# The Role of Local Public Goods for Fiscal Policy in the Spatial Economy*

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**Abstract**

We examine optimal spatial policies in a quantitative model where local public expenditures affect workers' labour force participation and distribution across regions in the presence of spatial externalities. We compare the competitive spatial equilibrium with an efficient allocation chosen by a benevolent social planner to emphasise the role of spatial externalities. Our results differ from previous studies that ignore the labour force participation margin, and we discuss the implications for spatial sorting and welfare. Neglecting this adjustment margin results in overestimating optimal taxes and the size of optimal redistribution across locations. Quantifying our framework using administrative labour market and tax data from Germany, we find that aggregate welfare increases by 1.3% when taxes and transfers are set according to optimal policy rules, which internalise all spatial externalities.

**JEL Codes:** H4, H7, J1, J2, J6, R2, R5

**Keywords:** Local Public Goods, Taxes, Transfers, Labour Force Participation, Spatial Sorting

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# 1 Introduction

Spatial policies aim to reduce geographical inequalities and promote growth and welfare in regions and cities. These policies usually involve transferring fiscal resources and providing local public goods to less developed locations. However, spatial policies can be challenging to design and implement effectively. While redistributive measures may improve the allocation of resources and opportunities among regions, they can also create market distortions, inefficiencies, and disincentives. In particular, redistributive policies can influence workers' location and employment choices, with unintended consequences for overall welfare.

This paper investigates the influence of fiscal policies on regional inequalities and welfare in a setting with spatial spillovers, worker mobility, and labour force participation. We build a spatial general equilibrium model that captures three main aspects for optimal spatial policies: First, it features workers with heterogeneous preferences and skills who supply labour across multiple sectors in each local labour market. Location choices generate spillover effects on productivity, wages and welfare, as well as externalities on public goods and services.[1] Second, local governments provide public goods financed by local labour income taxes and interregional transfers. Third, local public goods provision and fiscal spending can potentially affect local labour force participation through local "multiplier effects" and "fiscal externalities".

We compare the competitive spatial equilibrium, where goods and input factors are allocated across different locations and sectors, with the optimal allocation that a benevolent planner would choose. The planner aims to balance the marginal benefits of workers (such as their marginal product of labour and agglomeration benefits) with their consumption and congestion costs, considering their location and labour force participation responses. We demonstrate that the planner's solution can be implemented with three policy instruments: region-sector-group-specific tax rates that trade-off revenue generation and workers' supply responses, fiscal transfers to local governments that internalise spatial spillovers, and lump-sum transfers to households that redistribute the income from the immobile factor of production. Lastly, we use administrative data from Germany on labour market and tax outcomes to calibrate our model and assess the welfare effects of optimal spatial policies when workers adjust both the allocation and participation margin.

In our model, workers' skills and preferences for living and working in different regions and sectors are heterogeneous, which affects their sorting decisions (Redding and Rossi-Hansberg, 2017; Diamond, 2016; Rossi-Hansberg et al., 2019; Ahlfeldt et al., 2020). We consider locations and sectors that differ in their exogenous productivity levels, amenities and trade costs (Redding and Rossi-Hansberg, 2017; Diamond, 2016; Rossi-Hansberg et al., 2019; Ahlfeldt et al., 2020). Local governments in each location provide local public

[1] Previous studies have shown that inefficient spatial sorting may result in substantial welfare costs in a spatial framework with spillovers. In particular, Fajgelbaum and Gaubert (2020) define the spatial policies that allow tackling these inefficiencies.

goods and services that are non-tradable and rivalrous. These public goods and services, such as infrastructure, childcare, education, health, and security, are financed by local labour income taxes and spatial transfers from a central government (Fajgelbaum et al., 2019; Fajgelbaum and Gaubert, 2020; Henkel et al., 2021). Local public goods provision and fiscal spending can potentially increase local labour force participation through "multiplier effects" (Michaillat and Saez, 2019; Moretti, 2011), as public spending may shift the barriers to entering the labour market. [2] Furthermore, in the presence of worker mobility, fiscal expenditures can attract economic activity from other parts of the economy. This creates a "fiscal externality" (Flatters et al., 1974; Albouy, 2012), as workers do not consider the impact of their labour supply decisions on local budgets and spatial transfers. On the production side, firms combine human capital, land, and structures to produce intermediate goods in various sectors. These goods are traded imperfectly across regions and used as inputs for final consumption (Caliendo et al., 2018; Rossi-Hansberg et al., 2019). The production function of firms depends on geographic characteristics of locations, worker sorting, and spillovers from agglomeration forces.

The social planner maximises aggregate welfare, subject to constraints on public and private good consumption, production, employment, population, and aggregate resources. Similar to the literature concerned with optimal spatial policies under worker mobility (Fajgelbaum et al., 2019; Fajgelbaum and Gaubert, 2020; Rossi-Hansberg et al., 2019), the optimal allocation of public and private goods balances the marginal costs and benefits of additional workers in a location. We extend their framework to a case where the planner can optimally re-allocate funds between their uses for public and private consumption and worker reallocation occurs along different margins: workers' (expected) marginal productivity decreases in local market frictions. At the same time, employed workers also congest the public good to a more considerable extent.

The optimal allocation can be implemented with three policy instruments: region-specific tax rates follow a reverse U-shape in labour force participation as the planner trades off tax revenue hikes with workers' behavioural responses. Public goods are optimally provided according to an extended Samuelson rule: the planner chooses an aggregate share of value added that balances workers' preferences for both types of goods while simultaneously incorporating labour supply responses to fiscal spending that distort the ratio of marginal utilities for both goods' types. Overall, transfers to households and local governments are set such that workers internalise their external effects they impose on productivity ("agglomeration economies"), public good congestion and local fiscal budgets.

We apply the optimality rule for policy instruments to Germany's fiscal system and quantify our spatial general equilibrium model for 141 local labour markets in 2014. We consider two worker groups, females and males, and their spatial distribution as well as

[2] For example, higher public expenditures may induce workers to take up market employment by reducing commuting costs through infrastructure investments (Duranton and Turner, 2012; Gibbons et al., 2019) or by improving the availability and quality of public childcare and after-school programs (Baker et al., 2008; Cornelissen et al., 2018).

extensive labour supply decisions. We have six market sectors and one home market sector. The theoretical framework allows to identify labour market frictions that prevent workers from joining the local labour market and how local public investments can shift these barriers. Our model is informed with reduced-form estimates of the elasticity of extensive labour supply to public goods provision. We use the unique institutional context of the German fiscal equalisation system to measure the causal effects of fiscal budget shocks on local labour markets. The fiscal transfers depend on regions' population size, such that a nationwide Census can cause sudden changes in population counts and fiscal redistribution (Helm and Stuhler, 2021; Serrato and Wingender, 2016). Our empirical analysis reveals that the 2011 Census shock permanently altered transfers and local government budgets, causing non-employment rates in negatively affected regions to drop, with female workers reacting more strongly than male workers.

Implementing optimal taxes, subsidies and transfer rates implies substantial redistribution from rural regions to more urbanised parts of Germany as the planner incentivizes workers to relocate into highly productive regions. At the same time, the planner aims to increase private and public goods consumption in locations with small initial labour force participation (also the most populous regions in our application to Germany) in order to increase aggregate output in the economy.

Overall, public and private expenditure possibilities increase such that we find an aggregate welfare gain of about 1.3%. Total production grows between the two equilibria as the program increases the incentive for workers to migrate to high-productivity regions and sectors and (for female workers) to join the aggregate labour force.

**Related Literature.** Our paper contributes to several strands of literature. We build on prior research emphasising the significance of spatial sorting and the trade-offs between equity and efficiency in designing optimal spatial redistribution policies (Albouy, 2012; Colas and Hutchinson, 2021; Fajgelbaum and Gaubert, 2020; Fu and Gregory, 2019; Gaubert et al., 2021; Henkel et al., 2021; Rossi-Hansberg et al., 2019). In this literature, the location choices of workers determine the local labour supply. Local shocks to amenities, such as better transport infrastructure or parks, affect the relative attractiveness of locations and hence local labour supply. A vast literature, going back to Tiebout (1956), shows how spatially varying public good provision influences workers' location choices. We introduce a local labour force participation margin that depends on providing local public goods, creating additional externalities that affect the trade-off between efficiency and equity in spatial policy design.[3]

[3] Theoretically, we change the slope of the labour supply curve. As standard in the literature, the supply curve slopes upward as long as more people lower the average utility of a location. We split the amenity value of a place into a pure amenity term and public goods consumption. Higher population increases the local tax base and public goods provision but also implies more rivalry and congestion in public goods consumption, ensuring an upward-sloping local labour supply curve. Workers do not consider the effect of their labour force participation on local and national fiscal budgets, affecting policy choices. This creates an agglomeration spillover in the fiscal budgets of local and federal governments. At the same time, workers in the labour force ignore that they may cause higher congestion on a region's public goods

Our paper relates to the literature that uses spatial general equilibrium models to assess the impact of policy interventions on labour market outcomes across regions. Previous studies (Bilal, 2023; Jung et al., 2023; Kuhn et al., 2021) have analysed the causes of persistent unemployment disparities across local labour markets. Our paper focuses on how local public goods provision and fiscal policies affect workers' choices when local public expenditure generates positive externalities on labour force participation.[4] Similar to the literature of optimal government policy concerned with redistributive taxation (Diamond, 1998; Mirrlees, 1971, 1976; Saez, 2002; Rothschild and Scheuer, 2013) or efficient public expenditure (Samuelson, 1954), we use labour income taxation and transfers to finance public services and redistribute income to maximise a social welfare function.[5] In a spatial context where individuals can move between regions and sectors, we assume that workers differ in their tastes for not working (Saez, 2002) and incorporate "fiscal multipliers" that measure how changes in public expenditure and goods provision affect the labour force participation (Michaillat and Saez, 2019).

