National Income Taxation and the Geographic Distribution of Population

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Abstract

We study how different national taxation schemes interact with geographic variation in productivity and consumption amenities in determining regional populations. A neoclassical migration equilibrium model is used to analyze the current nominal income tax system in Norway. The analysis is based on estimated regional income differences accounting for both observable and unobservable individual characteristics and the value of experience. Given regional differences in incomes and housing prices, quality of life and productivity are calibrated to model equilibrium. Compared to an undistorted equilibrium with lump-sum taxation, nominal income taxation creates a disincentive to locate in productive high-income regions. The deadweight loss due to locational inefficiencies is 0.18% of gross domestic product (GDP). We study real income taxation and equal real taxes as alternative tax systems. Both alternatives generate a geographic distribution of the population closer to the undistorted equilibrium, and hence with lower deadweight loss. In an extension of the analysis, we take into account payroll taxes. The existing regionally differentiated payroll taxes to the disadvantage of cities generate a deadweight loss of 0.22% of GDP in an economy with lump-sum income taxation. The two distortionary taxes interact and strengthen each other and the combined distortionary effect of income and payroll taxation in the Norwegian system is 0.46% of GDP.

Keywords: Regional tax distortions; Payroll taxation; Cost of living; Amenities; Locational efficiency; Migration equilibrium

JEL codes: H24, H77, J61, R23

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1. Introduction

National income taxes may influence the geographic distribution of population. The variation in regional income and price levels reflects underlying productivities and amenities, and the handling of price variation in the tax system may affect households' choice of location. Most countries have nominal tax systems with variation in the real tax burden dependent on price levels. In this situation, income taxes may distort the allocation of the population to the disadvantage of high-income regions.

Only few studies have dealt with regional tax distortions. The income tax distortions generated by nominal price variation reflect a problem of cost of living adjustment, as discussed by Kaplow (1996), Knoll and Griffith (2003), and Puckett (2012). Albouy (2009) quantifies the deadweight loss of the US income tax system based on calibration of a neoclassical migration equilibrium model. We extend his work in three directions. First, we improve the empirical basis of identifying regional income differences by using rich individual register data to control for unobserved worker quality (individual fixed effects) and allowing for dynamic experience effects. Second, we extend the analysis of income taxation by investigating real income taxation and equal real taxes as alternatives to nominal income taxation. Third, we recognize the importance of other factors distorting the geographic allocation of the population, in particular regionally differentiated payroll taxes often used as instruments of regional policy. We show the deadweight loss of differentiated payroll taxes and how the deadweight loss of income taxes is affected by payroll taxes. We calibrate the migration equilibrium model to the current nominal income and payroll taxes in Norway, and compare with an undistorted equilibrium with lump-sum taxation and no payroll taxes.

In the analysis of income taxation, we study two alternatives: real income taxation and equal real taxes. In the alternative with real income taxation, we take into account variation in the cost of living and the real tax burden is proportional to real incomes. We also shed light on an old debate about the handling of amenities in the tax system. High quality of life allows for lower income in migration equilibrium and income taxation may distort the allocation of population to the disadvantage of low amenity regions. It should be noted that amenities not necessarily produce a tax distortion. If amenities are fully capitalized into land/housing prices, there are no regional disincentives of nominal income taxes. The details are elaborated by Knoll and Griffith (2003, section VII). Horizontal equity as a principle of taxation is discussed in the influential text of Musgrave (1959) and later clarified by Feldstein (1976), Musgrave (1976), and Rosen (1978). Musgrave (1990) offers an overview discussion. The key issue is the "income" concept applied in taxation. Wildasin (1990) relates this to the original contributions of Haig (1921) and Simons (1938) and argues that "it is the flow of utility that constitutes true income." In the migration equilibrium setting here, taxation of amenities means equal real taxes across regions.

The distortionary effect of income taxes depends on other taxes. We investigate the effects of the interaction between income taxes and payroll taxes. Regionally differentiated payroll taxes are a popular regional policy instrument in many countries. The existing literature on payroll taxes concentrates on tax shifting between employers and employees. Influential empirical studies include Gruber (1997) and Anderson and Meyer (2000), and more recently Saez et al. (2012). Most studies conclude that payroll taxes primarily are shifted to workers. Murphy (2007) emphasizes the mobility of workers and finds that the shifting of payroll taxes is more important for less-mobile workers. We offer an alternative analysis based on calibration of a migration equilibrium assuming perfect mobility. It is of interest in the future to establish a bridge between the two approaches and then look at degrees of imperfect mobility.

We apply the neoclassical migration equilibrium model developed by Albouy and associates, notably Albouy and Stuart (2014), but also Albouy (2012) and Albouy et al. (2013). The framework has primarily been used to value the bundle of consumption amenities across locations. Rappaport (2008) develops a similar model to determine consumption amenities. Albouy and Hanson (2014) apply the model to analyze taxation of housing. The core of the migration equilibrium models in the Rosen (1979) and Roback (1982) tradition captures the equalization of utilities across regions and the determination of income and price levels by amenities and productivities. Income levels can be high, reflecting high productivities or compensating for bad consumer amenities. Price levels, primarily housing prices, also reflect the attractiveness of the city.

The model is calibrated to capture basic aspects of the regional variation of wages and house prices and the tax system in Norway. The full equilibrium of the distribution of population in 89 labor market regions is established. The quantitative effects of income taxation are worked out in counterfactual analyses. We compare three alternative income tax systems with an undistorted equilibrium with lump-sum income tax and no payroll taxes. The analysis shows effects for the geographic distribution of the population and calculates deadweight losses. In an extension of the analysis, we study the effects of regionally differentiated payroll taxes and how the deadweight loss of income taxes is influenced by the payroll tax differentiation.

We benefit from rich register data of individual wages and housing prices to identify regional differences in wages and cost of living. The heterogeneity of the population and endogenous sorting represent an important challenge in the identification of regional wage differences. Albouy (2009) controls for observable worker characteristics, while we also include unobservable worker characteristics (identification based on movers) and allow dynamic learning effects from work experience to vary across regions (as emphasized by De la Roca and Puga, 2016). In this way, the analysis captures the agglomeration effects contributing to regional wage differences. Whereas the raw wage differences between rural and urban regions are large, the wage gap decreases when we control for observable and unobservable (individual fixed effects) characteristics of the workers, while higher learning effects in cities add to the differences.

