Public Policy and the Geography of Economic Activity

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Preface

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"When the mind is clear, empty of memories and knowledge, things are seen exactly as they are."
-Patañjali, *Yogasũtra, c.a. 400-200 BC*

To Corinne

Introduction

Many policy makers and academics are concerned about the rising inequality of economic activity between core and peripheral regions. According to the United Nations (2018) in 2007 for the first time, more than half of the world's population lived in urbanized areas. This share is expected to increase over the next decades. There is abundant evidence that highly productive firms and skilled workers concentrate in cities to take advantage of various forms of agglomeration externalities. Better job and income perspectives in cities are an important factor in explaining the rise in the concentration of population. Rural areas in the periphery host a disproportionately large share of less productive firms and low-skilled workers, who are subject to inferior job opportunities. This has lead to an increasingly uneven distribution of economic activity across space, which has exacerbated income inequality.

Despite the high relevance for policy makers, the economic literature still provides scarce robust evidence about policy interventions on the general equilibrium of the spatial economy. In recent years, an active and growing literature in the field of quantitative economic geography developed a framework that allows investigating complex general equilibrium ramifications of public policies (see Redding and Rossi-Hansberg 2017 for a review of the literature). This thesis contributes to the scientific literature by introducing and analyzing public policies in a quantitative spatial framework. Combining these models with regional data and structural estimation techniques, the following chapters study the implications of inter-regional transfer schemes, fiscal subsidies to owner-occupiers, and inter-state tax agreements on the geography of economic activity.

The novel quantitative framework used for these analyses accommodates multiple asymmetric locations that differ in terms of their local geography, productivity, and amenities. Thereby, the model's structural fundamentals are exactly mapped to the observed regional data. Having recovered the model's structural fundamentals, the underlying quantitative framework enables the simulation of model-based counterfactuals of public policy interventions.

In contrast to the previous reduced-form public policy literature, using a structural framework entails several advantages for policy evaluations. The model's structure allows quantifying consequences of heterogeneous treatment effects, which go beyond an estimation of marginal effects. Moreover, the framework allows computing changes in welfare, which are typically the ultimate interest of a policy maker and not identified in reduced-form approaches. Furthermore, the framework qualifies to investigate general equilibrium effects of public policy interventions taking into account complex spatial interactions between locations. In this regard, locations are not independent observations because they are systematically linked through trade, commuting, and migration flows. As the subsequent chapters show, spatial linkages of regions are essential for the evaluation of public policies. To get a comprehensive cost-benefit analysis, spatial spillovers have to be taken into account. Ignoring such interdependences in public policy evaluations leads to significant biases.

In Chapter 1, co-authored with Maximilian von Ehrlich, we conduct counterfactual experiments of European Union's (EU) place-based transfers (e.g. EU Structural and Cohesion fund) in an economic geography model and estimate its implication on the distribution of economic activity, migration, factor prices, goods prices, and welfare. We calibrate the model to EU regional data and estimate worker's welfare materialized under different distributions of transfers while keeping the government budget fixed. Thereby, the model's structure allows us to calculate the optimal distribution of place-based transfers by numerically solving for the highest attainable welfare. We then compare the model-based optimal distribution of different types of transfer investments (e.g. wage subsidies, technology investments, and investments in transportation infrastructure) to the distribution of economic activity. Overall, the policy induces residents to move to locations where the benefits of transfers are highest, thus shifting the demand for consumption or housing from core regions to the periphery. In turn, this reduces income and population inequality. In relation to prior reduced-form work in the literature, our framework allows us to analyze displacement effects of place-based policies on non-treated regions. More specifically, we show the shift of population from core to peripheral regions, which has important implications on the productivity and housing markets in non-treated regions.

In Chapter 2, I base my analysis on the same quantitative framework introduced above and characterize the efficient allocation of economic activity across space. To this end, I calculate optimal wage transfers for the EU that tackle spatial externalities and incentivize workers to migrate to the first-best allocation. I then compare i) the optimal wage transfers to ii) actual EU regional transfers and to iii) optimal transfers given the observed budget (i.e. a second-best allocation as calculated in Chapter 1). As a result, I find that the EU deviates from the first-best policy in directing an over-proportional high share of transfers to the most deprived regions. However, concentrating transfers to peripheral regions – as done in the actual EU regional policy and suggested by the second-best case – is preferred given the observed policy budget. To reach the first-best allocation, a significant increase in the budget is necessary. Thus, to attain the highest welfare gain, a central government must increase tax rates and distribute wage subsidies more evenly across space.

Chapter 3, co-authored with Simon Büchler and Olivier Schöni, investigates the spatially heterogeneous impact of the US federal mortgage interest deduction on the location and tenure decisions of households. We extend the general-equilibrium model to study worker's commuting and tenure decisions given the fiscal incentives to owner-occupiers. Despite being a major tax expenditure, repealing the MID would only slightly lower homeownership rates while leaving welfare unchanged. The policy is ineffective because it targets locations with congested housing markets. Thereby, the housing demand shifts toward areas that capitalize the subsidy into higher prices. A repeal of these fiscal incentives pushes owner-occupiers away from productive places leading to a decrease in commuting. In turn, the migration response of households lessens the spatial concentration of population and income and, thus, decreases regional inequality. We provide evidence that a repeal of the MID is to be preferred to an increase of standard tax deductions as recently implemented under President Trump's administration.

In Chapter 4, co-authored with Olivier Schöni, we again use the same class of structural economic geography models to analyze distributional consequences of Reciprocal Tax Agreements between US states. In our framework, states can enter Reciprocal Tax Agreements and allow workers to pay income taxes, where they live instead of where they work. We empirically show that states entering agreements have significantly lower tax rates. Thus, we associate the effect of entering an agreement with a reduction in fiscal competition due to inter-state cooperation. Considering this, we conduct a cost-benefit analysis of each of these agreements and show which agreements lead to welfare improvements.

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On the optimal design of place-based policies: A structural evaluation of EU regional transfers

joint with **Maximilian von Ehrlich**

1.1 Introduction

Public policy of most developed countries intervenes in the spatial distribution of economic activity. First of all, this concerns large-scale programs that are designed specifically for the purpose of directing resources towards well defined geographic areas such as inter-regional transfers, place-based subsidies and local tax exemptions. These interventions are usually motivated by the widespread concern that economic development generates unequal living conditions across regions. While there have been ample empirical studies about the effects of transfers in recipient regions, the general equilibrium effects of these policies are not well understood (Neumark and Simpson 2015). We make progress in this direction by evaluating the general equilibrium effects of European regional transfers based on recent advances in the quantitative analysis of economic geography (see e.g. Allen and Arkolakis 2014; Redding and Rossi-Hansberg 2017).

Place-based policies cover a range of measures: The most important ones include wage subsidies, investments in local transportation infrastructure, and transfers aimed at strengthening local productivity.[1] In our application of EU regional policy these categories represent about 80% percent of total expenditure. The relevance and nature of spillovers to non-treated regions – and thus the general equilibrium effects – vary significantly across these three general types of place-based policy instruments. For instance, wage subsidies exert spillovers via market-size effects, local transportation investments have immediate consequences for the entire transportation network, and local productivity gains dissipate to non-recipient regions via the price indices of imported goods.

Our analysis shows that EU regional transfers have improved welfare significantly for the period 2007-13. At the same time, we demonstrate that substantial further welfare gains could have been reached by reallocating transfers across regions without increasing the budget. By identifying the welfare-optimal spatial distribution for each transfers type, we show that wage subsidies should rather be directed to few poor and peripheral regions while investments in transport infrastructure are most efficient in highly productive and/or core regions. Investments in transport infrastructure and production amenities are complementary and have contributed

[1] We consider transfers focusing on local technological development as investments in production amenities, e.g. investments in local energy supply, schools or broadband technologies. For projects examples of EU regional policy see http://ec.europa.eu/regional_policy/en/projects.

more to welfare than wage subsidies.

We incorporate the main types of regional transfers into a quantitative model capturing costly inter-regional trade, population mobility and endogenous agglomeration economies. We fit the multi-region model to detailed data about European NUTS2 regions spanning a period of 20 years and thereby recover location fundamentals reflecting regional consumption and production amenities.[2] The application focuses on one of the largest regional policy schemes: The European Structural & Cohesion Funds. Already since 1975 these policies are central to the process of European integration and since then the budget has grown continuously. During the budgeting period 2007-13, the Structural & Cohesion Funds accounted for approximately one third of the EU's total budget (European Commission 2008). Using novel data that specifies not only the regional distribution of transfers but also the type of expenditure we obtain causal estimates of the direct (partial equilibrium) effects of transfers on local outcomes.

By estimating the core model parameters for the specific context of EU NUTS2 regions, we ensure that our model performs well in matching empirically observed patterns across European regions. Combining the model structure and the estimated parameters we are in a position to study the general equilibrium effects of transfers. In particular, we analyze the effects of place-based policies on aggregate efficiency and regional inequality, as measured by the coefficients of variation of income and population density. We compare the observed equilibrium to counterfactual scenarios where transfers are discontinued or distributed based on a naive rule that pays a uniform transfer to every region. Ultimately, we are interested in the degree of welfare gain one could reach by optimally designing the place-based policy without expanding the size of the program. To this end, we solve a global optimization problem and derive the welfare optimal distribution of transfers across regions for each transfer type given the current level of taxes.

The counterfactual simulations suggest that the EU place-based policy led to a positive welfare effect of 2.08% compared to a scenario without transfers. This effect is mainly driven by improvements in the average *level* of public infrastructure because the existing policy does not realize the potential of *distributing* the investments in a welfare optimizing way across regions. In particular, this becomes

[2]Eurostat, the statistical agency of the European Union, operates a regional classification scheme (**N**omenclature des **U**nités **T**erritoriales **S**tatistiques) where NUTS2 corresponds to regional entities of 0.8m to 3m inhabitants. Currently, the EU consists of 273 NUTS2 regions.

evident when comparing the current scheme to the uniform distribution of transfers. Considering all transfer types jointly, this naive rule dominates and would yield additional efficiency gains of 0.52 percentage points compared to the existing scheme. We find that switching to the optimal distributions for all transfer types while keeping taxes as well as the aggregate mix of types constant would raise aggregate welfare in the European Union by approximately 1.06 percentage points compared to the existing scheme. For individual transfer types, the most sizable benefits from moving to the optimal spatial distribution can be realized for wage subsidies: There, the existing benefit can be quadrupled.

Below, we discuss our approach with reference to the literature. We introduce the model in Section 1.3 and describe the estimation of model parameters in Section 1.4. Counterfactual policy scenarios are analyzed in Section 1.5. The last section summarizes and draws conclusions about potential reforms of transfers in Europe.

1.2 Literature

Our paper relates to a sizable strand of literature evaluating the effects of place-based policies (e.g. Glaeser and Gottlieb 2008, Kline and Moretti 2014, Neumark and Simpson 2015). Boldrin and Canova (2001) initiated a number of studies focusing on place-based policies in the EU. Becker et al. (2010) address the endogeneity of transfer recipience by exploiting a discontinuity in the mechanism that determined transfer eligibility and show that the policy induced local growth and income effects beyond a simple consumption stimulus.[3] In order to estimate the parameters underlying the link between local characteristics and transfers, we follow their quasi-experimental identification strategy but apply it to outcomes that have not yet been studied, i.e. we estimate the impact of regional transfers on local production amenities and transportation costs.

Most evaluations of place-based policies use reduced-form analyses and identify the local effects in recipient regions. Hence, they mostly ignore spillovers on other regions and thus quantify partial equilibrium effects. However, the aggregate efficiency of spatially targeted transfers depends critically on migration responses, adjustments in land rents and local prices in general. Migration responses to place-

[3]Further reduced-form evaluations of European regional policy include Midelfart-Knarvik and Overman (2002), Mohl and Hagen (2010), Pellegrini et al. (2013).

based transfers can be substantial as documented by Einiö and Overman (2016) and Ehrlich and Seidel (2018) for regional transfers in the UK and Germany. Consistent with our findings, Egger et al. (2014) document that EU transfers have reduced net migration across member countries. Complex spatial interactions occur not only via relocation of households and firms but also via interregional trade and investments.[4] Accordingly, for a comprehensive evaluation of the effectiveness of place-based policies, migration and trade channels are relevant. Reduced-form analyses are usually not capable of identifying these interdependencies. In particular, as these spillovers are not limited to neighboring regions, a structural framework is required to derive the net effect of place-based policies.[5] The EU recognizes the importance of spillovers and expects that "all Member States benefit from positive spillovers generated by investments in cohesion countries" (European Commission 2017). We show that partial equilibrium effects focusing on the local effects in recipient regions significantly overestimate the impact of wage subsidies and investments in production amenities. However, positive spillovers dominate for investments in transportation infrastructure.

In order to identify the general equilibrium effects of place-based policies we build upon recent work in quantitative economic geography (e.g. Allen and Arkolakis 2014, Caliendo et al. 2018b, Redding 2016, Desmet et al. 2018) and link it to data about regional characteristics. The combination of a structural model, regional panel data, and quasi-experimental variation in transfer recipience allows us to estimate almost all parameters of the model, compute spatial equilibria that materialize under different policy schemes, and to conduct welfare analyses. Assuming that the identified parameters of the model remain constant, we can compute the effects of large-scale policy changes. The non-linearities prevalent in economic geography (both in theory and data) make it particularly relevant to go beyond marginal changes as typically obtained in empirical evaluations.

Our paper closely relates to recent contributions in the quantitative analysis of the spatial effects of public policies: Fajgelbaum et al. (2019) and Eeckhout and Guner (2017) evaluate the degree of spatial misallocation due to taxes; Ossa (2017)

[4]E.g., an increase in local income will raise demand not only for locally produced goods but also for goods produced in regions that have close trade links with the transfer recipient. Similarly, changes in productivity and transportation costs will induce a reshuffling of bilateral trade.

[5]Some reduced form analyses reduce the issue of spillovers (i.e. the violation of the stable unit treatment value assumption in the identification of the treatment effect) by excluding observations in the spatial proximity of treated regions from the control group (e.g. Kolko and Neumark 2010).

analyzes welfare costs of subsidy competition in the US, and Gaubert (2017) studies the effects of place-based policies on the location choice of heterogeneous firms. We deviate from these papers in a number of ways: First, we compare different channels of place-based policies i.e. wage subsidies, investments in production amenities and in transportation infrastructure. Second, we derive the welfare optimal spatial distribution of different types of place-based transfers for a given tax setting. Third, we determine the factors that define the optimal place of investment for each type and show complementarities between different transfer types.[6] Simultaneous, independent work by Fajgelbaum and Gaubert (2018) show that the efficient, spatial allocation is characterized by a linear relationship between regional expenditure and wages which can be implemented by a combination of proportional taxes and lump sum subsidies. This is consistent with our findings for wage subsidies if we allow the federal government to set the level of taxes far beyond the observed level and abstract from non-local ownership of fixed factors.[7] However, we focus on the optimal distribution of wage subsidies for the observed level of taxes. In that case, wage subsidies are no longer lump sum but will be shifted to the poor regions since the proportional tax rate can only be used to a very limited degree to redistribute from high wage to low wage regions.

Furthermore, we relate to the literature analyzing investments in transportation infrastructure. Recent papers by Alder (2016), Fajgelbaum and Schaal (2017) identify the optimal transportation infrastructure network in trade models. Baum-Snow et al. (2018) analyze transportation infrastructure investments in China. Allen and Arkolakis (2016) develop an analytical solution for how infrastructure investments between neighboring regions impact trade costs between all other region dyads. We employ this framework and highlight the interrelations between investments in local transportation infrastructure and other transfers such as wage subsidies and investments in local production amenities.

[6]Fiscal equalization of local tax base as studied by Albouy (2012) and Henkel et al. (2018) for the US and Germany leads to regional redistribution but neither affects productivity nor trade costs.

[7]In this regard our optimal design of the transfer scheme can be understood as a second-best scenario for a government being constraint to keeping the tax rates constant. In order to reach the first-best spatial allocation of a 8.7% welfare gain, a proportional tax rate of approximately 38.13% would be required which amounts to about 156 times the observed level of the tax rate. For the implications of a flexible budget see Section 1.5.3.

1.3 Model

Our analysis builds on the framework introduced by Allen and Arkolakis (2014) and Redding and Rossi-Hansberg (2017) featuring multiple regions, endogenous agglomeration economies, and a land market mitigating the concentration of economic activity. The economy is endowed with $\bar{L} = \sum_n L_n$ workers in total and each worker inelastically supplies one unit of labor earning a wage w_n. Every region $n \in N$ is endowed with an exogenous quality-adjusted supply of land H_n. Workers have heterogeneous preferences across locations and, in equilibrium, mobility of workers equalizes indirect utility. Accounting for idiosyncratic location-specific preferences reduces mobility between regions.[8] Trade between regions i and n is inhibited by iceberg transport cost $d_{ni} \geq 1$, where the first subscript refers to the place of consumption. The model allows for unbalanced trade due to regional transfers and regional imbalances in asset holdings. A central government influences the distribution of economic activity by paying regions wage subsidies or by investing in local productivity amenities and local transportation infrastructure. In equilibrium, these three types of transfers are shown to exert quantitatively important spillovers on neighboring regions via trade, migration and imbalances in asset holdings. The directions of spillovers depends on the transfer type. In the following we lay out the model details and discuss how regional transfers and federal taxes are integrated.

1.3.1 Preferences, demand, and production

Utility of an individual ω residing in n has Cobb-Douglas form

$$U_n(\omega) = b_n(\omega) \left(\frac{C_n}{\alpha}\right)^{\alpha} \left(\frac{H_n}{1-\alpha}\right)^{1-\alpha} \quad , \tag{1.1}$$

where $\alpha \in [0,1]$, C_n represents a composite good, H_n is residential land use and b_n is a location-specific preference shifter which is drawn for each worker independently. The idiosyncratic amenity term b_n captures the idea that workers have heterogeneous preferences for living in each location. We assume that location preferences are

[8] Due to the principle of freedom of movements for workers in the EU, we allow for mobility across countries. An alternative assumption as in Redding (2012) would restrict mobility to within-country migration.

drawn i.i.d. across locations and workers from a Fréchet distribution with cumulative distribution function

$$G_n(b) = e^{-B_n b^{-\epsilon}}, \tag{1.2}$$

where the scale parameter B_n determines average amenities for location n and the shape parameter $\epsilon > 1$ governs the dispersion of the value of amenities across workers for each location.

We consider an Armington (1969) setup where the composite consumption good consists of a set of varieties differentiated by the place of origin. Individuals have constant elasticity of substitution preferences such that the varieties are aggregated according to

$$C_n = \left(\sum_{i \in N} c_{ni}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1.3}$$

where σ refers to the elasticity of substitution. Maximizing (1.3) subject to the budget constraint delivers total demand for a variety of the differentiated good $c_{ni} = \frac{p_{ni}^{-\sigma}}{P_n^{1-\sigma}} \alpha y_n L_n$ where y_n denotes region n's per capita income, L_n is location n's labor force, $P_n = \left(\sum_{i \in N} p_{ni}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ refers to the price index and $p_{ni} = p_i d_{ni}$ is the consumer price for a variety produced in i and consumed in region n.

The production side is characterized by external economies of scale where location n's productivity depends on local production amenities $\tilde{a}_n$ and the distribution of labor

$$a_n = \tilde{a}_n L_n^{\mu}. \tag{1.4}$$

Agglomeration elasticity $\mu \geq 0$ governs the strength of external agglomeration economies arising due to concentration of population. Spillovers in this specification are assumed to be *external* to firms and entirely *local*. Every location produces one unique differentiated variety under perfect competition which can be traded across regions. Alternatively, agglomeration economies may be imbedded in the spirit of the new economic geography which yields qualitatively similar results.[9]

Competitive markets lead to profit maximizing prices $p_{ni} = \frac{d_{ni} w_i}{a_i}$. Accordingly,

[9] We discuss the implications of the NEG approach for our channels of transfers in an earlier version of this paper, see Blouri and Ehrlich (2017). The main quantitative difference between the two models relates to the agglomeration elasticity which is in our case independent of the elasticity of substitution. As our data allows us to isolate local agglomeration economies and estimate μ for the sample of regions considered in our application we chose this class of model over a setting with increasing returns to scale at the firm level and monopolistic competition.

the value of trade flows from region i to n can be stated as

$$X_{ni} = \alpha y_n L_n \frac{p_{ni}^{1-\sigma}}{P_n^{1-\sigma}}. \tag{1.5}$$

Substituting the number of firms and profit-maximizing prices in the demand functions, we obtain the the fraction of region n's expenditure on goods produced in region i

$$\pi_{ni} = \frac{\left(\frac{d_{ni}w_i}{a_i}\right)^{1-\sigma}}{\sum_{k \in N}\left(\frac{d_{nk}w_k}{a_k}\right)^{1-\sigma}}, \tag{1.6}$$

as well as the price index in region n

$$P_n = \left(\frac{1}{\pi_{nn}}\right)^{1/(1-\sigma)} \frac{d_{nn}w_n}{a_n}. \tag{1.7}$$

1.3.2 Trade costs

Infrastructure investments represent one of the main instruments of European regional policy. Evidently these investments reduce transportation costs between two regions that are connected by a newly established or improved transportation link, say between regions r and i. Moreover, these investments are expected to impact trade costs for any other region pair for which the new link is located on the least-cost path. While these groups of beneficiaries can in principle be identified, the least-cost path itself is likely to be endogenous which complicates the analysis. Therefore we employ a framework recently developed by Allen and Arkolakis (2016) which assigns a certain probability for a good shipped between two regions that it passes any other region. The idea is that shipments are carried out by a continuum of traders with idiosyncratic costs for different routes. Accordingly, there is a non-zero probability that shipments between two regions pass any transportation link.

We refer to a transportation link as the direct connection between two adjacent regions r, i which incurs *direct* iceberg trade costs $\tilde{d}_{ri}$. For elements representing non-adjacent region pairs n and i it is assumed that $\tilde{d}_{ni} = \infty$. In particular, we specify direct trade costs as a function of road travel time $TravelTime_{ri}$ between adjacent regions:

$$\tilde{d}_{ri} = e^{\beta \cdot TravelTime_{ri}}. \tag{1.8}$$

The aggregate trade cost for shipping a good across non-adjacent locations n, i are given by the product of direct trade costs along the chosen path. We assume that path-specific trade-costs shocks occur and that traders choose the path by minimizing trade costs. In this setting, Allen and Arkolakis (2016) derive the expected trade costs from n to i as:

$$d_{ni} = \Gamma\left(\frac{\theta - 1}{\theta}\right)\left[\mathbf{I} - \tilde{\mathbf{D}}\right]_{ni}^{\frac{1}{\theta}}, \tag{1.9}$$

where $\theta > 0$ denotes the shape parameter of the Fréchet distributed trade-cost shocks, Γ denotes the gamma distribution, $\mathbf{I}$ is an identity matrix, and the direct iceberg trade costs enter in adjacency matrix $\tilde{\mathbf{D}} = [\tilde{d}_{ri}^{-\theta}]$. Due to path-specific shocks, which can also be interpreted as idiosyncratic tastes, trade between two regions can follow any route including the most indirect ones with a certain probability. However, the probability of passing a certain link decreases with the costs of the detour that arises from the deviation from the least-cost route that would be applicable without shocks. A transport investment at link ri is more relevant for trade between region pairs having their least-cost route in the proximity of ri and accordingly pass the link more frequently than for those region pairs with their least-cost route being distant from link ri.[10] In the following, we estimate the effect of transport investments on travel time between adjacent regions, which impacts direct trade costs $\tilde{d}_{ri}$ according to (1.8) and affects expected trade costs between all other regions according to (1.9).

In summary, we can reproduce the effect of a local transport-time reduction at any link ri for the aggregate European transport network. Such a modification of the transport network triggered by a local investment may result in a new spatial equilibrium with substantial relocation of economic activity far beyond the one explained by the direct effect on link ri.

[10]More details about the specification of trade costs in presented in Appendix 1.A.1. Alternatively we may specify trade costs according to a gravity model as in Anderson and Yotov (2010) which yields very similar levels of trade costs as illustrated in 1.A.1. Accordingly, our analysis of wage subsidies and investments in production amenities is independent of the way we specify trade costs whereas only the specification with endogenous least-cost path allows for a comprehensive evaluation of investments in transportation infrastructure.

1.3.3 Regional and federal government

The national governments levy labor income taxes (τ_n) which are transferred to the federal budget and used to finance aggregate transfers $T_n = T_n^w + T_n^a + T_n^d$. Reflecting the most important components of European regional policy, we consider local wage subsidies T_n^w, investments in local production amenities T_n^a and investments in local transportation infrastructure T_n^d – which reduce travel time across direct links. Thus, the government budget constraint is given by:

$$\sum_{n \in N} w_n L_n \tau_n = \sum_{n \in N} T_n. \tag{1.10}$$

Public investments in roads between regions n and i reduce $TravelTime_{ri}(T_i^d, T_r^d)$ entering (1.8). In particular, we specify the following relationship:

$$TravelTime_{ri} = \gamma_{ri} - \kappa^d \cdot ln\left(T_r^d + T_i^d + 1\right), \tag{1.11}$$

where $TravelTime_{ri}$ is constrained to positive values.[11] Note that T_n^d is adjusted by the number of $n's$ neighbors. These public investments reduce the travel time between all direct links which again feeds back to expected trade costs across adjacent and non-adjacent regions according to Section 1.3.2. We assume that investments in public transportation are non-rival given that the average road is not congested.[12]

A further channel of regional transfers concerns R&D activities, universities, broadband internet access, energy supply etc. which we assume to impact local productivity. Hence, we introduce public investments in local production amenities rendering regional technology endogenous:

$$ln(\tilde{a}_n) = ln(\bar{a}_n) + \kappa^a \cdot ln\left(T_n^a / L_n + 1\right). \tag{1.12}$$

Again a region specific level of productivity for a counterfactual situation without

[11]This constraint implies: $\gamma_{ri} > \kappa^d \cdot ln\left(\sum_n T_r^d + 1\right)\right)$ $\forall \{r, i\} \in N$ which is always fulfilled in the data. We also estimated the model using a log-log specification which however was an inferior fit with the data.

[12]A varying degree of rivalry is incorporated in an earlier version which is however not supported by the data. A further alternative includes complementarities of investments at the two nodes of a link. While these are empirically significant our main results remain unaffected.

transfers $\bar{a}_n$ is empirically obtained using detailed data about regional transfers.[13]

We model the effects of transfers on transportation infrastructure (T_n^d) and on production amenities (T_n^w) in a simple way and assume that all individuals have equal ownership of the specific factor producing these. Demand for infrastructure provision comes exclusively from the government which coordinates production and spatial distribution. Equal ownership allows us to clearly differentiate between T_n^d, T_n^a on the one hand and wage subsidies T_n^w which directly increase income only in region n on the other hand.[14] In Section 1.4 we describe the estimation of region- and link-specific fixed effects ($\gamma_{ri}, \bar{a}_n$) and the elasticities κ^a and κ^d.

Taxes in our model are locally distortive in the sense that higher labor taxes make a location less attractive for labor supply, but the tax has no effect on global labor supply. Note that inefficiencies of the public sector on the expenditure side are accounted for by the empirical estimates of κ^a and κ^d whereas we refrain from incorporating an excess burden of taxation. This would only affect the optimal size of the public sector and would not have immediate consequences for the spatial distribution of public spending which is the focus of this paper.

1.3.4 Regional income

Regional per capita income y_n stems from after-tax wages $w_n(1-\tau_n)$, per capita subsidies T_n^w/L_n, rent income $(1-\iota_n)H_n r_n/L_n$ and per capita payments from a global portfolio χ. We denote the tax rate by τ_n and the rent per unit of land by r_n.[15] As in Caliendo et al. (2018b) and Monte et al. (2018) we assume that land is owned by locals and non-locals. Hence, individuals contribute a share $\iota_n \in [0,1]$ of land rents to a global portfolio which redistributes rents as well as income from the sector producing transportation infrastructure and production amenities back to them in the form of a per-capita payment χ. Thereby, we allow for trade deficits across regions which is empirically relevant and particularly important in the context of place-based policy. For instance, regional transfers are likely to capitalize in local asset values which benefit not only local residents but any asset holders in the

[13]Empirical model-selection analysis yields the best fit for a log-log specification.

[14]An extension of the model assumes that infrastructure is built using local factors exclusively. For cost shares α over final goods and land this yields comparable marginal welfare effects of transfers across regions. Strengthening the micro-foundation in this way would require to adequately identify the relevant prices; for instance, construction firms operate on a multi-regional level and topography might be an important determinant of construction costs.

[15]Our results are robust to taxing aggregate income instead of wages.

recipient regions. Note that even with balanced asset holdings, trade imbalances apply in our model due to regional transfers. However, without taking into account imbalances in asset holdings we may overestimate the effect of transfers on trade imbalances. Aggregate regional income amounts to

$$y_n L_n = w_n L_n (1-\tau_n) + T_n^w + (1-\iota_n) H_n r_n + \chi L_n, \tag{1.13}$$

where T_n^w denotes the public wage transfers. Per capita payments accruing from the rent portfolio and from the production of infrastructure and production amenities can be expressed as $\chi = (1/\bar{L}) \sum_{n \in N} \left(\iota_n H_n r_n + T_n^d + T_n^a \right)$. The difference between tax payments, rental contributions to the global portfolio and the revenue out of it generates imbalances in trade accounts. Regions displaying a higher value of ι_n than the average are characterized by a trade surplus. Trade balance may be stated as

$$\Upsilon_n \equiv \iota_n H_n r_n + \tau_n w_n L_n - \chi L_n - T_n^w. \tag{1.14}$$

Due to Cobb-Douglas utility we can express the rental rate for land as $r_n = \frac{(1-\alpha) y_n L_n}{H_n}$ and reformulate per-capita income as

$$y_n = \frac{1}{\alpha + \iota_n - \alpha \iota_n} \left[w_n (1-\tau_n) + T_n^w / L_n + \chi \right]. \tag{1.15}$$

1.3.5 Residential choice

Using the above expressions for rental rate and price index (1.7) we obtain real income,

$$\frac{y_n}{P_n^\alpha r_n^{1-\alpha}} = \eta \left(\frac{a_n y_n}{d_{nn} w_n} \right)^\alpha (\pi_{nn})^{\alpha/(1-\sigma)} \left(\frac{H_n}{L_n} \right)^{1-\alpha}, \tag{1.16}$$

where $\eta = \frac{1}{1-\alpha}^{(1-\alpha)}$. Indirect utility of an individual in region n depends on real income and a stochastic amenity term at the place of residence $V_n(\omega) = b_n(\omega) \frac{y_n}{P_n^\alpha r_n^{1-\alpha}}$. Since consumption amenities follow a Fréchet distribution and indirect utility is a transformation of the random amenity draw, the cumulative distribution function of indirect utility is given by $G_n(V) = e^{-B_n \left(\frac{y_n}{P_n^\alpha r_n^{1-\alpha}} \right)^\epsilon V^{-\epsilon}}$. The probability that an individual prefers locations n over all other locations corresponds to the share of region n's population. Using the above distributions, the share of population in location n corresponds to

$$\lambda_n = Pr(V_n \geq \max\{V_k\}, \forall\, k \in N) = \frac{B_n \left(\frac{y_n}{P_n^{\alpha} r_n^{1-\alpha}}\right)^{\epsilon}}{\sum_{k\in N} B_k \left(\frac{y_k}{P_k^{\alpha} r_k^{1-\alpha}}\right)^{\epsilon}}, \tag{1.17}$$

where $\lambda_n = \frac{L_n}{\sum_{k\in N} L_k}$. A high value of ϵ implies that the location specific amenity draws are less dispersed. As a result, locations become better substitutes and an increase in the relative appeal of a location (i.e. increase in real wage) leads to a larger response in the fraction of workers who choose to locate there. In an extreme case of no location taste heterogeneity ($\epsilon \to \infty$) workers are not attached to specific locations such that the supply of labor becomes perfectly elastic.

From the cumulative distribution $G_n(V)$ follows that expected indirect utility of an individual living in n is given by

$$E[V_n] = \bar{V} = \delta \left[\sum_{k\in N} B_k \left(\frac{y_k}{P_k^{\alpha} r_k^{1-\alpha}}\right)^{\epsilon}\right]^{\frac{1}{\epsilon}}, \tag{1.18}$$

where $\delta = \Gamma(\frac{\epsilon-1}{\epsilon})$ is a constant term and $\Gamma()$ refers to the Gamma function. Population mobility implies that the expected indirect utility of an individual has to be identical across all potential destinations such that, in equilibrium, locations are chosen optimally. Further substituting population share (1.17) we obtain:

$$\bar{V} = \delta \left(B_n\right)^{\frac{1}{\epsilon}} \left(\frac{y_n}{P_n^{\alpha} r_n^{1-\alpha}}\right) \left(\frac{1}{\lambda_n}\right)^{\frac{1}{\epsilon}}, \tag{1.19}$$

If certain locations provide more utility than others, workers move to the place which offers the highest possible utility. Hence, an increase in nominal wages is ceteris paribus accompanied by an increase in local population share. Moreover, due to agglomeration benefits, larger markets are more productive and pay higher wages. However, an inflow of population bids up land prices, which acts as a dispersion force and reduces real income. To ensure a unique equilibrium dispersion forces must dominate agglomeration forces in equilibrium. This leads to the following parameter restriction $(1-\alpha) + 1/\epsilon > \alpha\mu$ and rules out that the whole population is located in one region.[16]

[16]For a detailed discussion see Redding and Rossi-Hansberg (2017) and equation (1.23) below.

1.3.6 General equilibrium

Given the set of parameters $\{\sigma, \mu, \alpha, \epsilon, \iota_n\}$ the general equilibrium can be expressed by the market clearing conditions on goods and labor markets, the government budget constraint, and the migration equilibrium condition. Market clearing on the goods market requires that location i's labor income is equal to the total expenditure for the goods produced in that location:

$$w_n \lambda_n = \alpha \sum_{k \in N} \pi_{kn} \lambda_k y_k, \tag{1.20}$$

where per-capita income is given by (1.15). Labor market clearing follows from (1.6) and the location choice probabilities (1.17) jointly with real income in (1.16) close the model. With 264 NUTS2 regions this yields a total of 70,488 equilibrium conditions.[17] Based on these conditions and data for $\{\lambda_n, y_n, H_n, d_{ni}, T_n^w, T_n^a, T_n^d, \tau_n\}$ we can recover the endogenous outcomes $\{a_n, \pi_{ni}, B_n, w_n\}$. All other endogenous variables can be expressed in terms of these recovered variables and the exogenous variables. Note that for the counterfactual welfare analyses we apply the exact hat algebra introduced by Dekle et al. (2007) such that the levels of location attractiveness (B_n) are not needed.

1.4 Estimation & calibration

As it is evident from the maps in Figure 1.1, our data covers almost all NUTS2 regions in the EU27.[18] The EU administers its place-based policies according to multi-annual budgeting periods. We fit the model to data for the three most recent budgeting periods, 1994-99, 2000-06 and 2007-13 in order to explore the validity of our model and to obtain time variation in local production amenities. For the analysis of counterfactuals we focus on the most recent budgeting period, 2007-13. In total, we observe data for 264 European NUTS2 regions which were eligible for EU transfers in the most recent period. Summary statistics of all our exogenous variables are reported in Table 1.A.3, and Figure 1.1 illustrates the spatial distribution of these

[17]Our system of equation has 264×264 bilateral trade shares according to (1.6) and 264 location choice probabilities (1.17), 264 equations for per-capita income (1.15) as well as 264 goods market clearing conditions (1.20) which sum up to 70,488 equations.

[18]Due to missing data our analysis excludes the remote islands Madeira (PT30), Açores (PT20), Canary Islands (ES70) and the French overseas territories (FR91, FR92, FR93, FR94).

variables.

Regional transfers: The EU Commission provides detailed information on regional transfers for all three budgeting periods. The data covers regional expenditures from all three sources of regional transfers, the European Regional Development Fund, the European Social Fund as well as for the Cohesion Fund. The transfers are classified according to 12 spending categories which we assign to the respective transfer types.[19] This assignment bases on the descriptions of representative projects financed via the respective categories. The allocation of transfer types is consistent with an empirical analysis exploring the significance of each individual transfer category for the respective outcome, i.e. travel time and local production amenities. In total, 37% of transfers were invested in production amenities, 34% in improvements of transportation infrastructure and 29% were channeled through wage subsidies.

The existing distribution of EU regional transfers is far from uniform, and place-based subsidies are strongly tied to regional economic development as well as political bargaining (e.g. Charron 2016). The highest transfer intensities were observed in the Southern and Eastern periphery of the EU as shown in panel a) of Figure 1.1. Notably, virtually all regions received a positive transfer from the central EU government. Yet, there is a substantial variation as total per capita transfers (T_n/L_n) ranged between 34 Cents and 892 Euros. The relative distribution of transfer types ($^{T_n^w}/_{T_n}, ^{T_n^a}/_{T_n}, ^{T_n^d}/_{T_n}$) across regions varies quite significantly as is shown in Table 1.A.3 and Figures 1.A.3 in the Appendix.

Population shares and regional income: Cambridge Econometrics' European Regional Database provides information on population, employment, and per capita income for every NUTS2 region and the whole time period. Since the model assumes full employment, our simulations use employment data for L_n as well as for the shares (λ_n).[20] Per capita income (y_n) is measured at 2005 constant Euros. Figure 1.1 illustrates the spatial distribution of per capita income and population shares.

[19]The categories are: 1) Energy, 2) Environment & natural resources, 3) Human resources, 4) IT infrastructure & services, 5) Research & Technology, 6) Business support, 7) Social infrastructure, 8) Technical assistance, 9) Tourism & Culture, 10) Urban & rural regeneration, 11) Transport infrastructure, 12) Other. We assign categories 1-5 to transfers in local production amenities (T_n^a), category 11 to transfers in transport infrastructure (T_n^d), and 6-10 to wage subsidies (T_n^w).

[20]Note that all results are robust to using population data instead.

Residential land supply: Information about residential land-use stems from the dataset "Ecosystem types of Europe" published by the European Environment Agency. This data provides habitat information for 100x100m cells. For residential land-use (H_n) we sum up all constructed, industrial and other artificial habitats for every NUTS2 region. Regional levels of H_n are shown in panel d) of Figure 1.1.

Price of land and contributions to global portfolio: We compute the price of the immobile factor – land – using the condition $r_n = {}^{(1-\alpha)L_n y_n}/{}_{H_n}$ jointly with data on regional per capita income (y_n), population (L_n) and residential supply of land (H_n) as described above. For the consumer's expenditure share in goods consumption we follow Eurostat (2016) and assume $\alpha = 0.75$.

The trade balance is calculated by calibrating each region's share of the immobile sector paid into the international portfolio ι_n. We solve for ι_n by minimizing the sum of squared errors between the observed trade balance Υ_n^{Data} and the model's trade balance as defined in (1.14):

$$\min_{\iota_n} \quad \sum_{n \in N} (\Upsilon_n^{Data} + T_n^w - \tau_n w_n L_n - \iota_n H_n r_n + \chi L_n)^2. \tag{1.21}$$

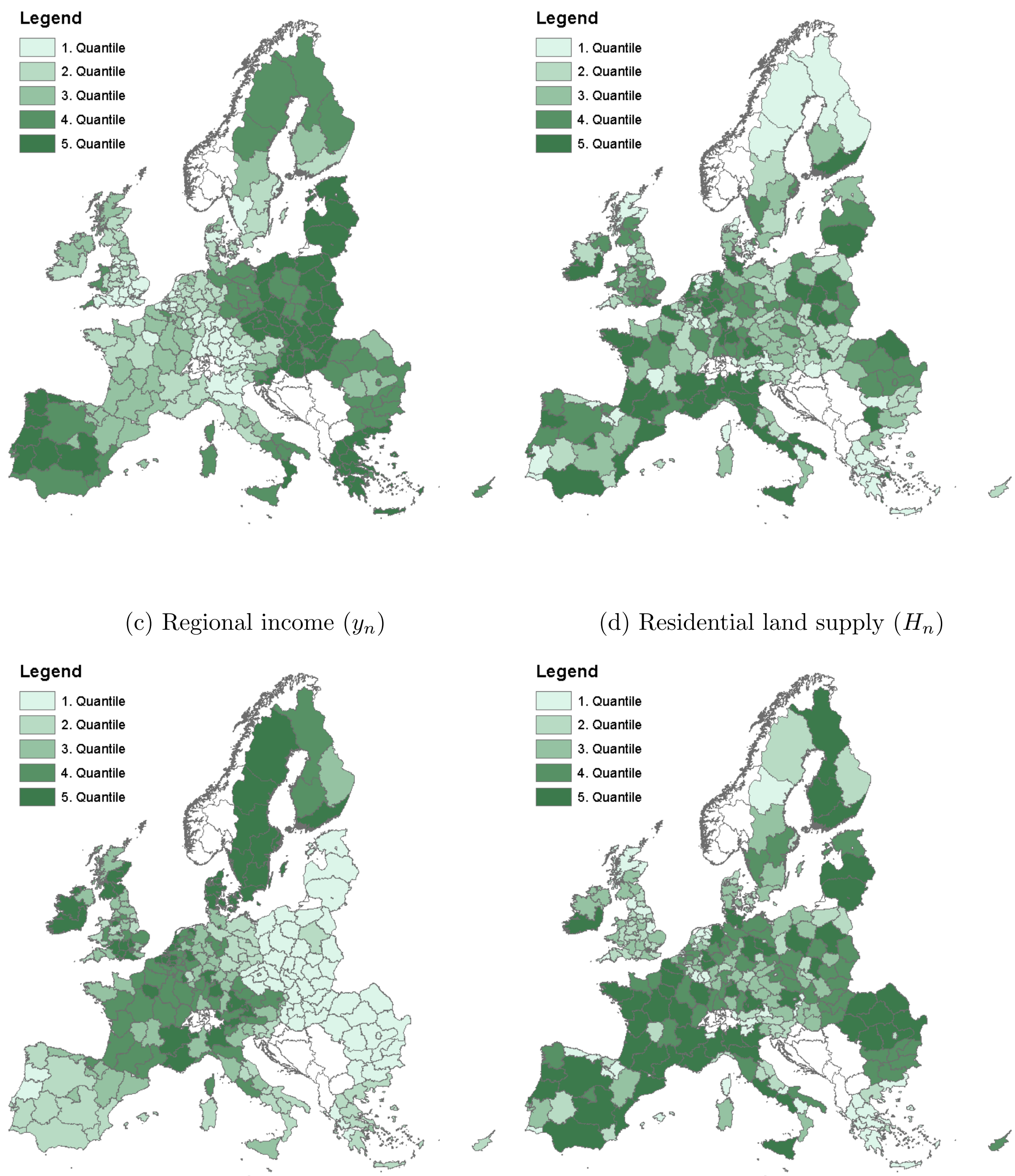
Data for annual trade balance Υ_n^{Data} stems from Eurostat and is only available at the country level. To obtain region n's trade balance, we weigh the country's trade balance by regional GDP. Figure 1.A.2 in Appendix 1.A illustrates the close fit between the data and the model's trade balance, where the correlation coefficient is 0.993.

Wages: We obtain region n's wages w_n by substituting income, wage transfers and payments from the international portfolio into equation (1.15). In our main analysis, we set tax rates (τ_n) constant across regions and thus tax revenue proportional to regional wages. This is legitimate as the two main sources of the EU budget are proportional to local income. By far the most important part of a country's contribution to the EU budget bases on a uniform rate applied to the gross national income (GNI) of each member state. In 2012, the EU-27 countries contributed 86.8% to the EU budget according to their GNI based valuation. The second most important component refers to contributions according to a harmonized VAT of 0.3%. The value added tax contributed about 13.1% to the total budget and

Figure 1.1: Overview of observed variables

(a) Total transfers per capita (T_n/L_n) (b) Population share (λ_n)

(c) Regional income (y_n) (d) Residential land supply (H_n)



Notes: The figures depict quantiles of the reported variables. A darker shading in the map indicates a higher value.

the remaining difference is accounted for by correction mechanisms.[21] Tax rates $\tau_n = \tau$ are obtained from the government budget constraint (1.10) equating transfer expenditure and total tax revenue:

$$\tau \sum_{n \in N} w_n L_n = \sum_{n \in N} T_n. \tag{1.22}$$

As a robustness check, we use information about the financial contributions to the EU budget and set taxes equal to country specific tax rates $\tau_n = \tau_c$ which are proxied by the the national contribution divided by GNI. In this case, we introduce a scaling parameter ν to ensure that the government budget constraint is fulfilled i.e., $\nu \sum_{n \in N} w_n L_n \tau_c = \sum_{n \in N} T_n$.

Transportation costs: We use equation (1.9) and information on $TravelTime_{ri}$ together with parameter estimates for θ and β to obtain expected transportation costs (d_{ni}). Using GIS software we identify adjacent NUTS2 regions and compute the elements of the adjacency matrix ($\tilde{\mathbf{D}}$) based on road $TravelTime_{ri}$ between the centroids of the respective regions which is provided by the RRG Database. The latter contains detailed information on different speed limits, slope gradients, congestion etc..[22] $TravelTime_{ri}$ is measured in hours travelled on roads in the years 1999, 2006, and 2013 for the respective periods. By minimizing the sum of squared errors between observed freight and gravity equation (1.5), we estimate the factor converting travel time to trade cost β. For this we need data on bilateral road freight among NUTS2 regions and set parameter values for the trade elasticity $\sigma = 5$ and heterogeneity of traders $\theta = 136.13$. The former stems from the European Transport Policy Information System for the year 2010 and we parameterize the elasticity of substitution (σ) and trade heterogeneity (θ) according to estimations obtained by Simonovska and Waugh (2014) and Allen and Arkolakis (2016).

The non-linear least square estimates of our gravity equation yield a value of $\beta = 0.068$. Figure 1.A.1 in the Appendix depicts a strong correlation of -0.709 between demeaned freight data and trade costs with estimated β. Our estimate is slightly

[21] Information about specific contributions to the regional policy budget is not available. Yet, the EU discloses countries' payments to the overall budget which are a constant proportion of countries' GDP. In contrast, the ratio of regional transfers to local GDP (at NUTS2 level) ranged from 0.0004 percent (London) to 4.6 percent (Hungary, Northern Great Plain).

[22] Note that we assume regions maintaining a ferry connection to be adjacent in order to ensure a comprehensive transport network and trade between the EU continent and the islands. Information about ferry connections is obtained from openstreetmap.org.

higher than the one obtained by Allen and Arkolakis (2016) which is likely due to differences in institutional settings and geography.[23] We refer to Appendix 1.A.1 for a more detailed discussion of the estimation of β.

Recovering location fundamentals and estimating elasticities $\{\epsilon, \mu\}$: We recover regional productivity by substituting (1.6) in goods market clearing (1.20). Given data for $\{\lambda_n, y_n\}$ and substituting parameters $\{\sigma, \alpha\}$, estimates of d_{ni} as well as the already recovered information about w_n we obtain $a_n, \tilde{a}_n$ and consequently equilibrium values for bilateral trade shares and real income (see Appendix 1.A.5 for details). Recall that we invert the model for the last three programming periods such that we obtain a panel of the model's equilibrium values.

The shape parameter of the Fréchet distribution of location preferences can be estimated from a log-linearized version of (1.17). The denominator of this equation is constant across all regions. By including region-specific fixed effects in the empirical specification we absorb time-invariant components of $\ln(B_n)$ such that we obtain ϵ as the coefficient on region- and time-specific real income. However, estimating (1.17) is complicated by the simultaneous relationship between real income and local employment. As is common in the literature we resort to a Bartik type instrument which is constructed by pre-determined sector shares across regions and growth dynamics of the sectors at an aggregate level (e.g. Bartik 1991; Diamond 2016). In particular, we use the sectoral employment shares of NUTS2 regions in the year 1985 and interact them with the growth rates at the EU level. As an alternative instrument we use the geographical centrality of a region which affects real income via the price index but does not have a direct effect on population shares. Our estimates yield values between 2.9 and 3.5 and thus we set $\epsilon = 3$ which is in line with Bryan and Morten (2015), Monte et al. (2018), and Redding and Rossi-Hansberg (2017).

Having specified ϵ, we substitute real income from (1.16) in population shares (1.17) and solve for regional consumption amenities B_n (see Appendix 1.A.6 for details).

We obtain the agglomeration elasticity μ by estimating equation (1.4) for the panel of regional productivities jointly with data on regional employment for the

[23] First, trade and geographic barriers might be higher in Europe than in the US which results in a higher factor converting travel time to trade costs. Second, transportation links are shorter for NUTS2 regions than for major cities located at the US Interstate Highway System as considered in Allen and Arkolakis (2016).

corresponding years. Importantly, because the model implies that higher local productivity reflects in higher wages and an inflow of population, OLS estimates of (1.4) yield biased estimates. Combes et al. (2010) propose to use information about the nature of soils in a region as an instrument for population density. The relevance of the instrument builds on the idea that some types of soils are more suitable to support a higher population density and more fertile soil has historically attracted a greater number of people. Since soil quality is no longer a relevant factor for productivity, it is a valid instrument to identify the effect of L_n and productivity. We compute regional soil indices at the NUTS2 level based on raster data provided by the European Soil Data Centre. Specifically, we follow Combes et al. (2010) and compute indices for *Depth to rock* as well as for the *Topsoil mineralogy*. As is shown in Appendix 1.A.3 both instruments turn out relevant in the first stage of the instrumental variable estimation and the instruments pass the Sargan test for overidentification. We estimate in our preferred specification an agglomeration elasticity of about $\mu = 0.1$ which is well in line with Allen and Arkolakis (2014) and somewhat below the estimates obtained by Brülhart and Mathys (2008) based on a dynamic GMM estimation for European NUTS2 regions.