Building on the recent literature that estimates the size of fiscal spending multipliers (Chodorow-Reich, 2019; Nakamura and Steinsson, 2014), we empirically examine the causal effect of government spending on local economies.[6] Exploiting census population count revisions as some form of "quasi-random" variation, we use a similar empirical strategy as Helm and Stuhler (2021) and Serrato and Wingender (2016). These revisions affect the distribution of federal funds and interregional fiscal transfers across regions. We exploit rich administrative data on labour markets to compare the economic outcomes of regions that face adverse fiscal shocks due to census revisions with those that do not. Local public spending affects labour force participation, especially for women. We contribute to the literature by combining these estimates with our spatial general equilibrium model to show how this additional margin creates additional spillovers and affects the optimal design of spatial redistribution policies. Under plausible parameter assumptions, it implies a force for less redistribution relative to a world with only regional migration and sectoral selection decisions.

In the following sections, we present evidence for the link between local public finance and labour force participation and estimate fiscal multipliers 2, introduce our spatial model with fiscal transfers and multipliers 3, outline the social planner's problem 4, quantify the model for Germany 5, show how to implement the optimal policy instruments 6, conduct counterfactual analysis 7, and conclude 8.

than non-employed workers. See Agrawal et al. (2022) for a recent discussion.

[4] Jung et al. (2023) develop a theory of optimal place-based labour policies using German data but did not consider the efficient taxation of workers or allocation of fiscal funds in the presence of amenity and agglomeration spillovers, instead focusing on a moral hazard externality.

[5] See Kreiner and Verdelin (2012) for a survey of the public economics literature on optimal public expenditure.

[6] Some studies have found local fiscal multipliers and strong positive spillovers across regions and sectors, such as Auerbach et al. (2020) in the U.S. Other studies have examined employment effects of infrastructure investments (Leduc and Wilson, 2017; Garin, 2019; Buchheim and Watzinger, 2022; Gadenne, 2017) and federal transfers (Corbi et al., 2019). Ramey and Zubairy (2018) provide aggregate multipliers for the U.S., while Gabriel et al. (2022) provide estimates for the Eurozone.

# 2 Empirical Evidence

We begin with empirical evidence that supports our quantitative spatial general equilibrium model, which includes labour supply responses along the extensive margin (participation in the labour force) and location (and occupational) choices. In this section, we describe the data used in our analysis and examine the spatial variation in labour force participation rates and public expenditures (proxied by fiscal capacity per capita) in Germany – our main focus of analysis. Next, we estimate the elasticity of extensive labour supply to local public expenditures, which is a crucial parameter for quantifying our model. Our findings show that the provision of public goods, financed through taxes and fiscal transfers, significantly influences workers' decisions to enter or exit the labour market and their location choices.

## 2.1 Data

To investigate the impact of changes to fiscal budgets and public goods provision on the local economy, we aggregate yearly official tax data and individual employment biographies from official social security records to 401 German counties.

**Local Public Finance Data.** We use official tax data provided by the German Statistical Office and the Federal Statistical Office (see Statistisches Bundesamt (2021b); Statistisches Bundesamt (2021a); Statistische Ämter des Bundes und der Länder (2021)). We follow the procedure in Henkel et al. (2021) to break down tax revenues at different levels and identify fiscal transfers within and between the Federal States. We compute local tax revenues before and after redistribution to determine net transfers and aggregate these variables to obtain empirical proxies of average tax revenues.[7]

**Administrative Labour Market Data.** We use employment information from German administrative records to track individuals' employment status.[8] Our sample includes individuals aged 15-65 (henceforth also "worker") who are either (full-time or part-time) employed or non-employed.[9] Non-employed workers include those actively searching for employment, participating in job creation or training, on paternity or sick leave, or seeking jobs without being registered as unemployed, thus accounting for the potential labour

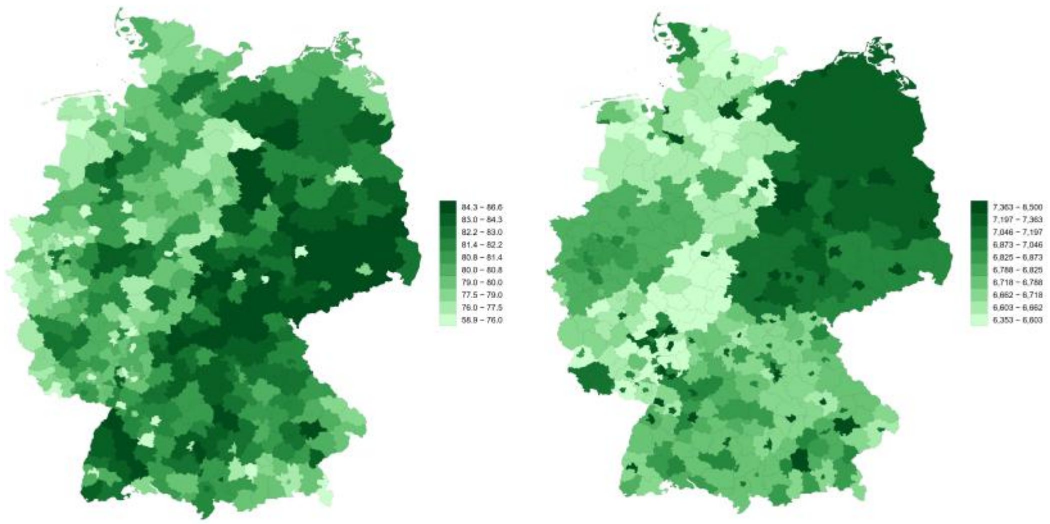
[7] Later, to quantify our model, we aggregate the data to 141 commuting zones (Kosfeld and Werner, 2012) to define local labour markets and relate the average tax revenues and fiscal transfers to these regions' aggregate wage income to obtain tax and transfer rates per region.

[8] "Weakly anonymous Version of the Sample of Integrated Labour Market Biographies (SIAB) - Version 7519 v1". Research Data Centre of the Federal Employment Agency (BA) at the Institute for Employment Research (IAB). DOI: 10.5164/IAB.SIAB7519.de.en.v1. The data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment Agency (BA) at the Institute for Employment Research (IAB) and, subsequently, remote data access.

[9] To construct our sample, we drop all marginally employed, like interns, student trainees, or unsteady workers and all workers who did die or emigrate during our observation period. Moreover, we keep only one observation for each individual and year, corresponding to the spell with the longest tenure that stretches over June 30th of a given year.

force. To calculate local non-employment rates, we aggregate the data to the local labour market level (district or commuting zone).

Panel (a) of Figure 1 illustrates the spatial variation in labour force participation rates across German districts, while Panel (b) suggests a link between public policies and labour force participation: regions with higher expenditures per capita on public goods (i.e., higher tax revenues after redistribution) tend to have higher participation rates.




(a) Local labour force participation rates (b) Local public expenditures per capita

Figure 1: Labour force participation and public spending in Germany

*Notes:* Panel (a) displays a map of labour force participation rates and Panel (b) maps expenditures per capita on public goods (i.e., higher tax revenues after redistribution) across German districts from 2008-2014. Darker colours represent higher values.

## 2.2 Elasticity of Extensive Labour Supply

High commuting costs (Duranton and Turner, 2012; Gibbons et al., 2019) or lack of public childcare and after-school programs (Baker et al., 2008; Cornelissen et al., 2018) may create barriers to entering the labour force, especially for female workers (Le Barbanchon et al., 2021). Local public investments can shift these barriers and change the size of the local labour force. We estimate the elasticity of extensive labour supply to public goods provision (the percentage change in non-employment when public expenditure increases by 1%) using regional population adjustments following a nationwide census.[10] The 2011

[10] We exploit a specific feature of the German re-distributive scheme: local population counts play a significant role in allocating fiscal revenues and expenditures. Higher population counts correlate positively with local fiscal funds and expenditures (see Panel (a) of Figure D.3). See Appendix D for more details.

Census led to sudden revisions in population counts and shocks to the fiscal redistribution scheme.[11]

**Empirical Approach.** We use a Treatment Effect framework to identify a causal effect on local public finance and labour markets. In particular, we implement an inverse probability-weighted treatment effect of the treated (IPW) estimator and a "doubly-robust" (IPWRA) estimator that both reweight observations by their propensity score (Acemoglu et al., 2019). The latter also adjusts potential outcomes for treated regions with linear regression. We assume that other economic or fiscal shocks did not correlate with the size of the Census shock and that we can model it as a function of observables.

We define treated regions, $d = 1$, as those with a Census shock one standard deviation below the median and control regions, $d = 0$, as those with one standard deviation above the median.[12] Let $Y_{i,t}^{g,s}(d)$ be the level of the potential outcome (in logs) for workers in group $g$ and region $i$ at time $t + s$, depending on treatment status $d \in \{0, 1\}$ at time $t$. Following Serrato and Wingender (2016), we then define the potential change in (log) outcome between the pre-shock period $t-1$ and later periods $t+s$ as $\Delta Y_{i,t}^{g,s}(d) = Y_{i,t}^{g,s}(d) - Y_{i,t-1}^{g}$ and estimate the propensity score of being in the treatment group with a probit regression.[13]

**Local Public Finance.** Our empirical findings show that the 2011 Census shock significantly impacted local public finance and labour force participation (non-employment). We find a sharp and significant negative response in fiscal capacity per capita (which proxies public expenditure) in treated districts. Compared to regions with an above-median Census shock, there was an immediate decrease by 2% in the first year after the Census when updated population counts were used for the calculation of fiscal transfers (see Panel (a) of Figure 2). The average treatment effect was 1.7% or 69 Euros per capita. This effect was immediate and persisted over time, with no reversal of pre-treatment growth rates. Our main results are further supported by alternative outcomes and estimators presented in Appendix D.3. Local jurisdictions did not compensate for decreasing tax and transfer revenues through increased public debt uptake or changes in the public employment payroll.