The data for Norway indicate small regional wage differences, large differences in housing prices, and even larger differences in population size. In this setting, changes in prices may give large changes in the geographic distribution of population. The calibration comes out with an elasticity of population with respect to the income tax burden of -2.64. There is positive correlation between the calibrated regional measures of quality of life and productivity. Wages and cost of living are highest in the large city regions, and consequently they pay higher taxes in the current nominal income tax system. This distorts incentives to the disadvantage of productive high-income cities, and generates a deadweight loss equal to 0.18% of income. The size of the effect is comparable to the results of Albouy (2009). We study real income taxation and equal real taxes as alternative tax systems. Both alternatives generate a geographic distribution of the population closer to the undistorted equilibrium, and hence with lower deadweight loss. In an extension of the analysis, we take into account payroll taxes. The existing regionally differentiated payroll taxes to the disadvantage of cities generate a deadweight loss of 0.22% of GDP in an economy with lump-sum income taxation. The distortion of income taxes depends on the design of payroll taxes, and the deadweight loss of nominal income taxation is reduced to 0.07% in an economy with regionally differentiated payroll taxes. The explanation is that regionally differentiated payroll taxes generate shift of population away from cities, and the distortionary effect of income taxation consequently is smaller. The combined distortionary effect of income and payroll taxation in the Norwegian system is 0.46% of GDP. As expected, the two distortionary taxes together create larger deadweight loss than each of them separately.

Section 2 presents the model, and section 3 documents the data and the calibration, including the nominal aspect of the income tax system. The impact of different income tax schemes on the regional allocation of population and resulting deadweight losses are analyzed in section 4. Section 5 addresses regionally differentiated payroll taxes and how they distort the geographic distribution of the population. Concluding remarks are offered in section 6.

2. The model

The neoclassical migration equilibrium model is the analytical framework used to analyze the geographic distribution of population. Earlier versions include Haughwout and Inman (2001), Rappaport (2008), and Albouy (2009). The model outlined by Albouy and Stuart (2014) is our starting point. They present the model at both level and log-linearized form and solve for the relationship between population, quality of life, and productivity. We work with the log-linearized version of their model, adding income tax structures, and simulate alternative tax designs based on similar parameterization. For any variable z_j, the log-differential $\hat{z}_j = \ln z_j - \ln \overline{z}$ approximates the percentage difference between region *j* and the national geometric average $\overline{z}$. The log-linearized version of the Albouy–Stuart model is given in section 2.1, while the added tax systems are outlined in section 2.2.

2.1 The basics of the migration equilibrium model

The model addresses the distribution of population across multiple regions in migration equilibrium. The population is homogeneous and mobile. The production is divided between two sectors: traded goods and housing.[1] Factors of production include land, capital, and labor. Factor prices are equal within regions (independent of sector). Land is immobile and receives a region-specific price. Capital is fully mobile across regions and receives the same price everywhere. The supply of capital in each region is perfectly elastic, whereas the national level of capital is fixed. Labor is fully mobile and wages vary across regions. International migration is ignored and national population is hence fixed. Regions differ exogenously in three aspects: quality of life, productivity in the traded sector, and productivity in the housing sector.

The consumer side of the model assumes a quasi-concave utility function dependent on per capita consumption of the traded good (x_j) and housing (y_j) given the exogenous level of quality of life (Q_j). We follow the Albouy (2009) assumption that quality of life enters neutrally into the utility function and is normalized with respect to the expenditure equation. The budget constraint equalizes consumption expenditures with post-tax income. The traded good is the numeraire with price equal to unity in all regions, while the housing price $(p_{H,j})$ is endogenous and varies across regions. Post-tax income consists of wages (w_j) and income from land and capital, adjusted for nominal tax payments (T_j). Taxes depend on the chosen tax system, as further described in section 2.2. Land and capital income is equal across regions, while post-tax income varies as wages and tax payments vary. In log-differential form, the budget constraint is given as:

$$s_x \hat{x}_j + s_y(\hat{p}_{H,j} + \hat{y}_j) = s_w \hat{w}_j - s_T \hat{T}_j \qquad (1)$$

where s_x and s_y are the expenditure shares for traded goods and housing, respectively, relative to total income, and s_w and s_T represent wages and tax payments, respectively, as shares of total income. Per definition, $s_x + s_y + s_T = 1$.

The aggregate price index (p_j) measures the region's cost of living and is a weighted average of the housing price and the traded sector price, with expenditure shares as

[1] The traded sector includes non-traded goods other than housing.

weights. Because the traded price is equal across regions, the log-differential of the aggregate price index is proportional to the housing price differential:

$$\hat{p}_j = \frac{s_y}{\bar{p}} \hat{p}_{H,j} \tag{2}$$

where $\bar{p}$ is the national geometric average of the price index.

Because households are fully mobile, the utility level is equalized across regions. Minimization of consumption expenditures subject to a constant utility level gives the demand functions for traded goods and housing, which imply the tangency condition (with σ_C as the elasticity of substitution between the two goods):

$$\hat{x}_j - \hat{y}_j = \sigma_C \hat{p}_{H,j} \tag{3}$$

Inserting the demand functions into $e_j = x_j + p_{H,j} y_j$ gives the expenditure function, which must equal post-tax income. The migration equilibrium condition in log-linearized form follows as:

$$s_y \hat{p}_{H,j} - s_w \hat{w}_j + s_T \hat{T}_j = \hat{Q}_j \tag{4}$$

Cost of living, wages, taxes, and quality of life vary across regions, but in migration equilibrium the utility level is the same everywhere. Higher cost of living or lower quality of life is compensated with higher post-tax income.

The production side of the model assumes constant return to scale production functions with Hicks neutral productivity. The production functions for the two sectors are similar, and in the traded sector we have total output of traded goods (X_j) depending on inputs of land $(L_{X,j})$, capital $(K_{X,j})$, and labor $(N_{X,j})$ along with traded sector productivity $(A_{X,j})$. Housing supply is represented by Y_j and factor inputs and productivity in the housing sector is denoted with subscript *Y*. Minimization of total costs subject to constant production generates three first-order conditions for each sector, which equilibrate factor price with the marginal product of the factor for land, capital, and labor, respectively:

$$\hat{L}_{X,j} = \hat{X}_j - \hat{A}_{X,j} + \theta_N \sigma_X (\hat{w}_j + \hat{b}_j - \hat{r}_j) - \theta_K \sigma_X \hat{r}_j \tag{5}$$

$$\hat{K}_{X,j} = \hat{X}_j - \hat{A}_{X,j} + \theta_L \sigma_X \hat{r}_j + \theta_N \sigma_X (\hat{w}_j + \hat{b}_j) \tag{6}$$

$$\hat{N}_{X,j} = \hat{X}_j - \hat{A}_{X,j} + \theta_L \sigma_X (\hat{r}_j - \hat{w}_j) - \theta_K \sigma_X \hat{w}_j - (\theta_L + \theta_K) \sigma_X \hat{b}_j \tag{7}$$

$$\hat{L}_{Y,j} = \hat{Y}_j - \hat{A}_{Y,j} + \phi_N \sigma_Y (\hat{w}_j + \hat{b}_j - \hat{r}_j) - \phi_K \sigma_Y \hat{r}_j \tag{8}$$

$$\hat{K}_{Y,j} = \hat{Y}_j - \hat{A}_{Y,j} + \phi_L \sigma_Y \hat{r}_j + \phi_N \sigma_Y (\hat{w}_j + \hat{b}_j) \tag{9}$$

$$\hat{N}_{Y,j} = \hat{Y}_j - \hat{A}_{Y,j} + \phi_L \sigma_Y (\hat{r}_j - \hat{w}_j) - \phi_K \sigma_Y \hat{w}_j - (\phi_L + \phi_K) \sigma_Y \hat{b}_j \tag{10}$$

The factor prices for land and labor are given by r_j and $b_j w_j$, respectively, where b_j equals one plus the payroll tax rate (which differs across regions). The capital price is the same in all regions and drops out of the log-linearized version of the model. In the traded sector, cost shares of land, capital, and labor are given by θ_L, θ_K, and θ_N. Similar cost shares in the housing sector are represented by ϕ_L, ϕ_K , and ϕ_N. Substitution elasticities are set equal between all factors of production and are given by σ_X and σ_Y in the traded and housing sector, respectively.