Transfer elasticity of production amenities and travel time: The transfer elasticities are estimated based on fixed effects regressions and regression discontinuity design (RDD) specifications of (1.11) and (1.12). In the latter case we exploit the fact that a substantial share of regional transfers (so-called Objective 1 transfers) are paid according to an allocation rule that gives rise to a discontinuity: Regions are eligible for the highest transfer intensity, if their per capita GDP falls below 75% of the EU average in some well defined years prior to the respective budgeting period (see Becker et al. 2010). We estimate these elasticities using data for all three budgeting periods. Accordingly, we employ the panel of recovered production amenities for 1994-99, 2000-06, 2007-13 and data for road travel times in these years for estimation of κ^a and κ^d, respectively. This allows us to exploit changes in transfer intensities over time in addition to the cross-sectional variation and thus to improve the causal identification of transfer elasticities. The benchmark results for the estimates of both transfer elasticities are displayed in Table 1.A.1 in Appendix 1.A.2. It is evident that higher regional transfer intensities increase production amenities and decrease road travel time. Moreover, the effects are highly significant across specifications. For our quantitative analysis we use the fixed-effect estimates

($\kappa^a = 0.006$ and $\kappa^d = 0.004$) noting that the confidence bounds are overlapping with the RDD estimates at conventional levels of statistical significance.[24] These point estimates imply that a one percent increase in per-capita transfers raises production amenities by about 0.006 percent by the end of the seven year period. A one percent increase in transfers to a transportation link yields a reduction of about 0.004 hours (equivalent to ca. 0.2 percent of the average travel time between links) at the end of the respective budgeting period. We use the estimated parameter κ^d jointly with data about link-specific travel time and transfers to compute γ_{ri} according to equation (1.11). Analogously we obtain the fundamental location amenities $\bar{a}_n$ from equation (1.12) using the estimates for κ^a.

Table 1.1: Estimation and calibration of parameters

Description	Par.	Value	Reference
Elasticity of prod. amenities	κ^a	0.006	Estimation in Table 1.A.1
Elasticity of transport infrastructure	κ^d	0.004	Estimation in Table 1.A.1
Share of consumption expenditure	α	0.75	Eurostat (2016)
Elasticity of substitution	σ	5	Simonovska and Waugh (2014)
Agglomeration elasticity	μ	0.1	Estimation in Table 1.A.2
Heterogeneity of preferences	ϵ	3	Estimation in Table 1.A.2
Factor converting $TravelTime_{ri}$ to $\tilde{d}_{ri}$	β	0.068	Estimation in Section 1.A.1
Heterogeneity of traders	θ	136.13	Allen and Arkolakis (2016)

Notes: The table reports estimated and calibrated parameters entering our model. The elasticity of substitution is within the range of common values in the literature and equivalent to Redding and Rossi-Hansberg (2017).

Table 1.1 provides information on all parameters entering our model. We performed numerous sensitivity checks and conclude that our qualitative results are robust to the choice of parameters within the usual range reported in the literature. An overview of our recovered variables is depicted in Figure 1.2. A number of observations stand out: First, wages are lowest in the east and south of Europe, whereas production amenities are highest in the core as well as in Scandinavia and generally in cities. Eastern Europe shows low production amenities both net of transfers and once the EU investments are accounted for. Second, land rents are evidently highest in cities and tend to be relatively high in the UK, Northern Italy and Southern Germany compared to areas with low land prices in Central

[24]Note that the elasticities for production amenities and travel time are not directly comparable with prior estimates in the literature focusing on GDP or employment growth.

and Eastern Europe. Third, Germany and Eastern Europe display a high share of contributions to the global portfolio indicating a trade surplus while low shares of global investments in France, Greece and Portugal result in a trade deficit. Fourth, consumption amenities are highest in Eastern Europe, the south of Spain, Greece, Portugal as well as in urban areas such as Paris, London, and Madrid. This captures on the one hand utility benefits conditional on real income and on the other hand regional migration costs. Fifth, the price index strongly correlates with the geographical market access as measured by the sum of trade costs. These patterns are well in line with stylized facts about economic geography in Europe and suggest that the model performs well in matching the distribution of economic activity.

1.5 Counterfactual analysis

We derive counterfactual changes in wages, trade shares and population shares which provide – jointly with direct effects of transfers on production amenities, trade costs, and income – sufficient statistics of the welfare effects of regional policy. A counterfactual change is denoted as $\hat{x} = \frac{x'}{x}$, where x is the observed variable and x' is the unobserved counterfactual value of x. In the counterfactual simulations, transfers enter in three ways: First, transfers influence the equilibrium via nominal wage subsidies raising income ($\hat{y}_n$). Second, transfers impact transportation costs and thereby alter trade costs ($\hat{d}_{ni}$) as well as regions' market access. Third, investments in production amenities proportionately raise production amenities ($\hat{\bar{a}}_n$) which reduce prices of varieties produced in recipient regions. According to expected utility (1.19) the change in welfare across regions is given by:

$$\widehat{\bar{V}} = \left(\frac{1}{\hat{\pi}_{nn}} \right)^{\frac{\alpha}{\sigma-1}} \left(\frac{\hat{y}_n \hat{\bar{a}}_n}{\hat{w}_n \hat{d}_{nn}} \right)^{\alpha} \left(\hat{\lambda}_n \right)^{\alpha\mu-(1-\alpha)-1/\epsilon} . \tag{1.23}$$

From this equation it is evident that a full cost-benefit analysis should not only consider direct effects of transfers ($\hat{y}_n, \hat{\bar{a}}_n, \hat{d}_{nn}$) in the recipient region but also account for changes in trade share, population and local wages. These changes are derived from the full system of counterfactual equilibrium equations shown in Appendix 1.B.

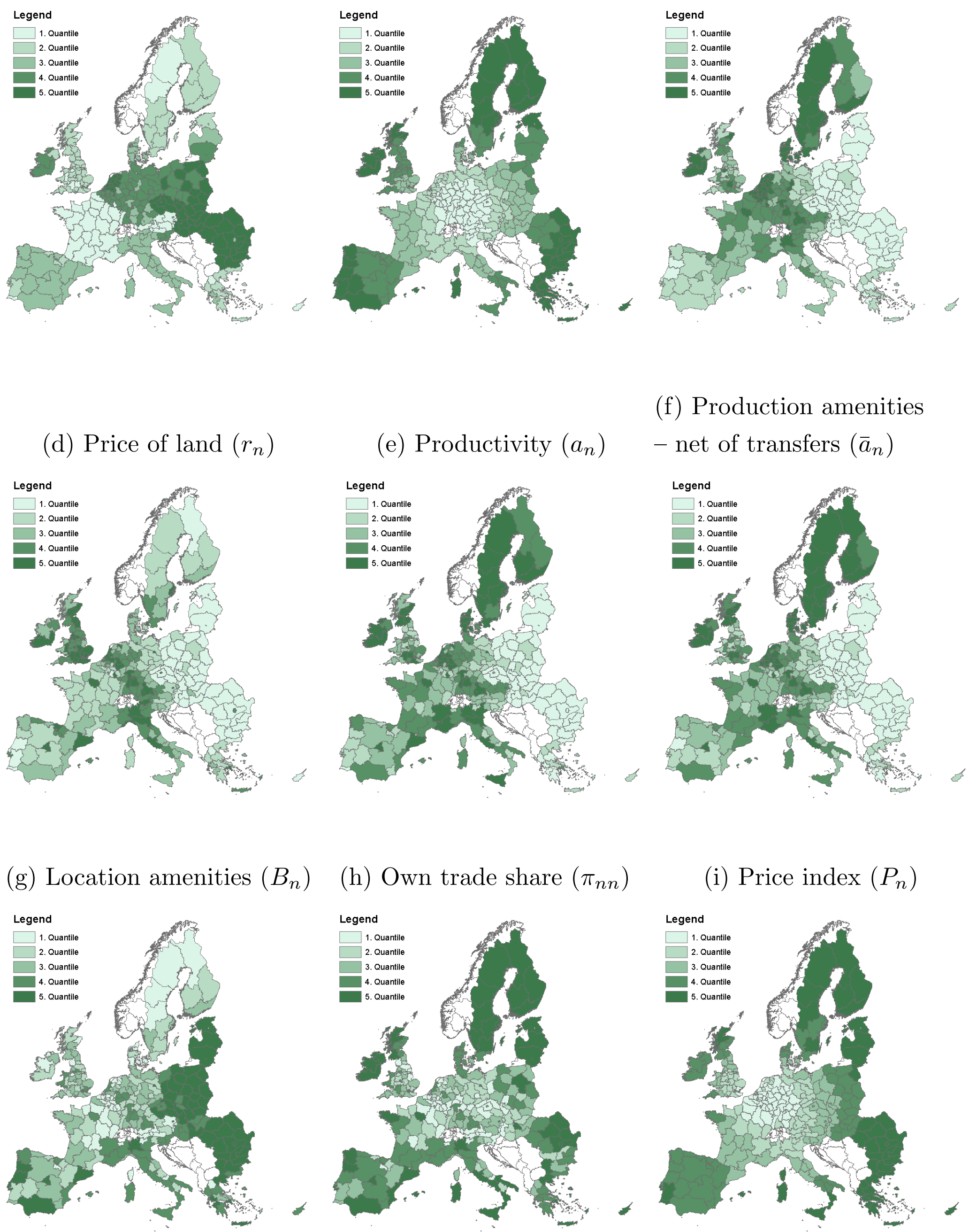
We isolate effects of different transfer mechanisms by studying three counterfactual situations: First, we analyze the effect of abandoning EU regional transfers altogether and set the corresponding tax rates to zero. The resulting outcome

Figure 1.2: Overview of estimated and recovered variables

(a) Share global portfolio (ι_n) (b) Trade costs ($\sum_i d_{ni}$) (c) Wages (w_n)

(d) Price of land (r_n) (e) Productivity (a_n) (f) Production amenities – net of transfers ($\bar{a}_n$)

(g) Location amenities (B_n) (h) Own trade share (π_{nn}) (i) Price index (P_n)



Notes: The figures depict quantiles of the reported variables. A darker shading in the map indicates a higher value.

provides a welfare measure of EU regional policy. In a second counterfactual analysis we show how the spatial equilibrium would change if transfers were distributed equally. In this case, the level of transfers is comparable to the observed one, in total and for each type. Hence, this counterfactual informs about how efficient the EU distributes transfers compared to a naive rule that gives every region the same. Third, we derive the optimal spatial allocation of transfers for each type of transfer separately as well as for the sum of transfer channels. This allows us to quantify potential efficiency gains from redistribution and to derive the factors that render a type of transfer efficient in some regions and inefficient in others. In these simulations we keep tax rates and the aggregate mix of transfer types in Europe at the observed levels such that the optimality criterion focuses on the spatial distribution of transfers rather than the size of the program.[25]

1.5.1 No-transfer scenario

What would be the (welfare) effects if the European Union abandoned its place-based policy scheme altogether? To analyze this question we set both transfers and tax rates to zero.

Expectedly, we find that productivity and income losses would be most pronounced in Southern and Eastern Europe where the per capita transfers are the highest. The change in transportation costs due to suspending transfers would generally be most pronounced in peripheral regions in the south, east and north of Europe. These direct effects would translate into changes in wages, own trade shares and population shares. In particular, our simulation suggests that substantially more workers would relocate from Southern and Eastern European regions to the Center and North of Europe. The increase of inter-regional migration would amount to 0.68 percent of the European population.[26] Figure 1.B.1 in the Appendix illustrates the changes predicted by the model for the no-transfer scenario.

Overall, the ten countries with the highest share of population emigrating would lose about 2.65 percent of their population when moving from the observed

[25]Even though tax rates remain constant at the observed level the total transfer budget may differ slightly between the observed and the counterfactual scenarios. This happens since changes in population and wages influence tax payments to the government budget. An alternative approach that yields similar results is to fix the budget and adjust the tax rates accordingly.

[26]According to European Commission (2014) the *international* migration within the EU amounted to about 1.2 percent of the working age population.

equilibrium to a situation without transfers.[27] At the same time, average nominal per capita income in the regions of these ten countries would be about 1.51 percent lower than in the observed equilibrium. Accordingly, our findings suggest that EU regional transfers were quite effective in reducing migration from new member states in the east to the center. On average, abolishing transfers would also significantly increase average own trade shares by 3.05 percent. Summing up over all welfare components we find that the EU place-based transfers raised welfare by approximately 2.08 percent compared to the no-transfer scenario.

How did the individual types of transfers contribute to the welfare gain and to changes in regional inequality? In Table 1.2 we summarize the effects of individual transfer types on welfare and regional inequality as measured by the coefficient of variation. Panel a) isolates the wage subsidies as one mechanism of regional transfers, panels b) and c) isolate the effects via production amenity gains and changes in transportation costs while panel d) considers all three transfer channels simultaneously.[28] In column (2) we report the change in welfare and inequality obtained with the observed spatial distribution of transfers relative to the counterfactual without transfers. Assuming that productivity and transportation costs remain unaffected by transfers, we find that the observed distribution of wage subsidies raised welfare by 0.05 percent. Reductions in regional inequality concern the second objective of regional policy. In this regard it turns out that the observed distribution of wage subsidies has in fact significantly reduced inequality in terms of nominal income as well as real income. Analogously, assuming that the only direct effect of transfers is to raise local productivity, we find that the welfare gain due to the observed allocation of transfers amounts to 1.21 percent. A significant reduction in inequality is obtained as the production enhancing effects of transfers are concentrated in poor and peripheral regions. Finally, panel c) of Table 1.2 isolates the effects of transport infrastructure investments. Transport infrastructure represents not only a major part of expenditure but also contributed to the second largest welfare gain which amounts to about 0.82 percent. However, transportation infrastructure investments have only contributed to a relatively small reduction in regional inequality in terms of nominal and real income.

[27]These countries are BG, CZ, EE, HU, LT, LV, MT, PL, RO, SK. The share of population of these 10 countries in the total European population is currently about 18.83 percent.

[28]Note that the aggregate welfare effect is not equivalent to adding the individual components in panels a), b), and c) because the individual transfers enter non-linearly. For instance, investment in transportation infrastructure and production amenities are complementary.

Considering the total effect of transfers via all three channels (Table 1.2d), we obtain a significant increase in welfare and a substantial reduction in regional inequality compared to the no-transfer scenario.

1.5.2 Uniform distribution of transfers

Another natural candidate for a policy experiment is to fix tax rates and distribute the government budget uniformly across regions. This naive distribution allows us to isolate the welfare implications of the regional distribution of transfers while keeping the level of taxes – required to finance the respective transfer type – and total expenditures for each type constant.

The consequences for welfare and regional inequality of this experiment are reported in column (1) of Table 1.2 where the effects are generally expressed relative to the no-transfer scenario. The counterfactual changes in local outcomes are depicted in Figure 1.B.2 in the Appendix. Moving from the observed to a uniform distribution of transfers, our model predicts significant immigration from Eastern and Southern Europe to the core and northern parts of Europe. Yet, the migration response would be less pronounced than in the case without transfers as the ten countries with the highest emigration would lose only about 2.17 percent of their population compared to the observed equilibrium. The reduction in nominal per capita income across regions in these countries would be about 1.38 percent compared to the observed equilibrium.

Looking at the different transfer types separately, we find that with regard to wage subsidies the existing distribution is more efficient than a uniform distribution as is evident from Table 1.2a. The welfare effect of the observed distribution of wage subsidies is more than twice the effect of a uniform distribution and inequality is notably lower.[29] A uniform distribution would allocate more transfers to the center and thereby reach a welfare increase of 0.34 percentage points via the production amenity channel (Table 1.2b) and 0.37 percentage points via the transportation infrastructure channel (Table 1.2c) compared to the welfare gain of the observed distribution. Summing up over all transfer types, the uniform distribution dominates the observed one from an aggregate welfare perspective: We estimate an increase in welfare of about 0.52 percentage points when moving from the observed to the

[29]Note that the uniform distribution already implies a certain redistribution from high to low income regions due to proportional taxes.

Table 1.2: Welfare and inequality effects of transfers

	(a) Wage subsidies (T_n^w)			(b) Production amenities (T_n^a)		
	Equal	Observed	Optimal	Equal	Observed	Optimal
	(1)	(2)	(3)	(1)	(2)	(3)
Welfare ($\hat{V}_n$)	0.02%	0.05%	0.20%	1.55%	1.21%	1.69%
$\widehat{CV}(y_n)$	-0.18%	-0.34%	-0.51%	-0.24%	-0.82%	-0.00%
$\widehat{CV}(y_n/P_n^\alpha r_n^{1-\alpha})$	-0.12%	-0.25%	-0.35%	-0.09%	-0.66%	0.01%

	(c) Transportation infrastructure (T_n^d)			(d) All transfers (T_n)		
	Equal	Observed	Optimal	Equal	Observed	Optimal
	(1)	(2)	(3)	(1)	(2)	(3)
Welfare ($\hat{V}_n$)	1.19%	0.82%	1.22%	2.60%	2.08%	3.14%
$\widehat{CV}(y_n)$	0.04%	-0.07%	0.05%	-0.18%	-1.22%	-0.44%
$\widehat{CV}(y_n/P_n^\alpha r_n^{1-\alpha})$	0.11%	-0.17%	0.16%	0.04%	-1.06%	-0.17%

Notes: The table compares outcomes relative to the no-transfer equilibrium. Columns 1 refer to an equal distribution of per capita transfers, columns 2 refer to the observed distribution of transfers, and columns 3 refer to the optimal distribution of total transfers (panel d) and individual transfer types (panels a, b, c). Panel a) considers transfer effects only via wage subsidies, panel b) considers transfer effects only via production amenities and panel c) considers only effects via investments in transport infrastructure. The first line shows the welfare changes in general equilibrium. Lines 2 to 3 show the changes in regional inequality as measured by the coefficient of variation (CV). In all counterfactual experiments we keep tax rates constant at the observed level. When we restrict the analysis to one transfer type we keep taxes at the level required to finance the observed budget of the respective transfer type.

uniform distribution of transfers (Table 1.2d). Overall, the comparison of columns (1) and (2) in Table 1.2 illustrates that the existing distribution goes further in reducing regional income inequalities than a uniform distribution but at the costs of lower efficiency obtained via investments in production amenities and transportation infrastructure.

1.5.3 Optimal distribution of transfers

From a policy maker's point of view, a crucial question is whether there are efficiency gains that can be reached by changing the distribution of transfers across regions while keeping the aggregate shares spent on each transfer type as well as the tax rates (i.e. the program budget) constant. To maximize aggregate welfare, we use a "Mathematical Programming With Equilibrium Constraints" (MPEC) approach as introduced by Su and Judd (2012) and applied by Ossa (2014, 2017) for optimal tariffs and subsidies. This numerical optimization routine maximizes regions' welfare and uses the model's equilibrium equations as constraints.[30]

We derive the optimal distribution of transfers for each type separately and report the corresponding optimal welfare changes and impacts on regional inequality in columns (3) of Table 1.2. Figure 1.3 shows the shares of the transfer budgets a region should receive according to the welfare optimizing algorithm. From Figure 1.3a it is evident that the optimal distribution of wage subsidies deviates significantly from the observed one. In particular, the welfare optimal policy issues transfers to only a few regions in Eastern Europe while cutting subsidies in most other recipient regions. A redistribution of wage subsidies according to our optimal allocation yields a welfare gain of 0.20 percent compared to the no-transfer scenario which is four times the gain achieved by the observed distribution (Table 1.2a). Importantly, the efficiency gain can be achieved at an even lower degree of regional income inequality. Focusing on transfers that operate via wage subsidies to a small set of regions allows for an unambiguous welfare increase without compromising regional equality. Note that an increase in the budget would clearly expand the number of recipient regions

[30]The routine proceeds as follows: First, we draw random initial values for transfer shares. Second, we compute the general equilibrium allocation based on this draw. Third, we supply this information to a numerical solver which maximizes a regions utility function. We randomize the initial values to show that the solver converges to the same solution suggesting that it is unique. For a detailed documentation of our numerical optimization approach we refer to Section 1.C in the Appendix.

according to the welfare optimal policy. For instance, in Figure 1.3b we show the resulting distribution that would apply if we substantially increase tax rates by a factor of 30. In this case, a larger share of regions would receive transfers.

The optimal distribution of investments in transportation infrastructure is presented in Figure 1.3d and indicates a very different pattern. The highest shares of the transfer budget are allocated to central regions in northern Italy, the Benelux countries, Germany, UK, and France. In order to maximize aggregate welfare, a transfer scheme focusing on transport cost reductions exerts the most significant spillover effects at central places. This implies a substantial reallocation of transfers compared to the current scheme: The correlation coefficient between the regional distribution according to the optimal scheme and the one of observed transfers under the official heading 'Transport infrastructure' is -0.11.[31] Such a reallocation could achieve an efficiency gain of about 0.40 percentage points compared to the existing distribution (Table 1.2c). However, this welfare gain would come at higher regional income inequality.

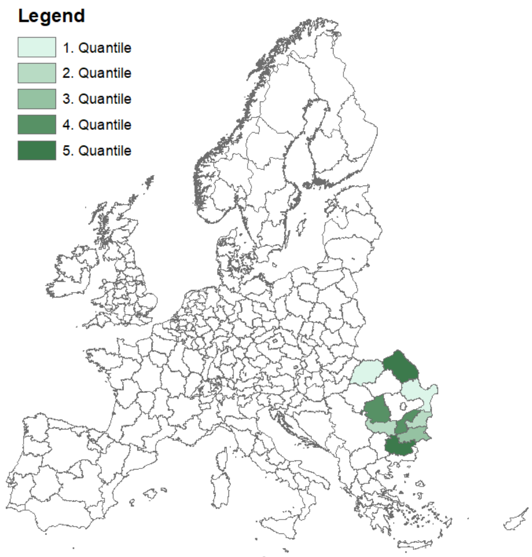
With regard to investments in local production amenities, the optimal pattern suggests the highest transfer shares in Germany and the UK where 0.22 percent and 0.12 percent of the total budget for T_n^a is supposed to be allocated. However, the optimal distribution generally advises a broad dispersion of transfers across European regions. The optimum is characterized by a welfare gain of 0.48 percentage points compared to the observed distribution and yields a higher degree of regional income inequality than the observed one (Table 1.2b).

Finally, allocating all transfers types according to their optimal distributions while keeping the aggregate budget for each transfer type constant one could realize an efficiency gain of 1.06 percentage points compared to the observed one while keeping tax rates constant (Table 1.2d). Hence, a mere improvement of the distribution of transfers substantially raises the welfare gain of EU regional policy. Notably, this comes at the costs of somewhat higher regional inequality than in the observed distribution. In Appendix 1.B.1 we analyze the potential efficiency gains if regional income inequality was to be held constant. Aggregate welfare gains would still be material but are 0.35 percentage points lower than without this constraint.

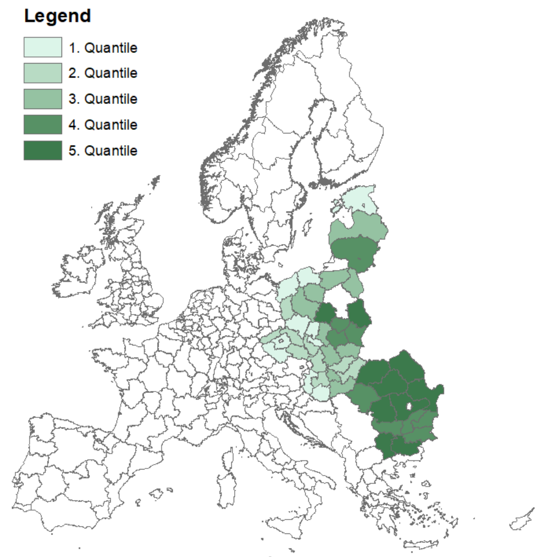
[31] Comparisons between the optimal and observed distributions of other transfer types yield similarly low correlations: -0.024 for total transfers; -0.0003 for wage subsidies (0.46 when restricting the sample to those with positive optimal level); 0.10 for investments in production amenities.

Figure 1.3: Optimal distribution of transfers

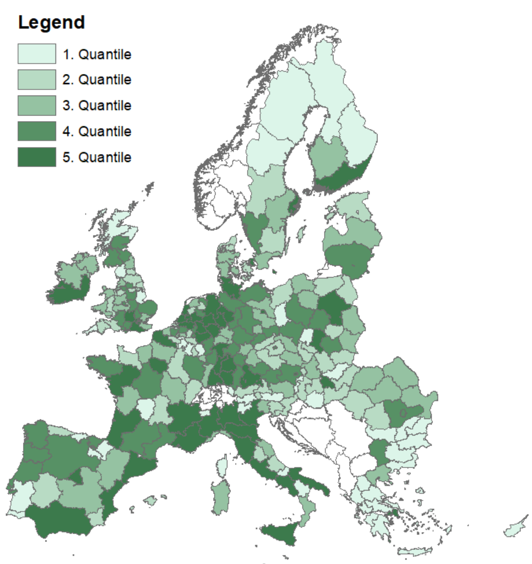
(a) Wage subsidies



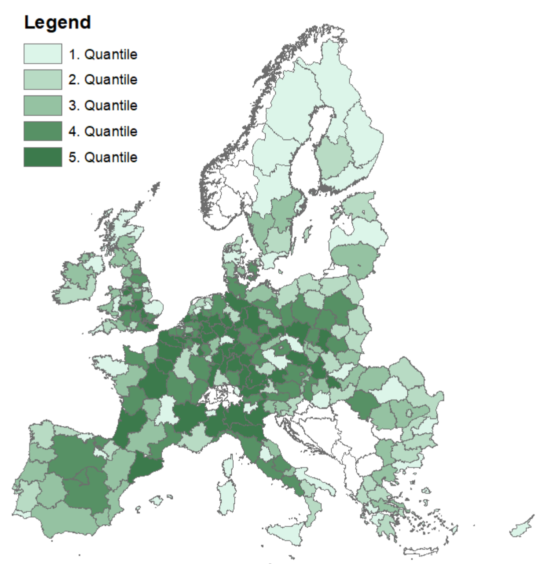
(b) Wage subsidies, high tax rates



(c) Investment in production amenities



(d) Investment in transport infrastructure



Notes: Panel a) shows the optimal distribution of wage subsidies at the observed tax rates. Panel b) also focuses on the optimal distribution of wage subsidies but is calculated according to a much higher budget where tax rates are multiplied by 30. Panel c) and d) show the optimal distributions of investments in production amenities and transportation infrastructure, respectively. In each case we hold tax rates used to raise the corresponding budget (i.e. either the budget for wage subsidies, investments in production amenities or investments in transportation infrastructure) constant at the observed level. The figures depict local shares of the total transfer volume according to quantiles where a darker shading represents a higher transfer share.

The migration responses in these scenarios are governed by the optimal distributions of transfer types in Figure 1.3. In the case of an optimal distribution of T^w it is evident that Romania and Bulgaria would be the beneficiaries. There, the population would increase by about 8.30 percent relative to the observed equilibrium. As a response to the optimal distributions of T^d and T^a we would see a population increase mostly in regions in the center of the EU. We illustrate the changes in population and other local outcomes for the simultaneous optimal distribution of T^w,T^a, and T^d in Figure 1.B.3 in the Appendix. This equilibrium would yield inter-regional migration of 0.87 percent of the population.

What about the optimal scale of the transfer program? Our scenario with an optimal distribution of transfers concerns a second-best allocation in the sense that we keep the level of taxes constant which prevents the complete internalization of prevailing externalities. The optimal scale of the program would be determined by the combination of the estimated transfer elasticities, prevailing externalities and the efficiency costs of raising the budget – via taxes on labor income. Abstracting from the latter, it would be efficient to expand the program as is evident from an increase of welfare in the scenario with high taxes (Figure 1.3b) compared to the optimal distribution given the observed taxes.[32] However, significant increases in taxes required to finance an optimally scaled transfer are unlikely to be politically enforceable.

In the following, we analyze the marginal welfare effects of transfer types across regions which outlines the intuition about the optimal allocations discussed above.

1.6 Marginal welfare effects of transfers

We decompose the marginal welfare effects of transfers into four components: The direct effect of transfers, the price index effect through adjustment in wages and the effects via changes in own trades shares and local population shares. Totally differentiating expected welfare, $\bar{V}$, with respect to transfers illustrates the weights

[32] Restricting transfer effects to income gains and further abstracting from the externality via heterogeneous non-local ownership of land, the distortions via productivity spillovers and congestion could be internalized using a combination of proportional taxes and lump sum transfers as shown in Fajgelbaum and Gaubert (2018). In this case the ranking of recipient regions according to their optimal net transfers under our fixed budget constraint corresponds to the one for the optimal budget.

put on these components:

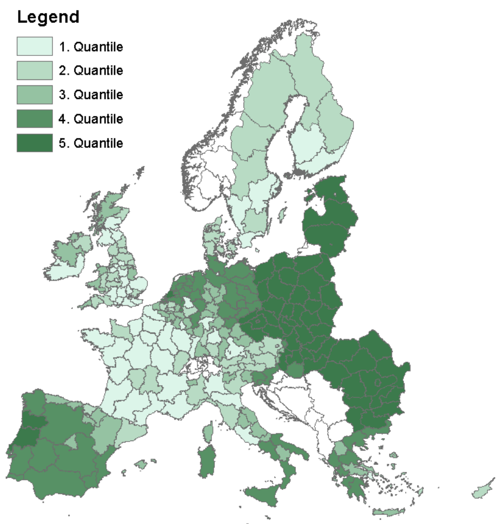
$$d\ln\bar{V} = -\frac{\alpha}{\sigma-1}\underbrace{d\ln\pi_{nn}}_{\substack{\text{Adjustment}\\ \text{own trade share}}} + \alpha\underbrace{\left(d\ln y_n + d\ln\tilde{a}_n - d\ln d_{nn}\right)}_{\text{Direct effects}} - \alpha\underbrace{d\ln w_n}_{\substack{\text{Price index}\\ \text{effect}}}$$
$$+\Big(\underbrace{\alpha\mu}_{\substack{\text{Agglomeration}\\ \text{force}}} - \underbrace{(1-\alpha)}_{\substack{\text{Dispersion}\\ \text{force}}} - \underbrace{\frac{1}{\epsilon}}_{\substack{\text{Taste}\\ \text{heterogeneity}}}\Big)\underbrace{d\ln\lambda_n}_{\substack{\text{Change in}\\ \text{population}}}. \quad (1.24)$$

The first welfare implication is common across a wide range of trade models and is due to changes in terms of trade which result in adjustments in own trade share as described in Arkolakis et al. (2012). Transfers affect local prices and thereby alter the terms of trade. Second, direct effects of transfers are unambiguously positive as they raise local income, productivity or reduce local trade costs. This part of the marginal welfare effect is characterized by decreasing marginal returns. Regions contributing a high share of the local rent income to the global portfolio display a smaller direct effect of transfers because a share ι_n of the increase in land values will be passed on to residents of other regions. Third, as local income increases, local production expands and pays higher wages which in turn translates into increases in the price index of this region. This, in turn, negatively affects welfare as local goods become relatively more expensive. Fourth, changes in population affect welfare through agglomeration forces, dispersion forces and heterogeneity of location tastes. As population concentrates in a location, productivity increases which makes the location ceteris paribus more attractive. A population inflow into a location is accompanied by an increase in land prices which, due to inelastic supply, leads to less housing consumption per capita. If workers have relatively heterogeneous tastes for regions (low ϵ), it is more likely that a large fraction of the individuals entering the regions have a low amenity draw. In the extreme case with homogeneous tastes ($\epsilon \to \infty$) there are no costs in terms of amenity mismatch. In accordance with the literature on quantitative economic geography, we restrict the parameter space to ensure that the agglomeration force is dominated by the dispersion forces i.e. that the last channel is always negative for population immigration.

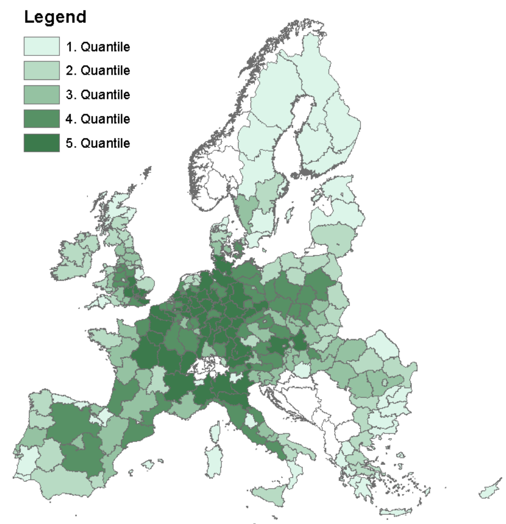
Regional distribution. In order to infer the spatial distribution of marginal welfare effects for each type of transfer, we conduct the following simulation experiments: we shock every region separately with a marginal transfer and

Figure 1.4: Regional distribution of marginal welfare effects of transfers

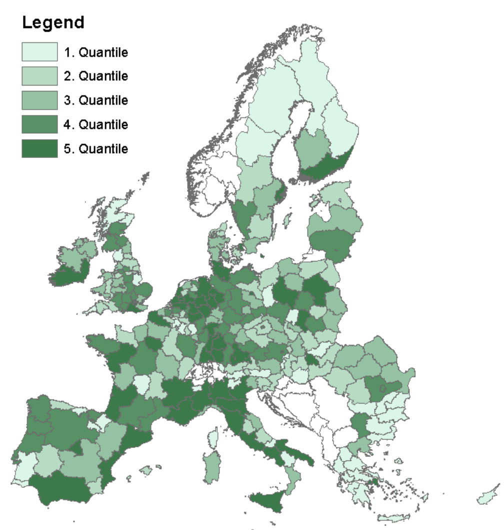
(a) Wage subsidy



(b) Investment in transport infrastructure



(c) Investment in production amenities



Notes: We refer to a unit increase of per capita transfers in panel (a) wage subsidies and (b) production amenity investments, whereas in panel (c) transport infrastructure investments we refer to a marginal increase in the absolute transfer level. The non-rival nature of transport infrastructure investments would otherwise yield a higher marginal welfare effect in densely populated regions. The figure depicts marginal welfare changes reported by quantiles. A darker shading represents a stronger effect, whereas a green color illustrates a positive effect.

obtain welfare changes relative to the situation without transfers. The government budget required for this experiment is again financed via the proportional tax rate introduced above and it is evidently negligible in this case. For the purpose of isolating the marginal utility gain by transfer type, we eliminate the potential responses of the respective other transfer types by alternately setting two out of the three transfer channels to zero. Note that according to our transfer functions we refer to a unit increase of per capita transfers in the case of wage subsidies and investments in production amenities and to a unit increase in the absolute level in case of infrastructure investments. Figure 1.4 illustrates the heterogenous distribution of marginal welfare effects: In panel a) we consider wage subsidies and observe a strong positive effect on welfare in peripheral and relatively poor regions. Overall, the welfare change due to a wage subsidy is highest in Eastern and Southern European regions. In contrast, in panel b) it is evident that investments in transportation infrastructure are most effective in the core. Panel c) displays the effectiveness of investments in production amenities: Marginal welfare effects tend to be high in urban areas but generally show a relatively mixed pattern.

Role of location fundamentals. The heterogeneity of marginal welfare effects must be driven by fundamental characteristics of the regions. In order to gain insights into the role of location fundamentals, we homogenize regions in terms of all location fundamentals such that general equilibrium outcomes of marginal welfare effects of transfers are ex-ante identical across regions. Then, we alternately set one of the location fundamentals to its recovered or observed value while keeping all others constant and calculate the marginal welfare effects of transfers for each region separately.[33] This returns a distribution of marginal welfare effects of transfers along the observed values of the location fundamental that is allowed to vary across regions. Following this procedure, we can make ceteribus paribus statements of how location fundamentals impact the marginal welfare effects of regional transfers.

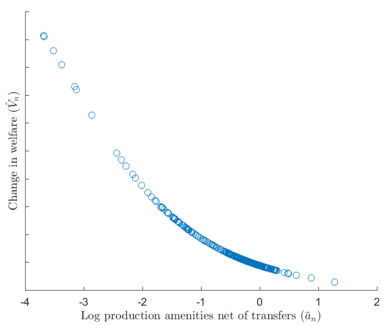
In Figure 1.5 we plot the respective marginal welfare effects against the distributions of fundamental production amenities and geographical accessibility (i.e. sum of trade costs). The correlations in panels a) and b) show that wage subsidies

[33] This exercise can also be interpreted as a difference-in-difference estimation of regional transfers, where the second difference is the same for all regions. The marginal welfare effect is $E[\hat{U}_{n,T,A}|T=1,A=0]-E[\hat{U}_{n,T,A}|T=0,A=0]-(E[\hat{U}_{n,T,A}|T=1,A=1]-E[\hat{U}_{n,T,A}|T=0,A=1])$, where $T=1$ indicates that region n received a marginal transfer and $A=1$ denotes that all location fundamental are set to it's average value for all regions and $A=0$ denotes that one specific location fundamental is set to it's observed value.

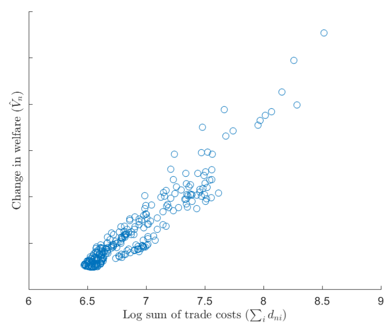
Figure 1.5: Location fundamentals and the marginal welfare effect of transfers

Wage subsidies

(a) Fund. production amenity ($\bar{a}_n$)

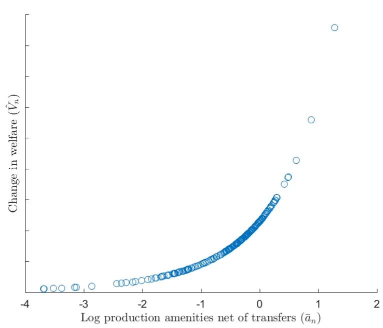


(b) Sum of trade costs ($\sum_i d_{ni}$)

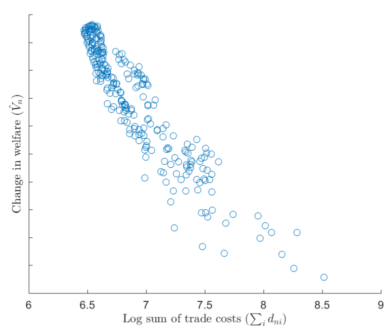


Investments in production amenities

(c) Fund. production amenity ($\bar{a}_n$)

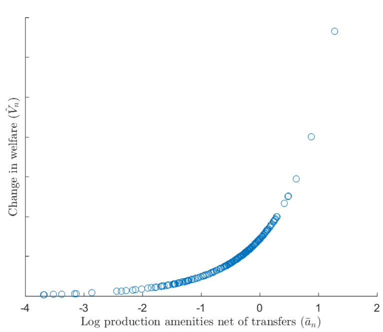


(d) Sum of trade costs ($\sum_i d_{ni}$)

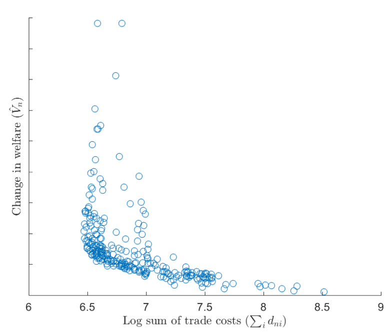


Investments in transportation infrastructure

(e) Fund. production amenity ($\bar{a}_n$)



(f) Sum of trade costs ($\sum_i d_{ni}$)



Notes: Transfers as well as all fundamental location characteristics (i.e. H_n, B_n, ι_n) except trade costs and fundamental production amenities are set to the average values such that general equilibrium outcomes of marginal welfare effects of transfers depend only on d_{ni} or $\bar{a}_n$. In the left-hand panel we set trade costs to the average value such that only fundamental production amenities $\bar{a}_n$ vary across regions. In the right-hand panel we set fundamental production amenities to the average value such that only trade costs $\sum_i d_{ni}$ vary across regions. In this case not only own trade costs but also trade costs to all neighboring regions vary such that we depict the marginal welfare effects against the sum of trade costs which results in a scattered pattern instead of an exact relationship. Each figure shows the marginal welfare effect of transfers. "Change in welfare" on the y-axis is normalized to facilitate comparison of welfare differences.

are most effective in regions with low productivity and low accessibility. The reason is as follows: Regions with low productivity or accessibility display relatively low income. In spatial equilibrium, they must be attractive in terms of less congestion on the housing market which implies a relatively low population density. Given a lower income, a marginal transfer yields a higher utility gain. When choosing locations, individuals do not factor in the externalities via productivity spillovers and congestion on the housing market. Moreover, the parameter constellation is such that congestion effects dominate agglomeration spillovers. Thus, transfers towards regions characterized by low population density and correspondingly low income improve efficiency.

Panels c) and d), show that investments in production amenities reach the highest welfare gains in regions with high fundamental production amenities and high accessibility. The first result is due to our transfer function (1.12) raising production amenities proportionally. Similar reasoning applies for the role of accessibility: Ceteris paribus, central places feature a higher population due to a lower price index that attracts population until indirect utility is equalized. With productivity spillovers according to (1.4), a higher population raises the productivity gain due to a marginal transfer.

Considering investments in transportation infrastructure (panels e) and f)) we find the highest welfare gains in regions with high fundamental production amenities and high accessibility. The first result is due to agglomeration economies – high productivity leads to dense population and a sizable market which raises the benefits of transport cost reductions. The latter result is due to positive spillovers via the transportation network: Central, highly accessible regions are relevant for trade between many region pairs because they are located in the close proximity of their respective least-cost routes. Accordingly, an improvement of the infrastructure in central regions will be passed on to the effective trade costs for a large share of other region pairs. Moreover, according to (1.11) the percentage reduction of travel time following a marginal investment is higher for adjacent region pairs with low travel time.

We illustrate the role of the remaining location fundamentals in Figures 1.B.4, 1.B.5, and 1.B.6 in the Appendix. Location amenities, residential land supply, and the share paid to global portfolio enter positively into the marginal welfare effects of all three transfer types. The reasons are intuitive as a social planner would ceteris paribus aim to allocate individuals to places with high consumption amenities and plenty of land available such as to leverage the fundamental merits of locations and minimize congestion costs.[34] A higher share of contributions to the global portfolio implies that the income gains from transfers are spread more broadly across regions. If regions are ceteris paribus identical due to decreasing marginal utility, a broad distribution generates a higher marginal welfare effect than a concentrated distribution.

Mix of transfer types. As shown above, the investments in local production amenities are optimally distributed towards central, well accessible places. At the same time, infrastructure investments are optimally allocated towards productive places which implies a complementarity between these two types of transfers. In contrast, for wage subsidies, the most efficient distribution is towards low productivity and low accessibility places.

The model also allows us to change the aggregate shares of the budget allocated to the different types. If we allocate the whole budget into either one of the transfer types, the maximum attainable welfare is lower than for the observed aggregate mix due to decreasing returns to each transfer type. As long as there is a certain mix between the three transfer types on the aggregate level, welfare is relatively insensitive to changes in the specific aggregate shares. However, it reacts strongly to changes in the regional distribution of transfers which is the focus of our analysis. One should bear in mind though that a comprehensive evaluation of changes in the aggregate shares should account for the durable nature of infrastructure and hence would call for a dynamic framework.

1.7 General vs. partial equilibrium responses

A simple cost-benefit analysis capturing only direct effects of transfers in recipient regions could lead to a significant misinterpretation of the welfare effects. According to (1.24) we define partial equilibrium effects of transfers as the direct changes in local income, production amenities and own trade costs which can be identified by reduced form analyses. However, direct effects induce adjustments in migration, trade and wages as captured by the general equilibrium model.

[34]Note that marginal utility increases in consumption amenities according to (1.1).

Table 1.3: General vs. partial equilibrium effects of the observed transfer distribution

	GE Welfare ($\hat{V}_n$)	PE Welfare	Difference
Wage subsidies	0.05	0.10	-0.05
Production amenities	1.21	1.39	-0.18
Transport infrastructure	0.82	0.04	0.78
All transfers	2.08	1.52	0.56

Notes: The table compares welfare of the observed distribution of transfers relative to the no-transfer scenario. Column 1 shows the welfare change for the general equilibrium analysis (equivalent to column 2 of Table 2). Column 2 shows the corresponding partial equilibrium welfare changes (see direct effects in equation (1.24)). The partial equilibrium changes exclude adjustments via migration, trade, and local wages (price index). For the PE welfare changes we report the averages across regions. All values are reported in percentage points.

Table 1.3 quantifies the differences between general and partial equilibrium responses to transfers. The results show that a policy maker taking only partial equilibrium effects into consideration overestimates the welfare effects in case of wage subsidies and production amenities. In case of investments in transportation infrastructure, the partial equilibrium in fact underestimates the aggregate welfare change. These opposite assessments arise due to investments in transportation infrastructure affecting the general equilibrium not only via own trade costs but also via reductions in travel time for other region pairs.[35] This implies further welfare gains that are not accounted for in partial equilibrium. In our application, the latter category of transfers turns out to be relatively important. Thus, considering the welfare effects across all transfer types, we find that a partial equilibrium approach would underestimate the aggregate gains. This conclusion is supported by a comparison with the reduced form literature: Becker et al. (2010) estimate an impact of Objective 1 transfers on growth of real income per capita of about 1.6 percentage points which is comparable to our partial equilibrium effect obtained for the sum of transfers in Table 1.3.[36]

1.8 Conclusions

In this paper we present a quantitative analysis of the general equilibrium effects of place-based policies. We integrate the three major types of regional transfers,

[35]Note that the adjustments in own trade costs are relatively minor because they are only caused by traders having a taste for non-optimal routes, i.e. detours bypassing the own region.

[36]The reduced form analysis by Pellegrini et al. (2013) finds a similar effect on income growth of approximately 0.9 percent.

i.e. wage subsidies, investments in local production amenities and investments in transportation infrastructure, into a rich economic geography framework. The model performs well in matching important patterns of the distribution of economic activity in Europe. Applying it to two decades of regional data, we estimate the parameters of the model and recover cross-sectional as well as time variation in location fundamentals. For the causal identification of the elasticities of local production amenities and trade costs with regard to transfers, we exploit changes in the regional eligibility for EU transfers.

We then perform counterfactual experiments where we remove transfers or redistribute them uniformly across regions. Overall, we find that the EU place-based policy led to a positive welfare effect of 2.08 percent for the period 2007-13 compared to a scenario without transfers. However, the policy does not realize the potential of distributing the investments in a welfare optimal way: A uniform distribution turns out to reach a higher welfare level for two out of three transfer types than the EU's current scheme.

Contrasting the welfare optimal distribution of transfers with the observed one provides us with a quantification of the potential welfare gains that could be realized. In total, switching from the observed to the optimal distribution could increase the efficiency gains of transfers by about fifty percent (from 2.08 percent to 3.14 percent compared to the no-transfer scenario). Regarding the type of transfers, there is no one-size-fits-all approach for optimal distribution: While wage subsidies should be limited to the few poorest regions, infrastructure investment should rather focus on central regions. This serves as a basis for our detailed derivation of the determinants of an optimal transfer scheme and the complementarities of different transfer types. We show that investments in local production amenities and transportation infrastructure can be leveraged by allocating them such as to maximize positive spillovers.

While there are certainly further dimension of heterogeneity in the effectiveness of transfers such as the quality of local institutions or differences in the production functions of public infrastructure, we believe that our systematic approach for an optimal distribution of a given transfer budget is informative for policy makers as it reveals the importance of adjustments via trade and migration.

Appendix

1.A Estimation and calibration

In this section we describe how we estimate the parameters and how we invert the model to recover location fundamentals.

1.A.1 Trade costs (d_{ni})

Trade costs are based on a framework developed in Allen and Arkolakis (2016). Trade is undertaken by a continuum of heterogeneous agents v who endogenously choose a path p with length K to get from n to i. We specify the cost of shipping a good from *adjacent* locations r to i as a function of road travel time[37]

$$\tilde{d}_{ri} = e^{\beta \cdot TravelTime_{ri}}, \tag{1.25}$$

where $TravelTime_{ri}$ is measured in hours and β is a factor converting travel time into transport costs. Aggregate trade costs $\check{d}_{ni}(p)$ from n to i are the product of the transport costs along path p

$$\check{d}_{ni}(p) = \prod_{k=1}^{K} \tilde{d}_{p_{k-1},p_k}. \tag{1.26}$$

Each trader faces a heterogenous path-specific taste $\epsilon_{ni}(p,v)$ to ship a good from n to i, which is assumed to be drawn i.i.d. from a Fréchet distribution with shape parameter $\theta > 0$. Total costs of a trader v travelling from n to i along path p are $\check{d}_{ni}(p)\epsilon_{ni}(p,v)$. Let $d_{ni}(v)$ indicate the costs of trader v choosing the trader-specific least-cost path between n and i

$$d_{ni}(v) = \min_{p \in P_k, K \geq 0} \check{d}_{ni}(p)\epsilon_{ni}(p,v). \tag{1.27}$$

We allow traders to choose any possible path to ship a good from n to i. The mistakes traders incur by choosing non-optimal routes is governed by the shape

[37] If n and i are not adjacent, then $\tilde{d}_{ni} = \infty$ indicates that there is no direct connection. We also assume that $\tilde{d}_{nn} = \infty$ and exclude outgoing paths starting and ending in the same location. However, this does not restrict traders to ship goods from n to n.

parameter θ. A higher value of θ indicates greater agreement across traders, where in the limit case of no heterogeneity $\theta \to \infty$ all traders choose the least-cost route. The calibration of θ determines the likelihood of mistakes and randomness in the choice of routes. Thus, the framework we use is a generalization of the least-costs approach and allows a trader to ship a good on second best routes. By using the properties of the Fréchet distribution, expected trade costs d_{ni} become

$$d_{ni} \equiv E_v[d_{ni}(v)] = c\left(\sum_{K=0}^{\infty}\sum_{p\in K}\check{d}_{ni}(p)^{-\theta}\right)^{-\frac{1}{\theta}}, \tag{1.28}$$

where $c \equiv \Gamma(\frac{\theta-1}{\theta})$ and consist of trade costs realized on all possible paths. Given the extreme value distribution, the probability a trader chooses path p and goes from n to i is given by

$$\Xi^d_{ni}(p) = Pr(\check{d}_{ni}(p) \leq \min\{\check{d}_{ni}(p)\}, \forall\, p \in P_K, K \geq 0) = \frac{d_{ni}(p)^{-\theta}}{\sum_{K=0}^{\infty}\sum_{p'\in P_{ij,K}}^{\infty} d_{ni}(p')^{-\theta}}. \tag{1.29}$$

As shown in Allen and Arkolakis (2016) expected trade costs can be expressed as a Neumann series with weighted adjacency matrix $\tilde{\mathbf{D}} = [\tilde{d}_{ni}^{-\theta}]$:

$$d_{ni}^{-\theta} = c^{-\theta}\sum_{K=0}^{\infty}\tilde{\mathbf{D}}_{ni}^{K}, \tag{1.30}$$

where $\tilde{\mathbf{D}}_{ni}^{K}$ is (n,i)'s element of adjacency matrix $\tilde{\mathbf{D}}$ to the power of K.[38] The Neumann series converges to $\sum_{K=0}^{\infty}\tilde{\mathbf{D}}_{ni}^{K} = (\mathbf{I}-\tilde{\mathbf{D}})^{-1}$, where $\mathbf{I}$ is the identity matrix. Reformulating the above equation we obtain equation (1.9) relating the adjacency matrix to expected trade cost

$$d_{ni} = c\left[\mathbf{I}-\tilde{\mathbf{D}}\right]_{ni}^{\frac{1}{\theta}}. \tag{1.31}$$

This expression takes into account that traders minimize heterogenous trader- and path-specific trade costs. By applying the matrix calculus described in Allen and Arkolakis (2016) we derive from equation (1.29) the probability of using link kl when

[38]Note, $\tilde{\mathbf{D}}_{ni} = 0$ indicates no connections between n and i, $\tilde{\mathbf{D}}_{ni} = 1$ indicates a costs-less connection and $\tilde{\mathbf{D}}_{ni} \in (0,1)$ indicates a costly connection.

shipping a good from i to n

$$\Xi_{ni}^{kl} = \left(\frac{1}{c} \frac{d_{ni}}{d_{nk} \tilde{d}_{kl} d_{li}} \right)^{\theta}. \quad (1.32)$$

The term d_{ni} in the numerator reflects expected trade costs from n to i, whereas the denominator represents expected trade costs from n to i along link kl. This equation provides a clear intuition: The more it costs to ship a good through link kl relative to the unconstrained route, the less likely it is that traders use this link. The probability of making wide detours decreases with higher degrees of trade routes agreement (high θ). As a result, the reduction of trade costs is more relevant the closer the improved bilateral link on the optimal route. Hence, an investment reducing *direct* trade costs of link $\tilde{d}_{kl}$ will have consequences for *expected* bilateral trade costs of all other regions. These effects are more pronounced the closer the *direct* link to the unconstraint one. Thus, investments reducing travel time only marginally affect effective trade costs of distant links.

