mathsf{b}} s^{\mathsf{b}}_{\mathsf{x}},\ s_{\mathsf{y}} = \mu^{\mathsf{a}} s^{\mathsf{a}}_{\mathsf{y}} + \mu^{\mathsf{b}} s^{\mathsf{b}}_{\mathsf{y}}$$
$$\hat{Q} = \mu^{\mathsf{a}} \hat{Q}^{\mathsf{a}} + \mu^{\mathsf{b}} \hat{Q}^{\mathsf{b}},\ \frac{d\tau}{m} = \mu^{\mathsf{a}} \tau'^{\mathsf{a}} s^{\mathsf{a}}_{\mathsf{w}} \hat{w}^{\mathsf{a}} + \mu^{\mathsf{b}} \tau'^{\mathsf{b}} s^{\mathsf{b}}_{\mathsf{w}} \hat{w}^{\mathsf{b}}$$

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

$$\hat{r} = \frac{1}{s_{\mathsf{R}}} \left(\hat{Q} + s_{\mathsf{x}} \hat{A}_{\mathsf{X}} + s_{\mathsf{y}} \hat{A}_{\mathsf{Y}} \quad \frac{d\tau}{m} \right) \tag{A.28}$$

$$\hat{w} \quad \frac{1}{s_{\mathsf{w}}} \left(s^{\mathsf{a}}_{\mathsf{w}} \mu^{\mathsf{a}} \hat{w}^{\mathsf{a}} + s^{\mathsf{b}}_{\mathsf{w}} \mu^{\mathsf{b}} \hat{w}^{\mathsf{b}} \right) = \frac{1}{\theta_{\mathsf{N}} s_{\mathsf{R}}} \left[s_{\mathsf{y}} \hat{A}_{\mathsf{X}} \quad s_{\mathsf{y}} \theta_{\mathsf{L}} \hat{A}_{\mathsf{Y}} + \theta_{\mathsf{L}} \left(\frac{d\tau}{m} \quad \hat{Q} \right) \right] \tag{A.29}$$

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. Thus, aggregating multiple worker types does not substantially alter overall price effects, however differential taxation does have some interesting quantity effects.

The relative wage difference

$$\hat{w}^{\mathsf{a}} \quad \hat{w}^{\mathsf{b}} = \frac{1}{s_{\mathsf{R}}} \left\{ \left(\frac{s^{\mathsf{a}}_{\mathsf{y}}}{s^{\mathsf{a}}_{\mathsf{w}}} \quad \frac{s^{\mathsf{b}}_{\mathsf{y}}}{s^{\mathsf{b}}_{\mathsf{w}}} \right) s_{\mathsf{x}} \hat{A}_{\mathsf{X}} \right\} +$$
$$\frac{1}{s_{\mathsf{R}}} \left\{ \left(s_{\mathsf{x}} \theta_{\mathsf{L}} + s_{\mathsf{w}} \frac{s^{\mathsf{b}}_{\mathsf{y}}}{s^{\mathsf{b}}_{\mathsf{w}}} \right) \frac{1}{s^{\mathsf{a}}_{\mathsf{w}}} \left(\frac{d\tau^{\mathsf{a}}}{m^{\mathsf{a}}} \quad \hat{Q}^{\mathsf{a}} \right) \quad \left(s_{\mathsf{x}} \theta_{\mathsf{L}} + s_{\mathsf{w}} \frac{s^{\mathsf{a}}_{\mathsf{y}}}{s^{\mathsf{a}}_{\mathsf{w}}} \right) \frac{1}{s^{\mathsf{b}}_{\mathsf{w}}} \left(\frac{d\tau^{\mathsf{b}}}{m^{\mathsf{b}}} \quad \hat{Q}^{\mathsf{b}} \right) \right\}$$

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.