Combining the first-order conditions gives the unit cost functions, which must equal the price level of the sector. In log-differential form, these zero-profit conditions are given as:

$$\theta_L \hat{r}_j + \theta_N (\hat{w}_j + \hat{b}_j) = \hat{A}_{X,j} \tag{11}$$

$$\phi_L \hat{r}_j + \phi_N (\hat{w}_j + \hat{b}_j) - \hat{p}_{H,j} = \hat{A}_{Y,j} \tag{12}$$

For given output prices, firms in high-productive regions pay higher land rents and wages.

Factor market clearing is given by:

$$\hat{L}_j = \lambda_L \hat{L}_{X,j} + (1 - \lambda_L) \hat{L}_{Y,j} \tag{13}$$

$$\hat{K}_j = \lambda_K \hat{K}_{X,j} + (1 - \lambda_K) \hat{K}_{Y,j} \tag{14}$$

$$\hat{N}_j = \lambda_N \hat{N}_{X,j} + (1 - \lambda_N) \hat{N}_{Y,j} \tag{15}$$

Total land supply in region *j* (L_j) is fixed, and the market clearing of land determines the endogenous land price. Given the sectoral demands for capital and employment, the other two conditions add up total capital (K_j) and total population (N_j) in region *j*. Finally, market clearing of the housing sector equilibrates housing supply with aggregate housing demand:

$$\hat{N}_j + \hat{y}_j = \hat{Y}_j \tag{16}$$

2.2 Alternative tax systems

To concentrate on the allocation of the population responding to income tax designs, we assume that the tax revenue finances a national public good that does not influence the rest of the economy. In the model, lump-sum taxes with no tax distortions are equivalent to zero income tax because of the log-differentiation form. We concentrate on the basics of the income tax system, only wage income including deductions and progressivity. How would the population be distributed geographically without tax distortions? The base run scenario is nominal income taxation, where tax payments are given by $T_j = \tau w_j - D$, with τ as the marginal tax rate and D representing nominal deductions (both equal across regions). Regions with different price levels and equal real wage levels face different tax burdens, both in terms of nominal and real tax payments. Regions with higher nominal wages and higher housing costs pay more in taxes. To quantify the misallocation of the population resulting from the current nominal income tax system, we compare with the case of lump-sum taxation.

The first alternative tax system is real income taxation, which relates real tax payments to real incomes. Nominal tax payments are adjusted for cost of living differences through price-indexed deductions; $T_j = \tau w_j - Dp_j$. Although real income taxation implies equal real tax burden for regions with the same real income level, regions with the same utility level (but different real income levels) face different real tax burdens. A region with high real income and low quality of life pays more in real taxes than a region with low real incomes and high quality of life. The second alternative tax system assumes equal real tax payments and represents taxation of amenities in this simple model of homogeneous population and equal utilities. The real tax burden is equal in regions with the same utility level.

We construct a common specification that captures the three tax systems, expressed in log-differential form:

$$\hat{T}_j = s_\tau \hat{w}_j - s_D \hat{p}_j \tag{17}$$

where s_τ is taxes net of deductions relative to total tax payments and s_D is price-indexed deductions as share of total tax payments. The parameters s_τ and s_D are used to distinguish between nominal income taxation $(s_\tau > 1, s_D = 0)$, real income taxation $(s_\tau > 1, s_D > 0)$, and equal real tax payments $(s_\tau = 0, s_D = -1)$. With nominal income taxation, tax payments vary across regions as nominal incomes vary. Real income taxation implies that nominal tax payments depend positively on nominal incomes and negatively on cost of living, and with larger weight on the income component. Finally, with equal real tax payments the nominal tax burden varies with the regional cost of living.

The payroll tax is introduced at the supply side of the model in equations (5)–(10) and is differentiated across regions in the underlying data described in the next section. The role of the payroll tax is investigated in an alternative with no regional differentiation.

Equations (1)–(17) determine 17 endogenous variables in each region, all in log-differential form: wages, taxes, and land rent $(\hat{w}_j, \hat{T}_j, \hat{r}_j)$, housing price and aggregate price index $(\hat{p}_{H,j}, \hat{p}_j)$, per capita consumption of traded goods and housing $(\hat{x}_j, \hat{y}_j)$, total output in the traded and housing sector $(\hat{X}_j, \hat{Y}_j)$, factor demands in each sector $(\hat{L}_{X,j}, \hat{K}_{X,j}, \hat{N}_{X,j}, \hat{L}_{Y,j}, \hat{K}_{Y,j}, \hat{N}_{Y,j})$, and aggregate capital and population in each region $(\hat{K}_j, \hat{N}_j)$.

3. Data and calibration

The calibration of the model is based on Norwegian data for wages, housing costs, taxes, and population across 89 labor market regions. The regional housing costs are estimated from data on house transactions. The transaction database of Statistics Norway contains information on all house transactions with the exception of transactions administered by the housing cooperatives. Data for about 427,000 house transactions are available for the period 2005–2010. The regression model assumes that the transaction price is a function of housing attributes (square meters, age of house, type of house, type of ownership, number of rooms and other characteristics) and a full set of regional fixed effects. Carlsen and Leknes (2015) explain the econometric model in more detail. The estimated model is documented in Appendix A. The housing price is increasing in size, declining in age, increasing in number of rooms, and affected by type of house and type of ownership. The estimated regional fixed effects, adjusted to make their mean equal to the national mean price level, represent the housing price level of the respective regions. Given the expenditure share of housing, the aggregate price index (measuring cost of living) follows from the regional housing cost data.