Estimation of trade costs. Using GIS software we identify adjacent NUTS2 regions where we assume regions maintaining a ferry connection to be adjacent. Ferry connections ensure a comprehensive transport network which connects the EU continent with the islands.The corresponding information is obtained from openstreetmap.com. Data about $TravelTime_{ri}$ between adjacent regions r and i stems from the RRG GIS Database and contains detailed information about different speed limits, slope gradients, congestion etc.. The variable $TravelTime_{ri}$ measures time (in hours) travelled on roads from the centroid of r to the centroid of i and is obtain at the NUTS2 level. To proceed and compute trade costs d_{ni}, we use equation (1.9) as well as information about direct trade costs $\tilde{d}_{ni}$ and parameters θ and β.

As Truck-specific trade data does not exist for Europe we set the Fréchet parameter governing heterogeneity of traders $\theta = 136.13$ according to estimates obtained by Allen and Arkolakis (2016). With this information and data about $TravelTime_{ri}$ we can specify adjacency matrix $\tilde{\mathbf{D}}$. The parameter calibrations for θ and σ together with gravity equation (1.5) and the definition of trade cost (1.9) can be used to estimate the factor converting travel time to trade cost β included in adjacency matrix $\tilde{\mathbf{D}}$. To obtain β we perform a non-linear least squares estimation and minimize the sum of squared residuals between observed and implied trade by the model

$$\min_{\beta} \sum_{n,i \in N} \left(\log(X_{ni}^{Data}) - \beta_0 - \frac{\sigma - 1}{\theta} \log([I - \tilde{\mathbf{D}}]_{ni}^{-1}) - \log(\delta_n) - \log(\eta_i) \right)^2 . \tag{1.33}$$

We demean trade and trade costs such that we can neglect the constant β_0 and importer and exporter fixed effects. Data on bilateral road freight X_{ni}^{DATA} among NUTS2 regions stem from the European Transport Policy Information System. We estimate a value of $\beta = 0.068$. Figure 1.A.1 panel a) depicts a strong correlation of -0.709 between the freight data and the values of trade costs obtained from the estimation approach described above.

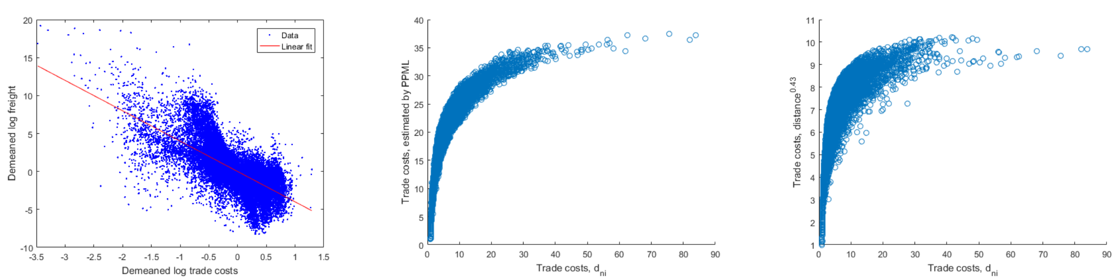
Robustness check. We compare the values for trade costs derived above with two alternative estimates. Specifically, we use a poisson pseudo-maximum-likelihood (Santos Silva and Tenreyro 2006) estimator and a purely distance based approach using a constant elasticity $d_{ni} = dist_{ni}^{0.43}$ as in Monte et al. (2018). Panels b) and c) in Figure 1.A.1 compare our benchmark estimates for trade costs d_{ni} with the two alternative approaches. Overall, our measure of trade cost is qualitatively similar to the alternatives as is evident from this figure and the high correlations.

Figure 1.A.1: Comparison of trade cost

(a) Modeled trade costs and observed freight

(b) Poisson-PML

(c) Distance based



Note: We use our estimate of $\beta = 0.068$ for the factor converting travel time to trade costs. This estimate minimizes the sum of squared residuals between demeaned log freight and demeaned log trade costs. The correlation between the trade costs in our benchmark model and traditional, alternative trade cost measures in panels (b) and (c) is 0.8 and 0.7, respectively.

1.A.2 Estimation of transfer elasticities (κ^a, κ^d)

In order to obtain transfer elasticities κ^a and κ^d we pool three time periods $t \in \{1999, 2006, 2013\}$ and run regression equations corresponding to (1.11) and (1.12). In the regression equations we add time fixed effects Ω^d_t, Ω^a_t, region fixed effects absorb $\gamma_{ri}, ln(\bar{a}_n)$, and $\zeta^d_{ri,t}, \zeta^a_{n,t}$ reflect the error terms:

$$TravelTime_{ri,t} = \gamma_{ri} - \kappa^d \cdot ln\left(T^d_{r,t} + T^d_{i,t} + 1\right) + \Omega^d_t + \zeta^d_{ri,t}, \tag{1.34}$$

$$ln(\tilde{a}_{n,t}) = ln(\bar{a}_n) + \kappa^a \cdot ln\left(T^a_{n,t}/L_{n,t} + 1\right) + \Omega^a_t + \zeta^a_{n,t}. \tag{1.35}$$

Table 1.A.1 reports the results of these regressions. For each of the two dependent variables – $ln(\tilde{a}_{n,t})$ and $TravelTime_{ri,t}$ – we run three types of specifications: columns (1) and (4) use total transfers to a region and a transportation link, $ln(T_{n,t}/L_{n,t} + 1)$ and $ln(T_{r,t} + T_{i,t} + 1)$ as the explanatory variables of interest; columns (2) and (5) represent our benchmark specifications using investments in production amenities and transportation infrastructure as shown in the equations above; columns (3) and (6) report the regression discontinuity specifications and show the effect of a binary indicator for whether a region received Objective 1 funds during the respective time period.

Transfers for the years 1999, 2006, and 2013 are measured as the average annual transfers between 1993-99, 2006-13, and 2007-13, respectively. Note that Objective 1 status was always assigned for the full budgeting period. By adding time-fixed effects we absorb any differences across periods that are common across regions. Region-fixed effects capture time invariant variation across regions.

While the fixed effects reduce potential endogeneity bias due to e.g. peripheral regions displaying a lower productivity and a higher transfer intensity, there may still be unobserved time-region-variant factors that influence transfer intensity as well as outcomes. Following Becker et al. (2010) we address these remaining endogeneity concerns by applying a regression discontinuity design. The regression discontinuity design exploits the fact that only regions with a per capita income of less than 75% of the EU average are eligible for the highest transfer intensity referred as Objective 1 funds.[39] Intuitively, this identification strategy rests on the idea that assignment of transfers is quasi-random for regions close to the threshold. Note that both RDD

[39] Thresholds are well specified to years prior to the beginning of the respective budgeting period and are measured in PPP terms.

Table 1.A.1: Direct effects of transfers

	Production amenities κ^a			Transportation infrastructure κ^d		
	FE		RDD	FE		RDD
	(1)	(2)	(3)	(4)	(5)	(6)
Total Transfers	0.007**			-0.007**		
	(0.003)			(0.003)		
Prod. transfers		0.006**				
		(0.003)				
Infra. Transfers					-0.004***	
					(0.001)	
Objective 1			0.015*			-0.028**
			(0.009)			(0.014)
Observations	712	712	712	2,990	2,990	2,990
No. regions/No. links	264	264	264	1,080	1,080	1,080

Notes: All specifications include time and region fixed effects. Columns (1) and (4) consider the sum of transfers across all types to a region or transportation link i.e. $T_{n,t}$ or $T_{ri,t}$. In column (2) the explanatory variable corresponds to investments in production amenities, $T^a_{n,t}$. In column (5) the explanatory variable corresponds to investments in transportation infrastructure, $T^d_{ri,t}$. Columns (3) and (6) report the RDD specifications where *Objective* 1 is the average treatment effect of Objective 1 transfers. RDD specifications include third order polynomial functions of the forcing variable which determined eligibility for Objective 1 transfers, i.e. per capita GDP relative to the EU average in the relevant years. In columns (1)-(3) we additionally control for the fraction of people having a tertiary education, log of consumption amenities, log of population density, and log of the sum of the distance to all other regions. We lose a few observations due missing data prior to 2007, non-EU membership, and due to changes in the NUTS2 definitions. The estimation of k^d uses only links with a common land border. Robust standard errors in brackets, * p<0.10, ** p<0.05, *** p<0.01.

specifications include third order polynomial functions of the forcing variable which determined eligibility for Objective 1 transfers, i.e. per capita GDP relative to the EU average in the relevant years.

Comparing the fixed effects specifications for total transfers (column 1) and investments in production amenities (column 2) shows that the estimated elasticities, κ^a, are very similar (0.006 and 0.007). This is due to the high correlation between T_n and T_n^a. Likewise the confidence bounds of the estimates for κ^d (0.004 and 0.007) are overlapping for total transfers (column 4) and investments in transportation infrastructure (column 5).

The point estimates for Objective 1 status do not directly correspond to the parameters κ^a and κ^d as the RDD specifications identify the average treatment effect of Objective 1 transfers. Hence, in order to compute the implied values of κ^a and κ^d we divide the treatment effect by the log difference of average transfer intensities of Objective 1 and non-Objective 1 regions. This yields corresponding values of $\kappa^a = 0.006$ and $\kappa^d = 0.005$. Thus, the RDD estimates support our preferred estimates of κ^a and κ^d in columns (2) and (5), respectively. Note that the choice of specification has only a minor effect on the analysis of the optimal spatial *distribution* of transfers and is more crucial for the *level* effects of transfers.

1.A.3 Estimation of heterogeneous location preferences and agglomeration elasticity (ϵ, μ)

In panel a) of Table 1.A.2 we show regression estimates of the heterogeneity of preferences and in panel b) we report the coefficients of the agglomeration elasticity as described in Section 1.4. For the estimations of both parameters we apply instrumental variable approaches using multiple instruments.

In columns (1) and (2) of panel a) we use centrality measured by the sum of distance to all other regions to instrument real income. While column (1) includes the whole sample, column (2) uses a reduced sample for which have data to compute a Bartik-type instrument. The Bartik instrument is used in columns (3) and (4) and it is formally defined for our three time periods as

$$Bartik_{n,t} = \sum_{ind} \left(\frac{L_{n,ind,1985}}{\bar{L}_{n,1985}} \right) \left(\frac{VA_{-n,ind,t} - VA_{-n,ind,1985}}{VA_{-n,ind,1985}} \right), \tag{1.36}$$

where the first term measures the sectoral employment share of a predetermined time period and the second term corresponds to the average growth rate in gross value added in industry ind of year t.[40] Subscript $-n$ indicates that region n's industry is excluded from the calculation of the average industry growth rates. The data to calculate the Bartik instrument stems from Cambridge Econometrics' European Regional Database and it is not available for the whole sample because we need sector shares well before the start of the first period (i.e. 1985). The latter does not exist for Eastern Europe. In column (4) we instrument real income using both a region's centrality and the Bartik instrument. The exogeneity assumption of our instruments is supported by the fact that estimates of all combination of instruments converge to values within a range of one standard deviation and that the instruments pass the Sargan test for overidentification.

For the estimation of the agglomeration elasticity in panel b) we use data about the quality of soils as an instrument for population shares. Specifically, in column (1) we employ dummy variables based on the "depth to rock" classification, whereas

[40] We use an industry classification covering the following sectors: Agriculture, industry, construction, wholesale-retail-transport & distribution-communications-hotels-catering, financial & business services, and non-market services

in column (2) we employ dummy variables based on the "Topsoil mineralogy" classification. The specification taking both instruments into account is reported in column (3). We find again strong support for the exogeneity assumption of our instruments, as all estimates of all combination of instruments converge to values within a range of one standard deviation and the instruments pass the Sargan tests.

Table 1.A.2: Heterogenous location preferences and agglomeration elasticity

Panel a) Heterogeneity of preferences ϵ				
	(1)	(2)	(3)	(4)
Real income $(\ln(y_n/P_n^\alpha r_n^{1-\alpha}))$	2.853***	3.326***	3.537**	3.340***
	(0.574)	(0.666)	(1.397)	(0.661)
Observations	712	584	584	584
No. regions	264	198	198	198
F first-stage	219.973	196.464	33.095	100.712
R^2	0.120	0.119	0.096	0.117
Overidentification (p-val)	.	.	.	0.871
Instruments:				
Centrality	Yes	Yes	No	Yes
Bartik	No	No	Yes	Yes
Panel b) Agglomeration elasticity μ				
	(1)	(2)	(3)	
Log population density	0.152***	0.095**	0.099***	
	(0.055)	(0.040)	(0.035)	
Observations	699	699	699	
No. regions	259	259	259	
F first-stage	5.727	12.711	9.404	
R^2	0.888	0.885	0.886	
Overidentification (p-val)	0.141	0.282	0.221	
Instruments:				
Land: Depth to rock (3 Dummies)	Yes	No	Yes	
Land: Topsoil mineralogy (4 Dummies)	No	Yes	Yes	

In panel a) we control for land area and in panel b) controls are the fraction of people having a tertiary education, log distance to coast, a dummy for coastal regions, area ruggedness, and fraction of area covered by water bodies. We lose a few observations due missing data prior to 2007, non-EU membership, and due to changes in the NUTS2 definitions. Robust standard errors in brackets, * p<0.10, ** p<0.05, *** p<0.01.

1.A.4 Trade balance

Figure 1.A.2 illustrates the estimation of the share of payments to the global portfolio (ι) discussed in Section 1.4 as well as observed and predicted trade balances. Regions characterized by high trade surpluses as for instance North and South Holland (NL32 and NL33) contribute most of their land rents to the global portfolio. We observe small deviations between the observed and predicted trade balances which is due to the bounds of $\iota_n \in (0, 1)$. An example where this parametric restriction is binding concerns regions with a substantial trade surplus. These regions should spend more than their returns from land to the global portfolio to exactly match the observed trade balance. Overall, we capture most of the heterogeneity of trade imbalances as is evident from the high correlation of 0.993 between modeled and predicted trade balances. Using the estimated ι_n, we can compute the per capita land rents paid into the global portfolio ($\frac{\iota_n H_n r_n}{L_n}$) as well as the payments every individual obtains from the portfolio of land and commonly owned government sector (χ).

1.A.5 Production amenity ($\tilde{a}_n$) and trade shares (π_{ni})

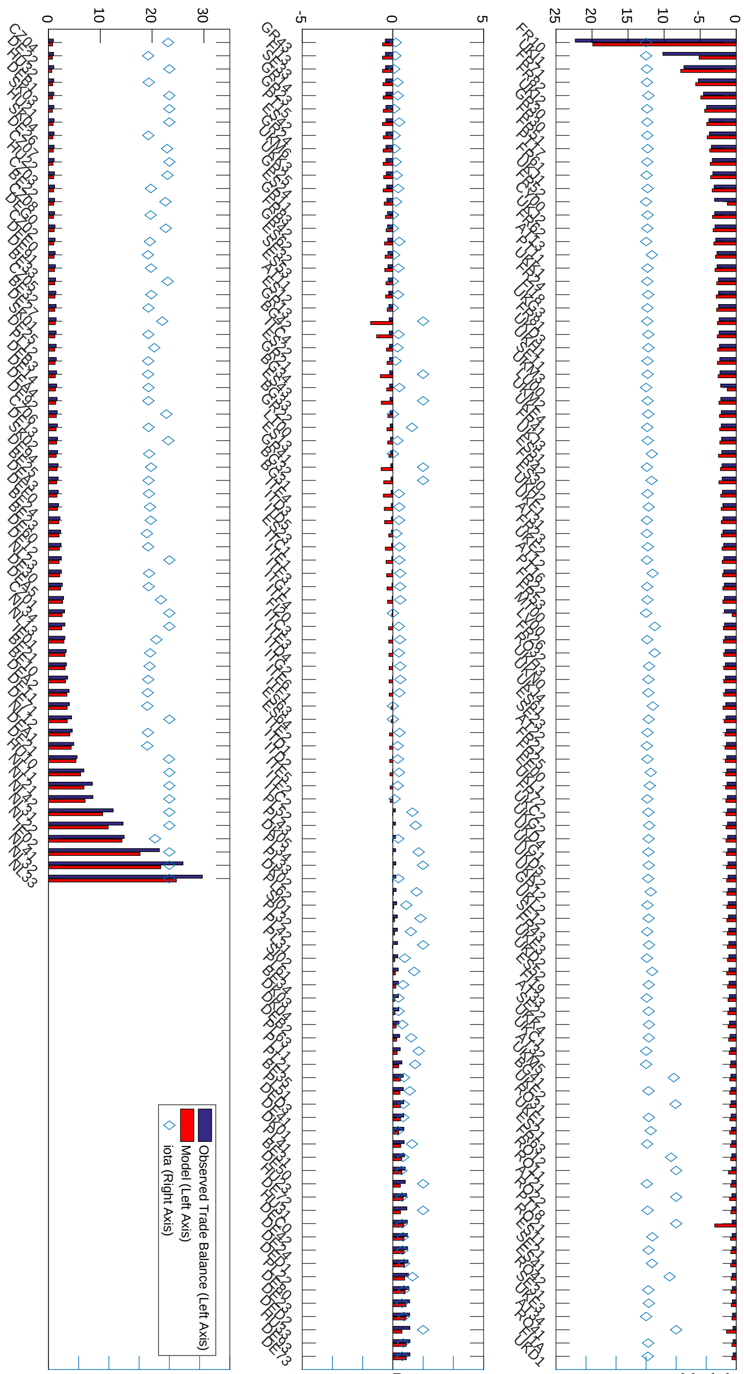
We recover production amenities and trade shares as follows: Substituting equilibrium equations (1.6) and (1.4) in (1.20) yields

$$\tilde{a}_i^{1-\sigma} L_n^{\mu(1-\sigma)+1} = \alpha w_i^{-\sigma} \sum_{n \in N} \frac{d_{ni}^{1-\sigma} L_n y_n}{\sum_{k \in N} \left(\frac{d_{nk} w_k}{a_k} \right)^{1-\sigma}}. \tag{1.37}$$

By using equation (1.37) we can recover location i's production amenity $\tilde{a}_n$, given data for $\{L_n, y_n\}$ and substituting parameters $\{\sigma, \alpha, \mu\}$, estimates of trade costs (d_{ni}) as well as the recovered information about wages (w_n). Assuming balanced trade, Redding (2016) in his Proposition 6 proofs that the solution to this equation is unique (up to scale). We check uniqueness of our solution by using random initial values for our fixed-point-iteration algorithm. As a result, we always converge to the exact same solution suggesting that the solution to this equation is unique, though it embodies unbalanced trade.

Once we know regions' production amenities we can recover productivity by (1.4) and bilateral trade shares according to (1.6). Again, we substitute data for population shares (λ_n), estimates of trade costs (d_{ni}) as well as recovered information on wages and production amenities $\{w_n, \tilde{a}_n\}$.

Figure 1.A.2: Comparison between modeled and observed trade balance and contribution to global portfolio ι_n



Notes: Blue and red bars illustrate the observed Υ^{Data} and solved trade balance Υ^{Model} according to (1.14), respectively. Diamonds show the contribution to the global portfolio ι_n that minimize the least square deviations between the modelled and observed values.

1.A.6 Location amenities (B_n)

A similar approach allows us to recover location amenities. Substituting (1.16) in population shares (1.17) we obtain

$$\lambda_n^{-1}\Phi_n B_n = \sum_{k\in N} B_k\Phi_k, \tag{1.38}$$

where $\Phi_n^{\frac{1}{\epsilon}} = \left(\frac{a_n y_n}{d_{nn}w_n}\right)^{\alpha} \pi_{nn}^{\alpha/(1-\sigma)} \frac{H_n}{\lambda_n}^{1-\alpha}$. Location amenities prevent people from consuming the highest attainable real income. Using equation (1.38) jointly with data for $\{\lambda_n, y_n, H_n\}$, already recovered information about $\{w_n, a_n, \pi_{nn}\}$, parameters $\{\sigma, \alpha, \epsilon\}$, and estimates of own trade costs (d_{nn}) we can recover $B_n^{\frac{1}{\epsilon}}$.

1.A.7 Summary statistics of exogenous and recovered variables

We present summary statistics of all our exogenous and recovered variables in Table 1.A.3. Table 1.A.4 shows that our recovered variables do not exhibit high correlations and capture sufficiently independent variation.

Table 1.A.3: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Own Trade Share (π_{nn})	0.09	0.13	0	0.89	264
Population (L_n), in tsd.	840.70	717.91	18.11	6055.46	264
Wages per-capita (w_n), in tsd.	38.55	17.48	2.34	145.88	264
Income per-capita (y_n), in tsd.	51.48	22.13	5.74	198.5	264
Trade costs (d_{ni})	4.14	3.97	1	83.97	69696
Bilateral trade costs (d_{ni})	4.15	3.97	1.02	83.97	69432
Own trade costs (d_{nn})	1	0	1	1	264
Direct trade costs ($\tilde{d}_{ri}$)	1.22	0.32	1.02	3.7	1352
Travel time ($TravelTime_{ri}$)	2.62	2.84	0.27	19.08	1352
Transfers per-capita (T_n/L_n)	136.84	190.34	0.34	891.56	264
in Obj. 1 regions	366.55	184.54	55	891.56	80
non-Obj. 1 regions	36.97	65.34	0.34	630.22	184
Objective 1 regions	0.3	0.46	0	1	264
Transfers (T_n), in mio.	84.19	129.72	0.25	808.98	264
Wage subs. (T_n^w), in mio.	24.16	37.24	0.02	272.25	264
Prod. (T_n^a), in mio.	31.37	46.44	0.1	273.39	264
Infrastr. (T_n^d), in mio.	28.66	56.94	0	432.86	264
Productivity (a_n)	2.69	1.62	0.09	15.13	264
Location amenity (B_n)	10.8	47.17	0.03	588.26	264
Land supply (H_n)	828.46	599.13	7.53	3366.19	264
Share global portfolio (ι_n)	0.33	0.34	0	1	264
Tax rates, in % (t_n)	0.25	0	0.25	0.25	264
Price index, in tsd. (P_n)	10.36	2.53	8.02	24.18	264
Rental price of land, in mio. (r_n)	16.51	21	0.45	277.69	264
Global portfolio return (χ)	3283.76	0	3283.76	3283.76	264

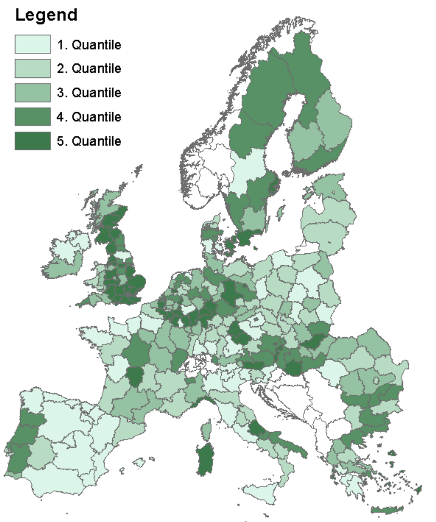
Notes: Population is measured in thousand inhabitants, per capita wages and per capita income are reported in thousand Euros, transfer levels are in million Euros, per-capita transfers in Euros, tax rates in percents, price index in thousand, and location amenity in 10^{16} units.

Table 1.A.4: Correlation matrix of recovered variables

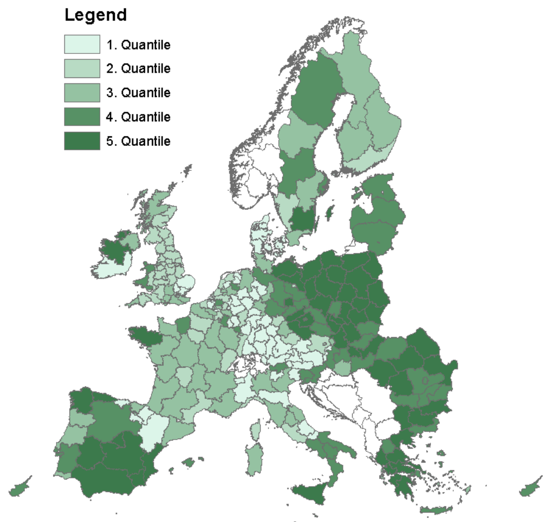
	a_n	B_n	π_{nn}
a_n	1	-0.288	0.204
B_n		1	0.060
π_{nn}			1

Figure 1.A.3: Share of transfers by type

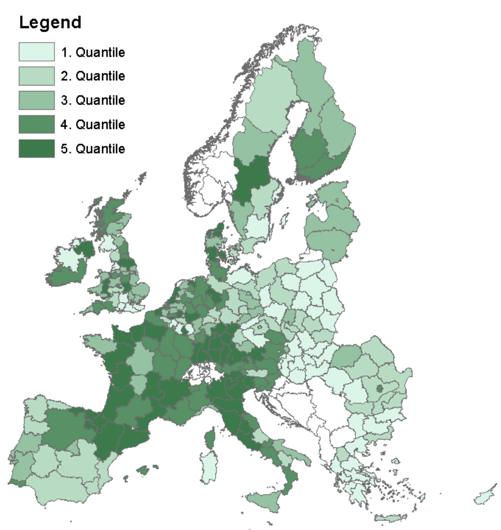
(a) Wage subsidy (T_n^w/T_n)



(b) Investment in transport infrastr. (T_n^d/T_n)



(c) Investment in prod. amenities (T_n^a/T_n)



Notes: The figures depict quantiles of the shares of transfers allocated to the three categories. A darker shading in the map indicates a higher share of the respective transfer category in total transfers paid to the respective region.

1.B Counterfactual analysis

In the following we derive a system of equations allowing us to undertake a model based counterfactual analysis of EU regional policy. Following Dekle et al. (2007) we denote a counterfactual change as $\hat{x} = \frac{x'}{x}$, where x is the observed variable and x' is the unobserved counterfactual value of x. Given model's parameters $\{\alpha, \mu, \sigma, \epsilon, \iota_n, \kappa^a, \kappa^d, \beta, \theta\}$ and variables $\{\lambda_n, w_n, \pi_{ni}, y_n, \tau_n, T_n, \gamma^d_{ri}, \bar{a}_n\}$ we use the following system of equations to solve for counterfactual changes in the model's endogenous variables $\{\hat{w}_n, \hat{y}_n, \hat{\lambda}_n, \hat{\pi}_{ni}, \hat{a}_n, \hat{d}_{ni}\}$ which determine changes in aggregate welfare.

Adjustments of regional wages follow directly from goods market clearing equation (1.20) and are

$$\hat{w}_i w_i \hat{\lambda}_i \lambda_i = \alpha \sum_{k \in N} \hat{\pi}_{ki} \pi_{ki} \hat{y}_k y_k \hat{\lambda}_k \lambda_k. \tag{1.39}$$

Changes in counterfactual productivity follow from (1.4) and become

$$\hat{a}_n = \hat{\bar{a}}_n \hat{L}_n^{\mu} \tag{1.40}$$

Next, we divide the counterfactual by the equilibrium trade share using (1.6) and obtain

$$\hat{\pi}_{ni} = \frac{\left(\frac{\hat{d}_{ni}\hat{w}_i}{\hat{a}_i}\right)^{1-\sigma}}{\sum_{k \in N} \left(\frac{\hat{d}_{nk}\hat{w}_k}{\hat{a}_k}\right)^{1-\sigma} \pi_{nk}}, \tag{1.41}$$

Similarly, we can substitute information on real income (1.16) in population mobility (1.17). To express the change in counterfactual population we divide the counterfactual with the equilibrium population share and obtain

$$\hat{\lambda}_n = \frac{(\hat{\pi}_{nn})^{\frac{\alpha\epsilon}{1-\sigma}} \left(\frac{\hat{a}_n \hat{y}_n}{\hat{d}_{nn}\hat{w}_n}\right)^{\alpha\epsilon} \left(\frac{1}{\hat{\lambda}_n}\right)^{(1-\alpha)\epsilon}}{\sum_{k \in N} (\hat{\pi}_{kk})^{\frac{\alpha\epsilon}{1-\sigma}} \left(\frac{\hat{a}_k \hat{y}_k}{\hat{d}_{kk}\hat{w}_k}\right)^{\alpha\epsilon} \left(\frac{1}{\hat{\lambda}_k}\right)^{(1-\alpha)\epsilon} \lambda_k}. \tag{1.42}$$

Using equation (1.15) we can express per capita income in the counterfactual equilibrium as

$$\hat{y}_n y_n = \frac{1}{\alpha + \iota_n - \alpha\iota_n}\left(\hat{w}_n w_n(1-\tau_n) + \frac{\hat{T}_n^w T_n^w}{\hat{\lambda}_n \lambda_n \bar{L}} + \hat{\chi}\chi\right), \tag{1.43}$$

where returns from global portfolio change due to adjustments in income and population are $\hat{\chi}\chi = (1-\alpha)\sum_n \iota_n \hat{y}_n y_n \hat{\lambda}_n \lambda_n + \sum_n \frac{1}{\bar{L}}(\hat{T}_n^d T_n^d + \hat{T}_n^a T_n^a)$. Tax rates are kept constant in our main analyses such that the transfer budget only changes marginally. This is because of the reallocation of population and changes in income which both have an impact on tax revenue. We run simulations for each investment type separately and alternately set two out of the three transfer channels to zero. Thus, local investments affect production amenities

$$\tilde{a}_n' = \bar{a}_n\left(\frac{\hat{T}_n^a T_n^a}{\hat{\lambda}_n \lambda_n \bar{L}} + 1\right)^{\kappa^a}, \tag{1.44}$$

or

$$TravelTime_{ri}' = \gamma_{ri}^d - \kappa^d \cdot \ln(\hat{T}_r^d T_r^d + \hat{T}_i^d T_i^d + 1), \tag{1.45}$$

where the trade cost routine (see Section 1.A.1) converts travel time to trade costs. Tax revenue must be equal to place-based policy expenditure such that government budget is always balanced

$$\sum_{n\in N} \hat{w}_n w_n \hat{\lambda}_n \lambda_n \hat{\tau}_n \tau_n = \sum_{n\in N} \hat{\lambda}_n \lambda_n \hat{T}_n T_n. \tag{1.46}$$

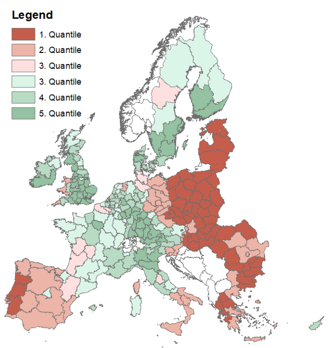
We obtain the change in aggregate welfare from expected utility (1.19):

$$\hat{\bar{V}} = \left(\frac{1}{\hat{\pi}_{nn}}\right)^{\frac{\alpha}{\sigma-1}} \left(\frac{\hat{y}_n \hat{\tilde{a}}_n}{\hat{w}_n \hat{d}_{nn}}\right)^{\alpha} \left(\hat{\lambda}_n\right)^{\alpha\mu-(1-\alpha)-\frac{1}{\epsilon}}. \tag{1.47}$$

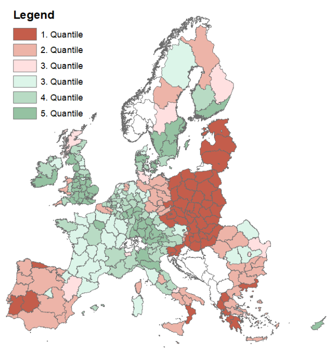
Equations (1.39)-(1.46) enable us to solve for counterfactual changes in wages $\hat{w}_n$, income $\hat{y}_n$, trade shares $\hat{\pi}_{ni}$, population shares $\hat{\lambda}_n$, production amenities $\hat{a}_n$ and own trade costs $\hat{d}_{nn}$ which are used to calculate counterfactual changes in welfare.

Figure 1.B.1: No-transfer scenario compared to observed distribution of transfers

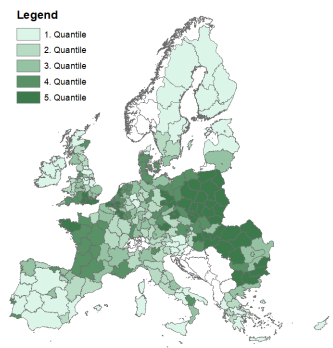
(a) Population ($\hat{\lambda}_n$)



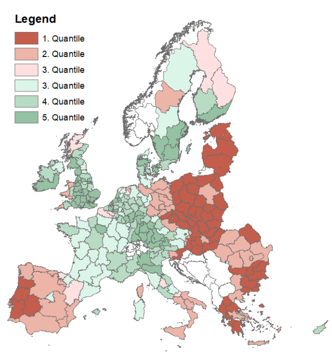
(b) Wages ($\hat{w}_n$)



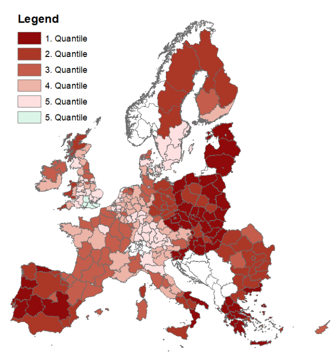
(c) Own trade share ($\hat{\pi}_{nn}$)



(d) Regional income ($\hat{y}_n$)

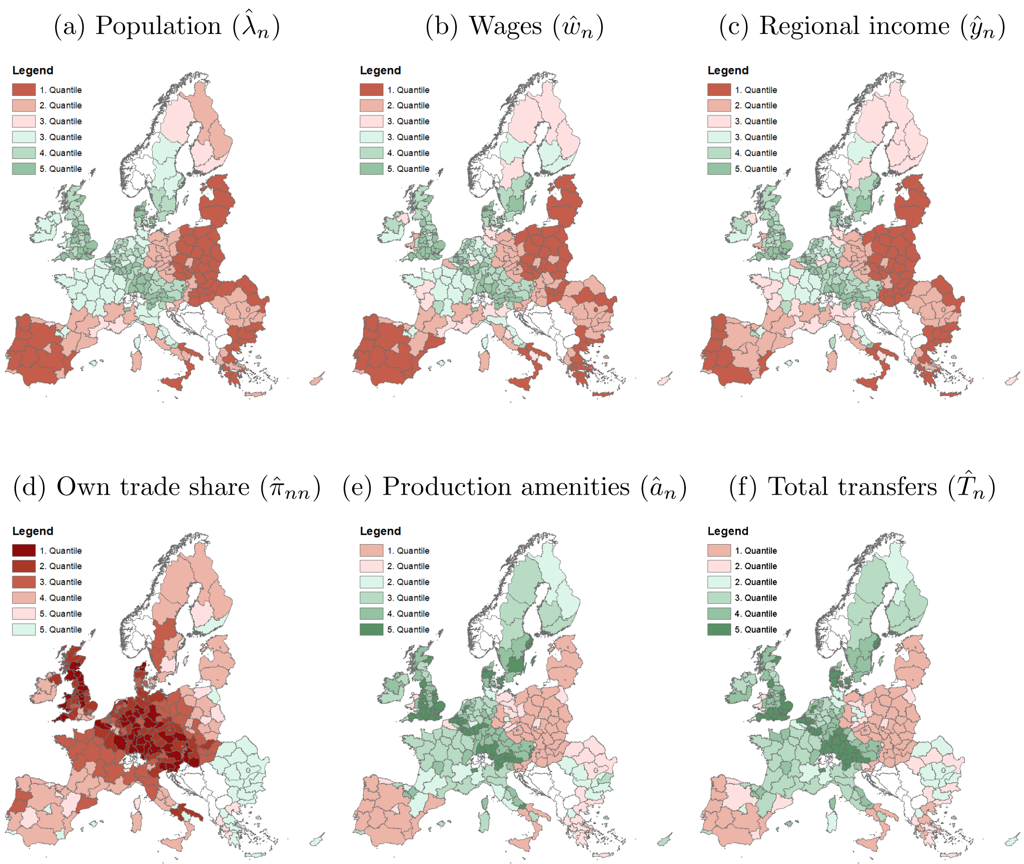


(e) Production amenities ($\hat{a}_n$)



Notes: Transfers operate through wage subsidies and investments in production amenities and transport infrastructure. The figure depicts changes in the respective variable reported by quantiles. A darker shading represents a stronger effect, where a green (red) color illustrates an increase (decrease). The change in total transfers ($\hat{T}_n = T'_n/T_n$) is zero as $T'_n = 0$ for all regions in the no-transfer scenario. See Figure 1.1 for the observed distribution of total transfers.

Figure 1.B.2: Uniform distribution of transfers compared to observed scenario

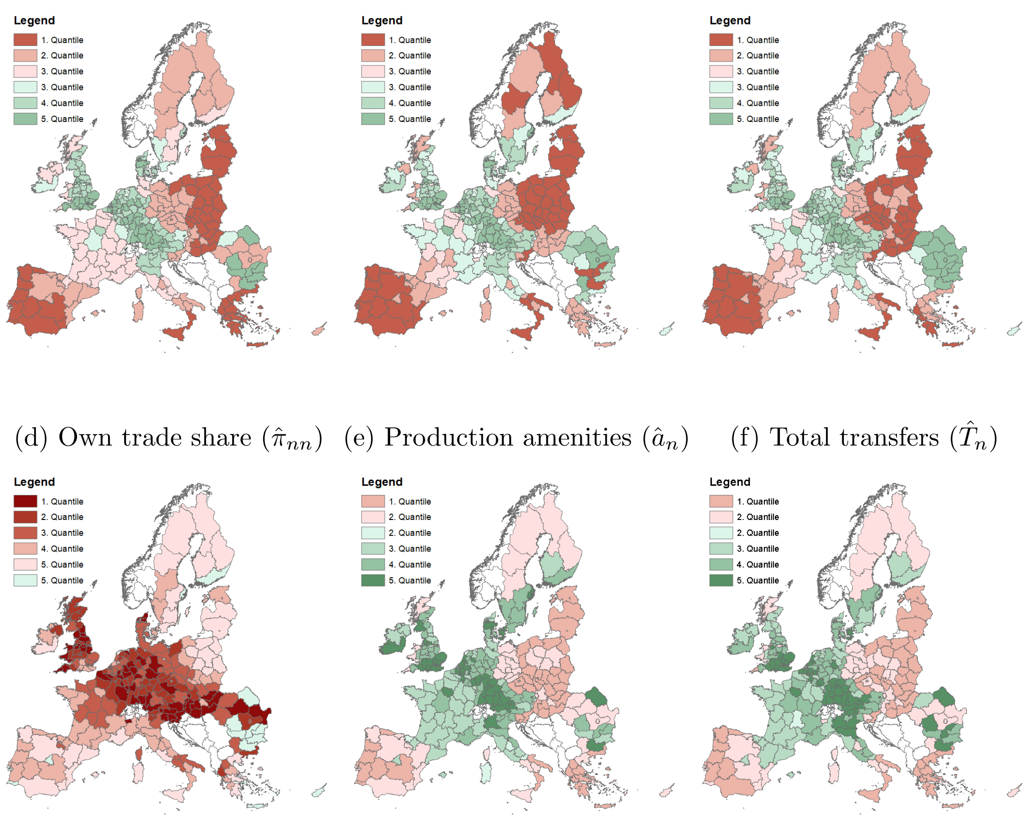


(a) Population ($\hat{\lambda}_n$) (b) Wages ($\hat{w}_n$) (c) Regional income ($\hat{y}_n$)

(d) Own trade share ($\hat{\pi}_{nn}$) (e) Production amenities ($\hat{a}_n$) (f) Total transfers ($\hat{T}_n$)

Notes: Transfers operate through wage subsidies and investments in production amenities and transport infrastructure. The figure depicts changes in the respective variable reported by quantiles. A darker shading represents a stronger effect, where a green (red) color illustrates an increase (decrease).

Figure 1.B.3: Optimal distribution compared to observed distribution of transfers



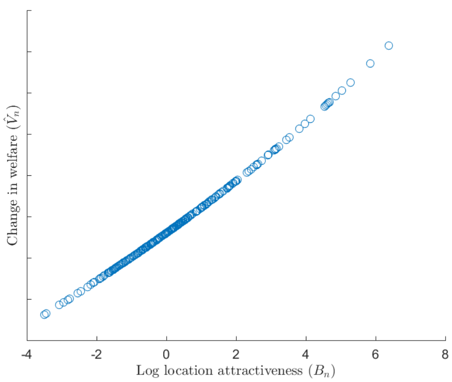
(a) Population ($\hat{\lambda}_n$) (b) Wages ($\hat{w}_n$) (c) Regional income ($\hat{y}_n$)

(d) Own trade share ($\hat{\pi}_{nn}$) (e) Production amenities ($\hat{a}_n$) (f) Total transfers ($\hat{T}_n$)

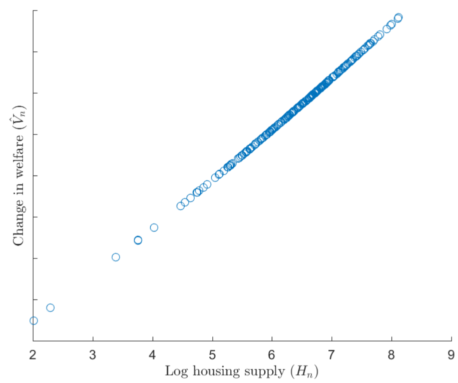
Notes: We consider the sum of transfers operating through wage subsidies, investments in production amenities and transport infrastructure. The figures above compare the observed equilibrium to a counterfactual situation where all three types of transfers are distributed optimally. The figure depicts changes in the respective variable reported by quantiles. A darker shading represents a stronger effect, where a green (red) color illustrates an increase (decrease).

Figure 1.B.4: Marginal welfare effects of wage subsidies

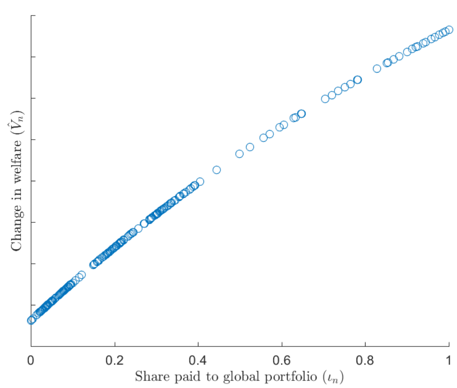
(a) Location attractiveness (B_n)



(b) Resid. land supply (H_n)



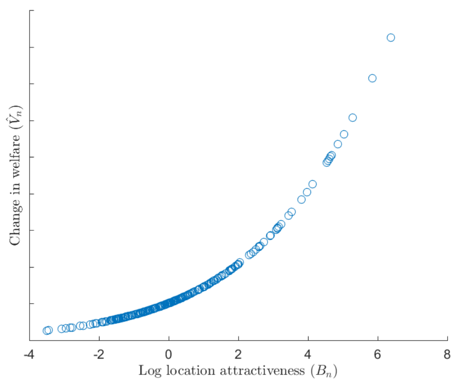
(c) Share to global portfolio (ι_n)



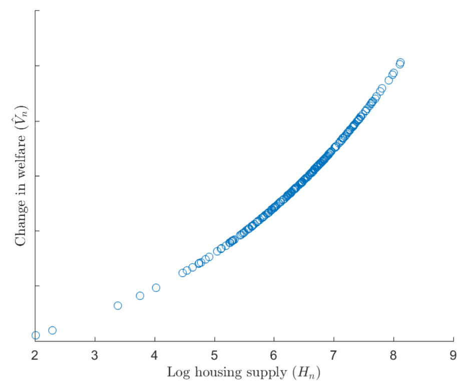
Notes: Transfers as well as all fundamental location characteristics (i.e. $\bar{a}_n, d_{ni}$) except location attractiveness, residential land supply and share to global portfolio are set to the average values such that general equilibrium outcomes of marginal welfare effects of wage subsidies depend only on B_n, H_n or ι_n. Each figure shows the marginal welfare effect of wage subsidies. "Change in welfare" on the y-axis is normalized to facilitate comparison of welfare differences.

Figure 1.B.5: Marginal welfare effects of investments in production amenities

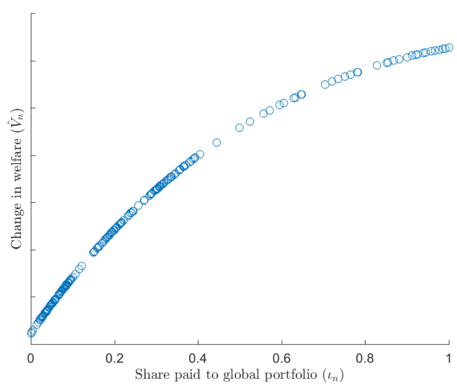
(a) Location attractiveness (B_n)



(b) Resid. land supply (H_n)



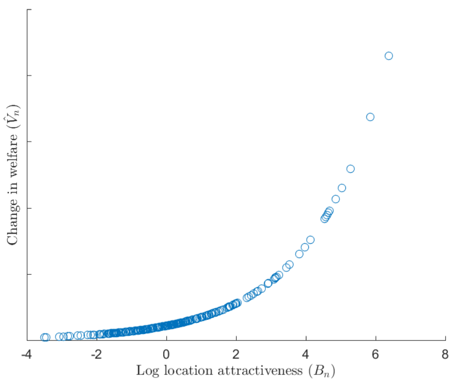
(c) Share to global portfolio (ι_n)



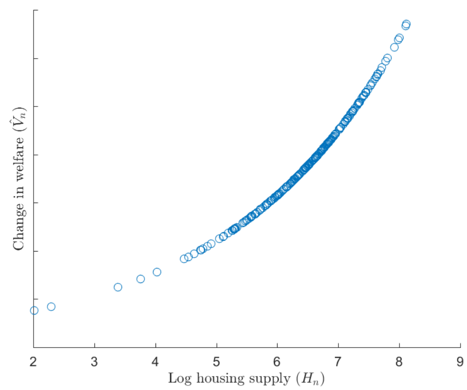
Notes: Transfers as well as all fundamental location characteristics (i.e. $\bar{a}_n, d_{ni}$) except location attractiveness, residential land supply and share to global portfolio are set to the average values such that general equilibrium outcomes of marginal welfare effects of investments in production amenities depend only on B_n, H_n or ι_n. Each figure shows the marginal welfare effect of investments in production amenities. "Change in welfare" on the y-axis is normalized to facilitate comparison of welfare differences.

Figure 1.B.6: Marginal welfare effects of investments in transport infrastructure

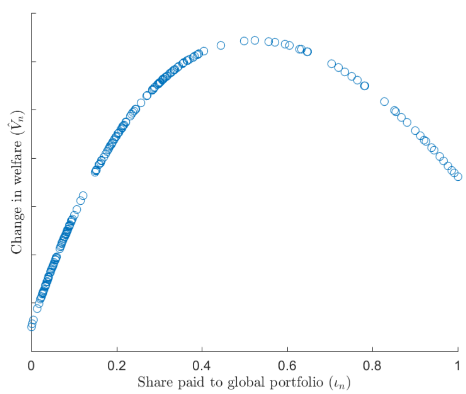
(a) Location attractiveness (B_n)



(b) Resid. land supply (H_n)



(c) Share to global portfolio (ι_n)



Note: Transfers as well as all fundamental location characteristics (i.e. $\bar{a}_n, d_{ni}$) except location attractiveness, residential land supply and share to global portfolio are set to the average values such that general equilibrium outcomes of marginal welfare effects of investments in transportation infrastructure depend only on B_n, H_n or ι_n. Each figure shows the marginal welfare effect of investments in transportation infrastructure. "Change in welfare" on the y-axis is normalized to facilitate comparison of welfare differences

1.B.1 Optimal distribution of transfers conditional on constant inequality

Given the aim of the European Union to enhance efficiency while strengthening regional cohesion, the objective function assumed in the benchmark model may not necessarily conform with the political ambitions. Our setting is flexible enough to incorporate an additional constraint which holds regional income inequality constant. In particular, we use the coefficient of variation as a dispersion measure because it is scale-invariant and differentiable such that we can provide the gradients for the MPEC approach solving the optimization problem. The results are summarized in Table 1.B.1. Recall that the optimal distribution of wage subsidies

Table 1.B.1: Welfare effects of transfers while holding income inequality stable

	(a) Wage subsidies		(b) Production amenities	
	Observed	Optimal	Observed	Optimal
	(1)	(2)	(1)	(2)
Welfare ($\hat{V}_n$)	0.05%	0.19%	1.21%	1.63%
$\widehat{CV}(y_n)$	-0.34%	-0.34%	-0.82%	-0.82%

	(c) Transportation infrastructure		(d) All transfers	
	Observed	Optimal	Observed	Optimal
	(1)	(2)	(1)	(2)
Welfare ($\hat{V}_n$)	0.82%	0.95%	2.08%	2.79%
$\widehat{CV}(y_n)$	-0.07%	-0.07%	-1.22%	-1.22%

The table compares outcomes relative to the no-transfer equilibrium. Columns 1 refer to the observed distribution of transfers and columns 2 refer to the optimal distribution of transfers holding regional income inequality (in nominal terms) constant. In panels a), b), and c) we isolate individual transfer types whereas panel d) considers the sum of transfers. We keep tax rates constant at the observed level. When we restrict the analysis to one transfer type we keep taxes at the level required to finance the observed budget of the respective transfer type.

does not only increase welfare but also reduces income inequality compared to the observed distribution. Consequently, restricting the level of inequality to the observed one comes at some efficiency costs compared to the unconstrained optimum in Table 1.2. With regard to investments in production amenities, transportation infrastructure as well as total transfers, the optimal distribution in Table 1.2 led to an increase in income inequality. In each case we can reach significant welfare gains over the observed distribution while holding inequality constant. However, the comparison of Tables 1.2 and 1.B.1 shows a trade-off between inequality and efficiency. The welfare gains are 0.06, 0.27, and 0.35 percentage points lower for T_n^a, T_n^d and total transfers T_n, respectively when restricting the optimal distribution to holding income inequality at the observed level.