[11] We define the Census shock $\Delta \ln \text{Census}_{i,2011}$ as the difference between local population counts at the end of 2010 and the results of the 2011 Census in May 2011, such that

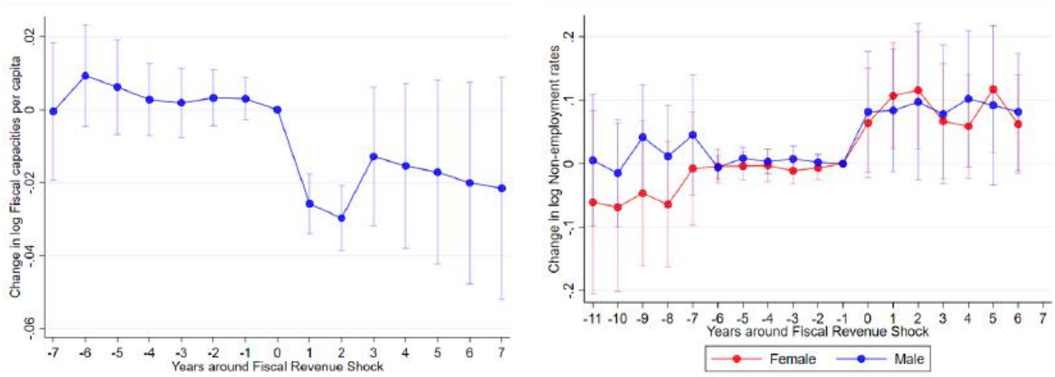
$$\Delta \ln \text{Census}_{i,2011} \equiv (\ln L_{i,\text{Census}} - \ln L_{i,2010}) * 100.$$

The Census shock was spatially differentiated, with some counties losing up to 7% of their population and others gaining 5% (see Panel (b) of Figure D.3).

[12] The 2011 Census Shock implied that most regions suffered negative fiscal shocks, while only a tiny fraction received a positive shock. Hence, we focus on binary treatments and solely on negative shocks. In other words, we abstract from heterogeneous effects of fiscal spending, depending on the qualitative sign of the shock as highlighted in Barnichon et al. (2022).

[13] Specifically, we use five lags of the outcome variable as explanatory variables and calculate the inverse probability-weighted treatment effect of the treated (IPW) $\hat{\beta}^{g,s} = \hat{\mathbb{E}}\left[\mathcal{W}_{i,t}\left(\Delta Y_{i,t}^{g,s}(1) - \Delta Y_{i,t}^{g,s}(0)\right)\right]$ using the (inverse) propensity scores $\mathcal{W}_{i,t}$ as weights.

**Non-employment.** Our analysis shows a 10% increase in non-employment rates after the Census-induced fiscal budget shock (see Panel (b) Figure 2). Male workers have slightly smaller and less significant coefficients than females.[14] Our findings are consistent with a simple triple-difference framework (see Appendix subsection D.3), which shows a 10% decrease in labour force participation rates in negatively treated regions, translating to a 0.8 percentage point decrease in participation rates relative to control regions.




(a) Fiscal capacities per capita

(b) Non-employment

Figure 2: Effect of 2011 Census shock on Local Public Finance and Non-employment

*Notes:* This Figure plots the event study coefficients using inverse probability weighting (IPW) with a probit treatment model and 95% confidence intervals for the Treatment Effect framework regressions. Panel (a) shows the event study coefficients on fiscal capacities growth. Panel (b) shows the coefficients on non-employment. Lags of the outcome variable and period effects are used as explanatory variables. Event periods are defined relative to the year of the Census shock. Standard errors are bootstrapped and clustered at the regional level.

**Discussion.** Our analysis reveals that public expenditure and goods provision significantly impact labour force participation in Germany. The 2011 Census shock considerably affected both local public finance and non-employment. Treated districts experienced a sharp decrease in fiscal capacity per capita compared to regions with a one standard deviation above-median Census shock. Furthermore, our findings show an increase in non-employment rates after the Census-induced fiscal budget shock, with higher elasticities of extensive labour supply for female than male workers. These results suggest the existence of so-called "fiscal multipliers", which measure how changes in public expenditure and public goods provision affect labour force participation. Should governments consider these workers' labour force participation adjustments when designing spatial redistribution policies? To address this issue, we propose a new framework for optimal spatial policies that incorporate worker heterogeneity, local public finance, and a local labour

[14]The IPWRA approach gives similar results with highly significant male coefficients. Appendix Table 3 displays the respective detailed estimates. Additionally, Appendix Figure D.5 shows that the public finance and the non-employment responses remain qualitatively similar when applying the IPWRA estimator.

force participation margin influenced by the provision of local public goods.

# 3 A Spatial Model with Heterogeneous Labour Force Participation Decisions and Public Goods Provision

The economy comprises $J$ regions and $S$ sectors, including a home market sector, and is populated by $L$ individuals. They are bound to a specific group $g \in G$, each featuring a total number of $L^g$ workers. Workers can move freely across regions and the $M \subset S$ market sectors but only learn about employment frictions (or costs) after moving. These frictions affect their decision to work in one of the market sectors $u \in M$ or remain in the home market sector $h$. Workers make labour supply decisions along both allocative and extensive margins. On the allocative margin, workers self-select into the region and market sector that offers them the highest returns. $L^g_{i,u}$ represents their spatial sorting and sectoral selection decision. On the extensive margin, they decide whether to leave the labour force. The number of non-employed workers in group $g$ who initially chose region $i$ and market sector $u$ as their place of work is represented by $L^g_{h|i,u} \leq L^g_{i,u}$.

See Appendix A for all formal proofs and a detailed description of all derivations.

## 3.1 Workers

**Preferences.** Each worker $\omega$ of group $g$ derives utility from consuming final goods and public services, and from living in a specific region $i \in J$ and sector $s \in S$. After choosing a region-sector pair $\{i, u\}$, workers maximise their utility by choosing consumption bundles $C_{s,u'|i,u}$ of local final goods at given prices $P_{i,u'}$, subject to their budget constraint:

$$\max_{\{C^g_{s,u'|i,u}\}_{u'=1}^{M}} \eta^g_{s|i,u}(\omega) \left( \frac{R_{s|i,u}}{L_i^{\chi}} \right)^{\alpha} \left[ \prod_{u'=1}^{M} (C^g_{s,u'|i,u})^{\beta^C_{u'}} \right]^{1-\alpha} \Psi^g_{i,u}(\omega) \quad \text{s.t.} \quad \sum_{u'=1}^{M} P_{i,u'} C^g_{s,u'|i,u} = I^g_{s|i,u}.$$

The utility function takes into account the provision of public goods by the local government, $R_{s|i,u}$, with sector-specific utility from local public expenditures.[15] $0 < \alpha < 1$ is the preference weight for local public services. $\chi \in [0, 1]$ governs the extent of rivalry of public goods consumption with $\chi = 0$ capturing the case of a pure local public good and $\chi = 1$ of full rivalry. Workers have idiosyncratic preferences $\Psi^g_{i,u}(\omega)$ for living and working in region-sector pair $\{i, u\}$, distributed according to a Fréchet distribution with shape parameter $\theta^g > 1$. Workers also differ in their utility from local amenities and employment costs, $\eta^g_{s|i,u}(\omega)$.

[15] We incorporate sector-specific utility from local public expenditures, acknowledging that workers in higher-income sectors may benefit more from publicly available services like infrastructure. Workers take these public expenditures as given, and we assume that all workers in market sectors enjoy the same level of public goods provision for simplicity.

Workers use their after-tax income $I^g_{s|i,u}$ for local private goods consumption, such that

$$C^g_{s,u'|i,u} = \beta^C_{u'} \frac{I^g_{s|i,u}}{P_{i,u'}}, \tag{1}$$

with shares $\beta^C_{u'}$ over the consumption of local goods satisfying $\sum_{u' \in M} \beta^C_{u'} = 1$. Substituting the equilibrium values from (1) in the utility function, we can write the indirect utility for a worker as a function of the after-tax real income, local public goods, and two idiosyncratic preference components $\{\eta^g_{s|i,u}(\omega), \Psi^g_{i,u}(\omega)\}$:

$$V^g_{s|i,u}(\omega) = \eta^g_{s|i,u}(\omega) \left(\frac{R_{s|i,u}}{L^\chi_i}\right)^\alpha \left(\frac{I^g_{s|i,u}}{P_i}\right)^{1-\alpha} \Psi^g_{i,u}(\omega). \tag{2}$$

This yields the region-specific price index as $P_i = \prod_{u'=1}^{M} (P_{i,u'}/\beta^C_{u'})^{\beta^C_{u'}}$.

**Labour Force Participation.** We introduce non-convexities in private and public goods consumption and costs of market employment to micro-found responses along the labour force participation margin. In section 4 we show to what extent these extensions have implications for the design of optimal spatial policies.

The timing of individual labour supply decisions is as follows: First, workers choose any of the $J * M$ heterogeneous pairs as a place and market sector to work based on their personal preference drawn from a Fréchet distribution. Then, all workers $L^g_{i,u}$ remain in the market sector $u \in M$ or join the home market sector $h$ given employment frictions. We first derive individual workers' labour force participation decisions and later endogenize their spatial sorting and sectoral decisions in section 3.4.

Workers receive location-sector-group-specific wage income $w^g_{s|i,u}$, taxed at rate $\mathcal{T}^g_{s|i,u}$, as well as an additive transfer $\mathcal{S}^g_{s|i,u}$ from the general government, where $\mathcal{S}^g_{s|i,u} = \mathcal{K}/L$ and $\mathcal{K}$ is a nation-wide portfolio. [16] In particular, it holds that

$$I^g_{s|i,u} = \left(1 - \mathcal{T}^g_{s|i,u}\right) w^g_{s|i,u} + \mathcal{S}^g_{s|i,u}, \tag{3}$$

Workers in the home market sector $h$ receive a fraction $1 - \gamma$ of the wage income as non-employment compensation, on top of the income from additive wage subsidies.