To quantify the effects of the income tax system we need good measures of regional wage differences. The heterogeneity of the population represents an important challenge in the estimation of regional wages, and geographic sorting may introduce measurement errors. The existing literature on tax distortions and population distribution controls for observable worker characteristics, whereas we are able to include unobservable worker characteristics using identification of differences based on movers. In addition, we allow dynamic learning effects from work experience to vary across regions, as emphasized by De la Roca and Puga (2016). The regional wage levels are estimated from administrative register data. The dataset covers all full-time workers in the private sector aged 25–65 during 2001–2010, which includes about 6.5 million worker-year observations. We exploit the panel dimension of the data, and use movements between regions to control for unobservable worker characteristics. The hedonic regression of hourly wages includes a set of worker observables (work experience, education, age) together with regional, worker, sector, and year fixed effects. The specification allows for the value of experience to vary across regions. The econometric model specification is based on Carlsen et al. (2016). Our measure of regional wages equals the estimated regional fixed effects plus the dynamic learning effect of work experience (calculated based on estimated coefficients and using the average 7.9 years of experience), adjusted to represent annual wages. The regional wage estimates are robust to controls for regional amenity values. Appendix A documents the estimated model for regional wages.

Taking into account deductions and progressivity in the current income tax system, nominal tax payments are given as (based on 2010 values):

$$T_j = 0.28(w_j - 115,010) + 0.09(w_j - 456,400) + 0.078w_j$$

$$= 0.448w_j - 73,279 \qquad (18)$$

The income tax has fixed nominal deductions, NOK 115,010 for the basic 28% income tax and NOK 456,400 for the top 9% income tax. In addition, there is a social security tax of 7.8%. This implies a tax rate of 44.8% and total deductions of NOK 73,279. [2] Nominal tax payments then follow directly from the wage data.

The payroll tax is differentiated at the local government level and is divided into five geographic zones; we use the actual rates as of 2010 to find total wage costs. Most of the population lives in zone 1 with the highest payroll tax rate of 14.1% and they populate 21 regions. In addition, 28 regions have a mix of local governments in the tax range 10.6–14.1%. Zone 2 covers the municipalities with the second highest payroll tax rate of 10.6% and include 12 regions. Three regions have local government with tax rates in the range 6.4–10.6%. The low rates are set for periphery regions: 6 regions with tax rate of 6.4% (zone 3), 14 regions with tax rate of 5.1% (zone 4), and 5 regions with tax rate of 0% (zone 5). The geometric average across regions is about 10%.

The model parameters are set based on available data and stylized facts. Taxes net of deductions relative to total tax payments (s_τ) and tax payments as share of income (s_T) are calculated from our data based on average values across regions, under the assumption that wages account for 75% of total income (s_w). The expenditure share for housing (s_y) is set consistent with Norwegian data from 2004 and equals 16%. The expenditure share for traded goods (s_x) then follows as a residual. In the base-run scenario with nominal income taxation, price-indexed deductions as share of total tax payments (s_D) are set equal to zero, while it differs from zero in the alternative tax systems. The substitution elasticities in

[2] In our data, all regions have wage levels that pay the top income tax. There is no deduction for the social security tax, but there is a minimum income requirement that does not affect our calculations. The five most Northern labor market regions have lower tax rates and larger deductions, but this is ignored to focus on the effect of the tax system.

consumption, traded goods production, and housing production, as well as key production parameters, follow the suggestions of Albouy and Stuart (2014). To establish the full equilibrium of the model, the remaining variables are calibrated consistent with the model equilibrium. We do not have data on land rent $(\hat{r}_j)$, so this variable is calculated from equation (12) under the assumption that productivity in the housing sector is equal across regions $(\hat{A}_{Y,j} = 0)$. The exogenous levels of quality of life $(\hat{Q}_j)$ and traded sector productivity $(\hat{A}_{X,j})$ follow from equations (4) and (11), respectively. Appendix B documents the rest of the calibration, as well as all parameter values.

Table 1 documents the regional data on population, wages, cost of living, nominal tax burden, and payroll tax rates, as well as the calibrated measures of quality of life and traded sector productivity. We separate between three groups of regions based on population size: cities of at least 150,000 inhabitants (7 regions), small cities with population between 65,000 and 150,000 (13 regions), and the remaining 69 regions. In addition, we define top and bottom quintiles of regions with respect to nominal income, cost of living, and real income levels (each quintile consists of 18 regions).

Table 1 about here

Population size differs greatly across labor market regions, as seen in column 1 of Table 1. On average, cities are three times larger than the national geometric average. The many small regions reflect long distances between labor markets "closed" by valleys, mountains, and fjords. The estimated regional wage levels follow from hedonic regressions controlling for observable and unobservable heterogeneities, while allowing dynamic learning effects of work experience to vary across regions. Cities have 9.2% higher wages than the average, and with Oslo on top with a wage premium of 12%. Top quintile high-income regions have wage differential of 5.2%, whereas the bottom quintile low-income regions have 3.3% lower wages than the average. Regional differences in wage costs are larger because urban high-wage regions face higher payroll taxes, as seen from column 3. In cities, one plus the payroll tax rate is 3.3% higher than the national average, which implies that wage costs $(\hat{w}_j + \hat{b}_j)$ are 12.5% above the national average. From panel *b* it follows that top quintile high-income regions have 7.6% higher wage costs than the average, whereas the bottom quintile low-income regions have wage costs 5% below average.

The analysis concentrates on the role of tax differentials and column 4 shows regional differences in the nominal tax burden given the current income tax system. With nominal income taxation, the tax differentials follow nominal income differences. The nominal tax burden varies from 4.7% below average in low-income regions to 7.5% above average in high-income regions. Cities have nominal tax burden 13% above average. Because high-income regions have larger tax burdens, regional differences in post-tax income are limited and vary from 5% above average in cities to 2% below average in the poorest rural regions.

As seen in column 5, cost of living in cities is 11% higher than the national average, reflecting urban housing costs more than 50% above average. Cost of living is highest in the larger Oslo area. The rich Asker/Bærum region west of Oslo has aggregate prices 16% above average, while Oslo city has a premium of 15%. The top and bottom 18 regions based on cost of living have prices about 9% above and below average, respectively. The differences also show up when we separate regions according to nominal and real income, with cost of living about 6% above average both in the top quintile regions with high nominal income and in the bottom quintile regions with low real income.

Given the data on regional wages, taxes, and cost of living, we calibrate quality of life and traded sector productivity consistent with migration equilibrium and zero-profit conditions, as shown in the last two columns of Table 1. Quality of life is strongly negatively correlated with real wages after tax, as migration equilibrium balances quality of life and post-tax real wages to equalize utility levels across regions. Cities and small cities have quality of life above the national average, as high cost of living pushes down post-tax real wages in these regions. Peripheral regions with high real wages have the lowest amenity values. Traded sector productivity varies with nominal wages, and cities have 15% higher productivity than the average.

Figure 1 about here

The correlation between traded sector productivity and quality of life equals 0.74. City regions have high productivity and amenity value, whereas small peripheral regions score low on both dimensions. Norway seems to lack the consumer-attractive regions where people want to live, but industry is disadvantaged. More surprisingly, high-productivity regions of low popularity among the public are also lacking. The scatterplot in Figure 1 shows the positive correlation between traded sector productivity and quality of life. Quality of life varies from 12% below average to 9% above average, whereas productivity varies from 16% below average to 19% above average. The degree of regional variation is comparable to international studies, represented by Albouy et al. (2013) across Canadian cities and Albouy (2016) on US data.