1.C Optimal transfers

The numerical optimization routine with a government setting the welfare optimizing transfer policy follows the Mathematical Programs With Equilibrium Constraints (MPEC) approach described in Su and Judd (2012) for economic models and particularly applied to trade models in Ossa (2014). We maximize indirect utility of one arbitrary region and take the model's equilibrium conditions as constraints. Given this nonlinear constrained optimization procedure the solution characterizes a spatial equilibrium defined in Section 1.3.6.

We either allow the government to provide per capita wage subsidies or to undertake investments in production amenities or transport infrastructure. Accordingly, we set two of our three transfer channels to zero to compute the optimal transfer shares. For all our optimizations we hold tax rates constant such that a shift in the transfer budget may only be generated by different distributions of transfers.

1.C.1 Solving approach

The step-by-step solution procedure for the problem stated above is as follows

1. We form a random initial guess for transfer shares (T_n^w,T_n^a or T_n^d) from a normal distribution with mean zero and variance 10^9. We take absolute values to ensure a positive initial guess and normalize it such that the sum is equal to 1.

2. Based on random transfer shares we compute equilibrium values for wages (w_n), population shares (λ_n), own trade shares (π_{nn}), indirect utility of region 1 (V_1) and total transfers paid ($\bar{T}$) satisfying equilibrium constraints (1.39)-(1.46). We take this as an initial guess for the endogenous variables.

3. We maximize welfare subject to the equilibrium constraints by numerically running the problem in Artely's Knitro solver.

For any random initial guess our problem converges to the same solution. In this optimal allocation utility is equalized, government budget is balanced and all equilibrium conditions (as described in Section 1.3.6) are fulfilled up to a small epsilon $\epsilon < 1^{-10}$.

Documentation of the optimization routine

In the following we describe the configuration of the optimization solver which should help the reader to understand our code in more detail. The main challenge of the optimization was to make the numerical routine feasible. First, in order to increase convergence rate it is necessary to scale all variables to a similar magnitude and set bounds accordingly. Second, we supply gradients of our objective function and equilibrium constraints and form a jacobian matrix. Both adjustments result in a considerable speed gain and enable us to solve the optimization problem in appropriate time on a high-end workstation (one optimization takes $\sim$ 2-4 hours). Before we discuss the gradients, we first state the maximization problem of our routine.

Stating the maximization problem

The Matlab file *cons_eq.m* contains information on all equilibrium equation (CA_n)-(CG_n), whereas the file *func.m* transmits the value of the objective function (OBJ_1) to the solver. Note that we specify the maximization problem in terms of regional transfer shares TS_n such that $TS_n\bar{T} = T_n$. The following description of the maximization problem applies to all three types of transfers. In the case of wage transfers TS_n refers to the regional share of wage transfers i.e. $TS_n\bar{T} = T_n^w$, while it refers to the regional shares of investments in production amenities and transport infrastructure for the other types, respectively.

$$\min_{\lambda_n, w_n, \pi_{nn}, TS_n, V_1, \bar{T}} \quad -V_1 \tag{OBJ_1}$$

subject to:

$$w_n - \alpha \frac{1}{\lambda_n} \left(\frac{w_n}{a_n}\right)^{1-\sigma} \sum_{i \in N} \left(\frac{d_{in} a_i}{d_{ii} w_i}\right)^{1-\sigma} \pi_{ii} y_i \lambda_i = 0, \qquad \forall \quad n \in N \tag{CA_n}$$

$$\pi_{nn} - \frac{\left(\frac{d_{nn} w_n}{a_n}\right)^{1-\sigma}}{\sum_{i \in N} \left(\frac{d_{ni} w_i}{a_i}\right)^{1-\sigma}} = 0, \qquad \forall \quad n \in N \tag{CB_n}$$

$$\lambda_n - \frac{B_n\left(\frac{a_n y_n}{d_{nn}w_n}\right)^{\alpha\epsilon}(\pi_{nn})^{\alpha\epsilon/(1-\sigma)}\left(\frac{H_n}{\lambda_n}\right)^{(1-\alpha)\epsilon}}{\sum_{i\in N} B_i\left(\frac{a_i y_i}{d_{ii}w_i}\right)^{\alpha\epsilon}(\pi_{ii})^{\alpha\epsilon/(1-\sigma)}\left(\frac{H_i}{\lambda_i}\right)^{(1-\alpha)\epsilon}} = 0, \qquad \forall \quad n \in N \qquad (CC_n)$$

$$V_1 - \bar{L}^{-(1-\alpha)}\delta\gamma\left(B_1\right)^{\frac{1}{\epsilon}}\left(\frac{a_1 y_1}{d_{11}w_1}\right)^{\alpha}(\pi_{11})^{\alpha/(1-\sigma)}\left(\frac{H_1}{\lambda_1}\right)^{1-\alpha}\left(\frac{1}{\lambda_1}\right)^{\frac{1}{\epsilon}} = 0 \qquad (CD_1)$$

$$\sum_{i\in N}\lambda_i - 1 = 0 \qquad (CE_1)$$

$$\sum_{i\in N} TS_i - 1 = 0 \qquad (CF_1)$$

$$\sum_{i\in N} w_i\lambda_i\bar{L}\tau_i - \bar{T} = 0 \qquad (CG_1)$$

where

$$y_n = \frac{1}{\alpha + \iota_n - \alpha\iota_n}\left(w_n(1-\tau_n) + \left(\frac{TS_n\bar{T}}{\lambda_n\bar{L}}\right)\kappa^w + \chi\right), \forall \quad n \in N$$

$$a_n = \tilde{a}_n\left(\frac{TS_n\bar{T}}{\lambda_n\bar{L}} + 1\right)^{\kappa^a}\left(\lambda_n\bar{L}\right)^{\mu} \quad, \forall \quad n \in N$$

$$d_{ni} = \Gamma\left(\frac{\theta-1}{\theta}\right)\left[\mathbf{I} - \tilde{\mathbf{D}}\right]_{ni}^{\frac{1}{\theta}},$$

$$TravelTime_{ri} = \gamma_{ri}^d - \kappa^d \cdot ln\left(TS_r\bar{T} + TS_i\bar{T} + 1\right). \qquad (1.48)$$

In the counterfactuals of optimal distributions of:

- Wage subsidies $\kappa^a = \kappa^d = 0$ and $\kappa^w = 1$
- Investments in production amenities $\kappa^w = \kappa^d = 0$ and $\kappa^a > 0$

- Investments in transportation infrastructure $\kappa^w = \kappa^a = 0$ and $\kappa^d > 0$.

Supplying gradients to the solver

For our optimization problem we compute the Jacobian matrix for all variables $x_n \in \{\lambda_n, w_n, \pi_{nn}, TS_n, V_1, \bar{T}\}$, all our constraints $C \in \{CA_n - CG_1\}$ and our objective function $\{OBJ_1\}$. The matrix $J_{C,x}$ shows the jacobian matrix of constraint C with respect to variable variable x.

$$J_{C,x} = \begin{bmatrix} \frac{\partial C_1}{\partial x_1} & \cdots & \frac{\partial C_n}{\partial x_1} & \cdots & \frac{\partial C_N}{\partial x_1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial C_1}{\partial x_n} & \cdots & \frac{\partial C_n}{\partial x_n} & \cdots & \frac{\partial C_N}{\partial x_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial C_1}{\partial x_N} & \cdots & \frac{\partial C_n}{\partial x_N} & \cdots & \frac{\partial C_N}{\partial x_N} \end{bmatrix}.$$

The Matlab file *cons_gradients.m* forms the overall Jacobian of our equation system. All corresponding derivatives are described further below. First, it is instructive to clarify the link between the notation used below and our code. Partial derivatives with respect to the own regions attribute i.e. $\frac{\partial y_k}{\partial x_k}$ are reflected by the full matrix in the Matlab code, whereas derivatives with respect to other regions attributes i.e. $\frac{\partial y_n}{\partial x_k}$ are only positive for the main diagonal such that a matrix $SAME$ is multiplied in the code. All own-region variables i.e. x_n are transposed whereas all non-own-region variables x_k are not transposed. A superscript (*) denotes for each variable an equilibrium value. In order to isolate a particular transfer channels we set the partial derivatives that are relevant for the respective transfer type to the following expressions: (i) For wage subsidies we activate (1.89)-(1.94) and (1.108), (ii) for investments in production amenities we activate (1.102)-(1.107) and (1.90), (1.95), and (iii) for investments in transportation infrastructure we activate (1.96)-(1.101), (1.90), (1.95) and (1.108) where we compute the Jacobian of constraints J_{C,TS_n} and $J_{C,\bar{T}}$ using numerical automatic differentiation methods.

In the following, we state the Jacobian matrix for the equation system, which we supply to the solver

$$\frac{\partial CA_n}{\partial \lambda_k} = \frac{w_n^*}{\lambda_n}\frac{\partial \lambda_n}{\partial \lambda_k} + (1-\sigma)\frac{w_n^*}{a_n}\frac{\partial a_n}{\partial a_k} - \frac{\alpha}{\lambda_n}\left(\frac{w_n}{a_n}\right)^{1-\sigma}\left(\frac{d_{kn}a_k}{d_{kk}w_k}\right)^{1-\sigma}\pi_{kk}y_k\lambda_k\left(\frac{(1-\sigma)}{a_k}\frac{\partial a_k}{\partial \lambda_k} + \frac{1}{y_k}\frac{\partial y_k}{\partial \lambda_k} + \frac{1}{\lambda_k}\frac{\partial \lambda_k}{\partial \lambda_k}\right) \tag{1.49}$$

$$\frac{\partial CA_n}{\partial w_k} = \frac{\partial w_n}{\partial w_k} - (1-\sigma)\frac{w_n^*}{w_n}\frac{\partial w_n}{\partial w_k} - \frac{\alpha}{\lambda_n}\left(\frac{w_n}{a_n}\right)^{1-\sigma}\left(\frac{d_{kn}a_k}{d_{kk}w_k}\right)^{1-\sigma}\pi_{kk}y_k\lambda_k\left(-\frac{(1-\sigma)}{w_k}\frac{\partial w_k}{\partial w_k} + \frac{1}{y_k}\frac{\partial y_k}{\partial w_k}\right) \tag{1.50}$$

$$\frac{\partial CA_n}{\partial \pi_{kk}} = -\frac{\alpha}{\lambda_n}\left(\frac{w_n}{a_n}\right)^{1-\sigma}\left(\frac{d_{kn}a_k}{d_{kk}w_k}\right)^{1-\sigma}y_k\lambda_k\frac{\partial \pi_{kk}}{\partial \pi_{kk}} \tag{1.51}$$

$$\frac{\partial CA_n}{\partial TS_k} = (1-\sigma)\frac{w_n^*}{a_n}\frac{\partial a_n}{\partial TS_k} - \frac{\alpha}{\lambda_n}\left(\frac{w_n}{a_n}\right)^{1-\sigma}\left(\frac{d_{kn}a_k}{d_{kk}w_k}\right)^{1-\sigma}\pi_{kk}y_k\lambda_k \times\left(\frac{(1-\sigma)}{a_k}\frac{\partial a_k}{\partial TS_k} + \frac{1}{y_k}\frac{\partial y_k}{\partial TS_k}\right)$$

$$\frac{\partial CA_n}{\partial V_1} = 0 \tag{1.52}$$

$$\frac{\partial CA_n}{\partial \bar{T}} = (1-\sigma)\frac{w_n^*}{a_n}\lambda_n\frac{\partial a_n}{\partial \bar{T}} - \frac{\alpha}{\lambda_n}\left(\frac{w_n}{a_n}\right)^{1-\sigma}\sum_{k\in N}\left(\frac{d_{kn}a_k}{d_{kk}w_k}\right)^{1-\sigma}\pi_{kk}y_k\lambda_k \times\left(\frac{(1-\sigma)}{a_k}\frac{\partial a_k}{\partial \bar{T}} + \frac{1}{y_k}\frac{\partial y_k}{\partial \bar{T}}\right)$$

$$\frac{\partial CB_n}{\partial \lambda_k} = (1-\sigma)\frac{\pi^*_{nn}}{a_n}\frac{\partial a_n}{\partial \lambda_k} - (1-\sigma)\pi^*_{nn}\pi^*_{nk}\frac{1}{a_k}\frac{\partial a_k}{\partial \lambda_k} \tag{1.53}$$

$$\frac{\partial CB_n}{\partial w_k} = -(1-\sigma)\frac{\pi^*_{nn}}{w_n} + (1-\sigma)\pi^*_{nn}\pi^*_{nk}\frac{1}{w_k}\frac{\partial w_k}{\partial w_k} \tag{1.54}$$

$$\frac{\partial CB_n}{\partial \pi_{kk}} = \frac{\partial \pi_{nn}}{\partial \pi_{kk}} \tag{1.55}$$

$$\begin{aligned}\frac{\partial CB_n}{\partial TS_k} &= (1-\sigma)\pi^*_{nn}\left(\frac{1}{a_n}\frac{\partial a_n}{\partial TS_k}\right) \\ &- (1-\sigma)\pi^*_{nn}\pi^*_{nk}\left(\frac{1}{a_k}\frac{\partial a_k}{\partial TS_k}\right)\end{aligned} \tag{1.56}$$

$$\frac{\partial CB_n}{\partial V_1} = 0 \tag{1.57}$$

$$\begin{aligned}\frac{\partial CB_n}{\partial \bar{T}} &= (1-\sigma)\pi^*_{nn}\left(\frac{1}{a_n}\frac{\partial a_n}{\partial \bar{T}}\right) \\ &- (1-\sigma)\pi^*_{nn}\sum_{k\in N}\pi_{nk}\left(\frac{1}{a_k}\frac{\partial a_k}{\partial \bar{T}}\right)\end{aligned} \tag{1.58}$$

$$\begin{aligned}\frac{\partial CC_n}{\partial \lambda_k} &= \frac{\partial \lambda_n}{\partial \lambda_k} + (1-\alpha)\epsilon\lambda_n^* \left(\frac{1}{\lambda_n}\frac{\partial \lambda_n}{\partial \lambda_k} - \frac{\lambda_k^*}{\lambda_k}\frac{\partial \lambda_k}{\partial \lambda_k}\right) \\ &\quad - \alpha\epsilon\lambda_n^* \left(\frac{1}{a_n}\frac{\partial a_n}{\partial \lambda_k} - \frac{\lambda_k^*}{a_k}\frac{\partial a_k}{\partial \lambda_k} + \frac{1}{y_n}\frac{\partial y_n}{\partial \lambda_k} - \frac{\lambda_k^*}{y_k}\frac{\partial y_k}{\partial \lambda_k}\right) \end{aligned} \tag{1.59}$$

$$\frac{\partial CC_n}{\partial w_k} = \alpha\epsilon\lambda_n^* \left(\frac{1}{w_n}\frac{\partial w_n}{\partial w_k} - \frac{\lambda_k^*}{w_k} - \frac{1}{y_n}\frac{\partial y_n}{\partial w_k} + \frac{\lambda_k^*}{y_k}\frac{\partial y_k}{\partial w_k}\right) \tag{1.60}$$

$$\frac{\partial CC_n}{\partial \pi_{kk}} = -\frac{\alpha\epsilon}{1-\sigma}\lambda_n^* \left(\frac{1}{\pi_{nn}}\frac{\partial \pi_{nn}}{\partial \pi_{kk}} - \frac{\lambda_k^*}{\pi_{kk}}\frac{\partial \pi_{kk}}{\partial \pi_{kk}}\right) \tag{1.61}$$

$$\frac{\partial CC_n}{\partial TS_k} = -\alpha\epsilon\lambda_n^* \left(\frac{1}{a_n}\frac{\partial a_n}{\partial TS_k} - \frac{\lambda_k^*}{a_k}\frac{\partial a_k}{\partial TS_k} + \frac{1}{y_n}\frac{\partial y_n}{\partial TS_k} - \frac{\lambda_k^*}{y_k}\frac{\partial y_k}{\partial TS_k}\right) \tag{1.62}$$

$$\frac{\partial CC_n}{\partial V_1} = 0 \tag{1.63}$$

$$\frac{\partial CC_n}{\partial \bar{T}} = -\alpha\epsilon\lambda_n^* \left(\frac{1}{a_n}\frac{\partial a_n}{\partial \bar{T}} - \sum_{k\in N}\frac{\lambda_k^*}{a_k}\frac{\partial a_k}{\partial T} + \frac{1}{y_n}\frac{\partial y_n}{\partial \bar{T}} - \sum_{k\in N}\frac{\lambda_k^*}{y_k}\frac{\partial y_k}{\partial \bar{T}}\right) \tag{1.64}$$

$$\frac{\partial CD_1}{\partial \lambda_k} = \frac{(1-\alpha)(1-\sigma)\epsilon + (1-\sigma)}{(1-\sigma)\epsilon} \frac{V_1^*}{\lambda_1} \frac{\partial \lambda_1}{\partial \lambda_k} - \frac{\alpha V_1^*}{a_1} \frac{\partial a_1}{\partial \lambda_k} - \frac{\alpha V_1^*}{y_1} \frac{\partial y_1}{\partial \lambda_k} \tag{1.65}$$

$$\frac{\partial CD_1}{\partial w_k} = -\alpha V_1^* \left(\frac{1}{y_1} \frac{\partial y_1}{\partial w_k} - \frac{1}{w_1} \frac{\partial w_1}{\partial w_k} \right) \tag{1.66}$$

$$\frac{\partial CD_1}{\partial \pi_{kk}} = -\frac{\alpha}{1-\sigma} \frac{V_1^*}{\pi_{11}} \frac{\partial \pi_{11}}{\partial \pi_{kk}} \tag{1.67}$$

$$\frac{\partial CD_1}{\partial TS_k} = \alpha V_1^* \left(-\frac{1}{a_1} \frac{\partial a_1}{\partial TS_k} - \frac{1}{y_1} \frac{\partial y_1}{\partial TS_k} \right) \tag{1.68}$$

$$\frac{\partial CD_1}{\partial V_k} = 1 \tag{1.69}$$

$$\frac{\partial CD_1}{\partial \bar{T}} = \alpha V_1^* \left(-\frac{1}{a_1} \frac{\partial a_1}{\partial \bar{T}} - \frac{1}{y_1} \frac{\partial y_1}{\partial \bar{T}} \right) \tag{1.70}$$

$$\frac{\partial CE_1}{\partial \lambda_k} = 1 \tag{1.71}$$

$$\frac{\partial CE_1}{\partial w_k} = 0 \tag{1.72}$$

$$\frac{\partial CE_1}{\partial \pi_{kk}} = 0 \tag{1.73}$$

$$\frac{\partial CE1}{\partial TS_k} = 0 \tag{1.74}$$

$$\frac{\partial CE_1}{\partial V_1} = 0 \tag{1.75}$$

$$\frac{\partial CE_1}{\partial \bar{T}} = 0 \tag{1.76}$$

$$\frac{\partial CF_1}{\partial \lambda_k} = 0 \tag{1.77}$$
$$\frac{\partial CF_1}{\partial w_k} = 0 \tag{1.78}$$
$$\frac{\partial CF_1}{\partial \pi_{kk}} = 0 \tag{1.79}$$
$$\frac{\partial CF_1}{\partial TS_k} = 1 \tag{1.80}$$
$$\frac{\partial CF_1}{\partial V_1} = 0 \tag{1.81}$$
$$\frac{\partial CF_1}{\partial \bar{T}} = 0 \tag{1.82}$$

$$\frac{\partial CG_1}{\partial \lambda_k} = w_k \tau_k \bar{L} \tag{1.83}$$
$$\frac{\partial CG_1}{\partial w_k} = \tau_k \lambda_k \bar{L} \tag{1.84}$$
$$\frac{\partial CG_1}{\partial \pi_{kk}} = 0 \tag{1.85}$$
$$\frac{\partial CG_1}{\partial TS_k} = 0 \tag{1.86}$$
$$\frac{\partial CG_1}{\partial V_k} = 0 \tag{1.87}$$
$$\frac{\partial CG_1}{\partial \bar{T}} = -1 \tag{1.88}$$

In addition to the partial derivatives of the Jacobian, we express the partial derivatives of the variables capturing the direct effects of transfers.

$$\frac{\partial y_n}{\partial \lambda_k} = -\frac{1}{\alpha + \iota_n - \alpha\iota_n}\left(\frac{TS_n\bar{T}}{\lambda_n^2\bar{L}}\right)\frac{\partial \lambda_n}{\partial \lambda_k} \tag{1.89}$$

$$\frac{\partial y_n}{\partial w_k} = \frac{1}{\alpha + \iota_n - \alpha\iota_n}(1-\tau_n)\frac{\partial w_n}{\partial w_k} \tag{1.90}$$

$$\frac{\partial y_n}{\partial \pi_{kk}} = 0 \tag{1.91}$$

$$\frac{\partial y_n}{\partial TS_k} = \frac{1}{\alpha + \iota_n - \alpha\iota_n}\left(\frac{\bar{T}}{\lambda_n\bar{L}}\right)\frac{\partial TS_n}{\partial TS_k} \tag{1.92}$$

$$\frac{\partial y_n}{\partial V_1} = 0 \tag{1.93}$$

$$\frac{\partial y_n}{\partial \bar{T}} = \frac{1}{\alpha + \iota_n - \alpha\iota_n}\left(\frac{TS_n}{\lambda_n\bar{L}}\right) \tag{1.94}$$

If no wage subsidies are paid, then (1.94) becomes

$$\frac{\partial y_n}{\partial \bar{T}} = \frac{1}{\alpha + \iota_n - \alpha\iota_n}\left(\frac{1}{\bar{L}}\right) \tag{1.95}$$

$$\frac{\partial d_{ni}}{\partial \lambda_k} = 0 \tag{1.96}$$

$$\frac{\partial d_{ni}}{\partial w_k} = 0 \tag{1.97}$$

$$\frac{\partial d_{ni}}{\partial \pi_{kk}} = 0 \tag{1.98}$$

$$\frac{\partial d_{ni}}{\partial TS_k} = A.Diff. \tag{1.99}$$

$$\frac{\partial d_{ni}}{\partial V_1} = 0 \tag{1.100}$$

$$\frac{\partial d_{ni}}{\partial \bar{T}} = A.Diff. \tag{1.101}$$

$$\frac{\partial a_n}{\partial \lambda_k} = -\tilde{a}_n \kappa^a \left(\frac{TS_n\bar{T}}{\lambda_n \bar{L}} + 1\right)^{\kappa^a - 1} \left(\frac{TS_n\bar{T}}{\lambda_n^2 \bar{L}}\right) \left(\lambda_n \bar{L}\right)^{\mu} \frac{\partial \lambda_n}{\partial \lambda_k} + a_n^* \frac{\mu}{\lambda_n} \frac{\partial \lambda_n}{\partial \lambda_k} \tag{1.102}$$

$$\frac{\partial a_n}{\partial w_k} = 0 \tag{1.103}$$

$$\frac{\partial a_n}{\partial \pi_{kk}} = 0 \tag{1.104}$$

$$\frac{\partial a_n}{\partial TS_k} = \tilde{a}_n \kappa^a \left(\frac{TS_n\bar{T}}{\lambda_n \bar{L}} + 1\right)^{\kappa^a - 1} \left(\lambda_n \bar{L}\right)^{\mu} \left(\frac{\bar{T}}{\lambda_n \bar{L}}\right) \tag{1.105}$$

$$\frac{\partial a_n}{\partial V_1} = 0 \tag{1.106}$$

$$\frac{\partial a_n}{\partial \bar{T}} = \tilde{a}_n \kappa^a \left(\frac{TS_n\bar{T}}{\lambda_n \bar{L}} + 1\right)^{\kappa^a - 1} \left(\lambda_n \bar{L}\right)^{\mu} \left(\frac{TS_n}{\lambda_n \bar{L}}\right) \tag{1.107}$$

If no investments in production amenities are paid then (1.102) becomes

$$\frac{\partial a_n}{\partial \lambda_k} = a_n^* \frac{\mu}{\lambda_n} \frac{\partial \lambda_n}{\partial \lambda_k} \tag{1.108}$$

Finally, the derivative of the objective function is as follows

$$\frac{\partial OBJ_1}{\partial \lambda_k} = 0 \tag{1.109}$$

$$\frac{\partial OBJ_1}{\partial w_k} = 0 \tag{1.110}$$

$$\frac{\partial OBJ_1}{\partial \pi_{kk}} = 0 \tag{1.111}$$

$$\frac{\partial OBJ_1}{\partial TS_k} = 0 \tag{1.112}$$

$$\frac{\partial OBJ_1}{\partial V_1} = -1 \tag{1.113}$$

$$\frac{\partial OBJ_1}{\partial \bar{T}} = 0 \quad . \tag{1.114}$$

2

Optimal allocation of economic activity

2.1 Introduction

Policy makers in most developed countries are concerned about the increase in the spatial concentration of economic activity. To countervail the rising inequality, governments often implement large-scale programs that specifically direct resources towards well-defined geographic areas. From an efficiency perspective, such interventions are often justified with positive agglomeration externalities. A large body of literature argues that the spatial concentration of economic activity leads to spillovers. Thereby, agglomeration economies create productivity gains, and tightness in the housing market generates congestion externalities. In this paper, I characterize the efficient allocation of economic activity, which internalizes all spatial spillovers. Comparing spatial policies to this natural benchmark helps academics and policy makers to identify efficient designs of spatial policies.

My analysis is based on economic geography models studied in Allen and Arkolakis (2014) and Redding (2016). Essentially, to incentivize workers to live in the efficient allocation, a transfer scheme is necessary. I follow Fajgelbaum and Gaubert (2018) in defining the optimal transfer scheme that tackles market externalities arising from the concentration of workers. In the optimal spatial allocation of economic activity, net marginal benefits of agglomeration balance the opportunity cost of attracting workers across all inhabited locations. By calibrating the model to European Union (EU) data, I show that a welfare gain of 4.7% can be reached if workers are allocated most efficiently. This implies that a central government must levy an average labor income tax of about 31% to finance transfers.

By comparing net transfers that restore the first-best allocation to the actual EU regional policy, I find that both policies target the same main beneficiaries. However, relative to the optimal policy, the actual EU regional policy distributes an over-proportional high share of the budget to its poorest regions. This deviation does not necessarily imply malpractice by the EU government as the optimal policy requires a significantly higher budget to reach the efficient allocation.

By calculating the policies' welfare impact under various budgets, I show that welfare gains of the actual EU regional policy are higher for the observed budget. Consequently, directing transfers to impoverished regions is efficient and in line with Blouri and Ehrlich (2019). In their study, they describe the optimal distribution of transfers given the observed budget, i.e. a second-best scenario, and show that the EU can improve its welfare gain by further concentrating wage subsidies to peripheral regions. However, as the size of the budget increases, spreading transfers more evenly across space becomes more efficient as suggested by the first-best policy.

The optimal policy's size is shaped by the distribution of the returns to the fixed factor. Because the immobile sector redistributes resources from high-income to low-income regions, the optimal policy must outweigh the shift of resources absent of any policy intervention. Different to Fajgelbaum and Gaubert (2018), I describe optimal transfers under region-specific ownership structures of the immobile sector. Having calibrated region-specific ownership structures, I show that regions with low ownership of the fixed factor are poorer (all else equal) and should receive a higher share of transfers to restore the first-best allocation.

The remainder of the paper is organized as follows. Section 2.2 introduces the model. Section 2.3 describe the data and calibration. Section 2.4 analyzes the optimal allocation. Section 2.5 summarizes the study and draws conclusions.

2.2 An economic geography model to describe aggregate efficiency

To study the optimal distribution of economic activity, I consider a framework, where households in location $i \in N$ have Cobb-Douglas preferences over a tradeable consumption good C_i and an inelastically supplied housing good H_i, with an expenditure share of consumption $\alpha \in \{0, 1\}$. The expected common utility component of workers is

$$U_i = B_i L_i^{\gamma^A} C_i^{\alpha} H_i^{1-\alpha}, \tag{2.1}$$

where γ^A denotes an amenity spillover elasticity, B_i refers to amenities and L_i denotes population in location i. The amenity spillover translates to the dispersion of worker's tastes or rivalry in location amenities allowing for imperfect sorting of workers. Tradeable goods production in region i is $X_i = \bar{a}_i L_i^{1+\gamma^P}$, where $\bar{a}_i$ is the exogenous production amenity of location i, and agglomeration spillovers γ^P governs the efficiency of labor to produce a tradeable consumption variety. The final consumption good is aggregated by a CES of traded commodities. Worker's income in location i is defined as

$$y_i = w_i + b_i + t_i, \tag{2.2}$$

where gross wage w_i equals to tradeable output per worker, b_i are workers rents from the immobile factor and t_i are per-capita net regional transfers in location i. Evidently, the policy creates trade imbalances amounting to the regional net size of the policy $t_i L_i$. Another source of trade imbalances stems from the distribution of the immobile sector's returns $b_i = \omega_i(1-\alpha)y_i + \frac{\sum((1-\omega_i)(1-\alpha)y_i L_i)}{\bar{L}}$, which are redistributed locally or commonly to residents according to parameter $\omega_i \in \{0, 1\}$. Thereby, a fraction ω_i of the rents is distributed to local residents and the remainder is evenly split across the whole population. Housing rents are owned locally if $\omega = 1$, whereas rents are owned commonly if $\omega = 0$. Overall, the aggregate redistribution of rents must be equal to the aggregate yields of the immobile sector, such that $\sum L_i b_i = (1-\alpha)\sum y_i L_i$.

Following Fajgelbaum and Gaubert (2018) the optimal allocation of workers is reached by equalizing marginal benefits and costs of workers across all inhabited locations. In my model, this condition is fulfilled if

$$(1+\gamma^P)w_i + \gamma^A y_i = y_i + E, \qquad \forall i \in N. \tag{2.3}$$

The left hand side of the above equation equals to the value of the marginal product of labor and marginal costs through amenity spillovers of workers living in i measured in expenditure equivalent units. The right hand side, measures the costs of additional workers in location i, where an additional worker inevitably translates into less consumption for other workers in i and a constant opportunity cost E of employing an additional worker in the economy. Combining the expression with (2.2), I get the optimal policy t_i^*, which implements the efficient allocation

$$t_i^* = s_i w_i + T_i, \tag{2.4}$$

where the labor income tax $s_i \equiv \frac{1+\gamma^P}{1-\gamma^A}[1-(1-\alpha)\omega_i] - 1$ and $T_i \equiv -\frac{\sum(1-\omega_i)(1-\alpha)y_i L_i}{\bar{L}} - \frac{s+1}{1+\gamma^P}E$. Thus, the parameters determining the optimal policy are the production and amenity spillover, the expenditure share in consumption goods, and the ownership of the immobile factor in location i. The constant opportunity cost E is to be chosen such that the policy's budget is balanced, i.e. $\sum t_i L_i = 0$. The redistribution of housing rents across workers is crucial to determine the size of the optimal policy. If local rents of the fixed factor are redistributed locally ($\omega = 1$), no trade imbalances from the immobile sector emerge. In turn, this implies a higher size of the optimal policy and more redistribution towards low-income regions through the policy in the efficient equilibrium. In contrast, if rents are commonly owned ($\omega = 0$), the ownership structure already entails a redistribution from rich to poor regions due to differences in the region-specific yields of the fixed sector. Hence, transfers in the optimal allocation must be smaller to compensate for trade imbalances arising from the immobile sector. Consequently, regions with a low ownership share of the fixed factor are poorer (all else equal) and receive a higher share of transfers in the efficient scenario.[1]

2.3 Data and calibration

To analyze regional policy in Europe, I employ the data described in Blouri and Ehrlich (2019) and adopt their calibration. In summary, I rely on regional transfers (structural and cohesion funds) from the EU Commission for the budgeting period 2007-13 aggregated to NUTS2 regions for the EU27 member countries. Cambridge Econometrics' European Regional Database provides information on employment (L_i), and per capita income (y_i). Information about residential land-use (H_i) stems from the dataset "Ecosystem types of Europe" published by the European Environment Agency. Trade costs (d_{ni}) for Europe are computed according to a model-based approach as described in Allen and Arkolakis (2016). In line with Blouri and Ehrlich (2019) I set the share of consumption expenditure $\alpha = 0.75$, the elasticity of substitution $\sigma = 5$, agglomeration elasticity $\gamma^P = 0.1$, and the heterogeneity of preferences $\gamma^A = -\frac{1}{3}$. Finally, I calibrate the region-specific ownership structure of the fixed factor ω_i equal to estimated values of Blouri and Ehrlich (2019).

[1] By ignoring regional differences in the ownership structure of the immobile sector the optimal policy (2.4) is equivalent to the expression presented in Fajgelbaum and Gaubert (2018). In their case, net transfers consist of a common labor income tax and a lump-sum component. Despite regional differences in location fundamentals, the optimal policy restoring aggregate efficiency becomes invariant across space.

2.4 Counterfactual analysis

In this section, I discuss the implications of three spatial policies on the distribution of economic activity relying on the framework outlined in Section 2.2. More specifically, I calculate the consequences of i) actual transfers, ii) second-best transfers as derived in Blouri and Ehrlich (2019), where optimal wage subsidies are calculated given the government is confined to increase the policy's expenses and iii) transfers restoring the first-best allocation as described in Section 2.2. Having computed counterfactual changes relative to the observed economy, I compare the policies' welfare gain for various budgets. Next, I start by providing an overview of the regional consequences of transfers restoring the efficient allocation.

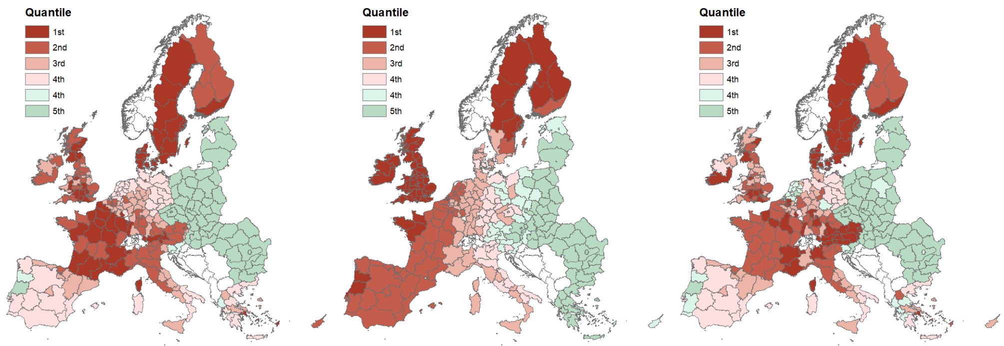
2.4.1 Optimal distribution of economic activity

The optimal policy reaching the first-best spatial allocation of workers requires on average a proportional income tax rate s_i of 31.3%. The corresponding average transfer T_i is 10'013 Euro. Implementing such a redistributive policy increases welfare by 4.7% relative to the observed economy. In a political economy, interventions are typically carried out under inequality considerations. Despite the welfare gain realized by implementing optimal wage subsidies, transfers to impoverished regions also achieve a more equal income situation than currently observed. Under the optimal scenario, the EU should direct transfers to peripheral regions, which decreases regional nominal income inequality by 35.5% as measured by a decrease in the Gini coefficient. Implementing the efficient allocation of economic activity requires that 15.9% of the EU population relocate to reach the highest possible welfare outcome of the economy. Figure 2.4.1 shows the spatial implications of implementing the first-best subsidy relative to the observed economy. Specifically, Panel a) shows the change in population, Panel b) depicts the change in wages and Panel c) reports the distribution of net transfers.

Table 2.4.1 shows how the ownership structure shapes the optimal policy. Assuming a local ownership structure, I get an optimal tax rate equal to 38.1% and a welfare gain of 6.0%. Focusing on the other extreme, where all rents are redistributed equally, I get an optimal tax rate equal to 17.5% and a welfare gain of 0.3%. Because the common ownership of the immobile sector creates trade imbalances absent of any policy, the welfare and size of the optimal policy varies considerably across the

Figure 2.4.1: Optimal allocation of economic acitivity

(a) Population ($\hat{\lambda}_n$) (b) Wages ($\hat{w}_n$) (c) Net Subsidies (t_n)



Note: The figures compare the efficient allocation to the observed economy. Changes in the respective variable are reported by quantiles. Dark shadings represent a stronger effect, where a green (red) color illustrates an increase (decrease).

specified cases. In my benchmark case discussed above, I focus on an intermediate case, where a region-specific share of the returns ω_i is redistributed to local residents of i and the remainder is split equally across all residents.

Table 2.4.1: Optimal policy: Varying the ownership structure

Scenario	Welfare gain	Tax rate ($-s_i$)	Transfers (T_i)
Complete local ownership ($\omega_i = 1$)	6.0%	38.1%	11'897
Region-specific ownership (estimated ω_i)	4.7%	31.3%	10'013
Complete common ownership ($\omega_i = 0$)	0.3%	17.5%	6'742

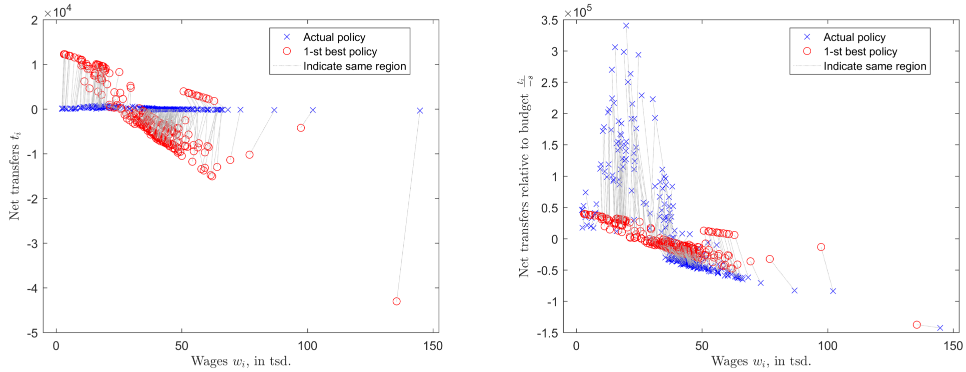
Notes: The table describes the optimal policy restoring aggregate efficiency under different assumption of the fixed factor's ownership structure.

2.4.2 Comparing the EU regional policy with the optimal allocation

The previous Section documents the potential welfare gains of reaching a first-best allocation of workers in Europe. Relative to the actual EU regional policy, optimal transfers in the first-best allocation differ in the size of the budget and the relative distribution of transfers to regions. In Figure 2.4.2 I compare the optimal subsidies that restore aggregate efficiency to the actual EU regional transfers. From Panel a), it is evident that the size of the EU regional policy is too small compared

Figure 2.4.2: Optimal compared to actual policy

(a) Net transfers (t_i) (b) Net transfer per tax rate ($t_i/{-s}$)



Note: The figures compare the first-best transfers to the actual regional policy of the European Union.

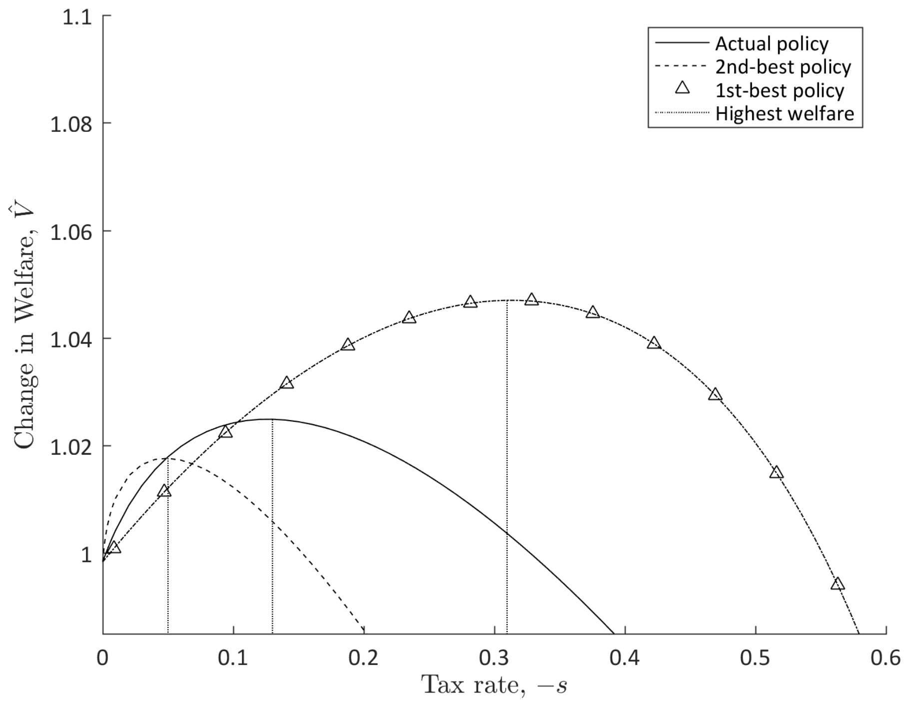
to the optimal policy. This is verified by the steeper curve of optimal net transfers. Panel b) compares net transfers of both policies relative to the size of the budget. As depicted, in both cases the main net beneficiaries are similar. This is supported by a correlation coefficient of 0.62, which confirms the strong positive relationship in the relative transfer distribution. However, relative to the size of the budget, the EU systematically deviates from the optimal policy by redistributing an over-proportional high amount of subsidies towards poor regions. In the next section, I investigate to what extent the concentration of transfers to poor regions is efficient.

2.4.3 Role of the program's size

The necessary tax rates to finance transfers in the efficient allocation are about 126 times higher than the tax rates of the actual EU regional policy. Under the same model assumptions, Blouri and Ehrlich (2019) numerically solve for the optimal distribution of transfers given the observed size of the policy budget does not change (i.e. a second-best policy). Following their optimization approach, I compare relative transfer shares materialized in this second-best scenario to the other policies. To investigate how deviations of the EU regional policy to the optimal policy affect welfare, I calculate the policies' welfare gains by varying the budget of the programs. More specifically, I conduct various policy simulations and compare the welfare outcome of i) the actual, ii) the second-best, and iii) the first-best scenario. To this end, I gradually increase tax rates (i.e. size of the budget) for the three policies while leaving the relative distribution of transfers unchanged.

Figure 2.4.3 shows the welfare effect of the policies under various budgets. Evidently, the relative distribution of transfers implementing the first-best allocation

Figure 2.4.3: Varying the size of the budget



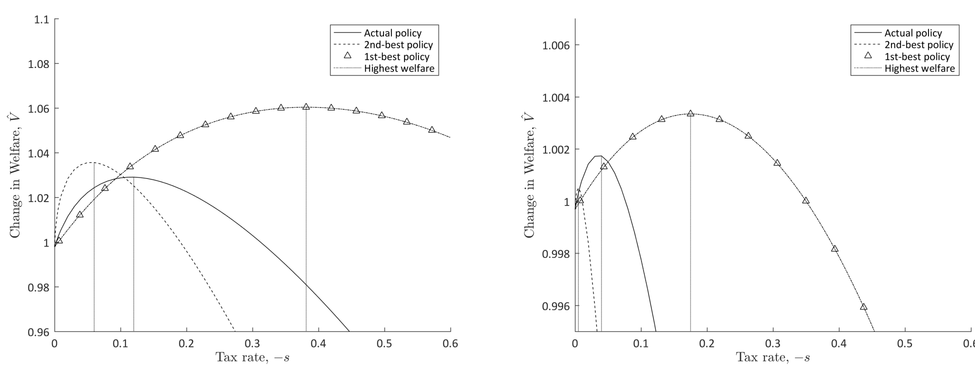
Note: The figure compares relative transfer shares to the observed regional policy of the European Union.

does not always achieve the highest welfare outcome. For lower budgets, the actual EU policy is to be preferred to the first-best allocation. In this context, the welfare gain of the actual EU policy is higher compared to the efficient policy. From a welfare perspective, concentrating the limited resources available to poorer regions is efficient. Despite the welfare gain of the actual EU regional policy, the EU can further improve its policy given the observed budget. As depicted and argued by Blouri and Ehrlich (2019), the second-best scenario achieves the highest welfare gain for the observed tax rate of 0.2%. However, the second-best policy reinforces the concentration of transfer spendings and directs all resources to a selection of poorest regions in the EU. For higher budgets, this extreme concentration is not welfare efficient and outperformed by the first-best, as well as by the actual EU regional policy. Finally, I conclude that transfers in Europe improve welfare as evident by investigating the zero tax rate case in the Figure. Abolishing EU regional policy leads to the same welfare loss of -0.16% for all three policies compared to the actual situation.

By emphasizing the role of the immobile sector, Figure 2.4.4 reports welfare effects for complete local and common ownership structures under varying budgets. As illustrated in Panel a) with local ownership and in Panel b) with common

Figure 2.4.4: Varying the size of the budget: Role of the immobile sector's ownership structure

(a) Local ownership ($\omega = 1$) (b) Common ownership ($\omega = 0$)



Note: The figures compare relative transfer shares to the observed regional policy of the European Union.

ownership, the qualitative pattern of the three policies remains stable. However, compared to my benchmark case, welfare gains change significantly across the specified ownership structures. Because the redistribution of the fixed factor's returns in Panel b) already entails a redistribution via trade imbalances, the size of the optimal policy and, thus, welfare gains are smaller as discussed in Section 2.4.1.

2.5 Conclusions

Public policies that target distinct regions significantly alter the geographic distribution of workers across space. In this paper, I study the optimal allocation of economic activity in a quantitative economic geography framework. I characterize the welfare-maximizing allocation of workers and describe the transfers that must hold in the efficient allocation. Three main results arise from my analysis. First, different to several studies of place-based policies, I show that transfers reallocating workers can lead to welfare gains. Second, the actual EU regional policy directs transfers to the same net beneficiaries as suggested by transfers restoring the first-best allocation.

Third, to reach the welfare gain of the first-best allocation, a significant increase in the budget is necessary and transfers should be distributed more evenly across space.

Moreover, I investigate how the size of the budget and rents of the housing sector render the optimal spatial policy. By analyzing welfare gains under various budgets, I show that an evenly distributed transfer scheme is only to be preferred for higher budgets. While a tax increase might politically be unenforceable, I show that the EU should favour the actual policy over the relative distribution of transfers restoring the efficient allocation. Limiting the budget to actual tax returns, the actual EU regional policy leads to a higher welfare because major shares of the transfer payments are directed to the most deprived regions.

The results of this study hold important lessons for the evaluation of spatial policies. There are undoubtedly further dimensions affecting the effectiveness of transfers such as the excess burden of taxation or the quality of local institutions. Despite this, I am convinced that the systemic approach of comparing actual market interventions to model-based optimal spatial policies is instructive to improve on the design of public policies.

3

The geography of housing subsidies

joint with **Simon Büchler and Olivier Schöni**

3.1 Introduction

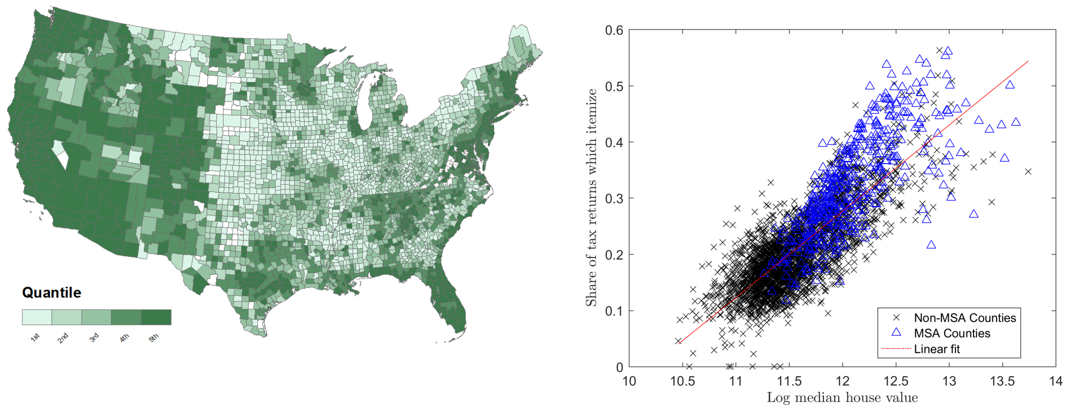
Every year, the US federal government forgoes tens of billions of tax revenue to subsidize homeownership. In 2013, the Mortgage Interest Deduction (MID) represented about 6% of the United States federal income tax revenue, that is about 98.5 billion USD. Yet this substantial tax expenditure is far from being equally distributed across the country's territory. In 2013, the average owner-occupier living in New York County (NY) received 1'813 USD in housing subsidies – about 2.13 times as much as the average owner-occupier in the US, whereas owner-occupiers of Sheridan County (WY) received an average of 222 USD per capita – about one fourth of the US average housing subsidy. In this paper, we investigate how this unequal geographic distribution of MID subsidies affects local labor and housing markets and, ultimately, welfare.