$$\hat{N}^{\mathsf{a}} \quad \hat{N}^{\mathsf{b}} = \quad \sigma_{\mathsf{X}} \left(\hat{w}^{\mathsf{a}} \quad \hat{w}^{\mathsf{a}} \right) \tag{A.30}$$

If workers have similar tastes, receive equal shares of income from labor, and pay the same marginal income tax rates, so that $s^{\mathsf{a}}_{\mathsf{y}} = s^{\mathsf{b}}_{\mathsf{y}}$, $s^{\mathsf{a}}_{\mathsf{w}} = s^{\mathsf{b}}_{\mathsf{w}}$, $\hat{Q}^{\mathsf{a}} = \hat{Q}^{\mathsf{b}}$, and $\tau'^{\mathsf{a}} = \tau'^{\mathsf{b}}$, then $\hat{w}^{\mathsf{a}} = \hat{w}^{\mathsf{b}}$ and $\hat{N}^{\mathsf{a}} = \hat{N}^{\mathsf{b}}$: 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.

$$\widehat{\left(\frac{N^{\mathsf{a}} d\tau^{\mathsf{a}} / m^{\mathsf{a}}}{N^{\mathsf{b}} d\tau^{\mathsf{b}} / m^{\mathsf{b}}} \right)} = \hat{N}^{\mathsf{a}} + s^{\mathsf{a}}_{\mathsf{w}} \hat{w}^{\mathsf{a}} \quad \hat{N}^{\mathsf{b}} \quad s^{\mathsf{b}}_{\mathsf{w}} \hat{w}^{\mathsf{b}} = \left(s^{\mathsf{a}}_{\mathsf{w}} \quad \sigma_{\mathsf{X}} \right) \hat{w}^{\mathsf{a}} \quad \left(s^{\mathsf{b}}_{\mathsf{w}} \quad \sigma_{\mathsf{X}} \right) \hat{w}^{\mathsf{b}}$$

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 $\sigma_{\mathsf{X}} \quad \min \left\{ s^{\mathsf{a}}_{\mathsf{w}}, s^{\mathsf{b}}_{\mathsf{w}} \right\}$ 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. 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.

If productivity differences affect only one type of worker equation (A.26c) becomes

$$c_{X}\left(w^{a}/A_{X}^{a}, w^{b}, r\right) = 1$$

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

$$\hat{N}^{a} \quad \hat{N}^{b} = \quad \sigma_{X}\left(\hat{w}^{a} \quad \hat{w}^{a}\right) + \left(\sigma_{X} \quad 1\right)\hat{A}_{X}^{a}$$

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

In the short-to-medium run, unskilled workers are generally less mobile than skilled workers (Bound and Holzer 2000). For greater insight, consider the case where a-types are mobile and b-types are fully immobile, distributed according to some pattern across cities. Furthermore, let $A_{Y} = 1$, $\phi_{L} = 1$ and $\theta_{L} = \theta_{K} = 0$, so that the following equations hold

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

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

$$s_{\mathsf{w}}^{\mathsf{a}}\hat{w}^{\mathsf{a}} \quad s_{\mathsf{y}}^{\mathsf{a}}\hat{r} = \quad \hat{Q}^{\mathsf{a}} + dT^{\mathsf{a}}/m^{\mathsf{a}} \tag{A.31a}$$

$$\theta_{\mathsf{N}}^{\mathsf{a}}\hat{w}^{\mathsf{a}} + \theta_{\mathsf{N}}^{\mathsf{b}}\hat{w}^{\mathsf{b}} = \theta_{\mathsf{N}}^{\mathsf{a}}\hat{A}_{\mathsf{X}}^{\mathsf{a}} + \theta_{\mathsf{N}}^{\mathsf{b}}\hat{A}_{\mathsf{X}}^{\mathsf{b}} \tag{A.31b}$$

$$\hat{N}^{\mathsf{a}} + \sigma_{\mathsf{X}}\left(\hat{w}^{\mathsf{a}} \quad \hat{w}^{\mathsf{b}}\right) = (\sigma_{\mathsf{X}} \quad 1)\left(\hat{A}^{\mathsf{a}} \quad \hat{A}^{\mathsf{b}}\right) \tag{A.31c}$$