The analytical solution for regional population can be expressed as[3]:

$$\hat{N}_j = \varepsilon_{N,Q}\hat{Q}_j + \varepsilon_{N,A_X}\hat{A}_{X,j} + \varepsilon_{N,A_Y}\hat{A}_{Y,j} \tag{19}$$

where $\varepsilon_{N,Q}$, ε_{N,A_X} , and ε_{N,A_Y} are the elasticities of population with respect to quality of life, traded sector productivity, and housing productivity, respectively. These reduced-form elasticities depend on structural parameters of the model, as elaborated by Albouy and Stuart (2014). In the empirical implementation of the model, regional differences in housing productivity are ignored due to lack of land rent data. Table 2 shows the calculated elasticities across different tax schemes. To be able to compare the effects of quality of life and traded sector productivity on population, the elasticity with respect to productivity is normalized by the size of the traded sector. In the base-run calibration, 1%-point increase in the quality of life differential generates an increase in the population differential of 14.9%-points. A comparable increase in traded sector productivity leads to 8.3%-points increase in the population differential. Compared with the lump-sum income tax scenario, all three tax systems have lower elasticity of population with respect to productivity, indicating that income taxes push workers away from high-productive areas and the effect is strongest with nominal income taxation. The elasticity of population with respect to quality of life is higher with nominal income taxation and real income taxation than in the case with lump-sum taxation. These tax systems give workers incentive to locate in high-amenity regions. The third tax system with equal real taxes based on taxation of amenities naturally pushes workers away from high-amenity regions.

[3] The complete expression also includes a term capturing population effects due to regionally differentiated payroll taxes.

Table 2 about here

4. Income tax systems and allocation of population

The natural reference point for evaluation of geographic distortions of tax systems is the situation where taxes are independent of where people live: lump-sum income tax and no payroll tax. In the model, lump-sum income tax is equivalent to no income tax because the model is log-differentiated. We refer to this as the undistorted equilibrium. In this case, the distribution of the population reflects the underlying economic conditions—amenities and productivities. Note that this is not a policy-neutral situation. Policies such as public infrastructure investments may influence the allocation of population through amenities. In this study, such factors are taken as given.

The approach is to calculate a nominal tax differential relative to lump-sum income tax for each of the three alternative income tax systems—nominal income taxation, real income taxation, and equal real taxes (while keeping payroll taxes equal across regions). The tax differential follows from income and/or price differences across regions, depending on tax design. The tax differential generates an allocation of the population different from the lump-sum income tax benchmark. The key responsiveness of the model is described by the elasticity of population with respect to the nominal tax burden. The elasticity results from parameterization and data and comes out as $\varepsilon_T = -2.64$. Given the linear structure of the model, the elasticity is the same for all regions. The varying population responses follow from the relevant tax differentials.

Table 3 shows the results for the same four classifications of regions as in Table 1. Columns 1–3 show the tax differentials of the three alternative tax designs, and the implied changes in population differentials follow in columns 4–6. With nominal income taxation, the tax differential is proportional to the variation in nominal income levels. The nominal tax system generates a tax differential of 10% in the top quintile high-income regions (panel b). Nominal income taxation is favorable for low-income regions, facing a tax burden 6.5% below the national average. As seen in panel a, the high-income regions basically consist of the cities. The cities have a positive tax differential of 16.8% with Oslo on top (about 20% higher tax payments than the average). Since nominal income and cost of living are positively correlated, the regions with higher costs also have positive tax differential. As shown in panel c, the top quintile high-cost regions have a tax differential of 7.1%.

The quantitative effects of the tax differentials can be large, and with nominal income tax the variation in the income level determines the strength of the migration incentive. The fourth column gives the change in the population differential between lump-sum taxation and nominal income taxation. The allocation reflects a nominal tax differential for the specific groups of regions shown in column 1. The 10% higher tax burden of high-income regions implies a decline in the population differential by 26.5%-points (consistent with an elasticity of -2.64). The change in the population differential in high-income regions reflects a reduction in the population from 123% above the national average with lump-sum taxation to 97% above average with nominal income taxation (not reported in the table). The average population differential in the low-income regions (panel b) expands by 17%-points (from 92% below average to 75% below average). Compared to the undistorted equilibrium, nominal income taxation implies migration from urban to rural areas. This decreases regional differences in housing costs, and the model implies an elasticity of about -0.9 for housing prices with respect to nominal tax payments. As discussed in relation to Table 1, income level, cost level, traded productivity, and quality of life are strongly correlated in the data. It follows that population shifts out of high-cost regions, high-productivity regions and high quality of life regions with nominal income taxation.

Table 3 about here

Nominal income taxation implies a cost of living distortion that can be solved by indexation of taxes—real income taxation. In this case, the real tax burden is proportional to real incomes, which implies that the nominal tax burden depends positively on nominal incomes and negatively on the cost of living, but with larger weight on the income component. Real income taxation generates high nominal tax burden for high-income regions (shown in panel b, column 2). High-income regions are dominated by cities, where very high nominal incomes generate positive tax differentials despite high prices. Real income taxation increases the tax burden of cities, but less than the nominal tax system. Cities have nominal tax burdens 11.2% above average with real income taxation compared to 16.8% with nominal income taxation. Compared to the lump-sum income tax scenario, real income taxation is a disadvantage to cities, but compared with the current nominal tax system, real income taxation represents an improvement for cities.

As argued in the introduction, real income taxation does not take into account the regional variation in quality of life. We modify the tax system so that we also include taxation of amenities. Given the assumptions of the model, this implies equal real taxes across regions. In this case, the nominal tax differentials are proportional to cost of living. The top quintile high-cost regions have positive tax differential of 7.3%, while the bottom quintile has negative differential of 7%, as shown in column 3 of Table 3. At the top of the list, we again find the largest city regions. Compared with the undistorted equilibrium, equal real taxes imply migration from cities and small cities toward the rest of the country. The movement from real income taxation to equal real taxes isolates the impact of amenity taxation, and as seen by comparing columns 2 and 3, the cost of such a reform is carried by the small cities. Small cities have low real incomes (and hence high amenity values) because the lower income level compared with cities is not matched by lower cost of living. Taxation of amenities favors peripheral regions with high real incomes and low amenity values (following from low cost of living). The difference between columns 2 and 3 in panel d shows that amenity taxation decreases the tax burden of the top quintile high real income regions by 7.4%-points, which increases the population differential by almost 20%-points (columns 5 and 6, panel d).