To this end, we start by developing a spatial general equilibrium model featuring the main characteristics of the US federal income tax system. In our model individuals respond endogenously to tax incentives by choosing where to live, where to work, and tenure mode. If they become owner-occupiers, they can decide whether to deduct from their taxable income a standard deduction, common to both renters and owners, or the interests paid on a mortgage loan. We calibrate our model to replicate the observed distribution of renters, owner-occupiers, commuting flows, and income across US counties. Keeping federal public expenditure constant, we find that suddenly repealing the MID would lower homeownership rates by only 0.19 percentage points, implying that the Federal Government has to forgo about 32′000 USD of income tax revenue to create a single new owner-occupier. The repeal would even slightly increase welfare by 0.01%, suggesting that every year US citizens would willingly pay about 37 million USD to abandon the MID.

The slightly positive welfare effect of the repeal is the aggregate result of heterogeneous responses occurring at the local level, which are mainly given by the migration response of residents from congested housing markets to more elastic ones, by a shift of the housing demand from the owner-occupied to the rental market, and by a decrease of costly commuting flows across counties. As a result of these responses, the spatial inequality of the income distribution across counties is lowered by 0.05%. When using the structure of the model to quantify the importance of spatial spillovers for the migration response of renters and owner-occupiers to the

Figure 3.1.1: County-level MID descriptives in 2013

(a) Average subsidy per homeowner (b) Probability of itemization



Note: Tax and MID subsidy data stem from Internal Revenue Service (IRS). Housing values provided by the American Community Survey (ACS) are averaged over 2009-2013. MSAs areas are defined according to Saiz (2010).

repeal, we find that approximately 33% of the residents' elasticity is due to non-local indirect effects. These non-local effects are mostly due to the spatial linkages between locations via commuting, whereas migration and trade are less important.

In our spatial framework, we allow locations to differ in terms of productivity, housing supply elasticity, and amenities. The spatial distribution of renters and owner-occupiers is determined by the opposing effect of agglomeration and dispersion forces. The accessibility via commuting to productive locations and home markets effects lead people to concentrate in some locations, whereas housing markets and idiosyncratic tastes for location and tenure disperse them. In this baseline setting, MID subsidies counter the dispersion force of housing markets for homeowners, as they are proportional to the periodic cost of ownership. Due to commuting linkages between locations, congested housing markets of productive locations do not necessarily prevent people from working in that location and, vice versa, low-productivity places might still attract residents. We match our model to observed data on the distribution of renters, owners, and commuting flows, as well as to estimated parameters for local housing supply elasticities, trade and commuting costs elasticities. The unique equilibrium solution of the model allows us to recover location fundamentals – productivity and individuals' taste for locations and tenure – that perfectly mimic the geographic distribution of the observed data.

Local housing supply elasticities are of particular importance in our setting, as they affect the equilibrium response of local housing markets to shifts in the housing demand. In order to analyze demand shifts between rental and onwer-occupied markets, we model two separate supply functions for these markets. This allows us to track tenure-specific equilibrium changes in the periodic costs of housing.[1] Following Saiz (2010) methodology, we use US Census data on housing prices and stock changes between 1980 and 2000 to estimate housing supply elasticities at the county level. Specifically, we use housing demand shifters exogenous to the economic channels present in the structural framework to recover the shape of the housing supply function. Complementing the existing literature, we find novel evidence that county-level housing supply elasticities show important spatial variation within urban areas and between urban areas and the countryside.

Our spatial framework entails several advantages. First, it allows us to investigate a variety of tax policies affecting housing subsidies across US counties. As shown in Figure 3.1.1, a spatial approach seems pertinent, as the distribution of per capita MID subsidies varies considerably across locations (panel a[2]) and itemization rates are spatially targeted to congested housing markets displaying high housing prices (panel b). Existing research has mostly focused on aggregate (MSAs) areas comprising these congested markets and estimated the average effect of a homogeneous marginal decrease of MID subsidies across aggregate areas. Second, the spatial linkages present in the structure of the model allow us to understand and quantify local spatial spillovers generated by the initial heterogeneous shock of the MID repeal, which affect the aggregate welfare response. In that regard, empirical research has to suppose that the Stable Unit Treatment Value Assumption (SUTVA) is fulfilled to estimate the causal impact of MID subsidies, which precludes the possibility of spatial spillovers within treated areas and from treated areas to non-treated ones.[3] Third, our model allows us to investigate the joint decision of where to live, where to work, and tenure mode. This is a novel mechanism not explored in the existing structural literature. In the real world, we do expect individuals to react to tax incentives by adapting their location and tenure choices, thereby altering the geographic distribution of residents and workers across space.

[1]A similar approach has been adopted by Glaeser (2008) in the case of skilled and unskilled worker consuming heterogeneous types of housing goods having separate supply functions.

[2]Gyourko and Sinai (2003) point out that the distribution of income-tax subsidies to owner-occupiers remain stable over time.

[3]A standard approach in the literature has been to use a high level of aggregation, such as MSAs, to alleviate these spatial spillovers. However, as pointed out by Monte et al. (2018), spatial linkages between locations remain important when using this level of aggregation.

Simulation results suggest that an unexpected MID repeal would lead to a slight welfare increase. However, such a repeal would likely be met with hostility by owner-occupiers. A legitimate question is thus whether the federal government might want to implement alternative policies to reduce the disparity in the tax treatment of renters and owner-occupiers. Despite not being its main aim, a recent example of such a policy is provided by the Tax Cuts and Jobs Act (TCJA), which was promoted by President Trump's administration and came into force in January 2018.[4] One of the major elements of President Trump's tax reform is the doubling of the standard deduction that households (both renters and owner-occupiers) can deduct from their taxable income. We use the general applicability of our structural framework to evaluate the welfare impact of this increase of the standard deduction. Following President Trump's reform, we find that homeowners' MID itemization rates drop from 30.4% to 0.65% and homeownership rates decrease by 0.02 percentage points, leading to a welfare decrease of 0.05% for the whole of the country. Put differently, every year US citizens would willingly pay about 544 million USD to avoid this specific feature of the TCJA. The welfare decrease is mainly due to the subsidization of housing in the countryside, which diverts workers from productive areas.

The present paper contributes to three strands of the literature. The first strand investigates the impact of the MID on ownership attainment and various economic outcomes.[5] Recent empirical research suggests that the MID is an ineffective instrument to increase homeownership. Hilber and Turner (2014) empirically show that the US federal and state MIDs capitalize into higher prices in major urban areas characterized by tightly regulated housing market, thus achieving little to improve homeownership rates. By endogenizing tenure choices and calibrating a two-region framework for Boston (MA), Binner and Day (2015) argue that it might be possible to reform the MID while leaving homeownership rates unchanged. Gruber et al. (2017) empirically analyse a major policy reform in Denmark, which led to a substantial reduction of the MID for top-rate taxpayers. Their findings provide strong evidence that removing the subsidy mainly lowered housing prices and had no effects on homeownership attainment. On the contrary, eliminating the MID led to a reduction in indebtedness. Sommer and Sullivan (2018) use a dynamic macroeconomic model to show that abolishing the MID in the US would lead to a

[4]Some features of the reform, such as the doubling of the standard deduction, are expected to come to an end in 2025.

[5]See Hilber and Turner (2014) for a comprehensive review of the literature.

higher welfare. The equilibrium channels driving this welfare gain are lower house prices, higher homeownership rates, and lower mortgage debt.

Another strand of the literature investigates the spatial (mis)allocation of workers and the role of housing supply. Calibrating a model for US metropolitan areas, Albouy (2009) analyses the impact of the US federal income taxation on the allocation of workers across space. He persuasively shows that for a given real income, workers in high-density areas end up paying more taxes than those in more remote areas. Adopting a structural approach, Diamond (2016, 2017) investigates the link between housing supply and labor markets. In particular, these studies show that, because affecting the migration response of workers, housing supply elasticities can be exploited to identify the slope of the labor demand curve. Fajgelbaum et al. (2019) investigate how the dispersion of US state income tax rates affects location choices of households across states. The authors show that the more pronounced the differences in income tax rates between US states are, the higher the welfare loss for the society, as workers spatially misallocate across space due to tax differentials. Hsieh and Moretti (2019) find that housing supply constraints misallocate workers by preventing them from working in productive areas, thereby hindering economic growth.

Finally, we contribute to the structural literature that investigates quantitative economic geography models by introducing several model extensions, such as households' joint decision of residential location, working place, and housing tenure. Monte et al. (2018) integrate the spatial interdependence of trade, commuting, and migration in a tractable model. Similarly, Favilukis and Van Nieuwerburgh (2017) assess the effect of out-of-town home buyers on major cities like New York in a model where heterogeneous households choose tenure and an optimal portfolio. Employing a structural framework, Blouri and Ehrlich (2019) characterize optimal regional policies that a central government can implement under budgetary constraints to improve welfare and reduce income inequality across locations.

The remainder of the paper is structured as follows. Section 3.2 presents the spatial equilibrium model. Section 3.3 describes the data, illustrates the estimation of county-level housing supply elasticities, and explains the counterfactual analysis. Section 3.4 investigates the impact of repealing the MID and analyzes the role played by spatial spillovers to determine the response of local residents to the repeal. Section 3.5 investigates the welfare implications of making MID itemization less attractive via a doubling of the standard deduction. Section 3.6 concludes.

3.2 A quantitative spatial model featuring housing subsidies

We consider an economy populated by a continuous measure $\bar{L}$ of workers that are distributed across N locations (US counties). Extending the theoretical framework by Monte et al. (2018), each worker decides in which location i to live, in which location j to supply one unit of labor inelastically, and its tenure model $\omega \in \{\mathcal{O}, \mathcal{R}\}$. The federal government levies income taxes at an average rate τ and uses the collected tax revenue to provide public goods G.[6] Workers earn a tenure-specific after-tax income y_{ni}^{ω} which is affected by the tax subsidies provided by the federal government.

3.2.1 Households' heterogeneous preferences

The indirect utility $V_{ni}^{\omega}(h)$ of a household h living in location n, working in location i, and having a tenure mode ω is given by the following Cobb-Douglas form

$$V_{ni}^{\omega}(h) = \frac{b_{ni}^{\omega}(h)}{\kappa_{ni}} G^{\beta} \left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}} \right)^{1-\beta}, \tag{3.1}$$

where $b_{ni}^{\omega}(h)$ is an idiosyncratic taste component for a specific combination of place of residence, place of work, and tenure. We assume that the scalar utility shifter $b_{ni}^{\omega}(h)$ is the i.i.d. realization of a random variable b_{ni}^{ω} having a Fréchet distribution with a cumulative density function $\Omega_{ni}^{\omega}(b) = e^{-B_{ni}^{\omega} b^{-\epsilon}}$. The scale parameter $B_{ni}^{\omega} > 0$ determines the average idiosyncratic value workers attach to a specific $n/i/\omega$ combination, whereas the shape parameter $\epsilon > 1$ characterizes the taste dispersion for such a combination. The higher the value of ϵ, the less dispersed the distribution of tastes.

The remaining components of the indirect utility are deterministic factors common to all workers having chosen a specific combination. The variable κ_{ni} denotes exogenous commuting costs in terms of utility beared by workers living in

[6] In Section 3.D of the Appendix we extend our framework to include a progressive tax schedule and show that our main results are left unchanged.

location n and working in i. Public good consumption is denoted by G and real after-tax income is given by $y^{\omega}_{ni}/P^{\alpha}_{n} r^{\omega 1-\alpha}_{n}$, where y^{ω}_{ni} denotes after-tax labor income, P_n is the price index of a basket of tradable goods, and r^{ω}_{n} is the tenure-specific cost of housing per unit of surface. The share of income spent for the composite consumption good is given by the parameter $\alpha \in [0, 1]$ and $\beta \in [0, 1]$ governs the workers' fondness for public good provision with respect to real after-tax income.

Each location specializes in the production of a single tradable consumption good. Workers consume a composite basket of goods C_n according to the following CES function

$$C_n = \left(\sum_{i \in N} c_{ni}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{3.2}$$

where c_{ni} denotes the aggregate consumption in location n of the good produced in i. The parameter σ governs the elasticity of substitution between tradable goods. In equilibrium, we have that $c_{ni} = \alpha \bar{y}_n R_n p_{ni}^{-\sigma} P_n^{\sigma-1}$, where R_n is the number of residents in location n and $\bar{y}_n$ is location's n per-capita disposable income. The price index P_n depends on the price of individual varieties p_{ni} according to $P_n = \left[\sum_{i \in N} p_{ni}^{1-\sigma} \right]^{1/(1-\sigma)}$. In turn, prices p_{ni} equal a local price p_i, determined where the good is produced, multiplied by iceberg trade costs d_{ni} between any two locations.

3.2.2 Location-specific disposable income

The amount of per capita disposable income $\bar{y}_n$ available in location n for tradable goods and housing consumption is given by the after-tax income of households and by the redistribution of public expenditure, mortgage interests, and rental payments to that location. We start by describing the per capita income $y^{\mathcal{O}}_{ni}$ of owner-occupiers living in n and working in i, which differs in three important aspects from the one of renters having chosen the same commuting pattern. First, owner-occupiers have to pay mortgage interests to the financial institution providing the mortgage loan. Second, owner-occupiers receive an additional source of income in the form of an imputed rent, which corresponds to the rent they would have to pay if they were to rent the house in which they currently live in.[7] Third, owner-occupiers choose between itemizing the MID or claiming a standard tax deduction. The after-tax

[7] As pointed out in literature, for example by Sinai and Gyourko (2004) and Sommer et al. (2013), the non-taxation of imputed rental income represents a fiscal disincentive for owner-occupiers to become landlords and rent out their property.

income of an owner-occupier is thus given by

$$y_{ni}^{\mathcal{O}} = w_i - \tau(w_i - \zeta_{ni}) + \frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}} - m_{ni}, \tag{3.3}$$

where

$$\zeta_{ni} = \max(s, \theta m_{ni}). \tag{3.4}$$

The term w_i denotes labor income, $\tau \in [0,1]$ is the flat income tax rate set by the federal government, and m_{ni} is the periodic interest paid on the mortgage loan. The income component $\frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}}$ is the imputed rent, which depends on the share λ_{ni}^{O} of owner-occupiers living in n and working in i and their corresponding aggregate housing consumption $H_{ni}^{\mathcal{O}}$.[8] The tax subsidy ζ_{ni} is affected by two exogenous parameters, the standard tax deduction s and $\theta \in [0,1]$, which governs the share of MID deductible from the taxable income. We introduce this second parameter to simulate changes in the deductibility of housing subsidies.[9] Because renters can only claim the standard tax deduction, their per capita disposable income is given by

$$y_{ni}^{\mathcal{R}} = w_i - \tau(w_i - s). \tag{3.5}$$

Note that in contrast to a standard user-cost approach, (3.3) is not necessarily equal to (3.5). This because workers' idyonsincratic preferences for location and tenure cause frictions between the rental and owner-occupied market, thereby leading to income differentials.

We now discuss the redistributive component of location's n income. We assume that public good expenditure, mortgage interests, and rental payments do not leave the economy. Rather, they accrue to a global portfolio held by a mix of federal contractors, financial institutions, and landlords. We follow Monte et al. (2018) and assume that in each location the holders of the portfolio consume tradable goods and housing proportionally to the number of residents in that location. The portfolio

[8]In our setting, owner-occupiers benefit from capital gains in the housing market via an increase in their imputed rental income. In Section 3.D.1 of the Appendix we extend the model to include property taxes, which decrease imputed rental income.

[9]A repeal of MID subsidies, as implemented in our counterfactual simulations, corresponds to the case $\theta = 0$ such that ζ_{ni}=s.

income Π that a location receives for each one of its residents is given by

$$\Pi = G + \frac{\sum_{n,i \in N}(\bar{L}\lambda^O_{ni} m_{ni} + H^R_{ni} r^R_n)}{\bar{L}}, \tag{3.6}$$

where H^R_{kf} is the total housing consumption of renters living in n and working in i, such that the term $\sum_{n,i \in N}(\bar{L}\lambda^O_{ni} m_{ni} + H^R_{ni} r^R_n)$ represents the total amount of mortgage interest and rental payments in the economy.

Total disposable income of region n is

$$\bar{y}_n R_n = \bar{y}^{\mathcal{O}}_n R^{\mathcal{O}}_n + \bar{y}^{\mathcal{R}}_n R^{\mathcal{R}}_n, \tag{3.7}$$

where R^ω_n is the tenure-specific number of residents. Expected disposable income $\bar{y}^\omega_n$ is given by tenure-specific income and per capita income from the global portfolio

$$\bar{y}^\omega_n = \sum_{k \in N} \lambda^\omega_{nk|n} y^\omega_{nk} + \Pi, \tag{3.8}$$

where $\lambda^\omega_{ni|n}$ is the tenure-specific share of workers residing in n and working in i, conditional on living in n, i.e. $\lambda^\omega_{ni|n} = \frac{\lambda^\omega_{ni}}{\sum_k \lambda^\omega_{nk}}$.[10]

3.2.3 Federal public good provision

Federal tax revenue is levied on the taxable labor income of renters and owner-occupiers. Provision of the federal public good G entering the utility of workers equals the per-capita tax revenue, such that

$$G = \frac{1}{\bar{L}} \sum_{n \in N} \left(\tau \bar{L} \sum_{k \in N} \lambda^{\mathcal{R}}_{nk}(w_k - s) + \tau \bar{L} \sum_{k \in N} \lambda^{\mathcal{O}}_{nk}(w_k - \zeta_{nk}) \right). \tag{3.9}$$

The provision of G varies according to tax subsidies s and ζ_{nk} that renters and owner-occupiers deduct from their wages. Higher subsidies imply a lower tax revenue and thus lower public good provision. Counterfactual simulations based on the

[10] There are two reasons for not adding portfolio income Π to the income y^ω_{nk} of renters and owner-occupiers. First, we don't want the real portfolio income to modify location and tenure choices of workers. If this were not the case, a household could decide to move to a given location to earn a higher portfolio income, which seems unrealistic. Second, according to the American Community Survey, over 2009-2013 about 81% of owner-occupiers in the US did not get any income from interests, dividends, or rental income.

parameters s and θ are thus unable to isolate the direct income effect of housing subsidies on workers' decisions. To solve this problem, we follow Fajgelbaum et al. (2019) and allow the federal government to adjust the average income tax rate to keep the provision of the public good unaffected by changes in the subsidies.[11]

3.2.4 Housing markets

Households' housing expenditure in our baseline model is tenure specific due to their idiosyncratic tastes for a given tenure mode in a specific location, and the fiscal incentive provided by housing subsidies. Given Cobb-Douglas preferences, the tenure-specific expenditure for housing of workers living in location n and working in i is

$$r_n^{\omega} H_{ni}^{\omega} = (1-\alpha) y_{ni}^{\omega} \bar{L} \lambda_{ni}^{\omega}, \tag{3.10}$$

where H_{ni}^{ω} is the aggregate tenure-specific housing demand of workers living in n and working in i and r_n^{ω} is the periodic housing cost. The tenure-specific total housing expenditure H_n^{ω} in location n is obtained by adding the expenditure of renters/owner-occupiers over all workplaces i and by including housing consumption from the holders of the portfolio. This leads to

$$r_n^{\omega} H_n^{\omega} = (1-\alpha) \bar{y}_n^{\omega} R_n^{\omega}, \tag{3.11}$$

where the right-hand side of (3.11) is equal to $\sum_i (1-\alpha)(y_{ni}^{\omega} + \Pi) \bar{L} \lambda_{ni}^{\omega}$.

Owner-occupiers subscribe mortgages with an absent financial institution charging periodic mortgage interests at an exogenous rate χ set by international capital markets. Aggregate mortgage interests of owner-occupiers living in location n and working in i are a constant fraction of the total owner-occupied housing value in that location

$$\bar{L} \lambda_{ni}^{\mathcal{O}} m_{ni} = H_{ni}^{\mathcal{O}} \mathcal{P}_n^{\mathcal{O}} \cdot \xi \cdot \chi, \tag{3.12}$$

where $\mathcal{P}_n^{\omega}$ is the value of housing per unit of surface and ξ is the loan-to-value ratio.[12] To convert the house value $\mathcal{P}_n^{\omega}$ into a periodic (annual) cost r_n^{ω}, we use the usual

[11] In Section 3.C.3 of the Appendix we relax this assumption and carry out counterfactual simulations where we allow public good provision to adjust in response to a change in the housing subsidies.

[12] Note that the global portfolio affects mortgage payments only via the periodic cost of owner-occupation. If this were not the case, a higher portfolio income would increase mortgage payments, which seems unrealistic.

finite horizon present value formula $r_n^\omega = \iota \mathcal{P}_n^\omega$, where $\iota = \frac{\chi}{(1+\chi)(1-(1+\chi)^{-t})}$ and t is the lifespan of the residential unit.

We now turn to the supply side of the housing market. To analyze demand shifts between rental and owner-occupied markets, we divide the two markets by modelling two separate supply functions. This allows us to track tenure-specific equilibrium changes in the periodic costs of housing. In line with Hsieh and Moretti (2019) and Monte et al. (2018), we define tenure-specific housing supply in location n as

$$H_n^\omega = \bar{H}_n^\omega \mathcal{P}_n^{\omega,\ \eta_n}, \tag{3.13}$$

where $\bar{H}_n^\omega$ in an unobserved scale parameter and $\eta_n \in [0, \infty]$ is the local housing supply elasticity. Note that we make the simplifying assumption that the elasticity of the two markets is the same. Put differently, we allow for unobserved supply shifters contained in $\bar{H}_n^\omega$, such as housing characteristics, to affect the supply of rental and owner-occupied properties, but we restrict the relative supply responsiveness to a price shock to be the same across the two markets. The hypothesis of same responsiveness seems reasonable if we assume that factors such as regulatory and geographic constraints do not impact the supply elasticity of the two markets differently. In equilibrium, housing demand equals housing supply, leading to the following expression

$$r_n^\omega = \left(\frac{(1-\alpha)\bar{y}_n^\omega R_n^\omega}{\bar{H}_n^\omega \iota^{\eta_n}} \right)^{\frac{1}{1+\eta_n}}. \tag{3.14}$$

3.2.5 Production

Under perfect local competition and constant returns to scale as in Armington (1969), each location specializes in the production of one type of tradable consumption good. Production amenities of region n are

$$a_n = \bar{a}_n L_n^\nu, \tag{3.15}$$

where $\bar{a}_n$ is a local exogenous productivity fundamental and L_n is the amount of workers. External agglomeration economies are captured by the parameter $\nu \geq 1$, which increases the productivity of workers. Due to this agglomeration parameter, workers supplying labor in larger labor markets are more productive, earning, ceteris paribus, higher nominal wages.

Because of the constant elasticity of substitution in (3.2) the aggregate value of bilateral trade flows X_{ni} is

$$X_{ni} = p_{ni}c_{ni} = \alpha\bar{y}_n R_n \frac{p_{ni}^{1-\sigma}}{P_n^{1-\sigma}}, \tag{3.16}$$

where profit maximizing firms cause prices to equal marginal production costs: $p_{ni} = \frac{d_{ni}w_i}{a_i}$. Using these profit-maximizing prices, we can compute location's n expenditure share for goods produced in location i

$$\pi_{ni} = \frac{\left(\frac{d_{ni}w_i}{a_i}\right)^{1-\sigma}}{\sum_{k\in N}\left(\frac{d_{nk}w_k}{a_k}\right)^{1-\sigma}}, \tag{3.17}$$

and the corresponding price index of the composite consumption good is given by

$$P_n = \left(\frac{1}{\pi_{nn}}\right)^{1/(1-\sigma)} \frac{d_{nn}w_n}{a_n}. \tag{3.18}$$

To clear traded goods markets, location's n workplace income must equal its expenditure on the goods produced in that location

$$w_n L_n = \alpha \sum_{k\in N} \pi_{kn}\bar{y}_k R_k. \tag{3.19}$$

3.2.6 Labor mobility and tenure choice

Workers are mobile and jointly choose the location n where to live, the location i where to work, and tenure mode ω to maximize their indirect utility V_{ni}^{ω} across all possible choices. Let $\bar{V}(h)$ denote this maximum utility level:

$$\bar{V}(h) = \max_{n,i,\omega} V_{ni}^{\omega}(h). \tag{3.20}$$

As explained in Section 3.2.1, the stochastic nature of the indirect utility $V_{ni}^{\omega}(h)$ comes from an idiosyncratic preference term b_{ni}^{ω} that is Fréchet distributed. Because b_{ni}^{ω} shifts multiplicatively the deterministic component of V_{ni}^{ω}, the indirect utility is also Fréchet distributed. We can thus write its cumulative distribution Ψ as

$$\Psi_{ni}^{\omega}(v) = e^{-\frac{B_{ni}^{\omega}}{\kappa_{ni}^{\epsilon}}\left(G^{\beta}\left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}}\right)^{1-\beta}\right)^{\epsilon} v^{-\epsilon}}. \tag{3.21}$$

The share of workers λ_{ni}^{ω} living in n, working in i, and having tenure ω is given by the probability that the utility provided by this specific combination exceeds the maximal attainable utility across all other choices, i.e. $\lambda_{ni}^{\omega} = Pr(V_{ni}^{\omega} \geq \max_{r,k,l} V_{rk}^{l}, \ \forall r, k, l)$. Using the fact that the variable $\max_{r,k,l} V_{rk}^{l}$ is also Fréchet distributed and that $\lambda_{ni}^{\omega} = E[P(\max_{r,k,l} V_{rk}^{l} \leq v | V_{ni}^{\omega} = v)]$, we have that

$$\lambda_{ni}^{\omega} = \frac{\frac{B_{ni}^{\omega}}{\kappa_{ni}^{\epsilon}}\left(G^{\beta}\left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}}{\sum_{k\in N}\sum_{f\in N}\sum_{l\in\omega}\frac{B_{kf}^{l}}{\kappa_{kf}^{\epsilon}}\left(G^{\beta}\left(\frac{y_{kf}^{l}}{P_k^{\alpha} r_k^{l 1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}}. \tag{3.22}$$

The parameter ϵ, which governs the dispersion of idiosyncratic tastes, affects the mobility degree of workers. In the case of no taste heterogeneity across locations and tenure ($\epsilon \to \infty$), local labor supply is perfectly elastic, implying perfect population mobility. The expected utility for residence n and workplace i is

$$E[\bar{V}(h)] = \bar{V} = \delta\left[\sum_{k\in N}\sum_{f\in N}\sum_{l\in\omega}\frac{B_{kf}^{l}}{\kappa_{kf}^{\epsilon}}\left(\left(G\right)^{\beta}\left(\frac{y_{kf}^{l}}{P_k^{\alpha} r_k^{l 1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}\right]^{\frac{1}{\epsilon}}, \tag{3.23}$$

where the expectation is computed according to the distribution of idiosyncratic preferences and $\delta = \Gamma(\frac{\epsilon-1}{\epsilon})$ is a Gamma function which depends on ϵ. Inserting commuting shares (3.22) into expected utility for the residence and workplace combination (3.23) yields

$$E[V_{ni}^{\omega}] = \delta\left(\frac{1}{\lambda_{ni}^{\omega}}\frac{B_{ni}^{\omega}}{\kappa_{ni}^{\epsilon}}\right)^{\frac{1}{\epsilon}}\left(G\right)^{\beta}\left(\frac{y_{ni}^{\omega}}{P_n^{\alpha} r_n^{\omega 1-\alpha}}\right)^{1-\beta}. \tag{3.24}$$

In equilibrium, we assume that workers do not want to change their place of residence, place of work, and tenure. This implies that the observed number of workers having chosen a specific combination must be equal to the corresponding number resulting from the distribution of idiosyncratic tastes. More precisely, summing over the probabilities across workplaces k, yields the number of tenure-specific residents in location n

$$R_n^w = \bar{L} \sum_{k \in N} \lambda_{nk}^w. \tag{3.25}$$

Similarly, summing over the probabilities across place of residence k, yields the numbers of tenure-specific workers in location n

$$L_n^w = \bar{L} \sum_{k \in N} \lambda_{kn}^w. \tag{3.26}$$

Finally, we ease notation and define the share of workers commuting from n to i as $\lambda_{ni} = \lambda_{ni}^{\mathcal{R}} + \lambda_{ni}^{\mathcal{O}}$, the total number of workers as $L_n = L_n^{\mathcal{R}} + L_n^{\mathcal{O}}$ and the total numbers of residents as $R_n = R_n^{\mathcal{R}} + R_n^{\mathcal{O}}$.

3.2.7 Equilibrium characterization

Given the set of parameters $\{\alpha, \beta, \nu, \sigma, \epsilon, \xi, \chi, s, \tau, \bar{L}\}$ and observed or estimated values for $\{\lambda_{ni}^\omega, w_n, r_n^\omega, \bar{y}_n^\omega, y_{ni}^\omega, R_n^\omega, L_n^\omega, \eta_n, d_{ni}\}$, we characterize the equilibrium of the baseline model with the following set of conditions. The budget of the federal government is balanced according to (3.9), local housing markets clear according to (3.14), local labor markets clear according to (3.17), tradable goods market clears according to (3.19), the price index formula is given by (3.18), and the spatial distribution of workers/ residents satisfies (3.22).

These conditions represent a system of $3N + 3N^2 + 1$ equations, where N is the number of locations (US counties), allowing us to recover the location fundamentals $\{a_n, B_{ni}^\omega, \pi_{ni}, G, \bar{H}_n^\omega\}$. All endogenous variables can be expressed in terms of these location fundamentals, exogenous variables, and parameters.[13]

As shown by Monte et al. (2018), this theoretical framework can be reformulated such that Allen et al. (2016) theorem can be applied to ensure the existence and uniqueness of the equilibrium.

[13] Section 3.C of the Appendix provides further details on how to use the structure of the baseline model to perform counterfactual simulations.

3.3 Data and estimation

In this section, we describe the data sources available at the US county level.[14] Additionally, we discuss the calibration and estimation of the exogenous parameters required to conduct counterfactual simulations.[15]

3.3.1 Data

Parameters provided by the literature: We set the elasticity of substitution between different varieties of tradable goods equal to $\sigma = 5$, as suggested by Simonovska and Waugh (2014). Following Davis and Ortalo-Magne (2011) and Redding (2016), we set the share of income spent by households for consumption goods equal to $\alpha = 0.7$. We set the taste dispersion parameter equal to $\epsilon = 3.3$, as in Monte et al. (2018) and Bryan and Morten (2015). Following Fajgelbaum et al. (2019), the propensity to public goods consumption is given by $\beta = 0.22$. The strength of the agglomeration force is $\nu = 0.1$, as in Allen and Arkolakis (2014). Trade costs depend on the geographic distance between counties and on an average trade cost elasticity ψ, such that $d_{ni}^{1-\sigma} = dist_{ni}^{\psi}$. The former is computed using GIS data, whereas the latter is calibrated according to Monte et al. (2018), who estimate $\psi = -1.29$. We conservatively set the lifespan of a house equal to $t = 40$, which corresponds to the median age of buildings according to the American Community Survey (ACS) over 2009-2013.

Housing data: Based on data published by Federal Reserve Economic Data (FRED), we set the country mortgage interest rate equal to $\chi = 0.04$. This rate corresponds to the mean mortgage interest rate offered by financial institutions in 2013 for a 30-year fixed mortgage. Using the American Community Survey (ACS), we collect the share of owner-occupiers at the county level. We calibrate the loan to value ratio to $\xi = 0.51$ using the balance sheet of households and nonprofit organizations provided the Financial Accounts of the Board of Governors of the Federal Reserve System (BGFRS). Specifically, we compute the LTV as the ratio of outstanding home mortgages to the value of real estate assets. Monthly rents and the value of owner-occupied houses are provided by the ACS.

[14]Due to data unavailability, we exclude 87 (2.8%) out of 3143 US counties from our analysis.

[15]A summary of the calibrated parameters is provided in Appendix 3.A.1. Additionally, in Appendix 3.A.2 we present descriptive statistics and maps of exogenous and recovered variables.

Labor and income tax rates: From the Bureau of Economic Analysis (BEA) we collect data on wages by place of work and the number of employees in 2013. By dividing total wages by employment, we obtain per capita wages by workplace w_i. We use information on average federal income tax rates τ provided by the TaxSim database of the National Bureau of Economic Research (NBER) in 2013.

Commuting flows: Data on bilateral commuting flows λ_{ni} at the county level stems from ACS for the years 2009-2013. Because the ACS does not report bilateral commutes by housing tenure, we assume identical commuting flows for owner-occupiers and renters in each county.[16] We calculate tenure-choice specific commuting shares λ^{ω}_{ni} by multiplying the share of owner-occupiers and renters per county with the commuting flow matrix λ_{ni}.

Income and subsidy data: To obtain disposable income of renters $y^{\mathcal{R}}_{ni}$, we use (3.5) together with data on renters per capita wages w_i and tax rates τ. Owner-occupiers disposable income $y^{\mathcal{O}}_{ni}$ follows from (3.3) together with data on per-capita wages w_i, where we set $\theta = 1$ in the baseline case. Next, we derive the mortgage interest rate m_{ni} to finance owning properties, which follows from substituting (3.10) and (3.2.4) into (3.12) and data on income $y^{\mathcal{O}}_{ni}$. We substitute bilateral income y^{ω}_{ni}, conditional commuting shares $\lambda_{ni|n}$, and the total number of workers $\bar{L}$, into (3.8) to recover $\bar{y}^{\omega}_{n}$. We solve for per capita expected disposable income $\bar{y}_n$ using (3.7) and the bilateral income of owner-occupiers $y^{\mathcal{O}}_{ni}$ and renters $y^{\mathcal{R}}_{ni}$. Finally, using the Internal Revenue Service (IRS) data we calibrate $s = 6'358$ USD to ensure that the share of households that itemize in the model matches the one observed in 2013.

Recovering location fundamentals: We recover regional productivity by substituting trade shares (3.17) in the market clearing condition (3.19). Given values for $\{L_n, R_n, d_{ni}, w_n, \bar{y}_n\}$, parameter values for $\{\sigma, \alpha\}$, and estimates of d_{ni}, we recover productivity a_n, production amenities $\bar{a}_n$ and equilibrium values for bilateral trade shares. To solve for net regional consumption amenities ${}^{B^{\omega}_{ni}}/_{\kappa_{ni}}$, we substitute prices from (3.18) and rents (3.14) in commuting shares (3.22).

[16] This hypothesis is supported by descriptive evidence provided by the ACS Micro-data on travel time by housing tenure, which suggests that, on average, renters commute daily only 1.2 minutes more than owner-occupiers, making it unlikely that their commuting flows significantly differ at the county level.

3.3.2 Estimation of county-level housing supply elasticities

Following Saiz (2010), we parsimoniously parameterize the inverse local housing supply elasticity as $\frac{1}{\eta_n} = \eta + \eta^{\text{built}} S_n^{\text{built}}$, where S_n^{built} is the predetermined share of developed land in a given county. The parameters η and η^{built} represent the common and local components of the (inverse) supply responsiveness at the county level, respectively, which have to be estimated. Specifically, the interaction with the share of developed land proxies the combined effect of geographic and regulatory constraints on local supply elasticities.[17]

In the appendix Section 3.B.1, we show that the inverse housing supply elasticity $\frac{1}{\eta_n}$ can be estimated using the following regression equation

$$\Delta \log \mathcal{P}_n = \alpha + \eta \Delta \log Q_n + \eta^{\text{built}} S_n^{\text{built}} \Delta \log Q_n + \bar{h}_n^*, \tag{3.27}$$

where $\Delta \log \mathcal{P}_n$ and $\Delta \log Q_n$ represent price per square meter and stock growth from 1980 to 2000, respectively.[18] The error term $\bar{h}_n^*$ represents unobserved price dynamics. Note that (3.27) exclusively exploits spatial (cross-sectional) variation to identify supply elasticity parameters, such that time dynamics are exclusively used to partial out time-invariant unobservables at the county level.

Estimating (3.27) by OLS likely leads to biased estimates due to the simultaneous effect of housing demand and supply in determining equilibrium prices and stock quantities. To solve this issue, we instrument changes in the housing stock $\Delta \log Q_n$ using exogenous demand shocks that are not modeled in our structural framework. Specifically, we predict shifts in housing demand at the county level using i) mean temperature levels in January, ii) fertility rates, and iii) a shift-share instrument for changes in the ethnic composition of residents.

We motivate the choice of instruments as follows. Counties having attractive amenities have progressively become more desirable over time, as pointed out by Glaeser et al. (2001) and Rappaport (2007). We thus expect temperature to positively correlate with an increase in demand over time. To the extent that

[17]According to Hilber and Robert-Nicoud (2013), more attractive places are developed first and, as a consequence, are more tightly regulated. On the other hand, Saiz (2010) argues that geographic constraints become binding only in developed places.

[18]Due to limited data availability, we use the average surface of consumed housing at the region level provided by the US census to compute prices per square meter. In the appendix Section 3.B.3, we conduct a robustness check by including additional housing characteristics measured at the county level.

individuals decide to live in the same county in which they are born – due for example to high idiosyncratic migration costs – predetermined fertility rates are also expected to shift housing demand upward as young adults start to bid on local housing markets, as argued by Chapelle and Eyméoud (2018). Finally, as argued by Altonji and Card (1991) and Saiz (2007), housing demand is also expected to evolve according to the (predetermined) ethnic composition of local residents. We follow and build on this proposition, and assume that the growth in local residents can be predicted by a weighted average of the growth (at the state level) of individuals belonging to a specific ethnicity, where the weights are given by the initial distribution of ethnic groups.[19]

Median housing prices of owner-occupied housing units and total housing stock at the county level are provided by decennial US censuses and available on IPUMS (Manson et al. 2017). GIS raster data on the share of developed land comes from the "Enhanced Historical Land-Use and Land-Cover Data Sets" provided by the US Geological Survey. This data set exploits high-altitude aerial photographs collected from 1971 to 1982.[20] Mean January temperature comes from the Natural Amenities Scale data published by the Department of Agriculture. County-level fertility rates, measured as live births by place of residence divided by the total population, are downloaded from IPUMS, which contains the Vital Statistics: Natality & Mortality Data and the population decennial census data. To calculate the shift-share instrument, we use ethnicity information using census data from IPUMS.

Table 3.3.1 shows estimated values of the parameters η and η^{built} in (3.27). In columns 1-3 we report estimation results when using each instrument separately. Column 4 show estimation results when all three instruments are used simultaneously. As required by the theory, the sign of estimated parameters is positive. In particular, the higher the share of developed land in a given county, the higher η_n, thus resulting into a lower local housing supply elasticity. Additionally, the magnitude of the estimated coefficients is relatively stable across the instruments used to predict housing demand growth.

Using the estimates of our preferred specification (column 4 of Table 3.3.1), we compute county-level supply elasticities as $\eta_n = 1/(\eta + \eta^{\text{built}} S_n^{\text{built}})$. We obtain supply

[19] We use the following main ethnic groups: White, Black or African American, American Indian and Alaska Native, and Asian and Pacific Islander, and a category encompassing remaining ethnic groups. See Appendix 3.B.2 for further computational details.

[20] Because the large majority of the data is collected before 1980, we consider it predetermined with respect to our period of analysis.

Table 3.3.1: County-level housing supply elasticity estimates

Dependent variable: Growth of housing prices per m^2 between 1980 and 2000 ($\Delta \log \mathcal{P}$)				
Instruments:	Log-temperature	Fertility rate	Shift-share ethnicity	All three instruments
	(1)	(2)	(3)	(4)
$\Delta \log Q$	0.685***	0.443***	0.353**	0.444***
	(0.215)	(0.144)	(0.151)	(0.147)
$S_n^{\text{built}} \Delta \log Q$	1.908**	2.026***	1.909**	2.088**
	(0.788)	(0.715)	(0.845)	(0.815)
Observations	3.098	3.098	3.098	3.098
Underidentification[a]	0.002	0.000	0.001	0.004
Weak identification[b]	8.963	13.890	10.252	15.697
Overidentification[c]	.	.	.	0.514

Note: Clustered standard errors at the state level in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a) P-value of the Kleibergen-Paap LM statistic. b) Kleibergen-Paap F-statistic. The critical values for 10/15/20% maximal IV size are 7.03/4.58/3.95 in columns 1-3 and 26.68/12.33/9.10 in column 4, respectively. c) P-value of Hansen J statistic.

elasticity values ranging from 0.39 (Queens county, NY) to 2.25 (Banner county, NB). In Sections 3.B.3 and 3.B.4 of the Appendix, we provide further evidence about the reliability of our estimates by controlling for potential supply shifters and comparing our estimates with those of Saiz (2010).

3.3.3 Counterfactual analysis

We use the theoretical framework presented in Section 3.2 to undertake model-based counterfactual simulations about the spatial implications of the MID. Specifically, we evaluate two alternative policies that modify how housing subsidies are allocated to individuals. With the first policy we analyze the economic impacts of suddenly repealing the MID. In the second counterfactual simulation, we investigate the general equilibrium effects of a doubling of the standard deduction, as recently implemented in the Tax Cuts and Jobs Act (TCJA) under President Trump's administration.

To quantify the welfare impact of modifying existing housing subsidies, we introduce the counterfactual 'hat' notation developed by Dekle et al. (2007) and denote a counterfactual change as $\hat{x} = \frac{x'}{x}$, where x is the observed variable and x' its counterfactual value. To avoid modeling potentially complex changes in the allocation of public good provision by the federal government, we follow Fajgelbaum et al. (2019) and keep public good provision constant in all our counterfactual simulations. Using (3.24), we can then write spending-constant ($\hat{G} = 1$) counterfactual changes in US welfare as

$$\widehat{\bar{V}} = \left(\frac{1}{\widehat{\lambda^{\omega}}_{ni}} \right)^{\frac{1}{\epsilon}} \left(\frac{\widehat{y^{\omega}}_{ni}}{\hat{P}_n^{\alpha} \widehat{r^{\omega}}_n^{1-\alpha}} \right)^{1-\beta} . \tag{3.28}$$

Equation (3.28) makes apparent that a cost-benefit analysis of modifying existing housing subsidies should take into account not only real income changes, but also changes in the commuting flows between local areas. A complete description of the system of equations characterizing counterfactual simulations is presented in Section 3.C.1 of the Appendix. To provide a better intuition of our results, in what follows we separately report counterfactual changes for each one of the endogenous variables entering (3.28).

3.4 Repealing the Mortgage Interest Deduction

We start our analysis by investigating the welfare impacts of repealing the MID for owner-occupiers. To this end, we shock the economic system by setting $\theta = 0$ in (3.4).[21]

3.4.1 Overall impact

Table 3.4.1 shows aggregate results for the whole of the country. We compute aggregate counterfactual changes of a given welfare component by computing a weighted average of changes at the county level. The weighting scheme is adapted depending on the considered welfare component.[22] Columns 1 to 3 show counterfactual results when location (place of residence and place of work) and

[21] In Section 3.C of the Appendix we provide further details on our counterfactual simulations. In the Appendix 3.D, we show the results of a repeal of the MID in presence of property taxes and a progressive tax schedule.

[22] We weight using the level of the relevant outcome variable observed in the baseline scenario. Changes in commuting are weighted using baseline commuting flows, changes in residents, income, price indices, housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

tenure choices are kept fixed as in the baseline scenario. Keeping location and tenure choices fixed, allows us to investigate the initial income impact of repealing the MID without diving into the sorting and tenure response of individuals. In columns 4 to 6 we do allow individuals to adapt their location and tenure choices to the repeal of the subsidy.[23]

In columns 1 to 3, owner-occupiers experience a negative income shock, while renters a positive one. This because owner-occupiers that were itemizing the MID cannot do so anymore and renters are those that mostly benefit from a tax rate reduction of 1.00% following the increase in the tax revenue of the federal government. Because owner-occupiers are more numerous than renters, the overall income effect is negative. This, in turn, leads to a decrease in the consumption of tradable goods and to a corresponding decrease in wages. Housing costs also decrease (increase) for owner-occupiers (renters) following the initial income shock. The increase in housing costs for renters does not compensate the decrease in the price of tradable goods and the income increase, resulting in a real income increase.

When individuals are allowed to relocate and choose their tenure mode, repealing the MID leads to a welfare increase of 0.01%. We observe a shift of the housing demand from the owner-occupied towards the rental market, as shown by the change in the number of residents reported in columns 4 and 5. In total, homeownership rate decreases by 0.19 percentage points due to the repeal. This shift of the housing demand amplifies the response of housing cost changes, leading to even higher (lower) periodic costs of renting (owning) a property. For renters, the increase in housing costs considerably dampens the positive real income increase, which only amounts to 0.02%. The decrease in regional income of owner-occupiers outweighs the decrease in housing cost and price index, leading their real income to decrease by 0.04%. Population mobility thus dilutes the real income gain experienced by renters, allowing owner-occupiers to also benefit – or limit their losses – following the repeal.[24]

Albeit the considerable size of the MID policy, we attribute the relatively

[23]The baseline outcomes for the two groups of columns (1 to 3 and 4 to 6) are the same, which allows us to compare their changes when pertinent. Because location and tenure choices are fixed in columns 1-3, thus leading to a welfare disequilibrium between renters and owner-occupiers, we do not report counterfactual changes in welfare, commuting flows, and residents for these columns.

[24]Note that because they face a unique local market price, differences in counterfactual price index changes between renters and owner-occupiers are exclusively due to differences in the weighting scheme.

Table 3.4.1: Repealing the Mortgage Interest Deduction

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0.01	0.01	0.01
Commuting ($\sum_{n\neq i} \lambda'_{ni} / \sum_{n\neq i} \lambda_{ni}$)	-	-	-	0.79	−0.59	−0.14
Residents ($\hat{R}_n$)	-	-	-	0.79	−0.43	-
Regional income ($\hat{y}_{ni}$)	0.15	−0.09	−0.01	0.14	−0.15	−0.08
Wages ($\hat{w}_i$)	−0.04	−0.03	−0.03	−0.03	−0.03	−0.03
Housing costs ($\hat{r}_n$)	0.05	−0.05	−0.02	0.44	−0.30	−0.03
Price index ($\hat{P}_n$)	−0.04	−0.04	−0.04	−0.03	−0.03	−0.03
Real income ($\hat{y}_{ni} / \hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}$)	0.16	−0.05	0.02	0.03	−0.04	−0.05

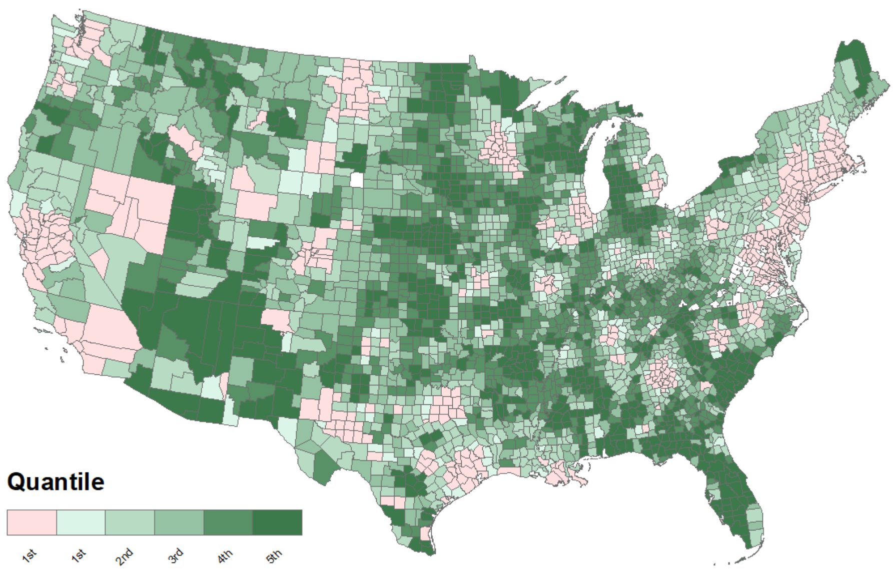
Note: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header ‘owners’ denotes owner-occupiers. In columns (1)-(3) workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns (4)-(6). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

small decline in homeownership rates to three main factors. First, in contrast to other studies, in our model workers have idiosyncratic preferences for tenure and locations, implying that they are imperfectly mobile and do not fully react to real income changes. Second, those areas in which owner-occupiers do not itemize the MID because housing values are not high enough are not affected by the repeal. Additionally, even in extremely expensive locations owner-occupiers can still claim the standard deduction. Third, in line with the reasoning of Hilber and Turner (2014), our estimated housing supply elasticities suggest that counties belonging to MSAs are fairly inelastic, thus leading to a capitalization on the subsidy in to higher housing prices.

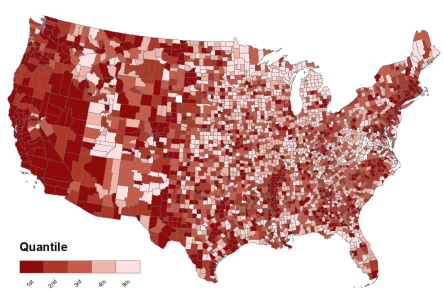
Welfare changes presented in Table 3.4.1 draw a global portrait of the welfare consequences of repealing the MID. However, as noted before, housing subsidies are unevenly distributed across space, with high productive areas receiving most of them. This uneven distribution implies that the repeal affects some areas more than others. In that regard, it is difficult to explain changes in incoming commuting flows in Table 3.4.1 without considering the geography of the repeal. In the next section, we thus analyze how the impact of the repeal changes across space and, in particular, how it affects the location and tenure decision across MSA and countryside counties. To this end, we exclusively focus on the case with varying location and tenure choices.