Each worker derives utility from public expenditures depending on the amount of publicly provided goods and the total number of other individuals consuming them. The individual labour market status determines how much each worker benefits from these public expenditures. The functional forms representing workers' incentive constraints are given by:

$$w^g_{s|i,u} = \begin{cases} (1-\gamma) w^g_{u|i,u} & \text{if } s = h \\ w^g_{u|i,u} & \text{if } s = u \in M \end{cases} \quad \text{and} \quad R_{s|i,u} = \begin{cases} \left(R_{u|i,u}\right)^{1-\rho^g_{h,R}} & \text{if } s = h \\ R_{u|i,u} & \text{if } s = u \in M, \end{cases}$$

[16] The set-up of the portfolio is discussed in detail in section 3.3.

with $\{\gamma, \rho^g_{h,R}\} \in [0,1]$.[17] The overall idiosyncratic preference component is given by:

$$\eta^g_{s|i,u}(\omega) = \begin{cases} \bar{A}^g_i \exp\left[\bar{B}^g_{h|i,u}\right] \varphi(\omega) & \text{if } s = h \\ \bar{A}^g_i \exp\left[-\mu^g_{u|i,u}\right] & \text{if } s = u \in M. \end{cases} \tag{4}$$

It contains a fundamental amenity term $\bar{A}^g_i$ common to all workers and participation costs $\exp\left[-\mu^g_{u|i,u}\right] \leq 1$ from joining either of the markets sectors $u \in M$. Besides the differences in participation costs and consumption, another difference between market workers and workers in the home market sector comes from an additional market friction term $\exp\left[\bar{B}^g_{h|i,u}\right] \varphi(\omega)$.[18] However, we remain agnostic about the precise microeconomic foundations of the market friction at this point.[19]

The home-market-specific friction term consists of an exogenous component $\exp\left[\bar{B}^g_{h|i,u}\right]$ and an idiosyncratic component $\varphi(\omega) > 1$, which allows accounting for individual labour force participation decisions. We assume that the individual-specific draws $\varphi$ come from a Pareto distribution with a worker-type-specific shape parameter $\epsilon^g > 1$:

$$G^g(\varphi) = 1 - \varphi^{-\epsilon^g}. \tag{5}$$

Workers join the home market sector $h$ as long as achievable indirect utility exceeds indirect utility in the chosen market sector $u$. There exists a unique region-sector-specific cut-off level for idiosyncratic shocks $\tilde{\varphi}^g_{s|i,u}$, above which workers join the home market sector:

$$\tilde{\varphi}^g_{s|i,u} = \left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right) \left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha} \left(\left[R_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}. \tag{6}$$

The parameter $\mathcal{B}^g_{s|i,u} \equiv \exp\left[\bar{B}^g_{h|i,u} + \mu^g_{u|i,u}\right]$ captures the total cost in terms of utility units for workers who join the labour force.

Using the properties of the Pareto distribution, the number of workers joining the home market sector $h$ in region $i$, who initially self-selected into the market sector $u$, is given by

$$L^g_{h|i,u} = \xi^g_{h|i,u} L^g_{i,u} = \left[\left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right) \left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha} \left(\left[R_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}\right]^{-\epsilon^g} L^g_{i,u}, \tag{7}$$

[17] Non-employed workers impose a lower congestion force on public goods since they do not regularly commute to work (Guglielminetti et al., 2023) or more often privately care for their young children (Brown and Herbst, 2022). We estimate the values of $\{\rho^g_{h,R}\}$ in an empirical approach outlined in section 5.

[18] To account for varying preferences for regions (Ahlfeldt et al., 2020) and sectors (Wiswall and Zafar, 2018), we allow idiosyncratic preferences and participation costs to differ by worker group.

[19] The market friction term could arise due to search frictions, entry costs of market employment, or workers disliking working (Mortensen, 2011; Cogan, 1981; Blundell and Shephard, 2012; Fajgelbaum et al., 2019; Chauvin, 2018). These costs and related preference terms could also include financial or time costs, such as saved commuting time (Le Barbanchon et al., 2021). By comparing these preference terms across regions and sectors, we can capture non-convexities of labour supply, such as the ability to work from home, the desire for flexible hours, and the emotional costs associated with maintaining a career (Cha and Weeden, 2014; Cubas et al., 2019; Dingel and Neiman, 2020; Erosa et al., 2022; Wasserman, 2022; Kleven and Kreiner, 2006).

where $\xi^g_{h|i,u} \equiv L^g_{h|i,u}/L^g_{i,u}$ denotes the share of workers in the home market sector $h$.

Several components affect local labour force participation decisions. High after-tax income compared to non-employment transfers induces workers to join the market sectors by increasing the opportunity cost of choosing the home market. However, this effect may decrease if there are significant market frictions or costs in region $i$ or sector $u$. Additionally, local expenditures can affect employment via so-called "fiscal multipliers" $\rho^g_{h,R}$. Increased public spending can raise the cut-off level (6), encouraging workers to enter the labour force.

### 3.2 Production

Firms in all market sectors produce a wide variety of intermediate goods. The production technology requires labour, land and structures, and materials from all market sectors (Caliendo et al., 2018, 2019). The producers of intermediate goods vary by their productive efficiency, which we denote by $z_{i,u}$ for each variety.

**Intermediate Goods Producers.** The output of a producer of an intermediate variety with efficiency $z_{i,u}$ is given by

$$y_{i,u}\left(z_{i,u}\right) = z_{i,u}\left[\left(h_{i,u}\left(z_{i,u}\right)\right)^{\kappa_{i,u}}\left(l_{i,u}\left(z_{i,u}\right)\right)^{1-\kappa_{i,u}}\right]^{\delta_{i,u}} \prod_{u'\in M}\left[M_{i,uu'}\left(z_{i,u}\right)\right]^{\delta_{i,uu'}}, \tag{8}$$

where $h_{i,u}(.)$ and $l_{i,u}(.)$ are the demand for land and structures and labour, respectively.[20] $M_{i,uu'}(.)$ denotes material inputs from sector $u'$, demanded by a firm located in region $i$ and operating in sector $u$ under efficiency $z_{i,u}$ to produce $y_{i,u}$ units of an intermediate variety. $\delta_{i,uu'}$ is the share of materials from market sector $u'$ in the production of market sector $u$ in region $i$, while $\delta_{i,u}$ denotes the share of total value added in gross output. We assume constant returns to scale technology, such that $\sum_{u'\in S}\delta_{i,uu'} = 1-\delta_{i,u}$. Finally, the parameter $\kappa_{i,u}$ denotes the share of land and structures in value added. The supply of local land and structure is exogenous, inelastic and denoted by $\bar{\mathcal{H}}_i$.

We assume that the different labour types are imperfectly substitutable inputs to the production function

$$l_{i,u}\left(z_{i,u}\right) = \left[\sum_{g\in G}\left(T^g_{i,u}L^g_{u|i,u}\left(z_{i,u}\right)\right)^{\frac{\sigma^g-1}{\sigma^g}}\right]^{\frac{\sigma^g}{\sigma^g-1}}, \tag{9}$$

where $L^g_{u|i,u}$ denotes the number of workers of type $g$ employed in region-sector pair $\{i,u\}$ and $\sigma^g > 1$ denotes the elasticity of substitution between workers of different types in the production of varieties.

[20] In this model, a fixed factor (it could also be capital if not land and structures) leads to a downward-sloping labour demand curve in each location. It acts as a congestion force (Redding and Rossi-Hansberg, 2017). It is important to note that fundamental productivity shifts local value and not total production in this setup, which ensures that any productivity increases translate into higher gross output.

Workers' productivity in region $i$ and market sector $u$ is determined by their group-specific human capital $T^g_{i,u}$. We allow for the possibility that extensive labour supply may cause positive productivity externalities ("agglomeration spillovers"). Fundamental productivity, therefore, consists of an exogenous component $\bar{T}^g_{i,u}$, which gets endogenously shifted by local labour supply, such that:

$$T^g_{i,u} = \bar{T}^g_{i,u} \left( \sum_{u \in M} \sum_{g \in G} L^g_{i,u} \right)^{\zeta^g},$$

where the productivity spillover has a constant group-specific elasticity $\zeta^g > 0$.[21] Denoting as $r_i$ the rental price of land and structures in region $i$ we obtain the following formulation for the cost of inputs $\lambda_{i,u}(z_{i,u})$ in region-sector pair {i,u} (see Appendix A.2 for details):

$$\lambda_{i,u}(z_{i,u}) \equiv \frac{\lambda_{i,u}}{z_{i,u}} = \frac{D_{i,u}}{z_{i,u}} \left( r_i^{\kappa_{i,u}} \left[ \sum_{g \in G} \left( \frac{T^g_{i,u}}{w^g_{u|i,u}} \right)^{\sigma^g - 1} \right]^{\frac{1-\kappa_{i,u}}{1-\sigma^g}} \right)^{\delta_{i,u}} \prod_{u' \in M} \left[ P_{i,u'} \right]^{\delta_{i,uu'}}, \tag{10}$$

with the constant $D_{i,u} \equiv \left( \delta_{i,u} (\kappa_{i,u})^{\kappa_{i,u}} (1-\kappa_{i,u})^{(1-\kappa_{i,u})} \right)^{-\delta_{i,u}} \prod_{u \in S} \left( \delta_{i,uu'} \right)^{-\delta_{i,uu'}}$ and $\lambda_{i,u}$ denotes the region-sector-specific unit cost index. Trade costs are represented by $\tau_{ij,u}$ and are of the 'iceberg' type. One unit of any variety of intermediate good $u$ shipped from region $j$ to $i$ requires producing $\tau_{ij,u} \geq 1$ units in region $j$. Given constant returns to scale and competitive intermediate goods markets, a firm produces only positive amounts of a variety as long as its price equals its unit production cost, $\lambda_{i,u}/z_{i,u}$.

We assume that across all varieties, market sectors, and regions, the idiosyncratic productivity levels $z_{i,u}$ are independently drawn from a Fréchet distribution such that the joint cumulative distribution function is given by

$$\phi_u (z_{i,u} ..., z_{J,u}) = \exp \left\{ - \sum_{i \in J} (z_{i,u})^{-\nu_u} \right\}, \tag{11}$$

where we normalise the scale parameter to unity, and the market-specific shape parameters $\nu_u > 1$ govern the variance of efficiency draws.