All three tax designs distort the geographical allocation of the population to the disadvantage of cities, and as we have seen the largest effect follows in a nominal income tax system. The main economic issue involved is the cost of tax distortion and the model results allow for a calculation of the deadweight loss. We follow the calculations of Albouy (2009) derived from the Harberger triangle, also applied by Albouy and Hanson (2014) for housing taxation. The starting point is the tax differential, the additional taxes paid in a region relative to the national average. The tax differential is determined by the income and/or price differentials, depending on the tax system. The tax differential can be positive or negative and gives incentive for migration between regions. The efficiency loss is given by the area of the Harberger triangle as understood in a regional allocation model—it equals half the size of the change in the tax differential times the induced change in the population differential averaged across regions. By multiplying this expression with the parameter s_T (tax payments relative to income), the deadweight loss is measured as share of GDP:

$$DWL = s_T \frac{1}{2} E\left(d\hat{T}_j \cdot d\hat{N}_j\right) \tag{20}$$

where $d\hat{T}_j$ and $d\hat{N}_j$ represent the changes in the tax differential and the population differential, respectively, from the undistorted situation with lump-sum taxation to the respective tax system (nominal income taxation, real income taxation or equal real tax burden). In the undistorted equilibrium, the tax burden is the same in all regions (equal to the national geometric average) and the tax differentials equal zero. Consequently the change in the tax differential is given by the tax differential of the tax system in question, $d\hat{T}_j = \hat{T}_j$. The population effect can be expressed as $d\hat{N}_j = \varepsilon_T \cdot d\hat{T}_j$, where ε_T is the elasticity of the population differential with respect to the tax differential. Inserting this into equation (20) and utilizing the fact that the expected value of the tax differential equals zero, the deadweight loss as share of GDP is proportional to the variance of the tax differential in the chosen tax system, and follows as:[4]

$$DWL = s_T \frac{1}{2} \varepsilon_T \cdot Var(\hat{T}_j) \tag{21}$$

Nominal income taxation creates a disincentive to locate in productive high-income regions, and generates a deadweight loss due to locational inefficiencies equal to 0.18% of income, as stated in row 1 of column 1 in Table 4. This is somewhat lower than the US estimate of Albouy (2009) of 0.23% of income. However, the magnitude of the deadweight loss depends on the measured variation in regional incomes. Whereas we control for both observable and unobservable characteristics of workers and allow the dynamic learning effect of experience to vary across regions, the regional income differences used in Albouy (2009) only control for observables. For comparison with the US results, we ignore the dynamic learning effect and control only for observable worker characteristics in the Mincer wage equation. The

[4] Alternatively, the deadweight loss can be calculated as $DWL = \frac{1}{2}\xi \cdot Var(s_T\hat{T}_j)$, where ξ is the elasticity of the population differential with respect to the tax differential as share of income. Given our parameterization, $\xi = -11.8$, compared with an elasticity of -6 in Albouy (2009). The size of the DWL is the same as in equation (21).

resulting deadweight loss given in row 3 of column 1 equals 0.271%, somewhat higher than the US case of Albouy. To illustrate the role of regional income variation further, we show in row 4 of column 1 that nominal taxation has a deadweight loss of 0.537% in the case where raw income differences are assumed to reflect productivity differences. On the other end of the scale, controlling for observables and unobservables while ignoring higher learning effects in cities implies lower regional income differences and the deadweight loss is down at 0.124% of income (row 2, column 1).

Table 4 about here

Real income taxation generates a geographic distribution of the population closer to the undistorted equilibrium, and hence with lower deadweight loss than nominal income taxation. As seen from row 1 of column 2, the locational inefficiencies amount to 0.096% of income. The deadweight loss is somewhat less responsive to measured income differences because the variation in taxation also depends on differences in cost of living. Equal real taxes are favorable for regions with low amenity value and low cost of living, which in our setting correspond to regions with low traded sector productivity. The deadweight loss is about the same as with real income taxation and equals 0.093% of income as shown in row 1 of column 3. The size of the deadweight loss is quite independent of measured income differences. It is the variation in cost of living that matters. The horizontal equity obtained by taxing amenities has real side costs when traded sector productivity is low in regions with low quality of life gaining population. Equal real taxes raise the population in small regions and have a more concentrated distribution of the population.

The analysis above calculates deadweight loss in an undistorted economy without payroll tax. In practice, a regionally differentiated payroll tax also affects the distribution of the population, and the deadweight loss of income taxation depends on the design of payroll taxes. If payroll taxes are differentiated among regions and with higher rates in more urban areas, the initial geographic distribution of the population is less urbanized. In this situation, the deadweight loss of income taxes is smaller because the city population is lower compared with an undistorted economy. Given the actual payroll tax rates of Norway, the deadweight loss of nominal income taxation decreases from 0.18% to 0.07% of GDP. The deadweight losses of real income taxation and equal real income taxes are also reduced in this case, and nominal income taxation still is the least efficient alternative. The combined distortionary effect of income and payroll taxation is analyzed at the end of in section 5.

5. Regionally differentiated payroll taxation and allocation of population

The analysis takes as a starting point an undistorted economy with lump-sum income tax and no payroll tax. This tax scenario is compared to the present system of regionally differentiated payroll taxes assuming no income tax distortion. In the base run, the payroll tax is equal to the national geometric average of 10.3%. The policy shift changes the economic conditions of the regions and leads to a new migration equilibrium with higher population in labor market regions with lower payroll tax. These regions face increased labor demand and demand pressure at the local housing market. Housing costs increase and workers are compensated with higher (pre-tax) wage level given quality of life. In the city regions the payroll tax increases, which results in lower labor demand, outmigration and lower housing costs. The housing cost effect tends to require lower wages to have migration equilibrium.

The wage cost differentials are shown in column 1 of Table 5, and the differentials are composed of tax rate differentials and nominal wage differentials in columns 2 and 3, respectively. The effects are presented for the five geographic zones and zone 1 basically reflects the city regions. The payroll tax differentials dominate, and the nominal wage differentials have the opposite signs. In the zone 1 regions, the payroll tax differential is 3.3% points above average, whereas the nominal wage differential is 2% below. In the model, the payroll tax is partly shifted to workers.

Column 4 reports the implied population differentials. In zone 1 regions, the reduction in the population differential is about 29%-points. The geographic distribution of the population is shifted toward the periphery when regional payroll differentiation is established. The quantitative effects of the model predictions for population reallocations primarily depend on the size of the substitution elasticities in production and consumption. We follow the assumptions of Albouy and Stuart (2014) with elasticities equal to 0.67. In a more rigid economy with limited substitution possibilities, movements in the population across regions are smaller. The elasticity at the production side is of particular importance, because the factor combinations change less, and consequently the labor demand effects are smaller.

Table 5 about here

The efficiency loss due to regionally differentiated payroll taxes is calculated based on the new migration equilibrium, similar to the income tax distortions in section 4. The deadweight loss as share of income follows as:

$$DWL = s_P \frac{1}{2} \varepsilon_P \cdot Var(d\hat{w}_j + d\hat{b}_j) \tag{22}$$

where ε_P is the elasticity of the population differential with respect to the wage cost differential and s_P represents wage costs as share of total income. The efficiency loss is proportional to the variance of the change in the wage cost differential from the undistorted equilibrium to the situation with lump-sum income tax and regionally differentiated payroll taxation $(d\hat{w}_j + d\hat{b}_j)$.