Figure 3.4.1: Repealing the Mortgage Interest Deduction: County-level counterfactual changes

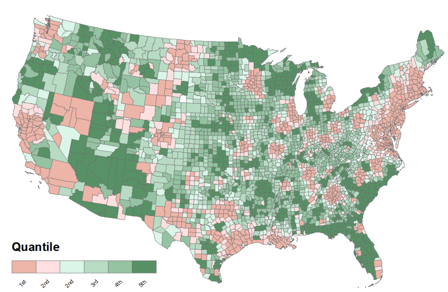
(a) After-tax income of owner-occupiers ($\hat{\tilde{y}}_n^O$)



(b) Homeownership rate ($\hat{R}_n^O/\hat{R}_n$)



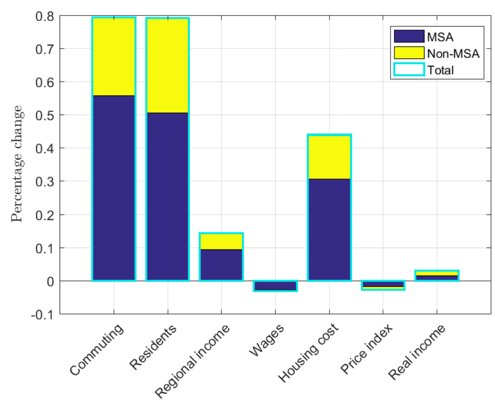
(c) Periodic cost of ownership ($\hat{r}_n^O$)



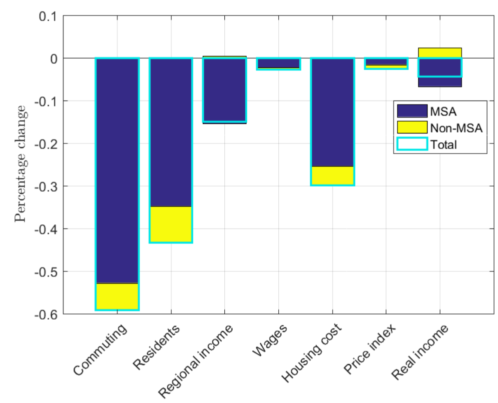
Note: We compute counterfactual changes by setting $\theta = 0$. Workers can change place of residence, place of work, and tenure mode. We depict positive (negative) growth in green (red). A darker shading represents a stronger effect.

Figure 3.4.2: Repealing the MID: MSAs vs. countryside

(a) Renters



(b) Owners



Note: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. Workers can change place of residence, place of work, and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

3.4.2 Changes in the spatial distribution

Figure 3.4.1 shows selected counterfactual changes that are particularly relevant for our analysis.[25] As it can be seen, the negative impact of the MID repeal on the after-tax income of owner-occupiers (panel a) is mostly concentrated in MSAs such as New York, San Francisco, and Chicago. Unsurprisingly, these are the places where homeownership rates and housing prices decrease the most (panels b and c). In fact, these areas feature high MID itemization rates and low housing supply elasticities. On the contrary, as shown in panel a, onwer-occupiers in the countryside experience even a positive income shock, an effect which was masked by the aggregation scheme in Table 3.4.1. In countryside areas the decrease in homeownership rates is more contained (panel b) and is mostly due to an increase in the periodic cost of ownership (panel c) caused by a shift of the housing demand. As evident from Figure 3.4.1, the impact of the repeal strongly varies between metropolitan areas and the countryside. In what follows we thus investigate counterfactual changes across these two areas.

Figure 3.4.2 shows a stacked barplot of the impact of repealing the MID for renters (panel a) and owner-occupiers (panel b) living in counties located within

[25]The interested reader might refer to Appendix 3.C.2 for the full set of maps representing counterfactual changes.

and outside major urban areas. Specifically, panels (a) and (b) of Figure 3.4.2 correspond to columns 4 and 5 of Table 3.4.1, respectively. Panels (a) and (b) show that the largest part of the impacts documented in columns 4 and 5 of Table 3.4.1 are driven by MSA regions. Non-MSA areas experience, in general, the same type of welfare impact (same sign) but of lower magnitude. A notable exception to this rule is the real income of owner-occupiers, which decreases in MSA areas but increases in the countryside. We explain this opposite effect with the fact that most owner-occupiers living in counties located in the countryside were not itemizing the MID in the baseline specification and thus fully benefit from the income tax rate decrease following the MID repeal.

When computing the aggregate effect of panels (a) and (b) of Figure 3.4.2, counterfactual changes for the welfare components of owner-occupiers dominate those of renters, mostly because they are more numerous. Because the MID repeal makes MSA counties which previously claimed the MID relatively less attractive compared to the baseline scenario, the aggregate effect also shows a clear shift of total residents from MSA to non-MSA areas (see Figure 3.C.1 in the appendix). A simple analysis of concentration (Gini) indices reveals that the repeal systematically lowers spatial inequalities of income across counties by 0.05%. We observe a similar reduction in spatial inequality for workers, and residents (see Table 3.C.1 in the Appendix).

Notably, because the wage response is approximately the same for columns 1-3 and 4-6, we argue that that increases in agglomeration economies occurring in the countryside due to the relocation of workers partially counter the loss in productivity occurring in MSAs. Indeed, renters counter the increase of rental costs by commuting over longer distances, whereas the decrease of ownership cost allows owner-occupiers to live closer to their place of work, resulting in a 0.41% decrease in commuting. Overall, commuting decreases by 0.10%. Because commuting is costly in terms of welfare, this overall commuting decrease improves welfare.

3.4.3 Housing subsidies and spatial spillovers

An important body of empirical work in economics aims to quantify the causal impact of place-based policies on a variety of economic outcomes. Recently, researchers have started to raise doubts about the reliability of empirical estimates describing the (average) treatment effect of place-based policies due to a potential violation of the Stable Unit Treatment Value Assumption (SUTVA).[26] Questioning the validity of the SUTVA seems natural when investigating policies affecting determined areas due to the spatial linkages between regions. In fact, these linkages might create spatial spillovers from treated to non-treated areas and from treated areas to other treated areas, thus biasing treatment effect estimates.

As discussed in the previous sections, MID subsidies are itemized, on average, only in places with congested housing markets displaying high housing costs. Moreover, housing subsidies are usually unequally distributed across itemizing areas, creating heterogeneous treatment effects. Virtually all studies aiming to quantify the impacts of housing subsidies across space rely on empirical analyses exploiting this variation in the magnitude of the subsidies among recipient regions. However, the aggregate efficiency of spatially targeted housing subsidies critically depends on migration and commuting responses, the shift between rental and owner-occupied demand, and local prices in general. Ignoring the spatial spillovers of the subsidies to other regions amounts to quantifying partial equilibrium effects.[27]

In this section, we suggest a model-based strategy allowing to quantify the magnitude of spatial spillovers for residential location choices and thus, indirectly, to determine whether they represent a sizable limitation of empirical studies.[28] To this end, in a first step we formalize the general equilibrium elasticity of local residents to housing subsidies. In a second step, we disentangle the impact of local and non-local effects (spatial spillover) on this elasticity.

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[26]See Baum-Snow and Ferreira (2015) for a comprehensive review of the issue.

[27]Some empirical studies try to alleviate the issue of spatial spillovers by excluding observations in the immediate proximity of treated regions from the control group. From a general equilibrium perspective, this is unsatisfactory for two reasons. First, spatial linkages are not necessarily limited to neighboring areas. Second, spillovers also occur within treated areas. In our structural model, spatial spillovers take the form of complex general equilibrium responses through labor mobility and trade linkages. Because we calibrate labor mobility with real-world patterns, these spillovers are not necessarily limited to neighboring regions.

[28]A similar analysis can be performed for the elasticity of other outcomes. We focus on the elasticity of local residents because of its relevance for the policy we analyze.

Understanding residential location choices

Let $\gamma^{R_n^\omega,\,\theta} = \frac{dR_n^\omega}{d\theta}\frac{\theta}{R_n^\omega}$ denote the tenure-specific elasticity of local residents to housing subsidies. By computing the total derivative of (3.25) with respect to θ, we have

$$\begin{aligned}\gamma^{R_n^\omega,\,\theta} =& (1-\beta)\epsilon\left(\sum_{k\in N}\frac{\bar{L}^\omega\lambda_{nk}^\omega}{R_n^\omega}\gamma^{y_{nk}^\omega,\,\theta} - \sum_{k\in N}\sum_{f\in N}\lambda_{kf}^\omega\gamma^{y_{kf}^\omega,\,\theta}\right)\\ &-(1-\beta)\epsilon\alpha\left(\gamma^{P_n,\,\theta} - \sum_{k\in N}\frac{R_k^\omega}{\bar{L}^\omega}\gamma^{P_k,\,\theta}\right)\\ &-(1-\beta)\epsilon(1-\alpha)\left(\gamma^{r_n^\omega,\,\theta} - \sum_{k\in N}\frac{R_k^\omega}{\bar{L}^\omega}\gamma^{r_k^\omega,\,\theta}\right) + \gamma^{\bar{L}^\omega,\,\theta}.\end{aligned} \tag{3.29}$$

where $\gamma^{\cdot,\,\theta}$ denotes the elasticity of a given variable with respect to housing subsidies.

Equation (3.29) tells us that the relative change in the spatial distribution of residents due to a relative change in housing subsidies is determined by three main channels. The first channel is the income response to the subsidy. The second and third channels describe the relationship between housing subsidies and the price of tradable goods and housing costs, respectively.[29]

The first term within the large parentheses always represents a change in the local attractiveness of a location with respect to income, tradable goods prices, and housing costs. The second term within the parentheses relates to a counterfactual change in the attractiveness of all other locations, as their income and prices also change. Put differently, residents in n might react to changes in housing subsidies even if location n is not directly affected by the repeal, but its relative attractiveness is. As such, even in counties where owners do *not* itemize the MID, the elasticity of residents might be different from to zero due to spatial spillovers. A few remarks are worth noting. First, each of the channels in (3.29) is tenure specific and, as such, can have opposite sign across tenure.

Second, a crucial role in the change of residents is played by the taste dispersion ϵ and the share of private expenditure $1-\beta$. Both parameters govern the degree of mobility of people, affecting their responsiveness to housing subsidies. For example, when $\epsilon \to 1$, individual taste is all that matters and residents do not respond to housing subsidies. When ϵ is higher, people are sensitive to a change in the subsidy.

[29] As before, we assume that the federal government adjusts tax rates to keep public good provision constant, such that the elasticity of public goods to housing subsidies is identically zero.

In a similar vein, the more people care about real income over public good provision, the stronger the incentives to relocate according to housing subsidies.

Third, the magnitude of the elasticities $\gamma^{\cdot,\theta}$ depends on exogenous location characteristics. For example, the income elasticity $\gamma^{y^{\omega}_{nk},\theta}$ is expected to be positive and large in magnitude in highly productive places located in MSA areas, which typically have congested housing markets. Similarly, changes in consumption prices $\gamma^{P_n,\theta}$ are linked to trade costs. The housing cost response to housing subsidies $\gamma^{r^{\omega}_n,\theta}$ depends on local housing supply elasticities.

Quantifying the importance of spatial spillovers

As shown by (3.29), the elasticity of local residents in county n is composed of *local* effects – originating from elasticities where $k = n$, i.e. $\gamma^{y^{\omega}_{nn},\theta}, \gamma^{P_n,\theta}$ and $\gamma^{r^{\omega}_n,\theta}$ – and *non-local* effects that arise from elasticities in other locations, where $k \neq n$, namely $\gamma^{y^{\omega}_{nk},\theta}, \gamma^{P_k,\theta}$ and $\gamma^{r^{\omega}_k,\theta}$. We use this distinction to separately quantify the role played by local and non-local income, consumption prices, and housing cost effects in the determination of local resident elasticities with respect to housing subsidies. Specifically, we investigate how much of the observed spatial variation of local resident elasticities is explained by local and non-local effects.

Specifically, we quantify local resident elasticities and the corresponding local and non-local components of (3.29) by simulating the MID repeal of Section 3.4. In a second step, we perform a Shorrocks-Shapley decomposition by regressing local resident elasticities on all possible combinations of the elasticity components and computing the corresponding R^2 for each combination. For each component, we then calculate the average improvement of the R^2 when adding that component as a covariate to the regression. This average improvement is interpreted as the relative importance of the component to explain the variation in the elasticity of residents. Table 3.4.2 shows the results.

Panel A of Table 3.4.2 evaluates the overall importance of local and non-local channels for renters and owner-occupiers, without distinguishing which endogenous channel responds to the subsidies. Our results suggest that 32% and 33% of the observed spatial variation in the elasticity of renters and owner-occupiers is due to responses having occurred in other areas, respectively. When assessing the relative importance of local and non-local effects for each channel entering (3.29), as shown in panel B, we find that income and housing costs represent the most important

Table 3.4.2: Importance of spatial spillovers for residents' elasticity

		Renters (1)	Owners (2)
Panel A: All channels			
	local	0.68	0.67
	non-local	0.32	0.33
Total[a]		1	1
Panel B: Individual channels			
Income	local	0.33	0.36
Income	non-local	0.21	0.18
Price index	local	0.14	0.03
Price index	non-local	0.03	0.03
Housing costs	local	0.25	0.33
Housing costs	non-local	0.05	0.07
Total[a]		1	1

Note: We compute counterfactual changes by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. The reported values correspond to the contribution of a given channel in a Shorrocks-Shapley decomposition of the residents' elasticity. [a] Because (3.29) is an analytical relationship, linearly regressing local resident elasticities on the full set of components leads to a perfect fit.

channels affecting the residential elasticities of renters and owner-occupiers, whereas the price index of tradable goods only plays a minor role. A good part of the importance of the income channel comes from non-local effects stemming from spatial linkages of the labor market via commuting flows. On the contrary, non-local effects do not represent a major component of the housing costs channel, implying that the migration response of residents is mostly affected when housing subsidies directly affect local housing markets.

These results seem to suggest that spatial spillovers are an important component of local elasticities of renters and owner-occupiers to housing subsidies. This importance highlights potential shortcomings of empirical analyses aiming to quantify the causal impact of the MID on economic outcomes and welfare.

3.5 Making MID itemization less attractive

Up to now we have concerned ourselves with the evaluation of the welfare impact of repealing the MID. Despite a repeal seems to be beneficial for the country, it would likely be met with hostility by voters and owner-occupiers in particular. A legitimate question is thus whether a government that aims to reduce the disparity in the tax treatment between renters and owner-occupiers can overcome this hostility by implementing a policy that makes MID itemization less attractive.

Despite not being its main purpose, a recent example of such a policy is provided by the TCJA, which was promoted by President Trump's administration and came into force in January 2018. One of the major elements of this tax reform is the doubling of the standard deduction that households can deduct from their taxable income.[30] The areas that benefit the most from the increase in the standard deduction in real terms are those located in the countryside, where President Trump's received most votes during the 2016 US presidential election. Unsurprisingly, most pundits expect an important drop in MID itemization rates.

In this section, we thus investigate the welfare impact of doubling the standard deduction s.[31] As in the previous section, we adjust income tax rates to keep federal public good provision constant.

3.5.1 Overall impact

Table 3.5.1 shows the simulation results when doubling the calibrated value of the standard deduction s – which increases from $6'358$ USD to $12'717$ USD – in (3.4). Columns (1) to (3) show the impact of the tax reform when individuals cannot adapt location and tenure choices in response to the increase of the standard deduction, whereas in columns (4) to (6) we allow for such a response.

In our simulations the share of owner-occupiers itemizing the MID drops from 30.4% to 0.65% after the tax reform comes into force, with only counties having highly congested housing markets continuing to claim the deduction. Doubling

[30]Other key elements of the tax reform are reductions in tax rates for businesses and individuals, family tax credits, limiting deductions for state and local income taxes (SALT) and property taxes, reducing the alternative minimum tax for individuals and eliminating it for corporations, reducing the number of estates impacted by the estate tax, and repealing the individual mandate of the Affordable Care Act.

[31]Despite our model is calibrated with 2013 data, changes in the tax system between 2013 and 2017 have been minor.

Table 3.5.1: Doubling the standard deduction

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	-0.07	-0.07	-0.07
Commuting ($\sum_{n\neq i}\lambda'_{ni}/\sum_{n\neq i}\lambda_{ni}$)	-	-	-	-0.43	-0.55	-0.51
Residents ($\hat{R}_n$)	-	-	-	-0.05	0.03	-
Regional income ($\hat{y}_{ni}$)	-0.09	-0.09	-0.09	-0.47	-0.51	-0.51
Wages ($\hat{w}_i$)	-0.31	-0.24	-0.26	-0.18	-0.13	-0.15
Housing costs ($\hat{r}_n$)	-0.16	-0.15	-0.16	-0.40	-0.38	-0.38
Price index ($\hat{P}_n$)	-0.33	-0.27	-0.30	-0.13	-0.12	-0.13
Real income ($\hat{y}_{ni}/\hat{P}_n^{\alpha}\hat{r}_n^{1-\alpha}$)	0.19	0.15	0.16	-0.26	-0.32	-0.31

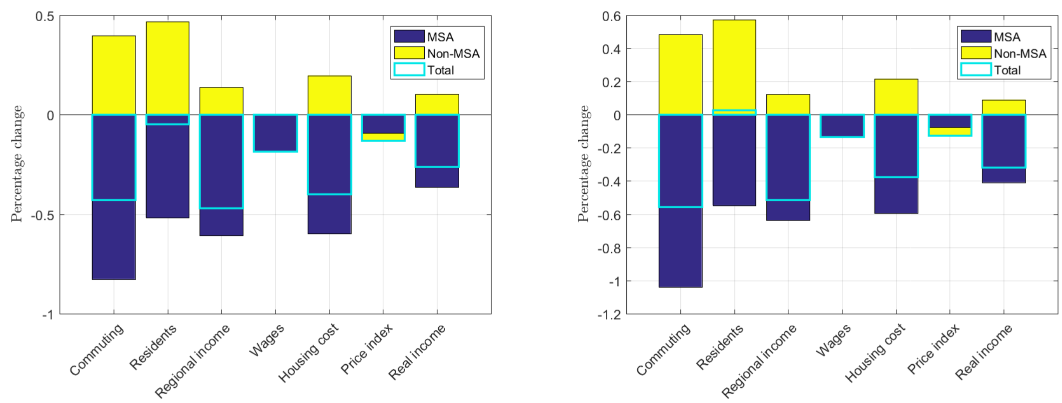
Note: We compute counterfactual changes by setting $s = 12'717$ USD. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns (1)-(3) workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns (4)-(6). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

the standard deduction considerably decreases the tax revenue of the federal government, which to keep public good provision constant is forced to increase income tax rates. This increase in tax rates negatively affects the after-tax income of residents that continue to claim the MID. Taxpayers for which the doubling of the standard deduction is only marginally beneficial are also hurt by the increase in tax rates and experience an income decrease. This negative income shock decreases the consumption of tradable and housing goods, negatively affecting the economy of the country and leading to a generalized wage decrease. However, because the cost of living decreases more than the decrease in the after tax income, renters and owner-occupiers experience a real income increase, with renters experiencing the biggest increase.

In the case of immobile renters and owner-occupiers, our analysis seems to suggest that doubling the standard deduction is beneficial, at least in terms of real income. When people can adapt location and tenure choices with respect to the baseline scenario, however, we find that the welfare of the country decreases by 0.05%. We explain these results as follows. In the mobility scenario, because

Figure 3.5.1: Impact of doubling the standard deduction: MSAs vs. countryside

(a) Renters (b) Owners



Note: We compute counterfactual changes by setting $s = 12'717$ USD. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. Workers can change place of residence, place of work, and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

being an owner-occupier becomes relatively less attractive in most locations, many individuals switch tenure and/or relocate to areas displaying more elastic housing markets.[32] This migration response to less productive areas further reinforces the regional income decrease, which lower the demand of tradable and housing goods even further with respect to the immobility case. The decrease in the price of tradable and housing goods is not strong enough to compensate the income decrease, which leads to a real income decrease, with renters experiencing a slightly less negative decrease. In turn, because the decrease in commuting flows does not compensate outweigh the decrease in real income, welfare decreases. Some of remaining owner-occupiers take advantage of lower housing costs to move closer to their work place, which results in a decrease of in-commuting.

Because, Table 3.5.1 only shows aggregate results for the whole of the country, in the next section we provide further evidence on the spatial displacement of the housing demand from MSAs to non-MSAs caused by the doubling of the standard deduction.

3.5.2 Changes in the spatial distribution

Figure 3.5.1 shows the impact for renters (panel a) and owner-occupiers (panel b) living within/outside MSAs of doubling the standard deduction . As it can be seen, non-MSAs counties are strongly affected by the policy, with a clear shift of residents to less productive areas. In fact, countryside counties – which usually display more elastic housing markets – become relatively more attractive than counties located within MSAs for two reasons. First, the real value of the standard deduction is considerably higher in the countryside. Second, in these places the standard deduction capitalizes less into housing costs than in counties with a lower housing supply elasticity. As is shown in Figure 3.5.1, the shift to the countryside decreases housing costs in MSAs counties, while housing costs in the countryside increase. The shift to places with lower agglomeration economies reinforces the decrease in regional income of owner-occupiers and renters observed in Table 3.5.1. Because people have to move outside MSAs to benefit from the doubling of the standard deduction, we observe that incoming commuting flows of MSA counties strongly decrease, whereas those of countryside counties increase.

3.6 Conclusions

Over the last decades, the staggering tax expenditure generated by the mortgage interest deduction has fueled a lively debate among politicians and academicians regarding its allocative efficiency. Evidence on the economic impacts of the unequal geographic distribution of housing subsidies is currently missing. To analyze the economic effects of this unequal distribution, we develop a spatial general equilibrium model in which individuals respond endogenously to tax incentives by choosing where to live, where to work, and tenure mode. We calibrate our model with data for US counties, estimating, in particular, local housing supply elasticities. The generality of the framework allows investigating a variety of simulations related to income-tax subsidies.

Simulation results suggest that repealing MID subsidies while keeping public expenditure constant leads only to a moderate decrease in homeownership rates while slightly increasing the country welfare. The welfare gain is mostly due to

[32] The countrywide ownership rate is slightly reduced by 0.02 percentage points.

a spatial displacement of the housing demand from congested housing markets in urban areas to more elastic housing markets in the countryside, and to a reduction in commuting flows between these areas. In contrast to previous research, we derive and quantify the importance of spatial spillovers for the displacement response of residents due to a change in the subsidies and find that they explain about one third of the response. In a separate simulation exercise, we show that a repeal of the MID is to be preferred to a lessening of the MID attractiveness through an increase of standard deductions as recently implemented under President Trump's administration.

Our results hold important lessons for the evaluation of housing and tax policies. Providing housing subsidies or income tax incentives significantly alters the geographic distribution of residents and workers across space, which, in turn, affect the aggregate efficiency of the policy. Non-local effects, arising via labor and goods markets, influence the efficiency of the policy, especially in areas having strong spatial linkages with other ones. This prompts for a serious costs-benefits analysis of policies that asymmetrically affect these well-connected regions, such as policies targeting major urban areas.

3.A Data appendix

This section contains further information about data calibration, as well as additional descriptive statistics of the outcome variables of the model.

3.A.1 Model calibration

Table 3.A.1: Calibration of the parameters

Description	Notation	Value	Reference / Source
Share of consumption expenditure	α	0.7	Davis and Ortalo-Magne (2011)
Share of public expenditure	β	0.22	Fajgelbaum et al. (2019)
Agglomeration force	ν	0.1	Allen and Arkolakis (2014)
Elasticity of substitution	σ	5	Simonovska and Waugh (2014)[a]
Heterogeneity of preferences	ϵ	3.3	Monte et al. (2018)
Loan to house value ratio	ξ	0.51	BGFRS
Mortgage interest rate	χ	0.04	ACS
Trade cost elasticity	ψ	-1.29	Monte et al. (2018)
Life span of housing structures	t	40 years	ACS
Standard deduction	s	6358$	IRS
Housing supply elasticity	η_n	-	Own estimation

Note: ACS: American Community Survey, BGFRS: Board of Governors of the Federal Reserve System, IRS: Internal Revenue Service. a) Simonovska and Waugh (2014) estimate $1-\sigma$ equal to a value of -4, which implies $\sigma = 5$.

3.A.2 Summary statistics

We present summary statistics of our exogenous and recovered variables in Table 3.A.2. Figure 3.A.1 shows the spatial distribution of selected observed and recovered variables of the model.

3.B Estimation of county-level housing supply elasticities

In this section, we provide further information on the estimation of county-level housing supply elasticities and on the reliability of our estimates.

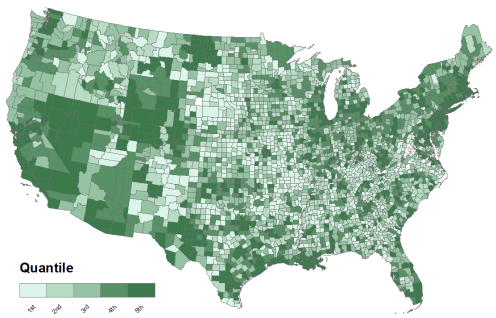
Table 3.A.2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Production amenities ($\bar{a}_n$)	1.56	0.68	0.55	10.64	3056
Commuters ($\bar{L}\sum_{n\neq i}\lambda_{ni}$)	15.87	61.27	0.01	2143.83	3056
Renters ($\bar{L}^R\sum_{n\neq i}\lambda_{ni}^R$)	5.2	26.36	0	1156.34	3056
Owners ($\bar{L}^O\sum_{n\neq i}\lambda_{ni}^O$)	10.67	36.56	0.01	987.49	3056
Own trade shares, in % (π_{nn})	41.91	21.99	1.58	99.57	3056
Housing supply elasticity (η_n)	1.69	0.44	0.39	2.25	3056
Wages per-capita (w_n)	37.23	8.08	20.14	104.37	3056
Income per-capita ($\bar{y}_n$)	54.85	7.4	40.38	112.07	3056
Owners ($\bar{y}_n^O$)	56.94	7.97	42	119.85	3056
Renters ($\bar{y}_n^R$)	49.46	6.53	37.15	100.66	3056
Workers (L_n)	58.57	206.16	0.14	5939	3056
Owners (L_n^O)	37.89	117.28	0.1	2876.75	3056
Renters (L_n^R)	20.68	92.27	0.04	3062.25	3056
Residents (R_n)	58.57	189.32	0.08	5734.31	3056
Owners (R_n^O)	37.89	106.3	0.04	2689.48	3056
Renters (R_n^R)	20.68	87.21	0.04	3044.83	3056
Periodic cost of renting (r_n^R)	8.1	2.16	2.95	20.8	3056
Periodic cost of ownership (r_n^O)	6.26	3.66	1.7	45.17	3056
Price index (P_n)	7.5	1.15	2.19	10.31	3056
Tax rates, in % (τ)	11.36	0	11.36	11.36	3056
Owner's tax deduction (ζ_n)	6.48	0.55	6.36	14.36	3056
Ownership rate (R_n^O/R_n)	0.72	0.08	0.19	0.94	3056
Sh. of commuters ($\bar{L}\sum_{n\neq i}\lambda_{ni}/L_i$)	0.26	0.11	0.02	0.91	3056
Owners ($\bar{L}^O\sum_{n\neq i}\lambda_{ni}^O/L_i^O$)	0.25	0.12	0.02	0.93	3056
Renters ($\bar{L}^R\sum_{n\neq i}\lambda_{ni}^R/L_i^R$)	0.28	0.13	0.02	0.91	3056

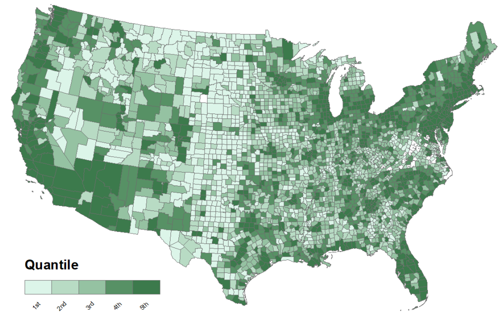
Note: Commuters, residents and workers are measured in thousand inhabitants, per capita wages, per capita income and rents are reported in thousand Dollars, Public good provision in million Dollars, and tax rates and trade shares in percent.

Figure 3.A.1: Overview of variables at the county level

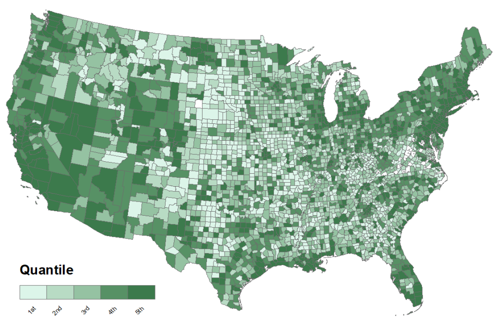
(a) Wages (w_n)



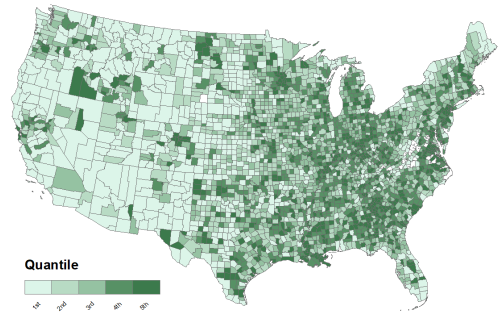
(b) Residents (R_n)



(c) Productivity (a_n)



(d) Sh. of commuters - Owners ($\sum_{n \neq i} \lambda_{ni}^{O} / L_i^O$)



Note: We depict positive (negative) growth in green (red). A darker shading represents a stronger effect.

3.B.1 From structure to empirics

We show how the supply equations (3.13) can be used to derive the empirical specification (3.27). There are three main reasons to use (3.27) to estimate (inverse) housing supply elasticities. First, it is based on directly observable variables, namely changes in housing prices and housing stock growth. Second, it corresponds to Saiz (2010) specification of housing suppy elasticities, which allows us to investigate the validity of our estimates at the MSA level (see Section 3.B.4). Third, it is easier to find instruments that capture relevant cross-sectional variation of the total housing stock.

Log-linearizing (3.13), first differencing, and rearranging the terms leads to

$$\Delta \log \mathcal{P}_n^{\omega} = \alpha^{\omega} + \frac{1}{\eta_n} \Delta \log H_n^{\omega} + \bar{h}_n^{\omega}, \tag{3.30}$$

where the error term $\bar{h}_n^\omega$ corresponds to mean-centered changes of the supply shifter $\bar{H}_n^\omega$. According to the Cobb-Douglas utility function, the term $\Delta \log H_n^\omega$ represents tenure-specific changes of the total consumption of housing surface. We decompose this total housing consumption as $\Delta \log H_n^\omega = \Delta \log \mathrm{Q}_n + \Delta \log \text{Share of } \omega_n + \Delta \log \text{Per capita } H_n^\omega$, where Q_n denotes the total housing stock in a given county. We can thus rewrite (3.30) as

$$\Delta \log \mathcal{P}_n^\omega = \alpha^\omega + \frac{1}{\eta_n} \Delta \log Q_n + \bar{h}_n^{\omega,*}. \tag{3.31}$$

The error term $\bar{h}_n^{\omega,*}$ now includes changes in the share of residents according to a given tenure mode and per capita housing consumption. Parametrizing the inverse housing supply elasticity $\frac{1}{\eta_n}$, we obtain

$$\Delta \log \mathcal{P}_n^\omega = \alpha^\omega + \eta \Delta \log Q_n + \eta^{\text{built}} S_n^{\text{built}} \Delta \log Q_n + \bar{h}_n^{\omega,*} \tag{3.32}$$

Because we assume the same housing supply elasticity for the rental and owner-occupied market, we drop the ω notation in the main text and use housing prices per square meter as dependent variable.

3.B.2 Shift-share instrument based on ethnicity

To calculate the shift-share instrument we follow Bartik (1991) and construct an exogenous housing demand shock by interacting the predetermined local ethnic composition of the population with the corresponding growth rates at the state level. The instrument should capture exogenous shifts of a given ethnicity at the county level while avoiding endogeneity issues associated with using local growth rates.

Denoting the shift-share ethnicity instrument for changes in the housing stock with $Z_n^{\Delta \log H}$, we use the following formula

$$Z_n^{\Delta \log H} = \sum_k \gamma_{n,k} \eta_k, \tag{3.33}$$

where $\eta_k = \frac{Pop_{k,-n,1990} - Pop_{k,-n,1970}}{Pop_{k,-n,1970}}$ represents the average ethnicity growth at the state level, excluding residents of county n, and $\gamma_{n,k} = \frac{Pop_{kn,1970}}{Pop_{n,1970}}$ denotes the local residential share of ethnicity k at the beginning of the period. Ethnicity k is defined according to the classification used in our data source assigning population to White, Black or African American, American Indian and Alaska Native, and Asian and Pacific Islander and other ethnicity residents.

3.B.3 Controlling for local supply shifters

One concern of our empirical specification is that unobserved supply dynamics contained in the error term of (3.27) correlate with the instruments, violating the exogeneity assumption necessary for the identification of the parameters. Therefore, in this section we analyze the stability of the estimated coefficients to the inclusion of control variables in (3.27) that might proxy changes in the construction cost of housing *and* potentially correlate with demand changes. In particular, we control for changes of per capita payroll in the construction sector and for changes in the quality of the housing stock over the considered period. The housing characteristics we investigate are the median number of rooms, median building year, and share of detached single-family houses in the county. Data on per capita payroll from 1980 to 1997 stems from County Business Patterns (CBP), while housing characteristic in 1980 and 2000 is published by the US census. Both data sets are provided by IPUMS. In addition to housing characteristics, we control for relative changes in homeownership rates that are included in the dynamics of the error term according to Section 3.B.1.

Table 3.B.1 shows the results. Despite losing about 16% of the sample due to data unavailability at the county level, controlling for supply shifters does not strongly affect our main elasticity estimates. The coefficient of the main effect does become less significant for the different instruments, but it remains approximately within one and a half standard deviation of our main estimates. On the contrary, the coefficient of the interaction effect responsible for the heterogeneity of housing supply elasticities becomes even more significant while displaying the same magnitude. This seems to suggest that these observed dynamics of the construction sector do not considerably affect the value of our housing supply elasticities estimates.

3.B.4 Comparison with Saiz (2010) MSAs elasticities

In this section, we compare our housing supply elasticity estimates with those computed by Saiz (2010). To this end, we assign each county to a Metropolitan

Table 3.B.1: County-level housing supply elasticity estimates including controls

Dependent variable: Change in log housing prices (per m^2) between 1980 and 2000 ($\Delta \log \mathcal{P}$)				
Instruments:	Log-temperature	Fertility rate	Shift-share ethnicity	All three instruments
	(1)	(2)	(3)	(4)
$\Delta \log Q$	0.550**	0.267	0.248*	0.299**
	(0.246)	(0.187)	(0.151)	(0.151)
$S_n^{\text{built}} \Delta \log Q$	2.196***	2.654***	2.470***	2.629***
	(0.737)	(0.666)	(0.746)	(0.759)
Controls	Yes	Yes	Yes	Yes
Observations	2.599	2.599	2.599	2.599
Underidentification[a]	0.002	0.000	0.002	0.002
Weak identification[b]	7.986	12.342	7.709	21.342
Overidentification[c]	.	.	.	0.685

Note: Clustered standard errors at the state level in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. a) P-value of the Kleibergen-Paap LM statistic. b) Kleibergen-Paap F-statistic. The critical values for 10/15/20% maximal IV size are 7.03/4.58/3.95 in columns 1-3 and 26.68/12.33/9.10 in column 4, respectively. c) P-value of Hansen J statistic.

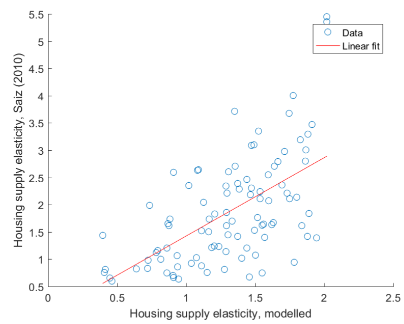
Statistical Area (MSA) and aggregate county-level elasticity using population weighted averages. As Figure 3.B.1a illustrates, our estimates show a strong positive correlation of about 0.6 with those of Saiz (2010). However, as evident from this figure, we tend to recover higher housing supply elasticities as Saiz (2010). The reason for this higher number is that Saiz (2010) potentially underestimates housing supply elasticities, as housing transactions occurring within MSAs likely occur in dense and more inelastic places.

3.C Counterfactual analysis

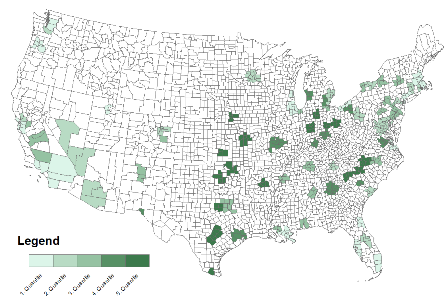
This section describes the system of equations that we use to simulate counterfactual policy experiments. Additionally, we provide complementary information on the simulation results presented in Section 3.4 and 3.5 of the main text.

Figure 3.B.1: Comparison of housing supply elasticity with Saiz (2010)

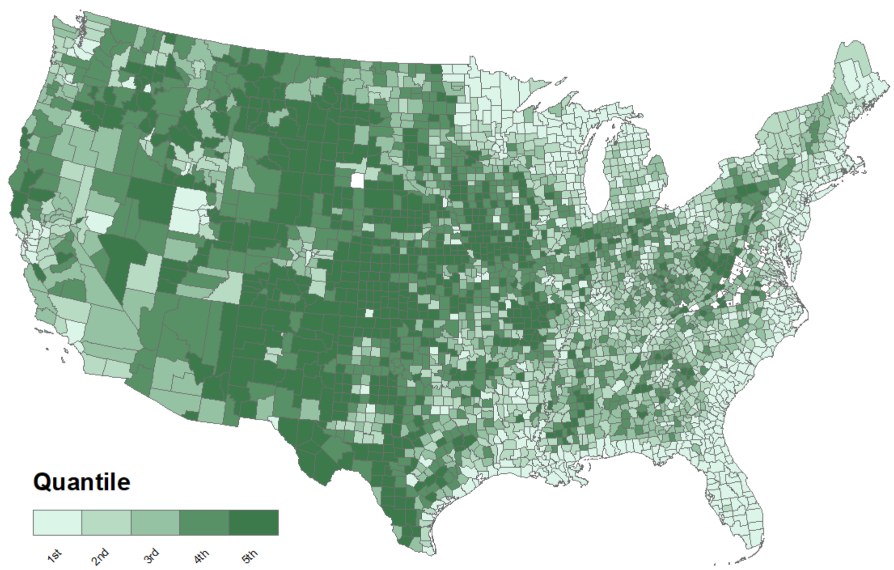
(a) Comparison with Saiz (2010)



(b) Saiz (2010)



(c) Own-computation (η_n)



Note: In panel a) and b) we compare our housing supply elasticity with estimates described in Saiz (2010), which are based on US metropolitan statistical areas (MSA)and in b) estimates of Saiz (2010), respectively. A darker shading in the map indicates a higher quantile. In panel c) we show recovered housing supply elasticities of our model reported by quantiles. We compute the median value for counties belonging to the same MSA and get a correlation coefficient between Saiz (2010) and our measures of 0.6.

3.C.1 System of equations

Let $\hat{x} = \frac{x'}{x}$ denote a counterfactual change, where x is an endogenous outcome variable of the baseline model and x' is its unobserved counterfactual value after a shock to the tax subsidies through θ or s. We solve the following system of equations with respect to counterfactual changes $\hat{x}$, where observed outcomes x of the baseline specification play the role of parameters.

The counterfactual equation for wages directly follows from equilibrium wages (3.19):

$$\hat{w}_i w_i \hat{L}_i L_i = \alpha \sum_{n \in N} \hat{\pi}_{ni} \pi_{ni} \hat{R}_n R_n \hat{\bar{y}}_n \bar{y}_n. \tag{3.34}$$

Counterfactual changes in the tenure-specific number of residents and workers are given by counterfactual changes in commuting flows, which can be derived from (3.25) and (3.26), respectively. This leads to

$$\hat{R}^{\omega}_n R^{\omega}_n = \bar{L} \sum_{k \in N} \hat{\lambda}^{\omega}_{nk} \lambda^{\omega}_{nk}, \tag{3.35}$$

$$\hat{L}^{\omega}_n L^{\omega}_n = \bar{L} \sum_{k \in N} \hat{\lambda}^{\omega}_{kn} \lambda^{\omega}_{kn}. \tag{3.36}$$

As a consequence, the total number of residents and workers is

$$\hat{R}_n R_n = \hat{R}^{\mathcal{R}}_n R^{\mathcal{R}}_n + \hat{R}^{\mathcal{O}}_n R^{\mathcal{O}}_n, \tag{3.37}$$

$$\hat{L}_n L_n = \hat{L}^{\mathcal{R}}_n L^{\mathcal{R}}_n + \hat{L}^{\mathcal{O}}_n L^{\mathcal{O}}_n. \tag{3.38}$$

We now turn to counterfactual changes to the per capita labor income of owner-occupiers. Because they have Cobb-Douglas preferences, households spend a constant fraction $(1-\alpha)$ of their income for housing consumption. It follows that $\frac{H^{\mathcal{O}}_{ni} r^{\mathcal{O}}_n}{\bar{L}\lambda^{\mathcal{O}}_{ni}} = (1-\alpha) y^{\mathcal{O}}_{ni}$. Using the definition of mortgage interest in (3.12) and expressing prices into a periodic cost as in (3.2.4), we obtain that $m_{ni} = (1-\alpha)\phi y^{\mathcal{O}}_{ni}$, where $\phi = \xi\chi\frac{(1+\chi)(1-(1+\chi)^{-t})}{\chi}$ defines the size of mortgage interests. Substituting these terms into (3.3) and rearranging yields the following elegant expression

$$y^{\mathcal{O}}_{ni} = \frac{w_i - \tau(w_i - \zeta_{ni})}{\alpha + \phi(1-\alpha)}.$$

Using this equation, we can write the counterfactual equation of the per-capital labor income of owner-occupiers as

$$\hat{y}^{\mathcal{O}}_{ni} y^{\mathcal{O}}_{ni} = \frac{\hat{w}_i w_i - \hat{\tau}\tau(\hat{w}_i w_i - \hat{\zeta}_{ni}\zeta_{ni})}{\alpha + \phi(1-\alpha)}, \tag{3.39}$$

where counterfactual changes in tax subsidies are given by

$$\hat{\zeta}_{ni}\zeta_{ni} = max(s, \theta \hat{m}_{ni} m_{ni}). \tag{3.40}$$

Note that because they represent exogenous parameters, we do not employ the hat notation for s and θ. However, depending on the simulation exercise, the reader must interpret s or θ in (3.40) as the new value of the parameter that generates the initial shock to the system of equations.

Renters per capita labor income directly follows from (3.5)

$$\hat{y}_{ni}^{\mathcal{R}} y_{ni}^{\mathcal{R}} = \hat{w}_i w_i - \hat{\tau}\tau(\hat{w}_i w_i - s). \tag{3.41}$$

Using (3.8), we can write counterfactual changes in the tenure-specific total income, which includes both labor income and a redistributive term from the global portfolio, as

$$\hat{\bar{y}}_n^{\omega} \bar{y}_n^{\omega} = \bar{L} \frac{\sum_{k \in N} \lambda_{nk}^{\omega} \hat{\lambda}_{nk}^{\omega} (\hat{y}_{nk}^{\omega} y_{nk}^{\omega} + \Pi \hat{\Pi})}{\hat{R}_n^{\omega} R_n^{\omega}}, \tag{3.42}$$

where counterfactual changes in the portfolio are given by

$$\Pi \hat{\Pi} = \hat{G} G + \sum_{k,f} (\hat{\lambda}_{kf}^{\mathcal{O}} \lambda_{kf}^{\mathcal{O}} m_{kf} \hat{m}_{kf} + (1-\alpha) y_{kf}^{\mathcal{R}} \hat{y}_{kf}^{\mathcal{R}} \hat{\lambda}_{kf}^{\mathcal{R}} \lambda_{kf}^{\mathcal{R}}), \tag{3.43}$$

Using (3.7), counterfactual changes of total income must satisfy

$$\hat{\bar{y}}_n \bar{y}_n = \frac{1}{\hat{R}_n R_n} \left(\hat{\bar{y}}_n^{\mathcal{R}} \bar{y}_n^{\mathcal{R}} \hat{R}_n^{\mathcal{R}} R_n^{\mathcal{R}} + \hat{\bar{y}}_n^{\mathcal{O}} \bar{y}_n^{\mathcal{O}} \hat{R}_n^{\mathcal{O}} R_n^{\mathcal{O}} \right). \tag{3.44}$$

Using (3.15), we obtain a counterfactual productivity given by

$$\hat{a}_n = \hat{L}_n^{\nu}. \tag{3.45}$$

Changes in the consumption price index are derived from (3.18) and must satisfy

$$\hat{P}_n = \left(\frac{1}{\hat{\pi}_{nn}} \right)^{1/(1-\sigma)} \frac{\hat{w}_n}{\hat{a}_n}. \tag{3.46}$$

Counterfactual changes in the tenure-specific cost of housing follow from (3.14) and are equal to

$$\hat{r}_n^\omega = \left(\hat{\bar{y}}_n^\omega \hat{R}_n^\omega\right)^{\frac{1}{1+\eta_n}}. \tag{3.47}$$

We compute counterfactual changes in mortgage interest by substituting (3.10) and (3.2.4) into (3.12), such that

$$\hat{m}_{ni} = \hat{y}_{ni}^{\mathcal{O}}. \tag{3.48}$$

Counterfactual trade shares are obtained using (3.17), which leads to

$$\hat{\pi}_{ni} = \frac{\left(\frac{\hat{w}_i}{\hat{a}_i}\right)^{1-\sigma}}{\sum_{k\in N}\left(\frac{\hat{w}_k}{\hat{a}_k}\right)^{1-\sigma}\pi_{nk}}. \tag{3.49}$$

Finally, we express tenure-specific counterfactual changes in commuting flows by dividing the counterfactual population mobility condition by the equilibrium mobility condition (3.22):

$$\hat{\lambda}_{ni}^\omega = \frac{\left(\hat{G}\right)^{\beta\epsilon}\left(\frac{\hat{y}_{ni}^\omega}{\hat{P}_n^\alpha \hat{r}_n^{\omega 1-\alpha}}\right)^{(1-\beta)\epsilon}}{\sum_{l\in\omega}\sum_{f\in N}\sum_{k\in N}\left(\hat{G}\right)^{\beta\epsilon}\left(\frac{\hat{y}_{kf}^l}{\hat{P}_k^\alpha \hat{r}_k^{l1-\alpha}}\right)^{(1-\beta)\epsilon}\lambda_{kf}^l}. \tag{3.50}$$

Note that (3.45) to (3.50) are expressed in terms of counterfactual changes (and not values) because the baseline level of the considered outcome is simplified.

We compute changes in the provision of the public good using (3.9)

$$\begin{aligned}\hat{G}G = \frac{1}{\bar{L}}\sum_{n\in N}\Bigg(&\bar{L}\tau\hat{\tau}\sum_{k\in N}\hat{\lambda}_{nk}^{\mathcal{R}}\lambda_{nk}^{\mathcal{R}}(w_k\hat{w}_k - s)\\ &+\bar{L}\tau\hat{\tau}\sum_{k\in N}\hat{\lambda}_{nk}^{\mathcal{O}}\lambda_{nk}^{\mathcal{O}}(w_k\hat{w}_k - \hat{\zeta}_{nk}\zeta_{nk})\Bigg).\end{aligned} \tag{3.51}$$

Equations (3.34)-(3.51) hold for each location and allow us to solve the system for counterfactual changes in commuting $\hat{\lambda}_{ni}^\omega$, public good provision $\hat{G}$, and real income $\frac{\hat{y}_{ni}^\omega}{\hat{P}_n^\alpha \hat{r}_n^{\omega 1-\alpha}}$. These changes build up the counterfactual value of the welfare, which using (3.24) is given by

$$\hat{\bar{V}} = \left(\frac{1}{\widehat{\lambda^\omega}_{ni}}\right)^{\frac{1}{\epsilon}}\left(\hat{G}\right)^{\beta}\left(\frac{\widehat{y^\omega}_{ni}}{\hat{P}_n^\alpha \widehat{r^\omega}_n^{1-\alpha}}\right)^{1-\beta}, \tag{3.52}$$

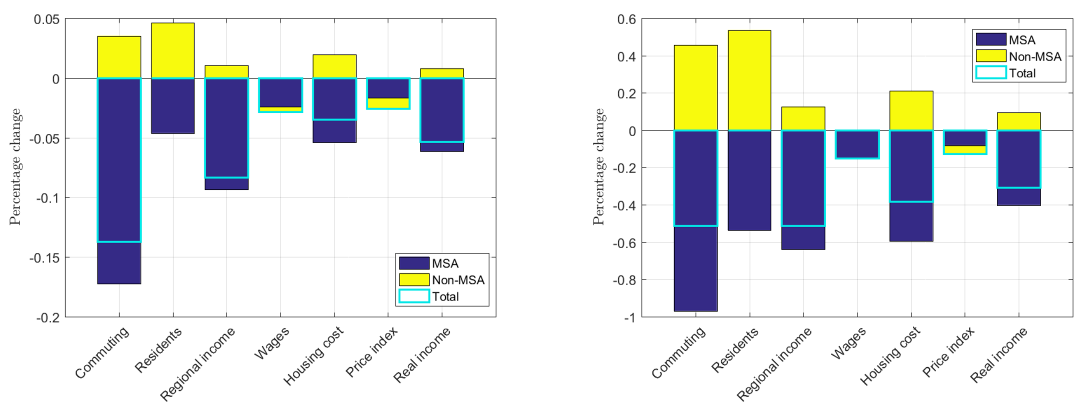
where counterfactual changes in utility are equalized across space and tenure such that no welfare arbitrage is possible across location and tenure mode.

3.C.2 Changes in the spatial distribution: further details

To complement our counterfactual analysis of Section 3.4 and 3.5, we show how tax subsidy reforms affects the spatial distribution of people, wage, and income across space when adding renters and owner-occupiers together. Figure 3.C.1 shows decomposition between MSAs and non-MSAs counties in the case of a repeal of the MID (panel a) and for a doubling of the standard deduction (panel b), respectively. Additionally, in Table 3.C.1, we illustrate how these changes in the tax subsidies affect the spatial dispersion of income across locations. Finally, figure 3.C.2 shows additional maps on the spatial distribution of main outcomes in the case of a repeal of the MID.