**Final Good Producers.** Final goods producers buy intermediate goods from the location where the acquisition cost, including trade costs, is the lowest. They combine intermediate goods demanded from sector $u$ and all regions into a local CES bundle (final good). Local final goods, in turn, are used as materials for the production of intermediate varieties and final consumption and as input into the production of local public goods. There are no fixed costs or barriers to entry in producing intermediate and final

[21] Similarly to Fajgelbaum and Gaubert (2020), productivity spillovers may depend on the distribution of worker types. We abstract from these restrictions and assume that spillovers have the same productivity-augmenting effect across all market sectors.

goods. Hence perfect competitive behaviour implies zero profits. Given the properties of the Fréchet distribution and the assumption of a CES aggregate final good, we derive the price of the aggregate good in market sector $u$ and region $i$ as

$$P_{i,u} = \Gamma\left(\gamma_u\right)^{\frac{1}{1-\sigma}} \left[\sum_{j\in J} \left(\lambda_{j,u}\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}}, \tag{12}$$

where $\gamma_u \equiv \frac{\nu_u+1-\sigma}{\nu_u}$ and $\Gamma(.)$ denotes the Gamma function. The functional assumptions on the distribution of efficiencies across regions finally allow deriving the share of total expenditures in region-sector pair $\{i,u\}$ that accrues to sector-$u$-goods from region $j$ as

$$\pi_{ij,u} = \frac{X_{ij,u}}{X_{i,u}} = \frac{\left(\lambda_{j,u}\tau_{ij,u}\right)^{-\nu_u}}{\sum_{n\in J}\left(\lambda_{n,u}\tau_{in,u}\right)^{-\nu_u}}, \tag{13}$$

with $X_{ij,u}$ being the expenditure in region $i$ on sector $u$ goods produced in region $j$ and $X_{i,u} = Y_{i,u}P_{i,u}$ being total expenditures on goods from sector $u$ in region $i$.[22] The cheaper the cost of production in region-sector pair $\{j,u\}$ or the smaller bilateral trade costs between region $j$ and $i$, the more producers in region $i$ purchase varieties from region $j$.

Local final goods are used either for private consumption, as materials or as an input for the local final public good, such that

$$P_{i,u'}Y_{i,u'} = \beta^C_{u'}C_i + \beta^R_{u'}E_i + \sum_{u\in M} M_{i,uu'}P_{i,u'}, \tag{14}$$

where $X_{i,u'} \equiv P_{i,u'}Y_{i,u'}$ denotes the total value of final goods production. $C_i$ is the total value of private consumption. $E_i = R_iP^R_i$ is the total expenditure of local governments on final goods, and $P^R_i$ denotes the optimal local price level of governments.

### 3.3 Ownership of Fixed Factors, Governments and Spatial Transfers

In describing the fiscal redistribution scheme and the public sector, we closely follow Henkel et al. (2021). Local governments run balanced budgets and could only use local tax revenues and rental income to provide public services and finance non-employment compensation. However, spatial transfers set by the Federal government alter local governments' budgets. Local governments use their available fiscal budgets to purchase final local goods as input to provide a local public good $R_i$, produced according to a Cobb-Douglas production function under no additional costs and with shares $\beta^R_{u'}$, such that $\sum_{u'\in M}\beta^R_{u'} = 1$. Local governments tax total labour income at the local rates $\mathcal{T}^g_{s|i,u}$. The Federal government collects local tax revenues and uses spatial transfers to redistribute them back to local governments according to the transfer rate $\rho_i$, which is proportional to the local labour income (and is negative for donor regions and positive for recipients). Local tax revenues and spatial transfers thus determine the fiscal budget of local governments, such

[22] Appendix (A.2) presents all derivations.

that

$$E_i = \left( \sum_{u \in M} \sum_{g \in G} \sum_{s \in h,u} (\mathcal{T}^g_{s|i,u} + \rho_i) w^g_{s|i,u} L^g_{s|i,u} \right) \tag{15}$$

In determining the ownership of fixed factors, we assume that local governments own the land and structures in all regions and rent them to firms at local rates. The revenue from rents enters a national portfolio used to finance non-employment compensation in all regions: $\mathcal{K} = \sum_{j \in J} \sum_{u' \in M} \left( \mathcal{H}_{j,u'} r_j - \sum_{g \in G} w^g_{h|j,u'} \xi^g_{h|j,u'} L^g_{j,u'} \right)$ here denotes the national portfolio of local rents, net of centrally funded non-employment compensation, where we let $\sum_{u' \in M} \mathcal{H}_{i,u'} r_i$ denote the total of local rents across all market sectors in region $i$. The remaining fraction of the portfolio gets redistributed to local workers.[23]

### 3.4 Spatial Sorting and Sectoral Selection

We endogenize workers' spatial sorting and sectoral selection decisions by allowing them to form expectations about their probability of becoming non-employed and use expected indirect utility to make their decisions.

By combining equations (2) and (7) and using the properties of the Pareto distribution, we derive the expected indirect utility of workers (see Appendix A.1 for details):

$$\begin{aligned} \bar{V}^g_{i,u}(\omega) &= \Psi^g_{i,u}(\omega) \bar{V}^g_{i,u} = \Psi^g_{i,u}(\omega) \sum_{s \in h,u} V^g_{s|i,u} \xi^g_{s|i,u} \\ &= \Psi^g_{i,u}(\omega) V^g_{u|i,u} \left( 1 + \frac{\xi^g_{h|i,u}}{\epsilon^g - 1} \right). \end{aligned} \tag{16}$$

Different externalities emerge from decisions at the extensive and allocative labour supply margin. An increase in local population imposes a negative externality on local worker welfare due to increased congestion of per capita public services when there is rivalry in public goods consumption (i.e. $\chi > 0$). Employed workers further impose two positive externalities on local economies by increasing local productivity levels through agglomeration economies and expanding the local tax base by shifting the fiscal budgets of local governments.

Workers choose the region-sector pair $\{i, u\}$ that maximises their expected utility $\bar{V}^g_{i,u}(\omega)$ in the first stage. We derive the expected indirect utility of type-g workers in the market sectors using the fact that the maximum of a Fréchet-distributed random variable is itself Fréchet distributed:

$$\mathcal{V}^g = \Gamma\left( \frac{\theta^g - 1}{\theta^g} \right) \left( \sum_{u \in M} \sum_{i \in J} \left[ \bar{V}^g_{i,u} \right]^{\theta^g} \right)^{\frac{1}{\theta^g}}. \tag{17}$$

[23] In a situation where local workers hold shares in a portfolio of the fixed factor, the competitive equilibrium will be inefficient. This concept has been discussed further by Redding and Rossi-Hansberg (2017).

Perfect worker mobility ensures that expected utility is equalised everywhere in the economy. Given our assumptions on the functional form of the preference shock distribution and the expected utility defined in equation (16), we get closed-form solutions for labour supply in spatial equilibrium:

$$L_{i,u}^g = \frac{\left(\bar{V}_{i,u}^g\right)^{\theta^g}}{\sum_{u\in M}\sum_{i\in J}\left(\bar{V}_{i,u}^g\right)^{\theta^g}} L^g. \tag{18}$$

The parameter $\theta^g$ controls the sensitivity of a region-sector pair's employment to changes in its relative expected after-tax per-capita real income, type-specific preferences, and the reaction in extensive labour supply of households to local public goods provision.

### 3.5 General Equilibrium

Given vectors of exogenous region-sector-specific characteristics $\{\bar{T}_{i,u}, \bar{B}_{h|i,u}, \mu_{u|i,u}^g, \bar{A}_i^g, \bar{\mathcal{H}}_i\}$, the total number of workers $L^g$, spatial policies $\{\mathcal{T}_{s|i,u}^g, \mathcal{S}_{s|i,u}^g, \rho_i\}$, and model parameters $\{\alpha, \beta_u^C, \beta_u^R, \theta^g, \epsilon^g, \delta_{i,s}, \delta_{i,su}, \kappa_{i,s}, \gamma, \rho_{h,R}^g, \sigma_g, \sigma, \tau_{ij,s}, \nu_s, \chi\}$, a general equilibrium of this economy is defined as a vector of endogenous objects
$\{I_{s|i,u}^g, P_i, L_{i,u}^g, L_{h|i,u}^g, w_{u|i,u}^g, h_{i,u}, r_i, P_{i,u}, M_{i,uu'}, \pi_{ij,u}, X_{i,u}, \lambda_{i,u}, E_i\}$. 13 sets of equations determine these components of the equilibrium vector. In a spatial equilibrium, markets for intermediate and final goods, labour, land and structures, and materials clear in all region-sector pairs and the local government budget constraint holds.

See Appendix section A.3 for a complete summary of all model market clearing conditions and 12 sets of equations, which determine the spatial equilibrium in our theoretical framework.

## 4 Social Planner Problem

In section 3, we characterised the competitive equilibrium in a spatial model that considers heterogeneous workers' labour force participation decisions that depend on providing local public goods. Now, we compare the competitive equilibrium with the socially optimal allocation of workers across regions and sectors. A utilitarian planner aims to maximise social welfare by considering the weighted sum of expected utility across all individuals in the economy. The planner considers that workers freely choose their region-sector pair $\{i, u\}$ when joining the labour force and make their extensive labour supply afterwards.

The competitive allocation may not align with the socially efficient solution if "spillover effects" are present. Workers may not consider the impact of their location decisions on local productivity via agglomeration economies or local public good consumption if these goods are rivalrous.[24] The effects of these externalities are discussed in detail in

[24]In our model, public goods may differ from Samuelsonian "pure public goods" as they are not equally available to all individuals. The consumption of public goods has a spatial and sectoral dimension, which affects how much everyone benefits from public spending.

Fajgelbaum and Gaubert (2020).[25] Our model highlights an additional public finance externality that can drive a wedge between competitive and social planner allocation. When making location and labour supply decisions, workers may not consider their impact on fiscal funds, public goods provision, fiscal distribution size, and ultimately the aggregate labour force of the economy in the presence of "fiscal multipliers" that measure how changes in public expenditure and goods provision affect labour force participation.