The deadweight loss equals 0.22% of GDP and is somewhat larger than the income tax distortions. The size of the loss depends on the income tax system. Nominal income taxation reduces the deadweight loss of payroll taxes because a smaller share of the population is located in cities. With nominal income taxation, the deadweight loss of regional differentiated payroll taxation is about 0.1% of GDP.

The combined distortionary effect of income and payroll taxation in the Norwegian system can be calculated. We compare a situation with lump-sum income taxation and no payroll tax with the Norwegian case of both nominal income taxation and regionally differentiated payroll taxation. As expected, the two distortionary taxes together create larger deadweight loss than each of them separately. The deadweight loss equals 0.46% of GDP. The distortionary effect of the payroll tax is increased when interacting with the income tax distortion.

6. Concluding remarks

The analysis addresses how different national taxation schemes interact with geographic variation in productivity and consumption amenities in determining regional populations. A neoclassical migration equilibrium model is used to analyze the current nominal income tax system in Norway. The analysis is based on estimated regional income differences accounting for both observable and unobservable individual characteristics and the value of experience. Given regional differences in incomes and housing prices, quality of life, and productivity are calibrated to model equilibrium.

The variation in incomes and prices has consequences for the regional allocation effects of income taxation. Compared to an undistorted equilibrium with lump-sum taxation, we find that nominal income taxation creates a disincentive to locate in productive high-income regions. The deadweight loss due to locational inefficiencies is 0.18% of GDP. We study real income taxation and equal real taxes as alternative tax systems. Both alternatives generate a geographic distribution of the population closer to the undistorted equilibrium, and hence with lower deadweight loss.

In an extension of the analysis, we take into account payroll taxes. The existing regionally differentiated payroll taxes, to the disadvantage of cities, generate a deadweight loss of 0.22% of GDP in an economy with lump-sum income taxation. The two distortionary taxes interact and strengthen each other and the combined distortionary effect of income and payroll taxation in the Norwegian system is 0.46% of GDP.

Regional misallocation is not much addressed in the tax literature. The findings in this paper indicate that the quantitative effects of tax distortions can be large when mobility is high. Future research could address possible heterogeneous effects across the population and the role of imperfect mobility and housing market adjustment.

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Appendix A: Hedonic regressions behind the regional measures of wages and housing costs

Appendix Table 1 Estimation of regional wages

	Log hourly wage
Experience	0.08***
	(0.0003)
$(\text{Experience})^2$	-0.001***
	(0.0000)
Experience cities	0.011***
	(0.0002)
$(\text{Experience cities})^2$	-0.000***
	(0.0000)
Experience cities x now in smaller region	-0.000
	(0.0002)
Experience high wage sector	0.005***
	(0.0004)
$(\text{Experience high wage sector})^2$	-0.000***
	(0.0000)
Experience high wage sector in cities	0.003***
	(0.0003)
Secondary education	0.021***
	(0.0019)
Tertiary education	0.119***
	(0.0029)
Regional indicators	Yes
Worker fixed effects	Yes
Year fixed effects	Yes
Sector fixed effects	Yes
High wage sector x Year fixed effects	Yes
Age controls	Yes
Observations	6,512,359

Notes: The regression is based on yearly data for all full-time workers in the private sector during 2001-2010. Sector fixed effects are at the 2-digit level and include 54 sectors. Regional indicators are at the NUTS-4 level, and correspond to 89 labor market regions. The age controls are given as 5-year intervals. Work experience is calculated in days from 1993 onward, and expressed in years. We separate between city regions and the rest. The city group is defined as regions with more than 150,000 inhabitants in 2010, which includes 7 regions. We also separate out the top 10 high wage sectors based on fixed sectoral effects. Standard errors are given in parentheses. *** indicates significance at the 1% level. The regression includes a constant term.

Appendix Table 2 Estimation of regional housing costs

	Log housing costs
Size (in square meters)	0.002***
	(0.0000)
Size squared	-0.000***
	(0.0000)
Gross size	0.002***
	(0.0000)
Gross size squared	-0.000***
	(0.0000)
Age of house	
1-5 years	-0.064***
	(0.0055)
6-10 years	-0.107***
	(0.0061)
11-20 years	-0.214***
	(0.0057)
21-30 years	-0.303***
	(0.0056)
31-50 years	-0.354***
	(0.0053)
51-100 years	-0.323***
	(0.0054)
> 100 years	-0.237***
	(0.006)
Type of house	
Detached	0.13***
	(0.0129)
Semi-detached	0.125***
	(0.0133)
Townhome	0.125***
	(0.0132)
Apartment	0.125***
	(0.013)
Multi-family residential/Apartment building	0.311***
	(0.0336)
Farm	0.155***
	(0.0183)
Type of ownership	
Share	-0.172***
	(0.002)
Stock	-0.033***
	(0.0052)
Bond	-0.664***
	(0.047)
Other	-0.161***
	(0.0285)

The table continues on the next page

	Log housing costs
No. of rooms	
2	0.241***
	(0.0061)
3	0.263***
	(0.0061)
4	0.295***
	(0.0064)
5	0.313***
	(0.007)
≥ 6	0.352***
	(0.0073)
Regional indicators	Yes
Monthly dummies	Yes
R^2	0.41
Observations	427,184

Notes: The regression is based on 427,184 house transactions during 2005-2010. Regional indicators are at the NUTS-4 level, and correspond to 89 labor market regions. The reference category for age of house, type of house and type of ownership is 0 years, other house types and owner, respectively. The regression also controls for floor, number of bedrooms, whether the house has been renovated, whether it has a balcony, boat place, carport, fireplace, common washroom, garden, elevator, and owned plot. Standard errors are given in parentheses. *** indicates significance at the 1% level. The regression includes a constant term.

Appendix B: Parameter values and model calibration

As described in section 3, the model calibration is based on Norwegian data for wages, housing costs, taxes, and population across 89 labor market regions, together with data and stylized facts on model parameters. Values of all parameters are given in Appendix Table 3.

To establish the full equilibrium of the model, the remaining variables are calibrated based on the model equations given in section 2. The price index $(\hat{p}_j)$ and nominal tax payments $(\hat{T}_j)$ follow directly from equations (2) and (17), respectively. We do not have data on land rent $(\hat{r}_j)$, so this variable is calculated from equation (12) under the assumption that productivity in the housing sector is equal across regions $(\hat{A}_{Y,j} = 0)$. The exogenous levels of quality of life $(\hat{Q}_j)$ and traded sector productivity $(\hat{A}_{X,j})$ follow from equations (4) and (11), respectively. We can then use equations (1) and (3) to solve for per capita consumption of traded goods and housing ($\hat{x}_j$ and $\hat{y}_j$, respectively). Given our data on regional population size $(\hat{N}_j)$ housing production $(\hat{Y}_j)$ follows from (16). Factor use in the housing sector $(\hat{L}_{Y,j}, \hat{K}_{Y,j}, \hat{N}_{Y,j})$ is calibrated from equations (8)–(10). Labor demand in the traded sector

$(\hat{N}_{X,j})$ follows from equation (15), and traded production $(\hat{X}_j)$ from equation (7). Land and capital use in the traded sector $(\hat{L}_{X,j}, \hat{K}_{X,j})$ are calibrated based on equations (5) and (6). Finally, total supply of land and capital in region *j* $(\hat{L}_j, \hat{K}_j)$ follow from equations (13) and (14).