$$\mu^{\mathsf{a}}\hat{N}^{\mathsf{a}} + \mu^{\mathsf{b}}s_{\mathsf{w}}^{\mathsf{b}}\hat{w}^{\mathsf{b}} \quad \left[\mu^{\mathsf{a}}s_{\mathsf{x}}^{\mathsf{a}}\sigma_{\mathsf{D}}^{\mathsf{a}} + \mu^{\mathsf{b}}\left(s_{\mathsf{y}}^{\mathsf{b}} + s_{\mathsf{x}}^{\mathsf{b}}\sigma_{\mathsf{D}}^{\mathsf{b}}\right)\right]\hat{r} = \mu^{\mathsf{a}}\hat{Q}^{\mathsf{a}} + \mu^{\mathsf{b}}dT^{\mathsf{b}}/m^{\mathsf{b}} \tag{A.31d}$$

The left-hand side of the (A.31d) can be rewritten as $\mu^{\mathsf{a}}\hat{N}^{\mathsf{a}} + \mu^{\mathsf{b}}s_{\mathsf{w}}^{\mathsf{b}}\hat{w}^{\mathsf{b}} + \left(\mu^{\mathsf{a}}s_{\mathsf{y}}^{\mathsf{a}} \quad |\eta^{\mathsf{u}}|\right)\hat{r}$ where

$$\eta^{\mathsf{u}} = \quad \left[\mu^{\mathsf{a}}\left(s_{\mathsf{y}}^{\mathsf{a}} + s_{\mathsf{x}}^{\mathsf{a}}\sigma_{\mathsf{D}}^{\mathsf{a}}\right) + \mu^{\mathsf{b}}\left(s_{\mathsf{y}}^{\mathsf{b}} + s_{\mathsf{x}}^{\mathsf{b}}\sigma_{\mathsf{D}}^{\mathsf{b}}\right)\right]$$

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

To simplify further assume tastes are homogenous ($s_{\mathsf{y}}^{\mathsf{a}} = s_{\mathsf{y}}^{\mathsf{b}} = s_{\mathsf{y}}$) that each type of worker gets the same share of income from wages ($s_{\mathsf{w}}^{\mathsf{a}} = s_{\mathsf{w}}^{\mathsf{b}} = s_{\mathsf{x}}$) and that productivity differences are neutral ($A_{\mathsf{X}}^{\mathsf{a}} = A_{\mathsf{X}}^{\mathsf{b}} = A_{\mathsf{X}}$) Solving the above conditions then yields

$$\hat{w}^{\mathsf{a}} = \frac{|\eta^{\mathsf{u}}|\,\hat{Q}^{\mathsf{a}} + s_{\mathsf{y}}\left(\frac{N^{a}}{N^{b}}\sigma_{\mathsf{X}} + s_{\mathsf{x}}\right)\hat{A}_{\mathsf{X}} + \left(|\eta^{\mathsf{c}}| + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{b}}\right)\frac{\mathsf{dT}^{a}}{\mathsf{m}^{a}} \quad s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{b}}\frac{\mathsf{dT}^{b}}{\mathsf{m}^{b}}}{s_{\mathsf{x}}\,|\eta^{\mathsf{u}}| + s_{\mathsf{y}}\frac{N^{a}}{N^{b}}\sigma_{\mathsf{X}}} \tag{A.32a}$$