Figure 3.C.1: MSAs vs. countryside: Renters and owner-occupiers

(a) Repealing the MID (b) Doubling the standard deduction



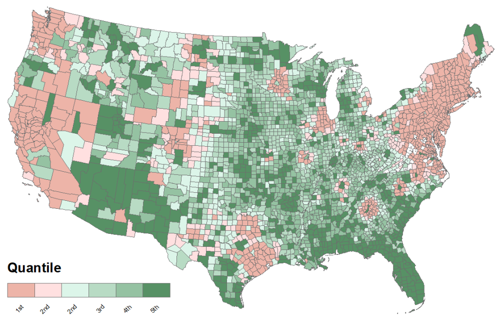
Note: Panel a) depicts counterfactual changes by setting $\theta = 0$ and Panel b) depicts counterfactual changes by setting $s = 12'717$ USD. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

3.C.3 MID repeal: Varying public good provision

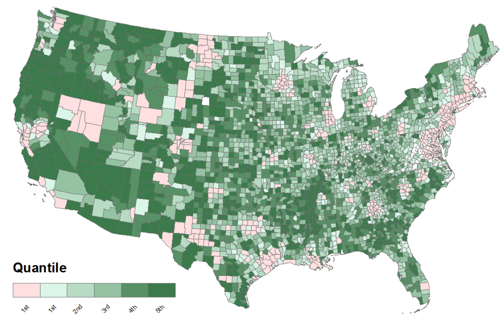
The MID repeal directly impacts the tax revenue of the federal government. In our benchmark model, the federal government adjusts tax rates to maintain public good provision constant. In this section, we validate our main results by assessing the welfare impact of the repeal when the federal government does adjust public

Figure 3.C.2: Repealing the Mortgage Interest Deduction: County-level counterfactual changes

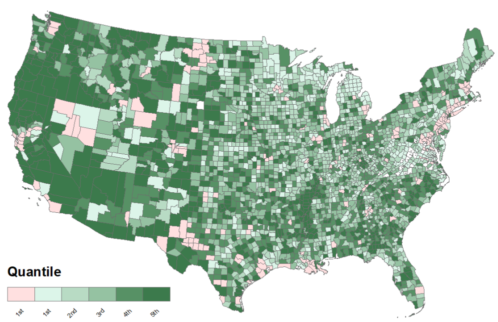
(a) Wages ($\hat{w}_n$)



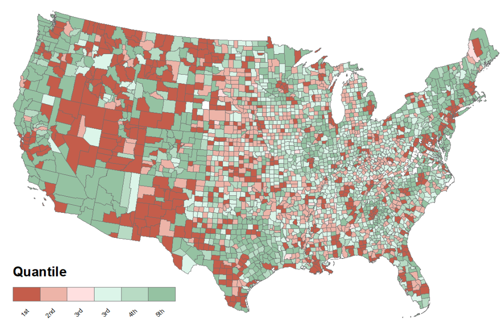
(b) Residents ($\hat{R}_n$)



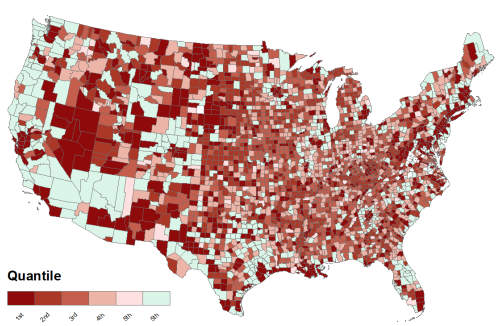
(c) Productivity ($\hat{a}_n$)



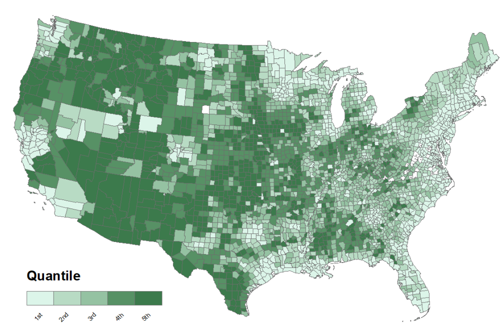
(d) In-commuters sh. - Own. ($\widehat{\sum_{n\neq i} \lambda_{ni}^O / \hat{L}_i^O}$)



(e) In-commuters - Owners ($\widehat{\sum_{n\neq i} \lambda_{ni}^O}$)



(f) Periodic housing cost - Renters ($\hat{r}_n^R$)



Note: We compute counterfactual changes by setting $\theta = 0$. The header ‘owners’ denotes owner-occupiers. Workers can change place of residence, place of work, and tenure mode. We depict positive (negative) growth in green (red). A darker shading represents a stronger effect.

Table 3.C.1: Impact of tax-subsidy reforms on spatial concentration

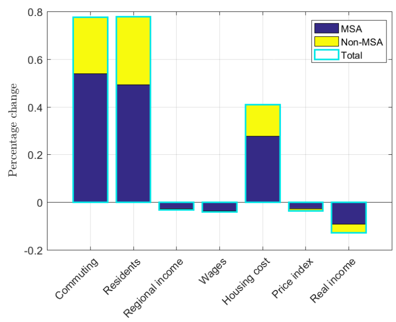
	Repealing the MID			Doubling the standard deduction		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Workers ($\widehat{Gini}(L_n)$)	−0.01	−0.06	−0.03	−0.26	−0.39	−0.34
Residents ($\widehat{Gini}(R_n)$)	−0.01	−0.06	−0.03	−0.24	−0.38	−0.33
Income ($\widehat{Gini}(y_{ni})$)	−0.05	−0.59	−0.46	−3.04	−3.55	−3.46
Real income ($\widehat{Gini}(y_{ni}/P_n^{\alpha} r_n^{1-\alpha})$)	−0.04	−0.40	−0.31	−2.21	−2.56	−2.52

Note: Columns (1)-(3) report counterfactual changes obtained by setting $\theta = 0$, and columns (4)-(6) report counterfactual changes obtained by setting $s = 12'717$ USD. Workers can change place of residence, work and tenure mode.

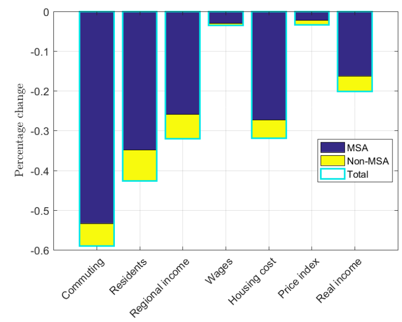
good provision in response to the repeal while keeping income tax rates constant. Table 3.C.2 shows the results. As it can be seen, in this setting the repeal leaves the response of location and tenure choices mostly unaffected and leads to a higher welfare increase. However, renters experience a negative (real) income change, as they do not benefit from lower income tax rates anymore. Figure 3.C.3 shows that our results concerning the shift of economic activity from MSA to non-MSA counties are still valid.

Figure 3.C.3: Repealing the MID: MSAs vs. countryside

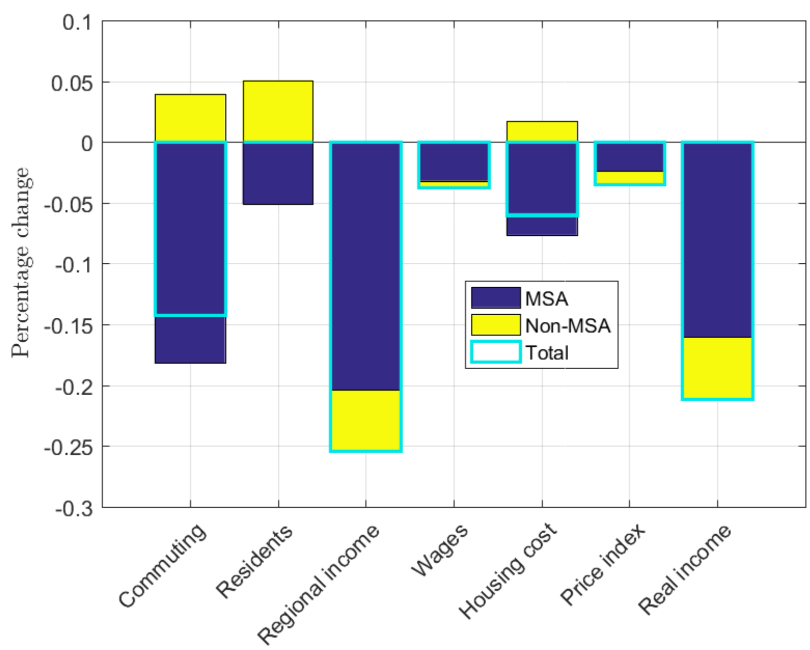
(a) Renters



(b) Owners



(c) Renters and owners



Note: The figure depicts counterfactual changes obtained by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Table 3.C.2: Repealing the Mortgage Interest Deduction

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0.28	0.28	0.28
Commuting ($\sum_{n\neq i}\lambda'_{ni}/\sum_{n\neq i}\lambda_{ni}$)	-	-	-	0.78	-0.59	-0.14
Residents ($\hat{R}_n$)	-	-	-	0.78	-0.43	-
Regional income ($\hat{y}_{ni}$)	-0.05	-0.28	-0.21	-0.03	-0.32	-0.25
Wages ($\hat{w}_i$)	-0.05	-0.04	-0.04	-0.04	-0.03	-0.04
Housing costs ($\hat{r}_n$)	0.02	-0.08	-0.05	0.41	-0.32	-0.06
Price index ($\hat{P}_n$)	-0.06	-0.05	-0.05	-0.04	-0.03	-0.03
Real income ($\hat{y}_{ni}/\hat{P}_n^{\alpha}\hat{r}_n^{1-\alpha}$)	-0.02	-0.23	-0.16	-0.13	-0.20	-0.21

Note: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns (1)-(3) workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns (4)-(6). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

3.D Model's extensions

In this section, we formalize two model extensions and present counterfactual results in the case of a MID repeal.

3.D.1 Property taxation

Property taxes account for less than 1% of the US federal tax revenue. However, because deductible from the taxable income at the federal level, *local* property taxes might affect the welfare and sorting decisions of individuals according to MID subsidies. In this section, we thus investigate the robustness of our results when households can deduct local property taxes from their taxable income in addition to MID subsidies.

In what follows we outline which equations of our baseline model change. Let τ_n^p denote local (county-level) property tax rates. Because owner-occupiers pay property taxes on the local housing value $\frac{1}{\iota}\frac{H^{\mathcal{O}}_{ni} r^{\mathcal{O}}_{n}}{\bar{L}\lambda^{\mathcal{O}}_{ni}}$, their regional income is

$$y^{\mathcal{O}}_{ni} = w_i - \tau(w_i - \zeta_{ni}) + (1 - \frac{\tau^p_n}{\iota})\frac{H^{\mathcal{O}}_{ni} r^{\mathcal{O}}_{n}}{\bar{L}\lambda^{\mathcal{O}}_{ni}} - m_{ni}, \tag{3.53}$$

where ζ_{ni} is given by

$$\zeta_{ni} = max\left(s, \theta m_{ni} + \frac{\tau^p_n}{\iota}\frac{H^{\mathcal{O}}_{ni} r^{\mathcal{O}}_{n}}{\bar{L}\lambda^{\mathcal{O}}_{ni}}\right). \tag{3.54}$$

When choosing whether to itemize, owner-occupiers thus weigh the mortgage interests and property taxes against the standard deduction. We can rewrite the disposable income of owner-occupiers as

$$y^{\mathcal{O}}_{ni} = \frac{w_i - \tau(w_i - \zeta_{ni})}{\alpha + (\frac{\tau^p_n}{\iota} + \phi)(1 - \alpha)}. \tag{3.55}$$

From (3.55) it is apparent that property taxation decreases the income of owner-occupiers with respect to our benchmark model.

To keep our model parsimonious , we assume that the tax revenue generated by property taxation is collected by the federal government and equally redistributed to workers. The federal budget must be balanced, such that

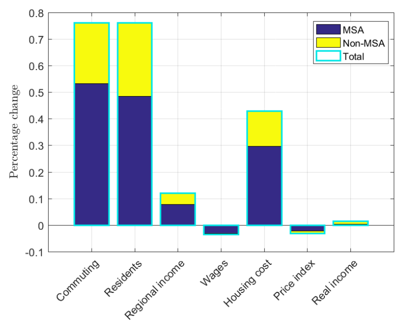
$$G = \frac{1}{\bar{L}}\sum_{n\in N}\left(\tau\bar{L}\sum_{k\in N}\lambda^{\mathcal{R}}_{nk}(w_k - s) + \tau\bar{L}\sum_{k\in N}\lambda^{\mathcal{O}}_{nk}(w_k - \zeta_{nk}) + \frac{\tau^p_n}{\iota}H^{\mathcal{O}}_{n} r^{\mathcal{O}}_{n}\right). \tag{3.56}$$

This approach allows us focus on the effect of the increase in tax deductions caused by property taxation without diving into considerations regarding the amount of local public good provision provided by local governments. In fact, note that the denominator in (3.55) simplifies in our counterfactual simulations, such that ζ_{ni} is the main terms through which property taxation acts on workers' choices.

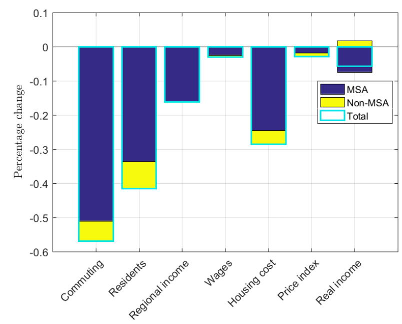
In our counterfactual simulations we set $\tau^p_n = 0.01$ across all location, This rate, which is based on the ACS 2009-2013, corresponds to the median payment of real estate taxes for the median housing value. We adjust the standard deduction to 8857 USD to match the observed itemization rate of individuals itemizing the MID. Table 3.D.1 and Figure 3.D.1 reports simulation results for repealing the MID in the presence of property taxes.

Figure 3.D.1: Impact of eliminating MID: Decomposing welfare effects

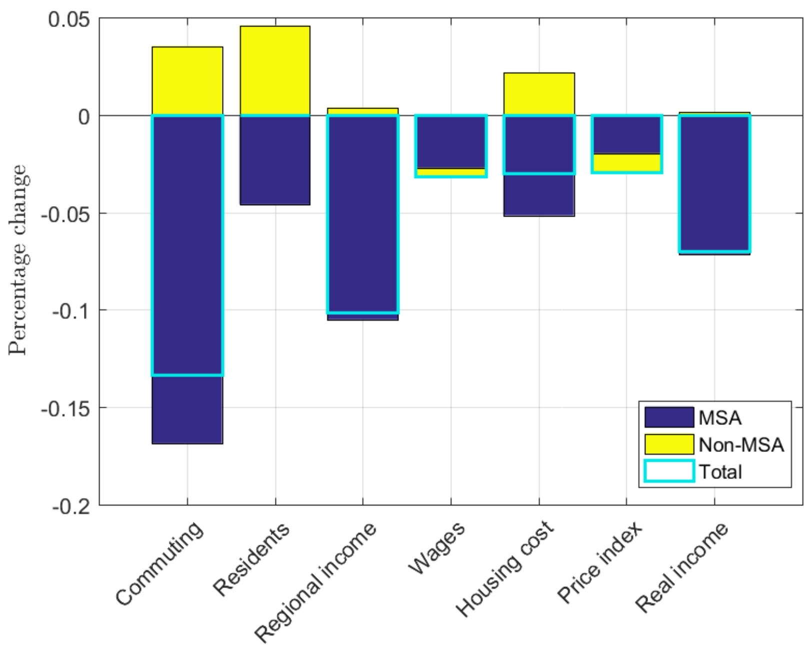
(a) Renters



(b) Owners



(c) Renters and owners



The figure depicts counterfactual changes obtained by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Table 3.D.1: Repealing the Mortgage Interest Deduction

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0	0	0
Commuting ($\sum_{n\neq i}\lambda'_{ni}/\sum_{n\neq i}\lambda_{ni}$)	-	-	-	0.76	−0.57	−0.13
Residents ($\hat{R}_n$)	-	-	-	0.76	−0.42	-
Regional income ($\hat{y}_{ni}$)	0.13	−0.10	−0.03	0.12	−0.16	−0.10
Wages ($\hat{w}_i$)	−0.04	−0.03	−0.03	−0.04	−0.03	−0.03
Housing costs ($\hat{r}_n$)	0.04	−0.06	−0.02	0.43	−0.28	−0.03
Price index ($\hat{P}_n$)	−0.04	−0.04	−0.04	−0.03	−0.03	−0.03
Real income ($\hat{y}_{ni}/\hat{P}_n^{\alpha}\hat{r}_n^{1-\alpha}$)	0.15	−0.06	0.01	0.01	−0.06	−0.07

Note: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns (1)-(3) workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns (4)-(6). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

3.D.2 Progressive tax schedule

In general, tax deductions become more valuable with rising income due to the progressivity of the tax system. Because tax progressivity makes the MID a regressive subsidy, it creates an additional systematic link between a location's productivity and the tax incentives for owner-occupiers to live in that location. We test the robustness of our main results with respect to this additional sorting effect.

In what follows we illustrate how a progressive income taxation affects the equations of our baseline model. In line with the literature, we model progressive tax rates by introducing a parameter $\upsilon > 0$ governing the progressivity.[33] The per-capita income of owner-occupiers is

$$y_{ni}^{\mathcal{O}} = w_i - \tau_{ni}^{\mathcal{O}}(w_i - \zeta_{ni}) + \frac{H_{ni}^{\mathcal{O}} r_n^{\mathcal{O}}}{\bar{L}\lambda_{ni}^{\mathcal{O}}} - m_{ni}, \tag{3.57}$$

[33] see Eeckhout and Guner (2017), Heathcote et al. (2017) or Fajgelbaum et al. (2019).

where $\zeta_{ni} = max(s, \theta m_{ni})$ and the tax rate relevant for homeowners is given by $1 - \tau_{ni}^{O} = (1-\tau)(w_i - \zeta_{ni})^{-\upsilon}$. Renters' income is

$$y_{ni}^{\mathcal{R}} = w_i - \tau_i^{R}(w_i - s), \tag{3.58}$$

where the relevant tax rate is given by $1 - \tau_i^R = (1-\tau)(w_i - s)^{-\upsilon}$. The MID thus creates a tax rate differential between owner-occupiers and renters because it shifts taxable labor income according to tenure mode. Tax payments of owner-occupiers and renters are given by

$$T_{ni}^{\mathcal{O}} = w_i - (1-\tau)(w_i - \zeta_{ni})^{1-\upsilon} \tag{3.59}$$

and

$$T_i^{\mathcal{R}} = w_i - (1-\tau)(w_i - s)^{1-\upsilon}, \tag{3.60}$$

respectively. Per capita tax revenue of the federal government must equal per capita public good provision, such that

$$G = \frac{1}{\bar{L}} \sum_{n \in N} \left(\bar{L} \sum_{\omega} \sum_{k \in N} \lambda_{nk}^{\omega} T_k^{\omega} \right). \tag{3.61}$$

A tax schedule is defined as progressive if marginal tax rates $\frac{\partial T^{\omega}}{\partial w}$ exceed the average tax rates $\frac{T^{\omega}}{w}$ for every level of wages w_n. This is true for renters and owner-occupiers if $\upsilon > 0$ and MID subsidies do not exist ($\theta = 0$). However, if $\upsilon > 0$ and MID subsidies are fully deductible ($\theta = 1$), the tax schedule is not necessarily progressive over the entire wage distribution of owner-occupiers. In fact, because owner-occupiers spend a constant share of their income for housing, the MID counteracts the progressive nature of the tax schedule. In this setting, at a specific cut-off point of the income distribution the tax schedule changes from regressive to progressive.

Our benchmark model features no tax progressivity ($\upsilon = 0$), thus imposing that marginal tax rates are equal to average tax rates. To introduce tax rate progressivity, we calibrate the progressivity parameter according to Eeckhout and Guner (2017), who estimate $\upsilon = 0.12$ for the US income tax system. We adapt the standard deduction to 6341 USD to match the observed share of people itemizing MID subsidies according to IRS data. Additionally, we calibrate the tax shifter τ

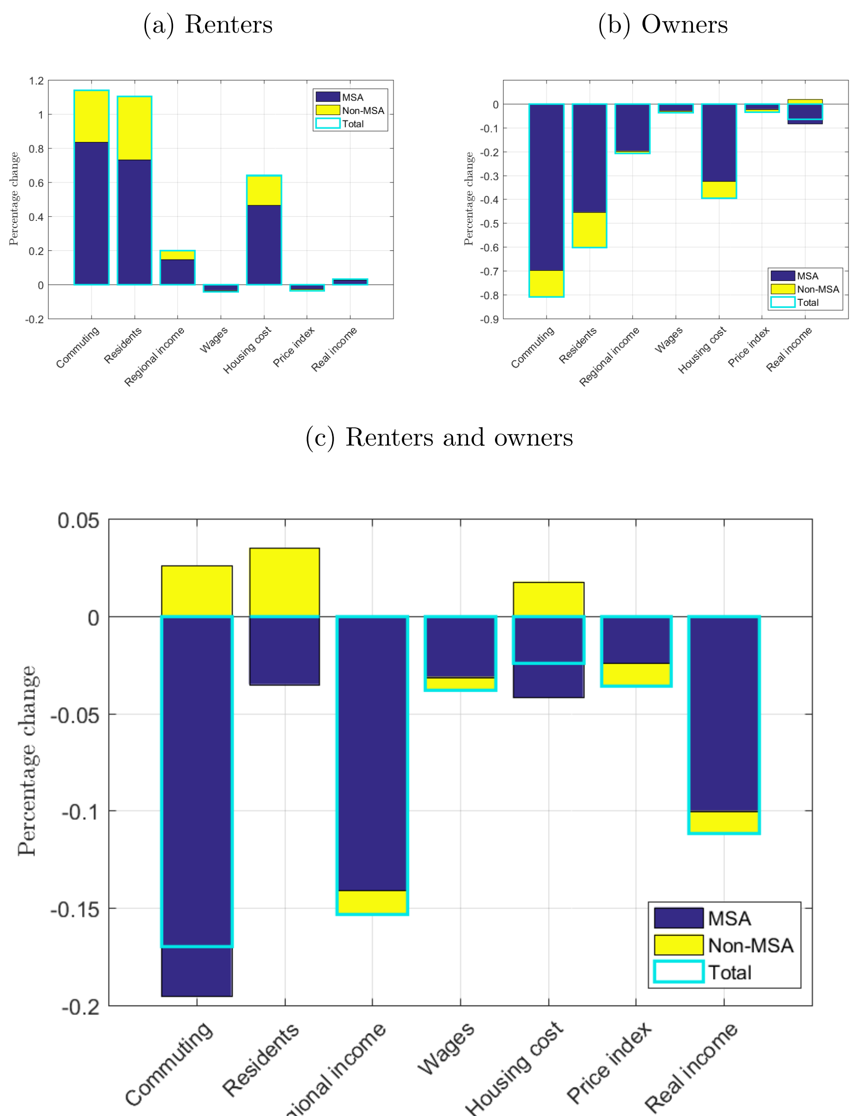
to match the government revenue of our benchmark chase, such that the results in the case of progressive tax rates are not affected by changes in public expenditure at the federal level. Table 3.D.2 and Figure 3.D.2 report the results of repealing the MID in the presence of tax progressivity.

Table 3.D.2: Repealing the Mortgage Interest Deduction

	Keeping location and tenure choices fixed			Varying location and tenure choices		
	Renters	Owners	Total	Renters	Owners	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	-	-	-	0.01	0.01	0.01
Commuting ($\sum_{n\neq i} \lambda'_{ni} / \sum_{n\neq i} \lambda_{ni}$)	-	-	-	1.14	−0.81	−0.17
Residents ($\hat{R}_n$)	-	-	-	1.10	−0.60	-
Regional income ($\hat{y}_{ni}$)	0.21	−0.13	−0.03	0.20	−0.21	−0.15
Wages ($\hat{w}_i$)	−0.03	−0.03	−0.03	−0.04	−0.04	−0.04
Housing costs ($\hat{r}_n$)	0.08	−0.07	−0.02	0.64	−0.40	−0.02
Price index ($\hat{P}_n$)	−0.04	−0.03	−0.04	−0.04	−0.04	−0.04
Real income ($\hat{y}_{ni} / \hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}$)	0.21	−0.09	0.01	0.03	−0.06	−0.11

Note: We compute counterfactual changes by setting $\theta = 0$. Counterfactual tax rates adjust to keep federal public expenditure fixed. The header 'owners' denotes owner-occupiers. In columns (1)-(3) workers do not adjust place of residence, place of work and tenure mode. We allow for these responses in columns (4)-(6). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Figure 3.D.2: Impact of eliminating MID: Decomposing welfare effects



The figure depicts counterfactual changes obtained by setting $\theta = 0$. The header 'owners' denotes owner-occupiers. Workers can change place of residence, work and tenure mode. MSAs are defined according to Saiz (2010). County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, prices, and housing costs are weighted by the number of residents. Changes in wages are weighted by the number of workers.

4

The welfare impact of reciprocal tax agreements

joint with **Olivier Schöni**

4.1 Introduction

Mobile workers sort according to tax incentives. Because tax incentives are comparatively higher in peripheral areas, this phenomenon has been typically considered welfare inefficient, as it drains away the labor force from highly productive places. However, as argued by Monte et al. (2018), over the last decades workers have become increasingly mobile in terms of commuting distance from the place of residence to place of work. This increased mobility allows workers to benefit from tax incentives where they live while still working in highly productive areas. Because taxpayers have become progressively more mobile, understanding the factors influencing income tax competition between US states has become more important. In this paper, we investigate how Reciprocal Tax Agreements (RTAs) between US states, which allow workers to pay income taxes where they live instead of where they work, affect the welfare of the country.

To this end, we employ a spatial general equilibrium model featuring the main characteristics of the US state income taxation. In our model, individuals react to tax incentives by choosing where to live and where to work, thereby altering the taxbase of the states. We calibrate our model to mimic the real-world distribution of residents, workers, commuting flows, and income across US counties. Our results suggest that existing RTAs increase the country welfare by 0.27%. If all US states were to enter an agreement with the other ones, the country welfare would further grow, with an increase by about 0.92%.

The positive impact of the agreements is mostly due to the endogenous tax rate response to entering an agreement. Empirically, we estimate that entering an additional agreement increases, on average, a state tax rate by 1.2 percentage points. We interpret this response as a decrease in tax competition, which allows the states entering the agreement to reverse their race to the bottom in tax rates to attract the taxbase. The contribution to aggregate welfare varies considerably depending on which states enter the agreement. We provide evidence that the higher the tax wedge between states, as captured by a higher tax rate dispersion across states, the stronger the welfare gains provided by tax agreements.

In our theoretical framework, we allow locations to vary regarding their productivity, housing supply elasticity, and amenities. The spatial distribution of residents and workers is characterized by the balancing of agglomeration and dispersion forces. Commuting flows and home markets effects encourage people to concentrate in some locations, while housing markets and idiosyncratic location preferences tend to disperse them. Specifically, commuting linkages between counties allow people to escape congested housing markets of productive locations. We match our model to real-world data on the distribution of residents, workers, and commuting flows, as well as to MSAs housing supply elasticities estimated by Saiz (2010). Because the equilibrium solution of the model exists and is unique, we are able to recover location fundamentals that perfectly match the observed data.

Our contribution to the literature is threefold. First, to the best of the authors' knowledge, the literature currently lacks a discussion on the welfare impact of RTAs and the channels through which they affect the spatial distribution of residents and workers across locations. By focusing their analysis on U.S. MSAs crossing state borders, Agrawal and Hoyt (2017) suggest a theoretical framework allowing to measure the welfare cost caused by inter-jurisdictional tax differentials due to changes in commute time. Rohlin et al. (2014) and Rork and Wagner (2012) empirically investigate the effects of RTAs on selected economic outcomes.

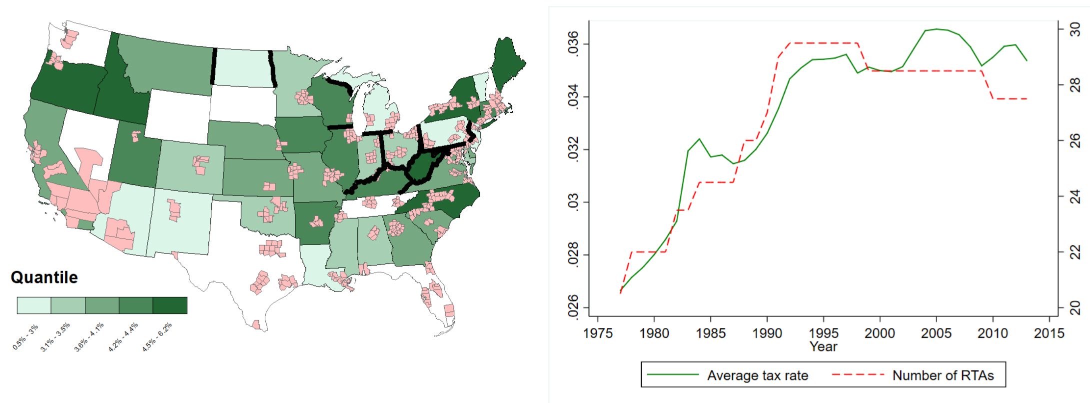
Second, by featuring engodenous residential and workplace location choices at the county level, the structural model allows us to investigate the local heterogenous sorting response of the tax base to tax policies implemented at a more aggregate level. As such, our welfare computation takes into account not only interstate migration and labor supply responses, but also *within* state effects. As pointed out by Albouy (2009), this mechanism is important, as fiscal incentives are unequally distributed across space even in the case of a central government taxation.

Third, dissociating place of residence and place of work allows us to separately investigate the role played by location fundamentals, such as local productivity and housing supply elasticities, in determining the impact of a tax agreement.

The rest of the paper is structured as follows. Section 4.2 briefly discusses the US institutional setting regarding labor income taxation and RTAs. In Section 4.3 we present our theoretical framework. In Section 4.4, we present the data used to calibrate the structure of the model and to investigate the endogenous response of income tax rates to reciprocal agreements. Section 4.5 illustrates the simulation results. Section 4.6 concludes.

Figure 4.2.1: Average state income tax rates and Reciprocal Tax Agreements

(a) Spatial distribution in 2013 (b) Historic evolution



Note: A darker shading in the map indicates a higher tax rate quantile. States in white do not tax labor income. Red shaded areas are part of a MSA regions and solid black lines indicate reciprocal tax agreements between neighboring states. MSAs areas are defined according to Saiz (2010).

4.2 Institutional setting

In 2013 income taxation represented about 36% of the tax revenue of US states according to the State & Local Government Finance data. Income tax rates vary considerably across states, with some states not taxing labor income at all.[1] In 2013, 28 RTAs were in place between 16 out of 42 contiguous US states taxing income.

Several incentives lead two or more states to enter a RTA. First, the acknowledgment from states hosting the biggest labor market that cross-state commuters mainly consume public services in their state of residence, generating little public expenditure in their place of work. Second, an effort to reduce the administrative burden generated by taxing cross-border commuters, which requires the two states to share their internal tax data.[2] Third, the agreement might be part of a broader deal aiming to improve fiscal cooperation between the two states.

Panel a) of Figure 4.2.1 shows the geographic distribution of average income tax

[1]US states not taxing labor income are: Florida, Nevada, New Hampshire, South Dakota, Tennessee, Texas, Washington, and Wyoming.

[2]The reduction in the administrative hurdle is because i) double taxation is avoided, implying that the state where the place of work is located doesn't have to handle the taxation of incoming commuters, and ii) place of residence taxation doesn't involve handling information from employers, and iii) the administrations of the two states do not have to exchange and cross-validate information regarding the place of work and residence of the taxpayers. Indeed, a reduction in the bureaucracy of handling the taxation the commuters is often cited as one of the main reasons to enter a RTA, see Rork and Wagner (2012).

rates in 2013 together with RTAs. As it can be seen, tax agreements are usually entered between states displaying a tax rate wedge, with at least one of the two states having a metropolitan area close to the border of the other state entering the agreement. Panel b) of Figure 4.2.1 shows the historic evolution of average tax rates and RTAs from 1977 to 2013.[3] From the mid seventies until the late nineties, tax rates have, on average, steadily grown. From 2000 to 2013, income tax rates have oscillated without showing any clear trend. Similarly, the total number of RTAs steadily grown up to 2000, and slightly decreased afterward. From 1977 to 2013, 22 RTAs were entered or repealed, providing a variation in the number of agreements for 44 US states.

4.3 Model

Our model builds on the theoretical frameworks introduced by Redding and Rossi-Hansberg (2017) and Monte et al. (2018). The economy of the country is endowed with a continuous measure of $\bar{L}$ workers which supply one unit of labor inelastically to one of the N locations (US counties) composing the country. Workers are mobile and choose where to live and where to work to maximize their indirect utility function. Agglomeration economies provide productivity incentives to workers to supply labor in dense labor markets, whereas idiosyncratic preferences for each place of work–place of residence combination and the cost of local housing disperse residents across space. Spatial sorting of households is affected by income taxes, which households pay to state governments. Cross state commuters are taxed either in their place of work or in their place of residence, depending on the existence of an agreement between the two states.

4.3.1 Workers' heterogeneous preferences

We assume that a worker ω living in county n and working in county i forms preferences according to the following indirect Cobb-Douglas utility function

$$V_{ni}(\omega) = \frac{b_{ni}(\omega)}{\kappa_{ni}} G_n^{\beta} \left(\frac{y_{ni}}{P_n^{\alpha} r_n^{1-\alpha}} \right)^{1-\beta} \quad , \tag{4.1}$$

[3] We focus on this time period because it corresponds to the one used in our empirical analysis. In fact, this time interval allows us to focus on the same panel of US states throughout time.

where $b_{ni}(\omega)$ is a random utility component capturing the idiosyncratic taste of a worker for a specific place of residence and workplace combination. We assume that b_{ni} follows a Fréchet distribution with cumulative density function $\Omega_{ni}(b) = e^{-B_{ni}b^{-\epsilon}}$, where the scale parameter B_{ni} determines the average bilateral amenity value and the shape parameter ϵ regulates the dispersion of individual idiosyncratic preferences.[4] A large value of the shape parameter ϵ implies that workers' tastes are less dispersed, making counties better substitutes to each other.

The remaining terms of (4.1) are deterministic and shift the idysioncratic taste distribution. Commuting costs in terms of utility are denoted by κ_{ni}. The second component of (4.1) captures the utility provided by local public good consumption G_n, where the parameter $\beta \in [0,1]$ governs the propensity for such consumption. The third term represents the utility derived from real income $\frac{y_{ni}}{P_n^{\alpha} r_n^{1-\alpha}}$ and follows from the optimization of Cobb-Douglas utility over consumption and housing goods. The variable y_{ni} represents after-tax income of workers living in n and working in i, P_n is the aggregate consumption price index, and r_n denotes the periodic cost of housing. The parameter $\alpha \in [0,1]$ governs the expenditure share of income y_{ni} spent on consumption goods.

Each county specializes in the production of a specific good. Workers living in county n consume a basket of goods C_n comprising all goods' varieties. Good varieties other than the one produced in location n are obtained by trading with other regions and workers can adjust their aggregate consumption by substituting across varieties according to the following formula

$$C_n = \left(\sum_{i \in N} c_{ni}^{\rho} \right)^{\frac{1}{\rho}}, \tag{4.2}$$

where $\sigma = \frac{1}{1-\rho}$ is the elasticity of substitution between different varieties. Maximizing (4.2) subject to the budget constraint delivers the aggregate consumption in n for each good variant $c_{ni} = \alpha \tilde{y}_n R_n \frac{p_{ni}^{-\sigma}}{P_n^{1-\sigma}}$, where $\tilde{y}_n$ denotes region's n average per capita disposable income and R_n is the number of residents.[5] The price index of the aggregate consumption good equals $P_n = \left[\sum_{i \in N} p_{ni}^{1-\sigma} \right]^{1/(1-\sigma)}$. The price p_{ni} of a specific variety produced in i and consumed in n consists of a local price p_i where

[4]Extreme value distributions were firstly introduced in discrete choice models by McFadden (1974) and extensively used in the structural literature. See Redding and Rossi-Hansberg (2017) for a survey.

[5]See the next section for further details on the definition of total disposable income.

the production takes place and trade costs d_{ni} between the two locations, that is $p_{ni} = p_i d_{ni}$.

4.3.2 Income taxation and public good provision

Per-capita disposable income of workers living in n and working in i is given by after-tax wages

$$y_{ni} = w_i(1 - \tau_{ni}), \tag{4.3}$$

where τ_{ni} is the relevant state tax rate.[6] Total labor income earned at a given location is obtained by multiplying the average per-capita wage $\bar{y}_n$ with the number of residents R_n, which equals the total labor income earned by stayers and outgoing commuters

$$\bar{y}_n R_n = \bar{L} \sum_{k \in N} \lambda_{nk} y_{nk}, \tag{4.4}$$

where λ_{nk} is the share of workers living in n and working in k.

The aggregate constant fraction of disposable income $(1 - \alpha)\bar{y}_n R_n$ paid by all workers for periodic housing services accrues to local landlords, who pay state income taxes on this additional source of income.[7] Total income $\tilde{y}_n R_n$ in a given location is thus obtained by multiplying the average per capita income $\tilde{y}_n$ with the number of residents R_n, which equals

$$\tilde{y}_n R_n = (1 + (1 - \tau_n)(1 - \alpha))\, \bar{y}_n R_n. \tag{4.5}$$

We now turn to the budget and public good provision of state governments. Let T_{ni} denote a dummy variable which is equal to 1 if the state in which county n is located has a reciprocal tax agreement with the state in which county i is located.[8] In our counterfactual simulations we evaluate the welfare impact of setting $T_{ni} = 1$ for one or several states. We express tax rates for commuters as $\tau_{ni} = \tau_n T_{ni} + \tau_i(1 - T_{ni})$,

[6]Because each county is uniquely associated to a state, for ease of exposition we do not explicitly introduce a state subscript for state taxes. Additionally, workers' income is only taxed once and accrues to either the place of residence or workplace location. In fact, in 2015 the Supreme Court ruled that the same income could not be taxed in two different states, thus banning double taxation in the US.

[7]An alternative way to redistribute the income from housing consumption across locations is to assume the existence of a hypothetical global housing portfolio owned by local landlords, such as in Caliendo et al. (2018b).

[8]If place of residence and place of work belong to the same state, causing taxes to be paid to the place of residence, we also set $T_{ni} = 1$.

where income tax rates τ_n only vary across states. If two states engage in a RTA ($T_{ni} = 1$), tax liabilities belong to the place of residence, while if no RTA between two states is in force ($T_{ni} = 0$) workers pay taxes to the state where they work. To balance their budget, states equal public good expenditure G_S to their tax revenue, such that

$$G_S = \bar{L} \sum_{n \in s} \Bigg(\underbrace{\sum_{k \in N} \lambda_{nk} w_k \tau_n T_{nk}}_{\substack{\text{Tax liabilities belonging} \\ \text{to residence regions}}} + \underbrace{\sum_{f \in N} \lambda_{fn} w_n \tau_n (1 - T_{fn})}_{\substack{\text{Tax liabilities belonging} \\ \text{to employment regions}}} \Bigg) + \underbrace{\sum_{n \in s} \tau_n \left(1 - \alpha\right) \bar{y}_n R_n}_{\substack{\text{Tax liabilities} \\ \text{of landlords}}} . \tag{4.6}$$

In addition to this tax revenue, we model a secondary state revenue $\bar{G}_S$ arising from sources that are exogenous to our structural framework, such as intergovernmental transfers, sale taxes, licenses, and corporate income taxes.[9] We assume that a state total tax revenue $G_S + \bar{G}_S$ is invested locally proportionally to the share of residents living in county n relative to the total number of residents R_S living in the state, such that nominal local public good is

$$\tilde{G}_n = \left(G_S + \bar{G}_S\right) \frac{R_n}{R_S}. \tag{4.7}$$

To take into account the fact that state governments must purchase local housing and consumption goods to provide public goods, we follow Caliendo et al. (2018a) and Fajgelbaum et al. (2019) and adjust the amount of state nominal tax revenue invested in a county to its local cost of living

$$G_n = \frac{\tilde{G}_n}{P_n^{\alpha} r_n^{1-\alpha}}. \tag{4.8}$$

4.3.3 Housing markets

Given Cobb-Douglas preferences, total housing expenditure in location n is given by

$$r_n H_n = (1 - \alpha) \tilde{y}_n R_n, \tag{4.9}$$

[9] Similarly to Binner and Day (2015), we model this external public good provision to allow states not taxing labor income to provide public goods. Note that in our counterfactual simulations only G_s is affected by entering RTAs, whereas $\bar{G}_s$ is unchanged.

where H_n is the total housing demand in terms of surface. On the supply side, we scale down Hsieh and Moretti (2019) approach to the county level, and assume that local housing prices are an increasing function of the number of residents according to

$$\mathcal{P}_n = \bar{h}_n H_n^{\eta_n}, \tag{4.10}$$

where $\bar{h}_n$ denotes unobserved location-specific characteristics affecting housing supply. The parameter $\eta_n \geq 0$ corresponds to the inverse local housing supply elasticity, i.e. $\frac{\mathcal{P}_n}{H_n}\frac{\partial H_n}{\partial \mathcal{P}_n} = 1/\eta_n$. As pointed out by Hsieh and Moretti (2019), limited land availability for new development and restrictive land use regulation decrease the supply responsiveness of local housing supply, leading to larger values of η_n. To link housing prices to periodic housing costs, we use the following present-value formula $r_n = \frac{\gamma}{1+\gamma}\frac{\mathcal{P}_n}{1-(1+\gamma)^{-\phi}}$, where γ is a discount factor and ϕ is the lifespan of a residential unit.

4.3.4 Production

Production amenities of location n depend on exogenous productivity fundamentals $\bar{a}_n$ and the amount of labor

$$a_n = \bar{a}_n L_n^{\nu}, \tag{4.11}$$

where $\nu \geq 0$ governs the strength of the agglomeration force. We follow Armington (1969) and assume that each region produces a differentiated consumption good under perfect competition. Profit maximizing prices are thus equal to marginal costs, such that $p_{ni} = \frac{d_{ni}w_i}{a_i}$. Due to agglomeration benefits, larger labor markets are more productive and thus offer higher nominal wages. Using (4.2), the value of bilateral trade flows is given by

$$X_{ni} = \alpha \tilde{y}_n R_n \frac{p_{ni}^{1-\sigma}}{P_n^{1-\sigma}}. \tag{4.12}$$

Substituting profit-maximizing prices, we obtain region's n expenditure share for goods produced in region i

$$\pi_{ni} = \frac{\left(\frac{d_{ni}w_i}{a_i}\right)^{1-\sigma}}{\sum_{k\in N}\left(\frac{d_{nk}w_k}{a_k}\right)^{1-\sigma}}, \tag{4.13}$$

as well as the price index in region n

$$P_n = \left(\frac{1}{\pi_{nn}}\right)^{1/(1-\sigma)} \frac{d_{nn} w_n}{a_n}. \tag{4.14}$$

4.3.5 Labor mobility

Workers jointly choose place of work and place of residence providing the highest utility. Since indirect utility is given by a stochastic bilateral amenity term, which is Fréchet distributed, times a deterministic component, the cumulative distribution function of V is

$$\Omega_{ni}(V) = e^{-\frac{B_{ni}}{\kappa_{ni}^{\epsilon}}\left(\left(\frac{G_n}{R_n^{\chi}}\right)^{\beta}\left(\frac{y_{ni}}{P_n^{\alpha} r_n^{1-\alpha}}\right)^{1-\beta}\right)^{\epsilon} V^{-\epsilon}}. \tag{4.15}$$

We compute the share λ_{ni} of workers living in n and working in i as the probability $Pr(V_{ni} \geq \max\{V_{rk}\}, \forall\, r, k \in N)$ of choosing a specific $n-i$ combination in a discrete choice setting. Using the properties of the Fréchet distribution we obtain

$$\lambda_{ni} = \frac{\frac{B_{ni}}{\kappa_{ni}^{\epsilon}}\left(\left(\frac{G_n}{R_n^{\chi}}\right)^{\beta}\left(\frac{y_{ni}}{P_n^{\alpha} r_n^{1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}}{\sum_{k\in N}\sum_{f\in N}\frac{B_{kf}}{\kappa_{kf}^{\epsilon}}\left(\left(\frac{G_k}{R_k^{\chi}}\right)^{\beta}\left(\frac{y_{kf}}{P_k^{\alpha} r_k^{1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}}. \tag{4.16}$$

In an extreme case of no location taste heterogeneity ($\epsilon \to \infty$) there is a perfect elastic supply of labor relative to a shock in the attractiveness of a county. The expected indirect utility of an individual commuting from n to i is then given by

$$E[V_{ni}] = \delta \left[\sum_{k\in N}\sum_{f\in N}\frac{B_{kf}}{\kappa_{kf}^{\epsilon}}\left(\left(\frac{G_k}{R_k^{\chi}}\right)^{\beta}\left(\frac{y_{kf}}{P_k^{\alpha} r_k^{1-\alpha}}\right)^{1-\beta}\right)^{\epsilon}\right]^{\frac{1}{\epsilon}}, \tag{4.17}$$

where $\delta = \Gamma(\frac{\epsilon-1}{\epsilon})$ is a constant term and $\Gamma()$ refers to the Gamma function. Substituting commuting shares (4.16) in (4.17), we obtain

$$E[V_{ni}] = \delta \left(\frac{1}{\lambda_{ni}}\frac{B_{ni}}{\kappa_{ni}^{\epsilon}}\right)^{\frac{1}{\epsilon}}\left(\frac{G_n}{R_n^{\chi}}\right)^{\beta}\left(\frac{y_{ni}}{P_n^{\alpha} r_n^{1-\alpha}}\right)^{1-\beta}. \tag{4.18}$$

Finally, by summing over all commuters for a residence/employment location we get the number of residents/workers living in county n

$$R_n = \bar{L} \sum_{k \in N} \lambda_{nk}, \qquad L_n = \bar{L} \sum_{k \in N} \lambda_{kn}. \tag{4.19}$$

4.3.6 Equilibrium

We characterize the structural equilibrium as satisfying the following conditions:

1. Government spending equals tax revenue according to (4.6) and (4.8).

2. Local housing markets clear according to

$$r_n = ((1-\alpha)\tilde{y}_n R_n)^{\frac{\eta_n}{1+\eta_n}} \left(\frac{\bar{h}_n}{\xi}\right)^{\frac{1}{1+\eta_n}}, \tag{4.20}$$

   where $\xi = \frac{1+\gamma}{\gamma}(1-(1+\gamma)^{-\phi})$.

3. Traded goods markets clear in every county, such that location's n total labor income must equal the total expenditure for goods produced in that location

$$w_n L_n = \alpha \sum_{k \in N} \pi_{kn} \tilde{y}_k R_k. \tag{4.21}$$

4. Workers sort across counties to maximize their indirect utility until they are, on average, indifferent across locations: $E[V_{ni}] = \bar{V}$.

We close the model using the income equations (4.3), (4.4), and (4.5), as well as residents and workers equation (4.19), productivity formula (4.11), and the price index formula (4.14).

By mapping the above framework into the model investigated by Allen et al. (2016), Monte et al. (2018) show that the equilibrium solution of this type of structural model exists and unique. In order to ensure unique equilibria – and rule out corner equilibria where all workers are located in one county – we follow Redding and Rossi-Hansberg (2017) and restrict the parameter space to $\sigma\left(1-\frac{\alpha}{1+1/\epsilon}\right) > 1$, in line with the parameterization suggested in the next section.

4.4 Data, empirics, and counterfactuals

In this section, we describe the data sources used to perform counterfactual simulations. Our data covers all US counties excluding those belonging to the states of Hawaii, Alaska, and all over-sea territories. Additionally, we discuss how we quantify the endogenous response of tax rates of states entering reciprocal tax agreements.[10]

4.4.1 Data and calibration

Parameters provided by the literature: We set the elasticity of substitution between different varieties of tradable goods equal to $\sigma = 5$, as suggested by Simonovska and Waugh (2014). Following Davis and Ortalo-Magne (2011) and Redding (2016), we calibrate the income share spent for consumption goods as $\alpha = 0.7$. We set the Fréchet parameter of households' idiosyncratic preferences equal to $\epsilon = 3.3$, as in Monte et al. (2018) and Bryan and Morten (2015). Workers' propensity for public goods consumption is given by $\beta = 0.22$, in line with Fajgelbaum et al. (2019). We set the strength of the agglomeration force $\nu = 0.1$, as done by Allen and Arkolakis (2014). Finally, we follow Monte et al. (2018) and calibrate housing supply elasticities across the 95 biggest US MSAs using Saiz (2010) estimates and set it equal to the minimum value for counties not belonging to a MSA.

Tax rates and RTAs: We use information on state average income tax rates τ_n provided by NBER TaxSim in 1977-2015. We calibrate τ_n for the year 2013 and complement these tax rates with data on reciprocal tax agreements over the same period by calculating tax rates τ_{ni} for commuters according to the reciprocity status T_{ni} reported by official sources.[11]

Commuting, residents, employment, and wages: Data on the bilateral commuting matrix λ_{ni} stems from the American Community Survey (ACS) over the period 2009-2013. The number of total employment $\bar{L}$ and wages by workplace w_n are provided by the Bureau of Economic Analysis (BEA) for the year 2013.

[10] A summary of the calibrated parameters is provided in the Appendix 4.A.

[11] We gather data from www.thebalance.com, which lists all reciprocal tax agreements between states and list corresponding state income tax exemption forms for a filing non-residence status in the state in which employment occurs.

Trade costs: Trade costs are a function of distance between counties and trade cost elasticity ψ, such that $d_{ni}^{1-\sigma} = dist_{ni}^{\psi}$. The former is computed using GIS data. The latter is calibrated according to Monte et al. (2018), who estimate $\psi = -1.29$.

Housing data: We measure housing value $\mathcal{P}_n$ using the median value of owner-occupied residential units at the county level reported by the American Community Survey (ACS) for the years 2009-2013. We set the discount factor to $\gamma = 0.05$, in line with the US average 30-year fixed mortgage rate in 2013 obtained from the FRED database of the Federal Reserve Bank of St. Louis. The lifespan of a house is $\phi = 100$ years, which according to the National Association of Home Builders (NAHB) corresponds to the average life expectancy of houses of brick masonry.