In particular, the social planner maximises the welfare function, which builds on equation (17):

$$\mathcal{W} = \sum_{g \in G} \mu^g U \left[ \Gamma \left( \frac{\theta^g - 1}{\theta^g} \right) L^g \left( \sum_{u \in M} \sum_{i \in J} \left[ \bar{V}^g_{i,u} \right]^{\theta^g} \right)^{\frac{1}{\theta^g}} \right]. \tag{19}$$

The welfare weights for each worker group are represented by $\mu^g$, $U(.)$ is an increasing and concave function of workers' utility, and the expected utility $\bar{V}^g_{i,u}$ is defined as in equation (16). While maximising the social welfare function, the social planner must consider several constraints related to public and private good consumption, production, employment, population, and intermediate and final goods markets.[26]

The social planner determines the distribution of workers across locations and sectors $(L^g_{i,u})$, the size of the local labour force $(L^g_{u|i,u})$, and the consumption of public and private goods in all sectors $\{C^g_{s|i,u}, C^g_{s,u'|i,u}, R^g_{u|i,u}, R^g_{s,u'|i,u}\}$. On the production side, the social planner selects optimal quantities of labour $L_{u|i,u}(z_{i,u})$, land and structures $\mathcal{H}_{i,u}(z_{i,u})$ and materials $M_{i,uu'}(z_{i,u})$ as inputs into intermediate goods production. Lastly, the social planner chooses the optimal intermediate goods production from all regions, $\tilde{y}_{ji,u}(\mathbf{z_u})$. Online Appendix A.5.2 shows that the planner chooses precisely the same quantities of production input factors and output as firms in the competitive equilibrium but allocates consumption and workers differently to account for the various externalities they impose on other consumers.

In particular, the planner allocates private and public goods such that the marginal utility of consumption equals regional price levels after controlling for workers' sorting and labour force participation responses to locally varying consumption possibilities. More importantly, we use the planner's problem setup to derive a condition on the allocation of workers' private goods consumption, which ensures that the equilibrium is efficient since it balances the marginal costs and benefits of workers of different groups across all locations.

**Proposition 1.** *The competitive equilibrium is efficient if the planner's problem is globally*

[25] Fajgelbaum and Gaubert (2020) propose a framework with endogenous amenities. In our model, public good provision is similar to endogenous amenities, funded by local taxes and transfers, as long as workers do not differentiate between public and private goods consumption (e.g. $\alpha = \mathcal{T}_i = 1$). Rossi-Hansberg et al. (2019) emphasise the importance of different employment sectors for optimal taxation.

[26] The exact setup of the social planner's problem is discussed in detail in Online Appendix A.5.1.

*concave and the following condition on private goods expenditure holds:*

$$\underbrace{W_{i,u}^{g}}_{\text{opportunity cost}} + \underbrace{\sum_{u' \in M} P_{i,u'} \sum_{s \in h,u} \xi_{s|i,u}^{g} C_{s,u'|i,u}^{g}}_{\substack{\text{consumption cost} \\ \text{(private)}}}$$
$$= \underbrace{\left(1 - \xi_{h|i,u}^{g}\right) w_{u|i,u}^{g}}_{\substack{\text{marginal product of labour} \\ \text{(private)}}} + \underbrace{\frac{\partial \left[\sum_{j \in J} \tau_{ji,u} \tilde{y}_{ji,u}\left(\mathbf{z_u}\right)\right]}{\partial T_{i,u}^{g}} \times \frac{\partial T_{i,u}^{g}}{\partial L_{i,u}^{g}}}_{\text{productivity spillovers}} + \underbrace{\frac{\partial \mathcal{W}}{\partial\left(R_i/L_i^{\chi}\right)} \frac{\partial R_i/L_i^{\chi}}{\partial L_{i,u}^{g}}}_{\substack{\text{marginal public goods} \\ \text{(congestion spillovers)}}} \tag{20}$$

Condition (20) highlights the various channels through which an additional worker $L_{i,u}^{g}$ in each region-sector pair $\{i, u\}$ impacts the local economy. The marginal worker raises productivity via agglomeration economies and increases the local labour force (with a certain probability) but also increases public good rivalry and puts a strain on the final goods resource constraint. Additionally, there is an opportunity cost for the marginal worker to be employed in region-sector $\{i, u\}$ relative to other parts of the economy, denoted by $W_{i,u}^{g}$, which is the multiplier on the resource constraint of workers of each type. Hence, this condition extends the results in Fajgelbaum and Gaubert (2020) and Rossi-Hansberg et al. (2019) to a framework where labour supply decisions are made along both the allocative and the extensive margin, and workers consume both private and public goods.

When labour force participation decisions are present, the marginal product of labour increases further in the local labour force participation rate. Employed workers also significantly strain local final goods constraints if they consume more final goods than non-employed workers. To assess the efficiency of the competitive allocation, data on public expenditures $R_i/L_i^{\chi}$ is required. The optimal allocation must balance private and public consumption in each location, given workers' preferences for each particular good.[27]

## 5 Data and Quantification

This section outlines the data and methods for obtaining the model parameters and identifying model-implied fundamental variables. We quantify the model using data on employment, wages, tax revenues, and spatial transfers by region and sector. In addition to the home market sector, we construct six market sectors, four of which include tradable and two non-tradable goods (Construction and non-tradable services). We also distinguish worker groups by gender. We apply the German fiscal redistribution scheme to 141 local labour markets for 2014.[28] Additional data sources and identification steps are in Appendix Section B. Table 1 lists the parameters and sources we use in our model quantification.

[27] See Online Appendix A.5.2 for details, derivations and proof of Proposition 1.

[28] In our model, individuals reside where they work. To address the issue that residents and commuters are treated by a different tax system, as discussed by Agrawal and Hoyt (2018), we quantify the model for 141 commuting zones, as defined by Kosfeld and Werner (2012).

## 5.1 Utility and Production Function Parameters

We use estimates of gender-specific productivity spillovers for Germany ($\zeta^M = 0.018; \zeta^F = 0.032$) from Ahlfeldt et al. (2020) and set the elasticity of substitution between male and female workers at $\sigma^g = 2.5$.[29] For the elasticity of substitution of varieties across regions, we use estimates from the standard gravity literature (Head and Mayer, 2014) and set $\sigma = 5$. We parameterise bilateral trade costs as a constant elasticity function of distance for tradable sectors and treat trade costs as infinite in non-tradable sectors.

Following equation (13), we estimate the combined sector-specific parameter $-\nu_s\zeta_s$ using standard gravity regressions based on bilateral trade flows from the Forecast of Nationwide Transport Relations in Germany 2030 (Schubert et al. (2014)). The estimated distance coefficients range between $-1.43$ and $-2.14$. They are statistically significant and firmly in line with estimates from the gravity literature (Head and Mayer, 2014). We parameterise trade costs according to ($\tau_{ij,s} = dist_{ij}^{\zeta_s}$), while, as in Rossi-Hansberg et al. (2019), setting trade elasticities to $\nu_s = 10$ for all sectors, which is well within the range of values considered by Head and Mayer (2014).

We use administrative labour market data from the IAB to calculate wages per region and sector. Non-employed workers receive a fraction of $1 - \gamma = 0.62$ of their respective market wages to match non-employment payments of workers in their first year of leaving the market sector in Germany. We calibrate the labour share in production, $1 - \kappa_{i,s}$ to match region-sector specific labour payments relative to value added and match the share of value-added $\delta_{i,s}$ to its data counterpart, e.g. on gross output from EU KLEMS (Stehrer et al. (2018)) and gross value-added from the regional economic accounts provided by the Statistical Office of the European Union (Eurostat). To determine the share of sector $u$ goods used in sector $s$ and region $i$, $\delta_{i,su}$, we rely on national input-output shares $\delta_{su}$ from the World Input-Output Tables (WIOD, see Timmer et al. (2015)), noticing that $\delta_{i,su} = (1 - \delta_{i,s})\delta_{su}$.

We assume perfect rivalry for local public goods and set $\chi = 1$ for our primary analysis. We borrow values for the preference weight for local public services $\alpha = 0.24$ from Fajgelbaum et al. (2019) and set the Fréchet shape parameter $\theta^g = 5$, which is well within the parameter range considered in the urban economics literature (Ahlfeldt et al., 2015; Monte et al., 2018; Fajgelbaum et al., 2019).[30] Next we calculate the shape parameter of the Pareto distribution to match micro estimates of extensive labour supply elasticity to market wages, which yields $\epsilon = 1.63$ for male workers and $\epsilon = 1.64$ for female work-

[29] Both parameter choices are within the range of other available estimates (Combes and Gobillon, 2015; Olivetti and Petrongolo, 2014). The literature on agglomeration economies (Rosenthal and Strange, 2004) documents values of agglomeration spillovers ranging from 0.01 to 0.06. Depending on the occupation of workers, Bhalotra and Fernández (2018) estimate the elasticity of substitution between men and women to be between 1.2 and 2.7 in Mexico, whereas Acemoglu et al. (2004) obtain a slightly larger estimate of 3.

[30] Given the Cobb-Douglas utility structure, $\alpha$ represents the expenditure share on public goods, which should equal the share of aggregate public expenditure to total value added. Local public finance data for Germany also suggests a similar value, which justifies our chosen value.

ers.[31] Finally, we follow Henkel et al. (2021) in computing local tax revenues and net fiscal transfers and relate them to local value added to obtain tax $\mathcal{T}_i$ and transfer rates $\rho_i$ per region. Using our calibration, unique values of expenditure shares $\{\beta_s, \beta_s^R\}$ exist, which ensure that all markets clear for all sectors in the aggregate, given the regional tax and transfer rates and derive model-consistent expenditures of all regions that rationalize goods market-clearing.[32]

The cost-minimising behaviour of producers ensures that bilateral trade flows decrease in the size of unit production costs. We identify unit costs $\lambda_{j,u}$ from model-consistent expenditures $X_{j,u}$ in all origin regions $j \in J$ demanded by workers in region $i$. In all tradable sectors, these translate into regional price levels. For non-tradable sectors, we rely on regional price level indices by sector, which we describe in more detail in Appendix B.1.

## 5.2 Local Productivity

We use derived local price levels for the tradable sector from the model, regional price indices for non-tradable sectors, and local land rent indices (Statistische Ämter des Bundes und der Länder, 2021) to identify group-specific productivity levels as the residual to unit costs. Intuitively, we fit gender-specific productivity levels to trade flows and goods expenditures (controlling for differences in income and expenditure on materials and land and structures) in an approach motivated by our spatial model.[33]

## 5.3 Local Amenities and Participation Costs

After controlling for after-tax real income and public goods provision, we recover overall amenities $\eta^g_{s|i,u}$ from equation (18) as the residual to observable labour supply. We decompose the overall amenity term into a fundamental term and region-sector-specific participation costs. We normalise overall amenities to a group-specific mean of 1 and regress the residuals on group-region effects to obtain fundamental amenities and participation costs. Finally, using estimates for participation costs, $\rho^g_{h,R}$ and observable labour force participation rates, wages, and public expenditures, we identify exogenous market frictions $\mathcal{B}^g_{s|i,u}$ as the residuum to equation (7).