$$\hat{w}^{\mathsf{b}} = \frac{|\eta^{\mathsf{u}}|\,\hat{Q}^{\mathsf{a}} + \left(\frac{\mathsf{s}_{x}|\ \ ^{u}|}{N^{a}} + s_{\mathsf{y}}\left(\sigma_{\mathsf{X}} \quad 1\right)\right)\hat{A}_{\mathsf{X}} \quad \left(|\eta^{\mathsf{c}}| + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{b}}\right)\frac{\mathsf{dT}^{a}}{\mathsf{m}^{a}} + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{b}}\frac{\mathsf{dT}^{b}}{\mathsf{m}^{b}}}{s_{\mathsf{x}}\frac{N^{b}}{N^{a}}|\eta^{\mathsf{u}}| + s_{\mathsf{y}}\sigma_{\mathsf{X}}} \tag{A.32b}$$

$$\hat{r} = \frac{\theta_{\mathsf{N}}^{\mathsf{a}}\sigma_{\mathsf{X}}\hat{Q}^{\mathsf{a}} + s_{\mathsf{x}}\left(\theta_{\mathsf{N}}^{\mathsf{a}}\sigma_{\mathsf{X}} + \theta_{\mathsf{N}}^{\mathsf{b}}\right)\hat{A}_{\mathsf{X}} \quad \theta_{\mathsf{N}}^{\mathsf{a}}\left(\theta_{\mathsf{N}}^{\mathsf{b}} + \sigma_{\mathsf{X}}\right)\frac{\mathsf{dT}^{a}}{\mathsf{m}^{a}} \quad s_{\mathsf{x}}\left(\theta_{\mathsf{N}}^{\mathsf{b}}\right)^{2}\frac{\mathsf{dT}^{b}}{\mathsf{m}^{b}}}{s_{\mathsf{x}}\theta_{\mathsf{N}}^{\mathsf{b}}\,|\eta^{\mathsf{u}}| + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{a}}\sigma_{\mathsf{X}}} \tag{A.32c}$$

$$\hat{N}^{\mathsf{a}} = \sigma_{\mathsf{X}}\frac{|\eta^{\mathsf{u}}|\,\hat{Q}^{\mathsf{a}} + s_{\mathsf{x}}\,|\eta^{\mathsf{c}}|\,\hat{A}_{\mathsf{X}} \quad \left(|\eta^{\mathsf{c}}| + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{b}}\right)\frac{\mathsf{dT}^{a}}{\mathsf{m}^{a}} + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{b}}\frac{\mathsf{dT}^{b}}{\mathsf{m}^{b}}}{s_{\mathsf{x}}\theta_{\mathsf{N}}^{\mathsf{b}}\,|\eta^{\mathsf{u}}| + s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{a}}\sigma_{\mathsf{X}}} \tag{A.32d}$$

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 $s_{\mathsf{x}}\,|\eta^{\mathsf{u}}| < s_{\mathsf{y}}\theta_{\mathsf{N}}^{\mathsf{a}}(1 \quad \sigma_{\mathsf{X}})$, which seems unlikely: even if $\sigma_{\mathsf{X}} = 0$, this would require $\theta_{\mathsf{N}}^{\mathsf{a}} > |\eta^{\mathsf{u}}|\,s_{\mathsf{x}}/s_{\mathsf{y}}$, 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 $\bar{u}^{\mathsf{a}}$, but the welfare of