Appendix Table 3 Calibrated model parameter values

Parameter	Description	Value
s_τ	Taxes net of deductions relative to total tax payments	
	- Nominal income taxation	1.45
	- Real income taxation	1.45
	- Equal real taxes	0
s_D	Price indexation of taxes	
	- Nominal income taxation	0
	- Real income taxation	0.45
	- Equal real taxes	-1
s_w	Wages as share of income	0.75
s_T	Tax payments as share of income	0.232
s_x	Expenditure share traded goods	0.608
s_y	Expenditure share for housing	0.16
s_p	Wage costs as share of income	0.828
σ_C	Elasticity of substitution in consumption	0.667
σ_X	Elasticity of substitution in traded goods production	0.667
σ_Y	Elasticity of substitution in housing production	0.667
θ_L	Traded sector cost share of land	0.025
θ_K	Traded sector cost share of capital	0.15
ϕ_L	Housing sector cost share of land	0.233
ϕ_K	Housing sector cost share of capital	0.15
λ_L	Share of land used in traded goods production	0.17
λ_N	Share of labor used in traded goods production	0.7
λ_K	Share of capital used in traded goods production	0.791
$\overline{p}$	Geometric average of the price index	1.008

Note: The parameters s_τ and s_D are used to capture different tax systems; see further descriptions in section 2.2.

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Table 1 Data on population, wages, nominal tax burden, payroll tax rate and cost of living, calibrated quality of life and traded productivity

Regions	Population $\hat{N}_j$	Wages $\hat{w}_j$	Payroll tax rate $\hat{b}_j$	Nom tax burden $\hat{T}_j$	Cost of living $\hat{p}_j$	Quality of life $\hat{Q}_j$	Traded productivity $\hat{A}_{X,j}$
Panel a:							
Cities	2.127	0.092	0.033	0.133	0.11	0.047	0.152
Small cities	1.136	0.002	0.022	0.003	0.052	0.039	0.045
Rest of country	-0.43	-0.01	-0.007	-0.014	-0.021	-0.012	-0.024
Panel b:							
High-income	0.829	0.052	0.024	0.075	0.059	0.024	0.088
Low-income	-0.654	-0.033	-0.017	-0.047	-0.05	-0.025	-0.064
Panel c:							
High-cost	1.099	0.036	0.018	0.052	0.088	0.053	0.087
Low-cost	-0.771	-0.018	-0.023	-0.026	-0.085	-0.058	-0.075
Panel d:							
High real income	-0.648	-0.005	-0.015	-0.008	-0.077	-0.057	-0.055
Low real income	0.495	0.003	0.003	0.004	0.064	0.048	0.038

Notes: The regional population data are from 2010. Data on wages and housing costs are based on hedonic regressions, as documented in Appendix A. Cost of living is proportional to housing costs, weighted by the expenditure share for housing. The nominal tax burden follows from the wage data given the current income tax system in Norway. The regionally differentiated payroll tax rates are given by the actual rates as of 2010. Quality of life and traded sector productivity are calibrated from the model based on data on wage, tax, and cost of living. All variables are measured as percentage deviation from the national geometric average (approximated by log-differentials). Panel *a* separates between three groups of regions according to population size: Cities defined as regions with at least 150,000 inhabitants (7 regions), small cities with population in the range 65,000–150,000 (13 regions) and the remaining 69 regions. Panels *b*–*d* separate between the top 20% and bottom 20% of regions according to nominal income, cost of living, and real income, respectively. Each group consists of 18 regions.

Table 2 Reduced-form elasticities across tax schemes

Tax scheme	$\varepsilon_{N,Q}$	$\varepsilon_{N,A_X} / s_x$
Lump-sum income taxation	12.4	14.3
Nominal income taxation	14.9	8.3
Real income taxation	16.0	9.3
Equal real taxes	11.0	12.1

Note: $\varepsilon_{N,Q}$ and ε_{N,A_X} represent the elasticity of population with respect to quality of life and traded sector productivity, respectively, while s_x is the relative size of the traded sector.

Table 3 Population and tax differentials across different tax schemes relative to undistorted equilibrium

	Change in tax differential $d\hat{T}$			Change in population differential $d\hat{N}$		
Regions	Nominal income taxation	Real income taxation	Equal real taxes	Nominal income taxation	Real income taxation	Equal real taxes
Panel a:						
Cities	0.168	0.112	0.103	-0.445	-0.297	-0.273
Small cities	0.027	-0.001	0.044	-0.07	0.002	-0.116
Rest of country	-0.022	-0.011	-0.019	0.058	0.03	0.05
Panel b:						
High-income	0.1	0.069	0.058	-0.265	-0.182	-0.154
Low-income	-0.065	-0.039	-0.046	0.172	0.103	0.123
Panel c:						
High-cost	0.071	0.028	0.073	-0.188	-0.073	-0.193
Low-cost	-0.051	-0.008	-0.07	0.134	0.02	0.184
Panel d:						
High real income	-0.023	0.015	-0.059	0.061	-0.038	0.155
Low real income	0.008	-0.022	0.045	-0.021	0.058	-0.119

Table 4 Deadweight loss (DWL) as percent of GDP across different tax systems (relative to undistorted equilibrium), dependent on estimation of regional income differences

	Tax system:		
Estimation of regional income differences:	Nominal income taxation	Real income taxation	Equal real taxes
Control for observable and unobservable characteristics, including dynamic learning effect	0.176%	0.096%	0.093%
Control for observable and unobservable characteristics	0.124%	0.066%	0.088%
Control for observable characteristics	0.271%	0.162%	0.1%
Raw income differences	0.537%	0.371%	0.114%

Note: The deadweight loss as percent of GDP is calculated from equation (21).

Table 5. Wage cost and population differentials of regionally differentiated payroll taxes relative to undistorted equilibrium

Payroll tax zone	Change in wage cost differential $d\hat{w}+d\hat{b}$	Change in payroll tax differential $d\hat{b}$	Change in wage differential $d\hat{w}$	Change in pop. differential $d\hat{N}$
Zone 1 (14.1%)	0.013	0.033	-0.02	-0.286
Zone 2 (10.6%)	0.001	0.002	-0.001	-0.02
Zone 3 (6.4%)	-0.014	-0.036	0.022	0.311
Zone 4 (5.1%)	-0.02	-0.049	0.029	0.416
Zone 5 (0%)	-0.039	-0.098	0.059	0.841

Figure 1 Scatterplot of traded productivity and quality of life across 89 regions