## 5.4 Elasticity of Extensive Labour Supply

The local labour supply elasticity $\rho^g_{h,R}$ is a crucial parameter for quantifying our model. Using the values for the Cobb-Douglas share of local public goods and the shape parameter

[31] In particular, our model implies $\frac{\partial L^g_{u|i,u}}{\partial (I^g_{u|i,u}/I^g_{h|i,u})} \frac{(I^g_{u|i,u}/I^g_{h|i,u})}{L^g_{u|i,u}} = (1-\alpha)\,\epsilon^g \frac{\xi^g_{h|i,u}}{1-\xi^g_{h|i,u}}$, which we evaluate at the average level of non-employment rates of each worker group and equalise it to micro labour supply elasticity at the extensive margin (Chetty et al., 2011). In particular we set the labour elasticity to 0.22 for male and 0.38 for female workers, which is well within the range of estimates for Germany (Bargain and Peichl, 2016) .

[32] See identification steps 1 - 5 in Appendix B.2 for further details and derivations.

[33] See identification steps 6 - 9 in Appendix B.2 for further details and derivations.

Table 1: Parameter Values

| Parameter | Description | Approach | Source |
|---|---|---|---|
| | **Preferences** | | |
| $\chi = \{0; 1\}$ | Rivalry in public goods cons. | Set | Fajgelbaum et al. (2019); Henkel et al. (2021) |
| $\alpha = 0.24$ | Cobb-Douglas preferences weight on public good | Set | Fajgelbaum et al. (2019); Henkel et al. (2021) |
| $\theta^g = 5$ | Fréchet shape parameter | Set | |
| $\epsilon^g = \{1.63, 1.64\}$ | Pareto shape parameter | Cal. | Mean $(1-\alpha)\,\epsilon^g \frac{\xi^g_{h\|i,u}}{1-\xi^g_{h\|i,u}}$ |
| | **Extensive Labour Supply** | | |
| $\rho^g_{h,R} = \{0.114; 0.146\}$ | Employed public goods cons. / Non-employed public goods cons | Est. | Section 2.2 |
| | **Production** | | |
| $\zeta^g = \{0.018; 0.032\}$ | Productivity spillovers | Set | Ahlfeldt et al. (2020) |
| $\sigma^g = 2.5$ | Elast. of substitution btw males and females | Set | Olivetti and Petrongolo (2014) |
| $\sigma = 5$ | Elast. of substitution of varieties | Set | Head and Mayer (2014) |
| $\nu_s = 10$ | Trade elasticity | Set | Head and Mayer (2014) |
| $\tau_{ij,s} = \{1, ..., 1.03\}$ | Trade cost | Est. | Trade flows from Schubert et al. (2014) |
| $1 - \kappa_{is} = \{0.08, ..., 0.95\}$ | Labour share in production | Cal. | Wage income/ Value added |
| $\delta_{i,s} = \{0.16, ..., 1\}$ | Share of value added | Cal. | Value added / Gross output |
| $\delta_{i,su} = \{0, ..., 0.54\}$ | Share of material inputs | Cal. | Input-Output Tables |
| $\beta_s = \{0.001,...,0.53\}$ | Expenditure share | Fit. | Equation (59) |
| | **Government** | | |
| $\mathcal{T}_i = \{0.21, ..., 0.44\}$ | Regional tax rate | Cal. | Tax revenues |
| $\rho_i = \{-0.15, ..., 0.22\}$ | Transfer rate | Cal. | Transfer payments |

Notes: "Calibrated" refers to fitting the model to observable data outlined under "data". We identify parameter values following the estimation steps outlined in appendix B.2 and using the data sets under "source". "Fitted" parameters match the model-consistent equations outlined under "source".

of the preference distribution $\alpha, \epsilon^g$, we recover the gender-specific elasticity of workers' extensive labour supply decisions concerning public good provision ($\rho^F_{h,R}, \rho^M_{h,R}$). We start by observing that the 2011 Census shock for treated regions was three percentage points larger than for the control regions.[34] At the same time, each additional percentage point increase in the Census shock led to 0.956% higher revenues per capita, as shown in Table 5. The average treated region, therefore, lost approximately 3% of its total fiscal capacity following the Census shock. Combining this with the average treatment effect in Table 3, the elasticities of public good provision to local employment are $\rho^F_{h,R} = (0.0575/1.64)/0.24 = 0.146$ for females and $\rho^M_{h,R} = 0.114$ for males.

## 6 Optimal Fiscal Policy

In this section, we further characterise the main predictions of the planner's solution and discuss how to implement the socially optimal allocation using different policy instruments. Since inefficient allocation only occurs on the consumer side, we can combine the optimality conditions on local goods consumption, regional labour supply as well labour force participation from the planner's problem to derive the socially optimal levels of private and public goods consumption together with the taxes, subsidies and transfers that implement them.

**Proposition 2.** *The optimal allocation can be achieved with region-group-sector-specific labour income taxes, region-sector-specific income subsidies and region-specific transfers from the planner to local governments to provide local public goods. These implement optimal levels of public and private goods consumption such that*

$$P_i C^g_{s|i,u} = \left(1 - \tilde{\mathcal{T}}^g_{s|i,u}\right) w^g_{u|i,u} + \tilde{\mathcal{S}}_{s|i,u} \quad \text{and} \quad P^R_i R_i = \tilde{E}_i.$$

The planner uses revenues from income taxation and profits from the immobile factor of production ("land and structures") to finance local public good provision and income subsidies to households. These are set such that workers internalise all "spillover effects" (e.g. agglomeration economies, public goods congestion, fiscal externality) in their location and labour force participation decisions. When determining the total size of income subsidies and local government transfers, the planner faces the additional constraint that aggregate expenditures must not exceed total income in the economy:

$$\begin{aligned} &\sum_{g\in G}\sum_{j\in J}\sum_{u'\in M} L^g_{j,u'} P_j \sum_{s\in h,u} \xi^g_{s|j,u'} C^g_{s|j,u'} + \sum_{j\in J} P^R_j R_j \\ &= \sum_{g\in G}\sum_{j\in J}\sum_{u'\in M} L^g_{j,u'} \left(1 - \xi^g_{h|j,u'}\right) w^g_{u|j,u'} + \sum_{j\in J}\sum_{u'\in M} \mathcal{H}_{j,u'} r_j \end{aligned} \tag{21}$$

With this condition, we solve for the optimal taxes, transfers, and subsidies solely using observable data at the region-sector-group level, which includes employment ($L^g_{i,u}$),

[34] See Table 2 for a summary of the 2011 Census shock across treated and non-treated regions.

market wages ($w^g_{u|i,u}$), non-employment rates ($\xi^g_{h|i,u}$), and several structural parameters $\{\alpha, \epsilon^g, \kappa_{is}, \rho^g_{h,R}, \theta^g, \chi, \zeta^g\}$ that we have either estimated or calibrated in an approach outlined in Section 5. In the following, we relegate all details on how the planner's problem can be implemented by a set of policy instruments (Proposition 2) and the underlying policy rules to Appendix A.5.3. We focus on characterising the optimally-set taxes, transfers, and subsidies in the main body of the paper and contrast them with the size of policy instruments we observe in our dataset.

**Optimal Income Taxes.** The social planner imposes a tax on local wage income to finance the additive wage subsidies and public goods provision, which are set to internalise spatial externalities. In particular, the social planner imposes region-group-specific tax rates as long as labour force participation rates vary across regions and worker groups. Figure 3 shows the optimal income tax rates, levied on employed (Panel (a)) and non-employed workers (Panel (b)) against different levels of non-employment rates.

In regions with low market frictions and non-employment rates, tax rates depend solely on labour supply elasticities and the Cobb-Douglas share of private goods consumption: $\tilde{\mathcal{T}}^g_{u|i,u} = \frac{1}{1+(1-\alpha)\theta^g}$ as $\xi^g_{h|i,u} \to 0$. Compared to this particular case, optimal tax rates follow a reverse U-shape in local non-employment rates $\xi^g_{h|i,u}$.

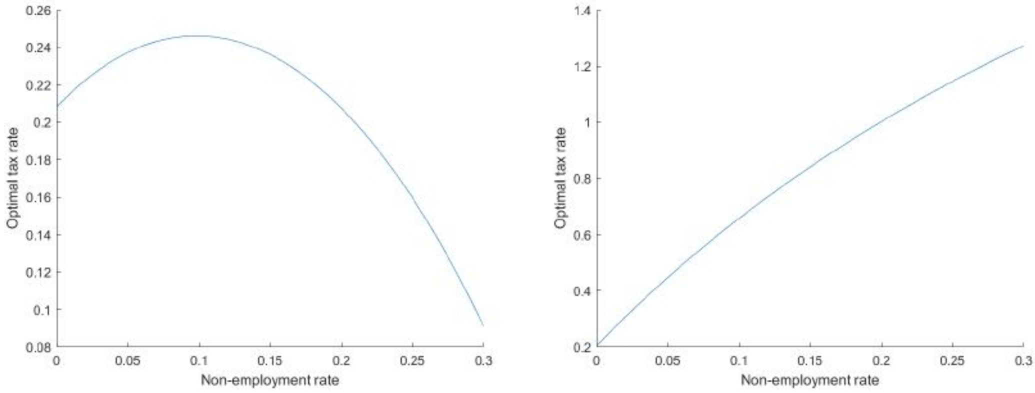
Starting from a world without non-employment, the social planner first raises local tax rates as labour force participation rates decrease to increase private goods consumption in regions with a large marginal utility of consumption, which is a decreasing function of local non-employment rates. However, higher tax rates simultaneously increase the behavioural responses of workers who are incentivised to leave the labour force. Since these behavioural responses are more significant in regions with high market frictions, the income tax rate follows a reverse U-shape as the planner balances higher behavioural responses with higher marginal utilities.