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

$$\frac{d[m^{\mathsf{b}} - e(r, u^{\mathsf{b}}; Q^{\mathsf{b}})]}{m^{\mathsf{b}}} = \hat{Q}^{\mathsf{b}} + \frac{(s_{\mathsf{x}}\,|\eta^{\mathsf{u}}| - s_{\mathsf{y}}\sigma_{\mathsf{X}})\,\theta^{\mathsf{a}}_{\mathsf{N}}\,\hat{Q}^{\mathsf{a}} + (s_{\mathsf{x}}\,|\eta^{\mathsf{u}}| - s_{\mathsf{y}})\,\hat{A}_{\mathsf{X}}}{s_{\mathsf{x}}\theta^{\mathsf{b}}_{\mathsf{N}}\,|\eta^{\mathsf{u}}| + s_{\mathsf{y}}\theta^{\mathsf{a}}_{\mathsf{N}}\,\sigma_{\mathsf{X}}}$$
$$+ \frac{(s_{\mathsf{y}}\sigma_{\mathsf{X}} - s_{\mathsf{x}}\,|\eta^{\mathsf{c}}|)\,\theta^{\mathsf{a}}_{\mathsf{N}}\,\frac{\mathsf{d}\mathsf{T}^a}{\mathsf{m}^a} - \left(s_{\mathsf{x}}\theta^{\mathsf{b}}_{\mathsf{N}}\,|\eta^{\mathsf{c}}| + s_{\mathsf{y}}\theta^{\mathsf{a}}_{\mathsf{N}}\,\sigma_{\mathsf{X}}\right)\frac{\mathsf{d}\mathsf{T}^b}{\mathsf{m}^b}}{s_{\mathsf{x}}\theta^{\mathsf{b}}_{\mathsf{N}}\,|\eta^{\mathsf{u}}| + s_{\mathsf{y}}\theta^{\mathsf{a}}_{\mathsf{N}}\,\sigma_{\mathsf{X}}}$$

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. If productivity differences are large, so that $\hat{A}_{\mathsf{X}}$ tends to vary more than $\hat{Q}^{\mathsf{a}}$, or substitutability of labor, σ_{X}, is high, then wage differentials of mobile and immobile will be highly correlated.

Taxes on mobile workers lower the welfare of immobile workers if $s_{\mathsf{x}}\,|\eta^{\mathsf{c}}| > s_{\mathsf{y}}\sigma_{\mathsf{X}}$ in which case wage losses dominate the reduction in local prices. 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.

The main results in the text hold if workers are identical ($\sigma_{\mathsf{X}} \to \infty$) but only a subset of workers are fully mobile. This case yields $\hat{w}^{\mathsf{a}} = \hat{w}^{\mathsf{b}} = \hat{A}_{\mathsf{X}}$, with $\hat{r} = (\hat{Q}^{\mathsf{a}} + s_{\mathsf{x}}\hat{A}_{\mathsf{X}} - \frac{\mathsf{d}\mathsf{T}^a}{\mathsf{m}^a})/s_{\mathsf{y}}$, 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: $A^{\mathsf{j}}_{\mathsf{X}} = A^{0\mathsf{j}}_{\mathsf{X}}\left(N^{\mathsf{j}}\right)^{\gamma}$, where γ measures the percent increase in productivity from a percent increase in a city's population. Amending condition (4b) to include these economies

$$\theta_{\mathsf{N}}\,\hat{w} + \theta_{\mathsf{L}}\,\hat{r} = \hat{A}^{0}_{\mathsf{X}} + \gamma\hat{N}_{\mathsf{X}}$$

Introducing an endogenous quantity differential, $\hat{N}_{\mathsf{X}}$, into the initial system of equations (4) determining price differentials, makes the model considerably harder to solve. To make matters simple, assume $\theta_{\mathsf{N}} = 1$, $\phi_{\mathsf{L}} = 1$ and consider only the effects of a head tax, so $p = r$, and $w = A_{\mathsf{X}}$. In this case, the wage and price differentials are

$$d\hat{w} = -\frac{\gamma s_{\mathsf{X}}\sigma_{\mathsf{D}}}{s_{\mathsf{R}} - \gamma s^2_{\mathsf{X}}\sigma_{\mathsf{D}}}\frac{dT}{m}$$
$$d\hat{r} = -\frac{1}{s_{\mathsf{R}} - \gamma s^2_{\mathsf{X}}\sigma_{\mathsf{D}}}\frac{dT}{m}$$

Stability requires $s_{\mathsf{R}} > \gamma s^2_{\mathsf{X}}\sigma_{\mathsf{D}}$. 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 $\theta_{\mathsf{L}} > 0$, 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.[vi]

D.6 Heterogeneous Export Goods

The model assumes 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.[vii] 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.

[vi] 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.

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