State expenditure: Data on the exogenous part of public expenditure $\bar{G}_S$ comes from the Government Finance Statistics, which includes detailed information on revenues and expenditures of state governments in 2013. We take values for total state revenues and subtract individual income taxes calculated by the model to calculate the exogenous part of government spending $\bar{G}_S$.[12]

4.4.2 Income tax response to Reciprocal Tax Agreements

We estimate the response of state income tax rates to entering RTAs. The direction of this response is not trivial, as there are likely two main opposing effects acting simultaneously. On the one hand, RTAs directly affect the tax base and the administrative costs of the two states entering the agreement. The former can increase or decrease depending on the commuting patterns observed between states, whereas the latter should arguably always decrease.

Therefore, a state expanding its tax base and reducing administrative costs when entering a RTA should, ceteris paribus, invariably lower its income tax rate. We argue that this tax reduction likely occurs also for states losing their tax base, because the reduction of administrative costs associated with the taxation of commuters allegedly more than compensates the tax base loss. In fact, it seems unlikely that a government facing re-election pressures willingly enters an agreement that worsens the public budget of its jurisdiction in the short run.

On the other hand, RTAs might indirectly increase income tax rates through a

[12]Because information about government revenue is missing for the state District of Columbia, we impute its value using a population weighted share of the US total tax revenue.

lessening of tax competition between states.[13] In fact, as pointed out in the public finance literature, equilibrium tax rates in a Nash equilibrium where jurisdictions compete with each other to attract the mobile tax base might be inefficiently low. To the extent that RTAs signal a willingness to cooperate in fiscal matters between jurisdictions, tax competition should decrease, thus countering the race to the bottom in income tax rates.

In what follows, we focus on the total number of RTAs a state enters, rather than on the reciprocity status. The total number of RTAs allows us to measure the total impact of the agreements on the tax base and administrative costs, and the decrease in the overall intensity of income tax competition. Let NT_{nt} denote the total number of RTAs state n has with another state in year t. We estimate the following equation

$$\tau_{nt} = \beta NT_{nt-1} + \mathbf{x}_{nt} + \phi_n + \phi_t + \epsilon_{nt}, \tag{4.22}$$

where ϕ_n and ϕ_t denote state and year fixed effects, and ϵ_{nt} is a stochastic error term. The coefficient β is the parameter of interest. The vector $\mathbf{x}_{nt}$ includes the following time-varying control variables: tax base characteristics – number of residents and per capita income –, political orientation – share of votes obtained in the last presidential election by the republican party and cumulative sum of republican wins for a presidential election –, and a measure of the intensity of tax competition in given area proxied by the interaction of time fixed effects with the number of neighbouring states.[14]

In equation (4.22) we include the 1-year lag of the total number of RTAs, such that simultaneity bias with income tax rates is avoided. However, estimating the β parameter in equation (4.22) by standard OLS might still lead to biased values due to the presence of unobserved tax rate dynamics. For example, trends in the political orientation not captured by our controls might simultaneously affect τ_{nt} and T_{nt}. To lessen endogeneity concerns due to omitted variable bias, we thus adopt an Instrumental Variable (IV) approach. The goal is to isolate exogenous

[13]See Brueckner (2003) and Wilson (1999) for an empirical and theoretical review of the tax competition literature.

[14]The share of votes obtained in the last presidential election by the republican party and the cumulative sum of republican wins in a presidential election are computed separately for a given state and the average value of its neighbors, respectively. Voting outcomes between two presidential elections are linearly interpolated.

variation in the (lagged) number of RTAs capturing a decrease in the intensity of tax competition. We build on the work of Agrawal and Hoyt (2017) and use the number of Compact Agreements (CAs) that a state has with other states, which we argue proxies for a willingness of a state to cooperate with neighbors. Because CAs are treaties regulating matters deemed of common concern between two (or more) states that we select to be *not* related to fiscal policies, they should be uncorrelated with the error term in (4.22).

We classify CAs in two main groups. The first group is provided by Agrawal and Hoyt (2017) who show that such group is positively and significantly correlated with tax reciprocity status. The group contains CAs related to water management, child welfare, lottery, insurance, health, and planning. We complement this first group with a second one containing the remaining agreements from which we drop tax-related ones. This second group includes agreements on Corrections and Crime Control, Education, Conservation and Environment, Motor Vehicles, Public Safety, Elections, Energy, Wildland Fire Protection, Boundary, Property, Health Care Licensure, Medical Licensure, Transportation, Agriculture, Building Construction and Safety, Bridge Navigation and Port Authorities, and Parks and Recreation.

We define the vectors of instruments $\mathbf{Z}_t^g,\ g = 1, 2$ as containing, for a given group of compact agreements, the total number of CAs a state n has with other states in year t and the corresponding squared term, capturing the potential nonlinear relationship between RTAs and compact agreements. Given that $\mathbf{Z}_t^1$ and $\mathbf{Z}_t^2$ contain relevant instruments, we rely on the following identifying assumption

$$E(\epsilon_{nt} \mid \mathbf{Z}_{t-1}^1, \mathbf{x}_{nt}, \phi_n, \phi_t) = E(\epsilon_{nt} \mid \mathbf{Z}_{t-1}^2, \mathbf{x}_{nt}, \phi_n, \phi_t) = 0. \tag{4.23}$$

The identifying assumption (4.23) is satisfied if the number of compact agreements observed at a given point in time is orthogonal to income tax rates dynamics.[15] Estimation results are shown in Table 4.4.1.

Columns 1-3 show the robustness of parameter estimates when we use $\mathbf{Z}_{t-1}^1$ and $\mathbf{Z}_{t-1}^2$ to linearly predict NT_{nt-1} and progressively include controls. To account for the count character of NT_{nt-1}, Column 4 shows the estimated parameter when we instrument using the predicted values of NT_{nt-1} from a Poisson regression with $\mathbf{Z}_{t-1}^1$ and $\mathbf{Z}_{t-1}^2$ as predictors. To reduce potential problems due to weak instruments,

[15] One advantage of having two groups CAs is that we can test the orthogonality assumption of our instruments.

Table 4.4.1: Impact of reciprocal tax agreements on average income tax rates

Dependent variable: State income tax rates (1977-2012)				
	(1)	(2)	(3)	(4)
Number of RTA's (1-year lag)	0.012***	0.012***	0.013***	0.012***
	(0.0028)	(0.0033)	(0.0038)	(0.0032)
Time FE	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Tax base controls	No	Yes	Yes	Yes
Political controls	No	No	Yes	Yes
Time FE x Nb. Neighbors FE	No	No	Yes	Yes
Instruments				
Compact agreements, group 1	Yes	Yes	Yes	Yes
Compact agreements, group 2	Yes	Yes	Yes	Yes
Observations	1'764	1'764	1'764	1'764
Underidentification[a] (p-value)	0.0269	0.0283	0.007	0.0002
Weak identification[a] (F statistic)	8.677	8.800	9.435	27.67
Overidentification[b] (p-value)	0.485	0.298	0.286	-

Note: HAC robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. A truncated kernel with a 10-year lag is used to model time autocorrelation. Estimates are obtained by Limited Information Maximum Likelihood (LIML) estimation. a Kleibergen-Paap LM statistic. b Kleibergen-Paap F statistic. All values of the Kleibergen-Paap F statistics are above the 10% maximal LIML size of the critical values computed by Stock and Yogo. Interstate agreements, group 1 instruments include the number and squared number of compact agreements related to water management, child welfare, lottery, insurance, health, and planning. Group 2 instruments include the number and squared number of compact agreements related to Corrections and Crime Control, Education, Conservation and Environment, Motor Vehicles, Public Safety, Elections, Energy, Wildland Fire Protection, Boundary, Property, Health Care Licensure, Medical Licensure, Transportation, Agriculture, Building Construction and Safety, Bridge Navigation and Port Authorities, and Parks and Recreation.

we estimate equation (4.22) by LIML. Our preferred specification suggests a 1.2 percentage point increase of income tax rates for any new RTA entered by a given state.

A few facts are worth noting. First, the estimated coefficients are stable to the inclusion of additional controls. Second, diagnostic statistics allow us to reject the model's underidentification, weak identification, and overidentification across all specifications. Specifically, these results reinforce our claim about the exogeneity of the two groups of instruments. Third, using Poisson predictions as (single) instrument considerably improves the Kleibergen-Paap F statistic. In Appendix 4.D, we show that parameter estimates obtained using the two groups of instruments separately are close to each other, suggesting that they converge in probability to the same value, as required by equation (4.23).

4.4.3 Counterfactual welfare

We rely on the structural framework of Section 4.3 to perform counterfactual simulations with respect to the RTAs between US states. In what follows, we adopt the notation of Dekle et al. (2007) and denote a counterfactual change as $\hat{x} = \frac{x'}{x}$, where x is an observed outcome and x' its unobserved counterfactual value after we shock the RTAs. To perform model-based counterfactual analysis, we derive counterfactual changes in commuting shares, public good provision, residents, workers, income, price index, and housing prices. These measures represent sufficient statistics for the counterfactual change in welfare.[16] Specifically, welfare change is computed by dividing the counterfactual welfare by the observed expected utility (4.18), which leads to

$$\widehat{V} = \left(\frac{1}{\hat{\lambda}_{ni}} \right)^{\frac{1}{\epsilon}} \hat{G}_n^{\beta} \left(\frac{\hat{y}_{ni}}{\hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}} \right)^{1-\beta}. \tag{4.24}$$

4.5 Welfare impact of Reciprocal Tax Agreements

In this section, we quantify the welfare effect of existing and potential RTAs between US states. To provide a better intuition of the channels at work in our structural framework, we first start by conducting a visual analysis of the simulation results when the sample of counties is restricted to the states of New Jersey, Pennsylvania, and New York and a new agreement is concluded between the states of New York and New Jersey. We then analyze the welfare contribution of individual agreements to the country welfare. In a next step, we analyze the general equilibrium implications for the whole country when real world and potential RTAs between US states are entered.[17] We conclude by discussing the link between the welfare impact of RTAs and the tax rate dispersion across US states.

[16] A full description of the system of equations characterizing our counterfactual simulations is presented in Section 4.C in the Appendix.

[17] We restrict our analysis to potential agreements between neighboring states, as commuting flows between non-neighboring states are usually small.

4.5.1 Evidence from the New York metropolitan area

We quantify the impact of a RTA between the states of New York and New Jersey for counties located in the three states intersected by their common metropolitan area. We focus on these states because characterized by substantial cross-border commuting flows – about 16% of all commuters cross a state border to reach their place of work – and their average tax rates vary considerably, with New York displaying the highest income tax rate (4.46%), followed by New Jersey (3.03%), and Pennsylvania (2.98%). New York county hosts the largest fraction of workers across the three states (12.4%) and, overalll, the state of New York is the biggest employer in the metropolitan area. Note that in our simulations we keep public good provision fixed by adjusting tax rates. This allows us to better isolate the mechanisms underlying the structure of the model.

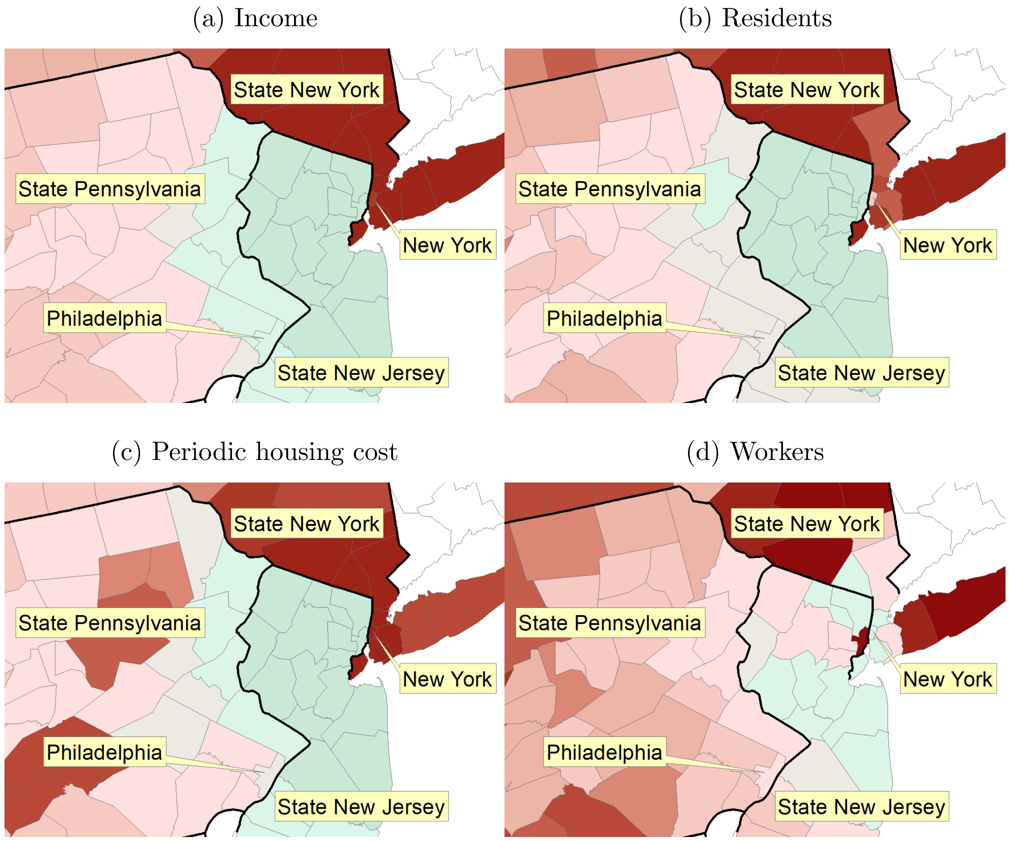
By focusing on the metropolitan area, Figure 4.5.1 shows counterfactual changes in relevant outcome variables following the agreement. Overall, with an increase of 0.002%, the tax agreement is beneficial for the welfare of the three states. Let us discuss the implication of the agreement for the states of New York and New Jersey first. Entering the agreement causes a loss of the tax base for the State of New York. Because tax rates are higher in New York, workers migrate to the state of New Jersey while still working in one of the most productive counties in the state of New York. Following the loss of its tax base, New York increases income tax rates, which leads to the negative income shock displayed in Panel a).

A spatial displacement of the residential housing demand can easily be identified in Panel b and c), where we see the number of residents decrease in counties belonging to New York while it increases in New Jersey counties. Housing costs react accordingly to this spatial shift of the housing demand. Because of commuting, the spatial shift of residents, however, is not perfectly matched by the one of workers, as shown in Panel d).

By shifting residents, the agreement also shifts workers to New Jersey, but not uniformly so. This because it is attractive to work in productive areas in New York – which earn higher wages – while living in New Jersey. For example, we observe that the number of worker in the county of New York increases after the agreement.

Part of the positive welfare impact of the agreement is thus given by a migration response in conjunction with commuting flows, which allow people to benefit from tax wedges and housing supply elasticity differentials while supplying labor in

Figure 4.5.1: Impact of a Reciprocal Tax Agreement between New York and New Jersey

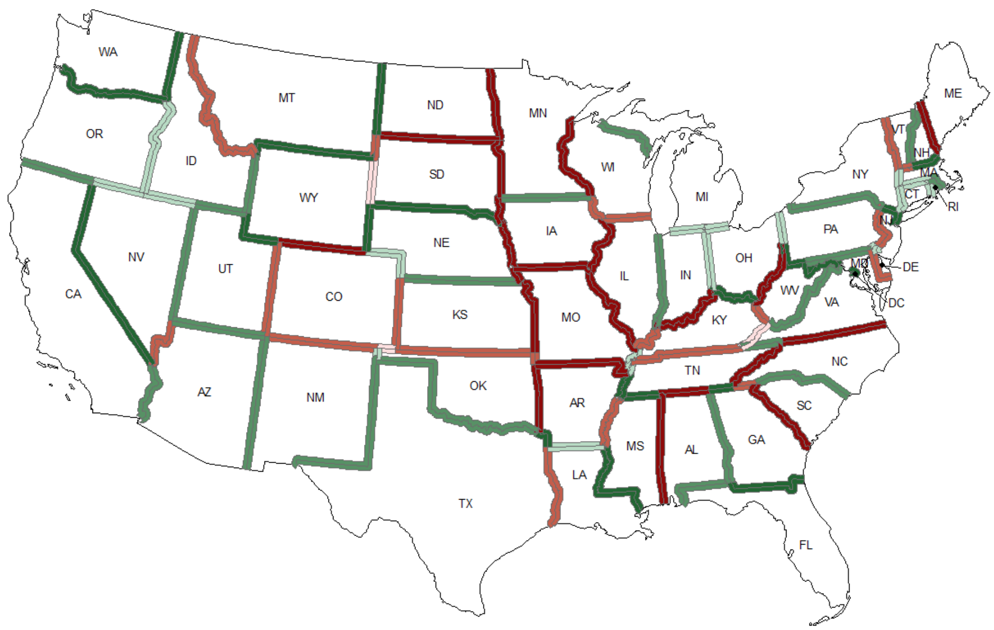


Note: The figure depicts counterfactual changes of the corresponding variable by quintiles. Public good provision is kept constant. A green (red) color represents a positive (negative) change, with a darker shading represents a larger magnitude in absolute terms. The unit of observation is at the county level, with solid black lines indicating state borders.

productive places. Residents in New York benefit from less congested housing market.

The other part of the welfare impact comes from the equilibrium response of the state of Pennsylvania, which, despite not directly taking part in it, is affected by the agreement. In fact, because living in New Jersey and Pennsylvania have similar tax rates and following the agreement living in New Jersey has become comparatively more attractive, we observe that part of the housing demand is shiftet from Pennsylvania to New Jersey. This further drives up prices in New Jersey and depresses those in Pennsylvania. The fact that part of the economic activity has shifted to New Jersey, also leads people live at the border of Pennsylvania and commute to New Jersey.

Figure 4.5.2: Welfare effect of individual Reciprocal Tax Agreements



Note: The figure depicts marginal welfare changes reported by quantiles. A darker shading represents a stronger effect, whereas a green (red) color illustrates a positive (negative) effect. All potential agreements include existing agreements plus fictive agreements with neighboring states.

4.5.2 Welfare impact of individual tax agreements

We quantify the welfare impact of individual RTAs in the case of existing agreements plus potential agreements between neighboring states. Figure 4.5.2 shows the results. As it can be seen, not all agreements are welfare improving. This is likely due to equilibrium effects that the governments of the two states do not take into account when entering the agreement. As we have seen in the previous section, concluding a RTA triggers migrations, commuting, and income responses in counties belonging to states not entering the agreement, especially those located close to the two states.[18] However, we speculate that the welfare impact of an agreement is mostly driven by the location fundamentals of the two states entering the agreement. In section 4.5.4, we show that the welfare impact of the agreements is linked, for example, to the tax rate dispersion across US states.

[18]An alternative explanation might be that the decrease in the administrative hurdle following the agreement is not included in our model. However, it seems unlikely that the reduction of administrative costs is of relevance for the welfare effects of the whole of the country.

4.5.3 Tax agreements and US welfare

In this section, we investigate the impact of existing, and existing and potential tax agreement on the country welfare and its components. This approach allows us to investigate whether new RTAs between neighboring states amplify or dampen the welfare impact of existing ones. Table 4.5.1 shows the results when progressively modifying the assumptions concerning income tax rates and public good provision. We show aggregate counterfactual changes by computing a weighted average of county-level ones, where the weighting scheme changes according to the considered welfare component.[19] In Columns 1-2 tax rates adjust to keep public expenditure of US states constant, thereby eliminating endogenous responses due to changes in public good provision. Columns 3-4 show simulation results when tax rates are kept fixed and states adjust public good provision in response to an agreement. Finally, in columns 5-6 we report results when tax rates adjust endogenously to RTAs according to the estimates of Section 4.4.2 and public good provision can vary.

In Columns 1-2, which correspond to the setting of Sections 4.5.1 and 4.5.2, existing agreements do not affect welfare and only to a small extent its components. In fact, the increase in regional income is approximately compensated by an increase in the price of tradable goods and by an increase in costly commuting flows. Entering new agreements amplifies the aforementioned effects, leading to a welfare increase of 0.028%. This because people can migrate across all US states to live in counties offering the most attractive tax incentives while commuting to more productive locations, as shown by the increase in commuting flows reported in column 2. Because more people commute to productive locations, wages increase. Regional income goes up even further, as states adjust tax rates downward to keep public good provision constant. The increase in regional income drives up prices of tradable goods and the periodic cost of housing but not enough to compensate for the increase in regional income, such that real income increases. This increase in real income outweighs the increase in costly commuting flows, leading to the observed welfare increase.[20]

[19]Specifically, changes in commuting flows are weighted using baseline commuting flows. We weight changes in residents, income, price indices, housing costs using the baseline number of residents. Changes in wages are weighted by the baseline number of workers.

[20]In the case of constant public good provision, $\hat{G_n}$ drops out from (4.24), such that welfare changes are exclusively driven by the opposing effects of changes in commuting flows and real income.

Table 4.5.1: Entering Reciprocal Tax Agreements

Agreements	Existing	All	Existing	All	Existing	All
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Counterfactual changes (in %)						
Welfare ($\hat{V}_n$)	0	0.028	0.001	0.006	0.274	0.924
Commuting ($\sum_{n \neq i} \lambda'_{ni} / \sum_{n \neq i} \lambda_{ni}$)	0.001	0.054	0.001	0.071	0.110	0.220
Regional income ($\hat{y}_{ni}$)	0.002	0.056	0.003	0.026	−0.301	−4.229
Wages ($\hat{w}_i$)	0.003	0.016	0.003	0.013	0.638	0.960
Housing costs ($\hat{r}_n$)	0	0.019	0	0.004	−0.016	−1.136
Price index ($\hat{P}_n$)	0.003	0.014	0.003	0.011	0.632	0.933
Real income ($\hat{y}_{ni} / \hat{P}_n^{\alpha} \hat{r}_n^{1-\alpha}$)	0	0.040	0.001	0.017	−0.767	−4.565
Public good provision ($\hat{G}_n / \hat{R}_n^{\chi}$)	-	-	0.003	−0.017	4.443	23.716
Varying tax rates	Yes[a]	Yes[a]	No	No	Yes[b]	Yes[b]
Constant public good provision	Yes	Yes	No	No	No	No

Note: The table reports weighted mean changes in outcomes relative to the no-tax-treaty equilibrium. The first part of the table shows weighted changes of outcomes calculated at the county level and the lower part reports changes in regional inequality as measured by Gini indices. Columns (1)-(2) refer to the effects of tax agreements where state governments vary tax rates to keep public expenditure constant, in (3)-(4) state governments do not change tax rates, whereas in columns (5)-(6) state governments adjust tax rates in response to entering tax agreements (see Table 4.4.1). Changes in welfare, line (1), are equalized across counties, changes in commuting, line (2), are weighted by the number of commuters, changes in residents, income, rents, prices and public good provision, lines (3), (5), (7)-(10), are weighted by the number of residents, and changes in workers and wages, lines (4) and (6), are weighted by the number of workers.

In columns 3-4 we observe that keeping tax rates fixed and letting state governments adjust the amount of public good provision only lowers the magnitude of the channels, leaving the direction of the effects unchanged with respect to the previous case. Notably, the amount of public good provision reverses sign when all potential agreements are implemented in addition to existing ones. This effect points toward a loss, on average, of the tax base, which now concentrates in locations offering the best combination of tax incentives and labor market access to productive locations.

Finally, columns 5-6 show that US welfare can be greatly increased if tax rates respond endogenously to RTAs, with a welfare increase of 0.274% in the case of existing agreements and of 0.924% when potential agreements with neighboring states are also implemented. The sign of the counterfactual changes is the same for existing and potential agreements, with larger magnitudes observed in the latter case. Unsurprisingly, the regional income channel is reversed with respect to Columns 1-4, as the decrease in tax competition leads to a generalized increase of tax rates. On the one hand, the increase of tax revenue generates a consistently higher public good provision. On the other hand, the tax burden increase more than compensates agglomeration benefits increasing wages, leading to a decrease in the per capita after-tax income of workers. This negative income shock decreases housing demand, which displays lower periodic costs. The price of the tradable goods increases because the increase in public expenditure is mostly allocated to such goods and only to a minor extent to housing.

Figures 4.B.3 4.B.4 and 4.B.5 in Appendix 4.B provide further visual evidence on the spatial displacement of residents for the settings described in Columns 1-2, 3-4, and 5-6, respectively.

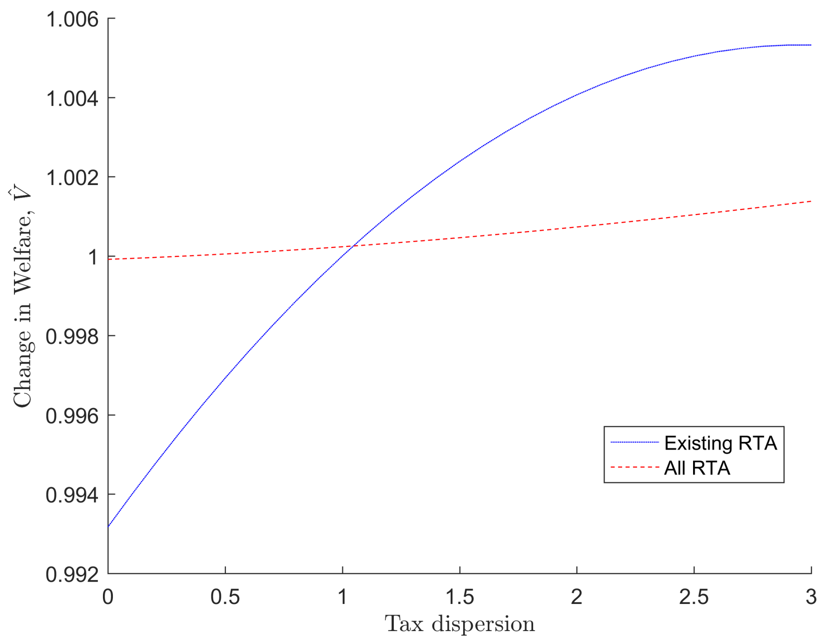
4.5.4 Tax dispersion and tax agreements

As documented in Section, 4.5.2, the impact of individual agreement varies depending on the states entering it. In this section, we quantify how the dispersion of tax rates across US states, which we here consider as location fundamentals, affects the welfare impact of the tax agreements. Figure 4.5.3 illustrates counterfactual results when public good provision by states is held constant.

As it can be seen, in the case of zero tax dispersion (flat tax rate), all potential RTAs are only slightly harmful for the country welfare, whereas existing agreements decrease the country welfare to a larger extent. However, as the tax rate dispersion increases, the welfare impact of existing agreements grows at a considerably higher rate. The observed unitary tax dispersion, which corresponds to simulation results of Columns 1-2 of Table 4.5.1, is approximately the turning point where both existing and potential agreements become welfare improving and where existing RTAs are more profitable than all potential agreements. We explain these patterns as follows.

In the case of flat taxation, workers cannot benefit from tax wedges between states to increase their after-tax income. The agreements, however, still affect the tax base of state governments. When the tax dispersion increases, tax wedges also increase, leading people to relocate across counties to increase their after-tax income and, in the end, welfare.

Figure 4.5.3: Tax dispersion, Reciprocal Tax Agreements, and US welfare



Note: State public good expenditure is kept fixed. The dispersion of income tax rates is measured by the standard deviation of such tax rates across US states.

4.6 Conclusions

Over the last half-century, many US states have subscribed or rescinded a tax agreement with one of their neighbors. Evidence on the general equilibrium effects of such agreements across geography is currently missing. To fill this knowledge gap, we develop a spatial general equilibrium model featuring salient characteristics of the US state income taxation and allowing workers to choose where to live and where to work according to tax incentives. We calibrate our model using county data and empirically estimate, in particular, the endogenous response of income tax rates to an agreement. The general applicability of our framework allows us to investigate the welfare impact of existing and potential reciprocal tax agreements between US states.

Our counterfactual simulations suggest that existing agreements between US states are beneficial for the country welfare. Welfare gains are higher if all potential agreements were entered. These positive welfare effects are mostly due to tax rate wedges between states, which allow workers to benefit from favorable taxation in their place of residence while working in productive locations. In a setting in which states enter an agreement to lessen the intensity of tax competition with neighboring states, the welfare impact of reciprocal tax agreement is considerably higher.

Our quantitative analysis sheds new light on the effects of income taxation on the allocation of workers and residents across space. By creating tax incentives for residents in suburban and countryside areas that are well connected with urban centers, we can decongest housing markets and boost labor supply in productive locations, thereby increasing the country welfare.

4.A Data appendix

This section provides further information on data calibration, as well as descriptive statistics of the endogenous variables of the model.

Table 4.A.1: Summary of calibrated parameters

Description	Par.	Value	Reference
Share of consumption expenditure	α	0.7	Davis and Ortalo-Magne (2011)
Share of public expenditure	β	0.22	Fajgelbaum et al. (2019)
Agglomeration force	ν	0.1	Allen and Arkolakis (2014)
Elasticity of substitution	σ	5	Simonovska and Waugh (2014)
Heterogeneity of preferences	ϵ	3.3	Monte et al. (2018)
Building life span	ϕ	100 years	
Discount factor	γ	0.05	FRED
Housing supply elasticities	η_n	-	Saiz (2010)
Trade cost elasticity	ψ	-1.29	Monte et al. (2018)

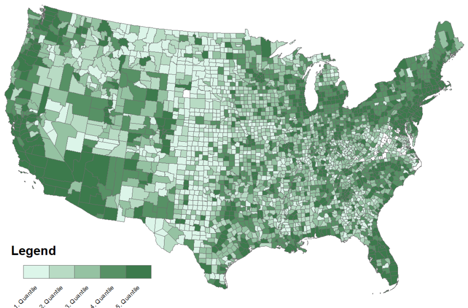
Note: The table reports calibrated parameters entering our model.

Simonovska and Waugh (2014) estimate a trade elasticity of -4. To make this result comparable to our study, this yields $\sigma - 1 = 4$, which implies $\sigma = 5$. This value is within the range of accepted parameters in the trade literature and equivalent to the value used by Redding and Rossi-Hansberg (2017). Additionally, Desmet et al. (2018) and Redding (2016) consider traded goods across countries and use the value $\sigma = 4$ estimated by Bernard et al. (2003). In contrast, Allen and Arkolakis (2014) estimate a value of $\sigma = 9$ and argue that this must likely represent an upper bound of an acceptable parameter value.

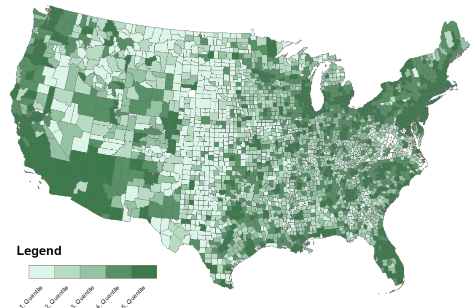
4.B Appendix figures

Figure 4.B.1: Overview of selected observed variables

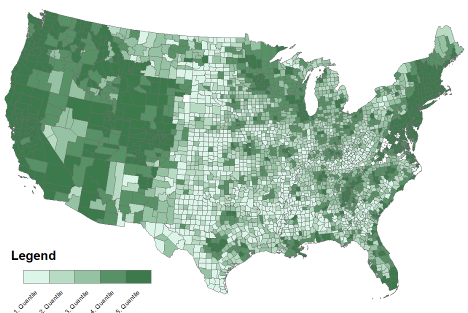
(a) Workers (L_n)



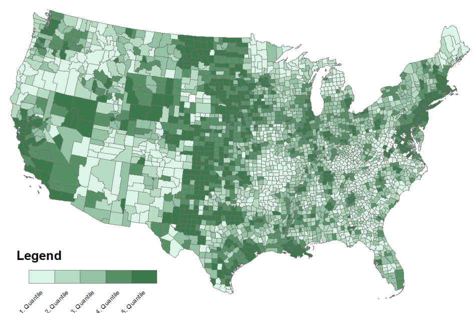
(b) Residents (R_n)



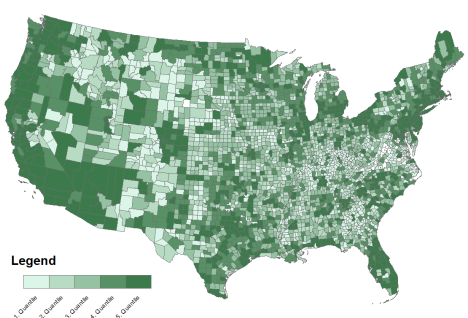
(c) Housing rents (r_n)



(d) Regional income ($\bar{y}_n$)



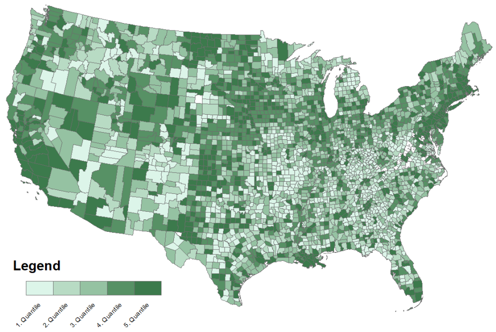
(e) Developed land ($\bar{H}_n$)



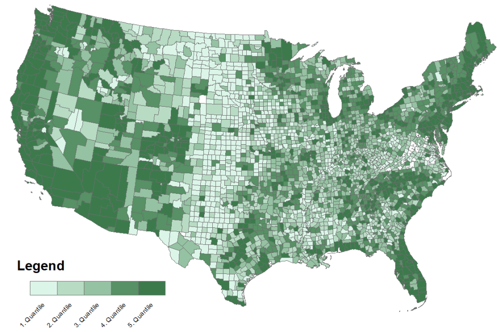
Note: The figure depicts quantiles of the reported variables. A darker shading in the map indicates a higher quantile.

Figure 4.B.2: Overview of recovered variables

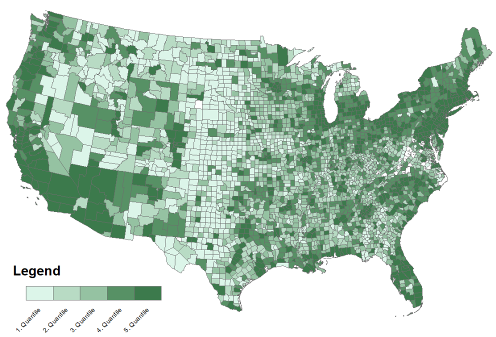
(a) Production amenities ($\bar{a}_n$)



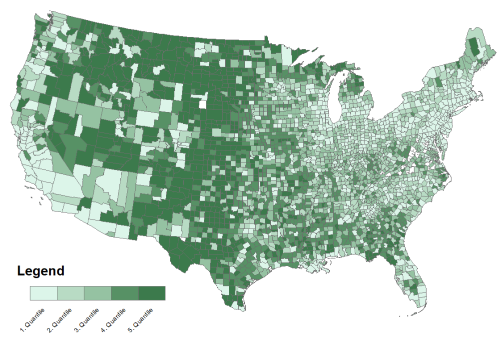
(b) Consumption amenities (B_{nn}/κ_{nn})



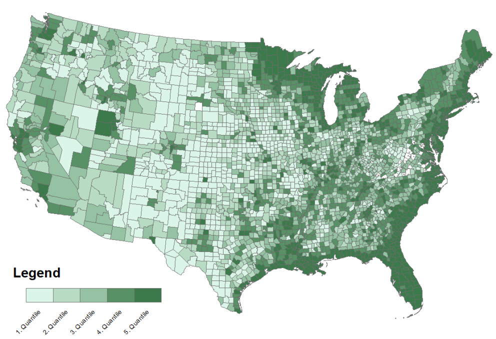
(c) Public good (G_n)



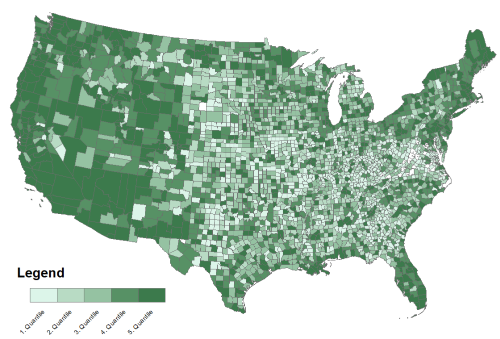
(d) Price index (P_n)



(e) Inverse housing supply elasticity (η_n)



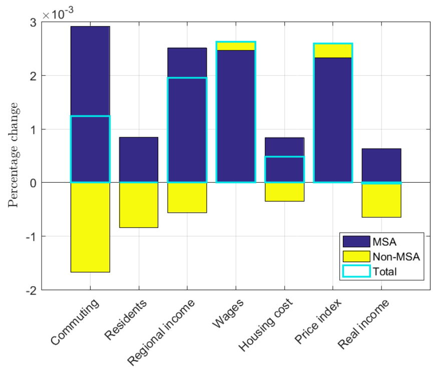
(f) own trade share (π_{nn})



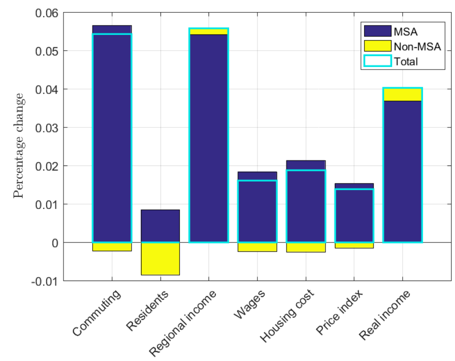
Note: The figure depicts quantiles of the reported variables. A darker shading in the map indicates a higher quantile.

Figure 4.B.3: Impact of reciprocal tax agreements, constant public good provision: MSA to Non-MSA

(a) Existing Agreements



(b) All Agreements

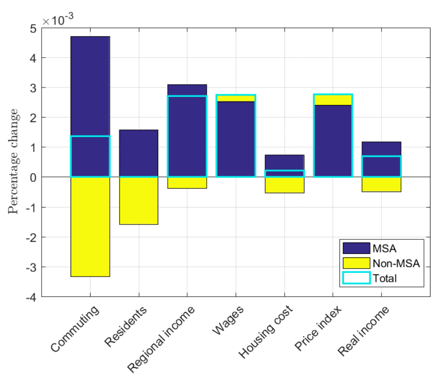


Note:

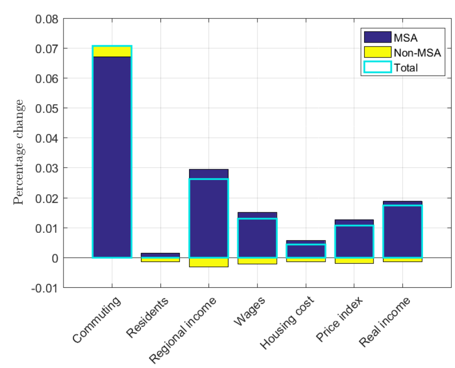
Counterfactual tax rates adjust to keep public expenditure fixed. The sample is split in counties, which are above and below the median distance to other states. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Figure 4.B.4: Impact of reciprocal tax agreements, constant tax rates: MSA to Non-MSA

(a) Existing Agreements



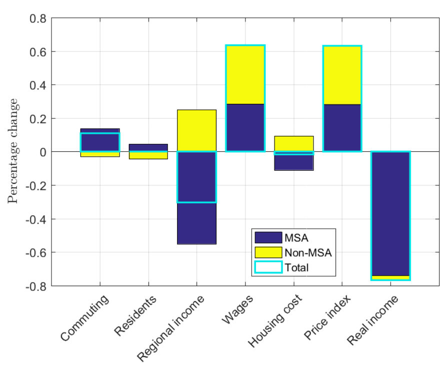
(b) All Agreements



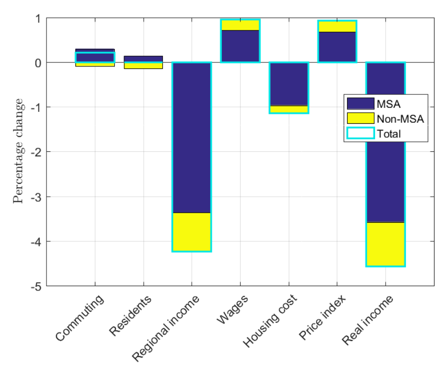
Note: Counterfactual tax rates are constant so that public expenditure varies. The sample is split in counties, which are above and below the median distance to other states. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

Figure 4.B.5: Impact of reciprocal tax agreements, endogenous tax rates: MSA to Non-MSA

(a) Existing Agreements



(b) All Agreements



Note: Counterfactual tax rates change according to the number of RTA a state engages so that public expenditure varies. The sample is split in counties, which are above and below the median distance to other states. County-level counterfactual changes are aggregated using weighted averages based on the distribution of outcomes in the baseline scenario. Changes in commuting are weighted by the number of commuters. Changes in residents, (real) income, rents, and prices are weighted by the number of residents. Changes in wages are weighted by the number of workers.

4.C Counterfactual analysis

In this section we derive a system of equations that allow us to undertake a model-based counterfactual analysis of reciprocal tax agreements. Following Dekle et al. (2007) we denote a counterfactual change as $\hat{x} = \frac{x'}{x}$, where x is the observed variable and x' is the unobserved counterfactual value of x. Thus, the counterfactual wage equilibrium follows directly from equilibrium wages (4.21):

$$\hat{w}_i w_i \hat{L}_i L_i = \alpha \sum_{n \in N} \hat{\pi}_{ni} \pi_{ni} \hat{R}_n R_n \hat{\tilde{y}}_n \tilde{y}_n, \tag{4.25}$$

Changes in residents and employers are linked to changes in commutes and can be derived from (4.19)

$$\hat{R}_n R_n = \bar{L} \sum_{k \in N} \hat{\lambda}_{nk} \lambda_{nk}, \tag{4.26}$$

$$\hat{L}_n L_n = \bar{L} \sum_{k \in N} \hat{\lambda}_{kn} \lambda_{kn}. \tag{4.27}$$

Counterfactual changes in expected income is a constant fraction of wages as evident from (4.5)

$$\hat{\tilde{y}}_n \tilde{y}_n = (1 + (1 - \tau_n)(1 - \alpha)) \hat{\bar{y}}_n \bar{y}_n. \tag{4.28}$$

Dividing counterfactual by equilibrium productivity using (4.11) we get

$$\hat{a}_n = \hat{L}_n^{\nu}. \tag{4.29}$$

From (4.3) we can state per capita income for every pair of residential and working place location in the counterfactual situation given changes in wages, tax rates and expected income from housing

$$\hat{y}_{ni} y_{ni} = \hat{w}_i w_i \hat{t}_{ni} t_{ni}, \tag{4.30}$$

where for convenience reasons we denote the counterfactual change in tax rates as $\hat{t}_{ni} = \frac{1-\tau'_{ni}}{1-\tau_{ni}}$. Changes in consumption price index are derived from (4.14) and are

$$\hat{P}_n = \left(\frac{1}{\hat{\pi}_{nn}} \right)^{1/(1-\sigma)} \frac{\hat{d}_{nn} \hat{w}_n}{\hat{a}_n}. \tag{4.31}$$

Counterfactual changes in the housing rents follow from (4.20) and are equal to

$$\hat{r}_n = \left(\hat{\bar{y}}_n \hat{R}_n\right)^{\frac{\eta_n}{1+\eta_n}}. \tag{4.32}$$

Expected wages in the counterfactual situation can be expressed by using (4.4)

$$\hat{\bar{y}}_n \bar{y}_n = \bar{L}\frac{\sum_{k\in N} \lambda_{nk}\hat{\lambda}_{nk}\hat{y}_{nk}y_{nk}}{\hat{R}_n R_n}. \tag{4.33}$$

Next, we divide the counterfactual by the equilibrium trade share using (4.13) and obtain:

$$\hat{\pi}_{ni} = \frac{\left(\frac{\hat{w}_i \hat{d}_{ni}}{\hat{a}_i}\right)^{1-\sigma}}{\sum_{k\in N}\left(\frac{\hat{w}_k \hat{d}_{nk}}{\hat{a}_k}\right)^{1-\sigma}\pi_{nk}}. \tag{4.34}$$

Similarly, we can express the counterfactual commuting change by dividing the counterfactual population mobility condition by the equilibrium mobility condition (4.16):

$$\hat{\lambda}_{ni} = \frac{\left(\frac{\hat{G}_n}{\hat{R}_n^X}\right)^{\beta\epsilon}\left(\frac{\hat{y}_{ni}}{\hat{P}_n^\alpha \hat{r}_n^{1-\alpha}}\right)^{(1-\beta)\epsilon}}{\sum_{f\in N}\sum_{k\in N}\left(\frac{\hat{G}_k}{\hat{R}_k^X}\right)^{\beta\epsilon}\left(\frac{\hat{y}_{kf}}{\hat{P}_k^\alpha \hat{r}_k^{1-\alpha}}\right)^{(1-\beta)\epsilon}\lambda_{kf}}. \tag{4.35}$$

From these changes we calculate the provision of the public good in state S using (4.6)

$$\begin{aligned}\hat{G}_s G_s = \bar{L}\sum_{n\in S}\sum_{k\in N}\lambda_{nk}\hat{\lambda}_{nk}w_k\hat{w}_k\tau_n\hat{\tau}_n T_{nk}\hat{T}_{nk} + \\ \bar{L}\sum_{n\in S}\sum_{f\in N}\lambda_{fn}\hat{\lambda}_{fk}w_n\hat{w}_n\tau_n\hat{\tau}_n(1 - T_{fn}\hat{T}_{fn}).\end{aligned} \tag{4.36}$$

State provision of public goods is redistributed with respect to resident shares and corrected for local prices as evident in (4.8)

$$\hat{G}_n G_n = \left(\frac{\left(\hat{G}_s G_s + \bar{G}_s\right)\hat{R}_n R_n}{\hat{R}_s R_s} + \hat{\tilde{G}}_n \tilde{G}_n\right)\frac{1}{\hat{P}_n^\alpha P_n^\alpha \hat{r}_n^{1-\alpha} r_n^{1-\alpha}}. \tag{4.37}$$

Equations (4.25)-(4.37) hold for each location and enable us to solve for counterfactual changes in commuting $\hat{\lambda}_{ni}$, changes in provision of public good $\frac{\hat{G}_n}{\hat{R}_n^X}$ and real income $\frac{\hat{y}_{ni}}{\hat{P}_n^\alpha \hat{r}_n^{1-\alpha}}$ for all locations n. In order to assess the welfare effects of reciprocal tax agreements, we substitute these changes by using the expected utility equation (4.18)

$$\widehat{E[V]} = \left(\frac{1}{\hat{\lambda}_{ni}}\right)^{\frac{1}{\epsilon}} \left(\frac{\hat{G}_n}{\hat{R}_n^{\chi}}\right)^{\beta} \left(\frac{\hat{y}_{ni}}{\hat{P}_n^{\alpha}\hat{r}_n^{1-\alpha}}\right)^{1-\beta}. \tag{4.38}$$

4.D Endogeneizing state income tax rates

In this section, we provide further results on the impact of RTAs on state income tax rates. Panel A of Table A shows the estimated impacts when using the two groups of instruments $\mathbf{Z}^1_{t-1}$ and $\mathbf{Z}^2_{t-1}$ separately. Estimates based on $\mathbf{Z}^1_{t-1}$ tend to have lower values than those obtained using $\mathbf{Z}^2_{t-1}$, although, for example, the estimated impact presented in column (6) is less than 1.6 standard deviations from the one of column (3). Similar to Table X, results remain stable to the inclusion of additional control. Panel B of Table A report first stage estimation results. As expected, high numbers of compact agreements correlate positively with RTAs. For example, above 27 compact agreements in column (6), about 4% of our sample. We find similar first stage relationship for the two groups of instruments, although the linear term is only significant for the second group.

Table 4.D.1: Impact of reciprocal tax agreements on average income tax rates

	Panel A: IV-second stage estimates					
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable: Average income tax rates (1977-2012)						
	Group 1			Group 2		
RTA (1-year lag)	0.0074***	0.0058**	0.0073**	0.0119***	0.0115***	0.0132***
	(0.0025)	(0.0024)	(0.0034)	(0.0027)	(0.0030)	(0.0035)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Tax base controls	No	Yes	Yes	No	Yes	Yes
Political controls	No	No	Yes	No	No	Yes
Time FE x Nb. Neighbors FE	No	No	Yes	No	No	Yes
Observations	1'764	1'764	1'764	1'764	1'764	1'764
Underidentification[b] (p-value)	0.120	0.115	0.0962	0.00426	0.00464	0.000922
Weak identification[b] (F statistic)	10.60	11.68	9.013	14.54	14.66	14.86
Overidentification (p-value)	0.294	0.141	0.200	0.582	0.415	0.340
Instruments	Panel B: IV-first stage estimates					
Compact agreements, $\mathbf{Z}^1$	-0.0547	-0.0434	-0.0232			
	(0.0481)	(0.0515)	(0.0465)			
Compact agreements, $\mathbf{Z}^1$ squared	0.0066***	0.0065***	0.0053***			
	(0.0019)	(0.0019)	(0.0018)			
Compact agreements, $\mathbf{Z}^2$				-0.0838**	-0.0835**	-0.0799**
				(0.0355)	(0.0344)	(0.0343)
Compact agreements, $\mathbf{Z}^2$ squared				0.0037***	0.0037***	0.0035***
				(0.0009)	(0.0008)	(0.0007)

Notes: HAC robust standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. A truncated kernel with a 10-year lag is used to model time autocorrelation. US Census Regions include Northeast, Midwest, South, and West. Interstate agreements, group 1 instruments include the number and squared number of compact agreements related to water management, child welfare, lottery, insurance, health, and planning. Group 2 instruments include the number and squared number of compact agreements related to Corrections and Crime Control, Education, Conservation and Environment, Motor Vehicles, Public Safety, Elections, Energy, Wildland Fire Protection, Boundary, Property, Health Care Licensure, Medical Licensure, Transportation, Agriculture, Building Construction and Safety, Bridge Navigation and Port Authorities, and Parks and Recreation. Controlling for region fixed effect interacted with time ones partials out any unobserved dynamic specific to these regions, such as heterogeneous economic shocks potentially affecting state tax revenue and, ultimately, tax rates. Notably, estimation results are left unchanged by the inclusion of such fixed effects.

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