Female workers are less likely to be in the labour force, resulting in slightly higher tax rates for male workers at the average labour force participation rates of the counterfactual equilibrium.Tax rates on non-employed workers are significantly larger at conventional levels of non-employment rates, such that an increase in tax rates pushes workers into the labour force, especially in regions with large labour force potential.[35]

In our application to the German context, optimal taxation implies harmonisation of regional tax rates across the economy ( Figure D.6 in Appendix) and a particularly strong tax decrease in the most populous and urbanised areas of Germany, since labour force participation rates are comparatively small in those locations ( Figures 1 and D.7) .

**Optimal Public Goods Provision.** The planner reallocates fiscal funds towards those locations which have the highest marginal benefit from public good consumption. Thus,

[35]Tax rates levied on non-employed workers may exceed unity, so the additive income subsidies must partly finance tax payments. The concavity of the planner's problem ensures that private goods consumption is positive for workers of all types and employment sectors.




(a) Workers in the labour force (b) Workers not in the labour force

Figure 3: NON-EMPLOYMENT RATES AND OPTIMAL INCOME TAX RATES

*Notes:* This Figure plots the optimal tax rates against non-employment rates, defined as the ratio of non-employed workers to the total labour force. Panel (a) plots the tax rates levied on the wage income of workers in the labour force, $\tilde{\mathcal{T}}^g_{u|i,u}$, whereas Panel (b) plots the tax rates levied on non-employed workers, $\tilde{\mathcal{T}}^g_{h|i,u}$. Optimal rates are determined according to equations (48) and (49). See appendix A.5.3 for details. Tax rates may exceed unity (Panel (b)) as long as lump-sum income subsidies ensure positive consumption possibilities.

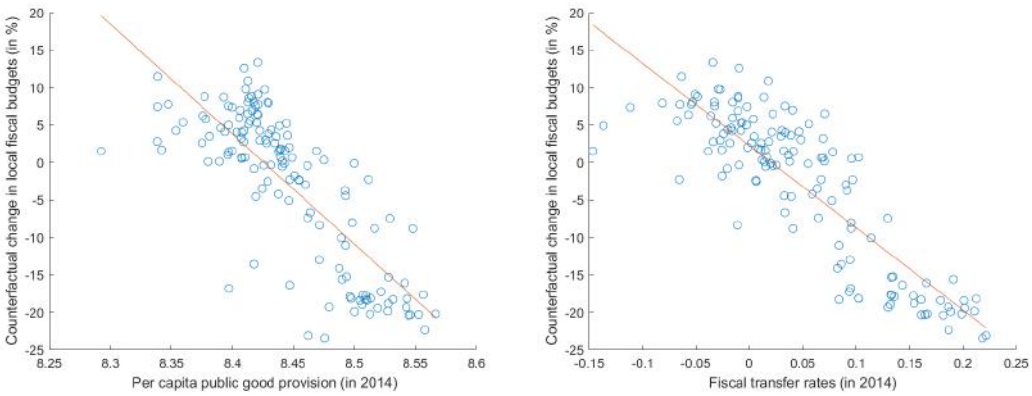
in the counterfactual equilibrium, we tend to observe redistribution of funds away from locations with high initial public good provision (Panel (a) of Figure 4). In the context of Germany, this entails increased redistribution into Western Germany and a (partial) reversal of the initial fiscal redistribution system (Panel (b) of Figure 4). [36]

The correlation between initial public expenditure and change in fiscal transfers is, however, not perfect, since fiscal transfers are furthermore used as a policy tool to internalise spatial externalities: all else equal, they are chosen as to incentivise workers to move to locations where they impose the largest spillovers on local productivity but little increase in public good congestion. [37] The effect of the local labour force participation rate on government transfers is theoretically ambiguous. On the one hand, high non-employment rates decrease the local marginal product of labour (Proposition 1) and the agglomeration economy benefit. On the other hand, market frictions are also lowered to a more significant extent when public expenditure is reallocated into these regions via "fiscal multipliers" (Equation (7)).

**Relation to the Samuelson Rule.** Final goods may be inputs into private and public goods consumption and materials in different market sectors. While the planner cannot

[36] We highlight the spatial distribution of optimal public expenditure in Panel (d) of Figure D.8 in the Online Appendix.

[37] Net agglomeration benefits are significantly smaller in the biggest metropolitan areas as long as local population acts as a net congestion force. This is also highlighted in Panel (b) of Figure D.8 of Online Appendix D.5. Furthermore, spatial inequalities in net agglomeration increase between the baseline and counterfactual equilibrium (Panel (c)).




(a) Initial public good provision

(b) Initial fiscal transfer rates

Figure 4: Optimal fiscal transfers

*Notes:* This Figure plots the percentage change in fiscal budgets between the initial endowment of locations and the optimal allocation against the per capita public good provision in 2014 (Panel (a)). Panel (b) plots the change in fiscal budgets against initial fiscal transfer rates. The planner's allocation of fiscal funds is determined according to the optimal fiscal policy rule (Equation (54) in Appendix A.5.3).

alter input-output linkages, she re-allocates final goods optimally between their uses as inputs into private and public goods consumption, taking workers' preferences for either type of good as given.

**Proposition 3.** *Assume there is only one group of workers and market sector (G=M=1) in the economy. Then the optimal public goods expenditure satisfies*

$$(1-\alpha)\sum_{i\in J}\Psi_i\tilde{E}_i + \alpha\left(\sum_{i\in J}\tilde{E}_i - c\right) = \alpha \times \textit{Value Added}, \tag{22}$$

*where*

$$\Psi_i \equiv \frac{\left(\epsilon - 1 + \xi_{h|i}\right)}{\left(\epsilon - 1 + \xi_{h|i}\left[1 - \epsilon\rho_{h,R}\right]\right)} \quad \textit{and} \quad c = \epsilon\rho_{h,r} \times \sum_{i\in J}\xi_{h|i}\Psi_i\left(w_{u|i}L_i\right)$$

Proposition 3 implies that if an economy is made up solely of homogeneous worker groups and market sectors, then the optimally-provided public expenditure is simply a fraction $\alpha$ of total value added in the economy under Cobb-Douglas utility and absent "fiscal multipliers" (e.g. $\rho_{h,R} \to 0$). Proposition 3, therefore, extends the Samuelson rule of public goods expenditure (Samuelson, 1954) to a framework with labour force participation responses to fiscal spending. For $\rho_{h,R} > 0$, non-employed workers profit to a lesser degree from local public goods provision, which decreases the marginal utility of local public goods expenditure (via the parameter $\Psi_i$) and induces a planner to provide less than ($\alpha \times$ value added) public goods in the aggregate. The constant $c$ accounts for switchers between labour market status when additional units of public goods are provided locally. As a result, we find that the fraction of value added provided as public goods is smaller than $\alpha$ in the counterfactual equilibrium.[38]

**Additive Income Subsidies.** The planner rebates income tax and land rent revenues to consumers, net of the optimally-set transfers to local governments used for public goods provision. The planner considers localised spatial externalities when optimally allocating workers across regions and sectors and uses additive income subsidies as a second policy instrument for worker reallocation. Regarding our application to Germany, Figure D.9 of Online Appendix D.5 shows that worker income for private good consumption is highly correlated with public good consumption (Panel (a)), yet correlates negatively with non-employment benefits (Panel (b)). The combination of increasing consumption possibilities and decreasing benefits in the home market create incentives to join the labour force especially for women in urbanised areas (where they are furthermore most productive), thereby forcing workers to internalise "fiscal externalities".

## 7 Counterfactual Analysis: Shocks to Fiscal Transfers

Our model extends the standard spatial economics framework by focusing on the role of extensive labour supply decisions as an additional adjustment channel. In this section, we highlight the role of fiscal policy in local labour supply decisions and the spatial distribution of economic activity in general equilibrium. We also show how the additional role of extensive labour supply decisions changes the quantitative predictions of implementing optimal fiscal policy.

**Implementation.** To characterise an economy in general equilibrium with optimally-determined policy instruments, we first invert the spatial model and solve for the economy's fundamental productivities, amenities and market frictions. We use the data-implied tax rates, local fiscal capacities and the German redistribution system for 2014.

We then feed the optimal policy instruments into this quantitative framework to solve iteratively for a new spatial equilibrium. Since prices, wages, the distribution of workers, and the size of the labour force change endogenously to this initial fiscal shock but simultaneously also affect the size of optimally-set policy instruments, we adjust them in each iteration according to the policy rules. A counterfactual equilibrium is found when all markets clear, the aggregate resource constraint (21) holds and taxes $\tilde{\mathcal{T}}^{g}_{s|i,u}$, income subsidies $\tilde{\mathcal{S}}_{s|i,u}$ and local fiscal transfers $\tilde{E}_i$ are set optimally to maximise the welfare function (19), subject to constraints on public and private goods consumption, production, local employment and population as well as goods markets.

**Local Effects.** Implementing the optimal fiscal policy results in substantial fiscal redistribution across space, particularly from rural and Eastern German regions to the biggest metropolitan regions of West Germany. The optimal fiscal policy thus (partly) reverses

[38]See Appendix A.5.3 for details and a proof of proposition 3.

the current fiscal redistribution scheme. As a result, we observe increased consumption possibilities by up to 15 % in parts of Western Germany (see Panel (a) of Figure 5), which triggers rural-urban migration, especially into Southern Germany (Panel (b) of Figure 5). This is not surprising since the planner attempts to redistribute into the regions with the largest marginal utility of consumption, which are most likely to be found in the biggest metropolitan areas, given the size of urban quality-of-life premia (Ahlfeldt et al., 2020).

In the counterfactual equilibrium, expected utility must be equalised across all region-sector pairs in the presence of worker mobility. In-migration raises prices of non-tradables such that we observe significant real wage decreases in population-receiving locations (Panel (c) of Figure 5).

While we do tend to observe increased labour force participation in locations with high initial consumption shocks, the correlation is not perfect: General equilibrium income effects also increase labour force participation in parts of Eastern Germany (especially in the capital, Berlin). Mobility, employment rate, wage, and price adjustments continue until the average utility of workers is equalised across regions and sectors in the new counterfactual equilibrium.

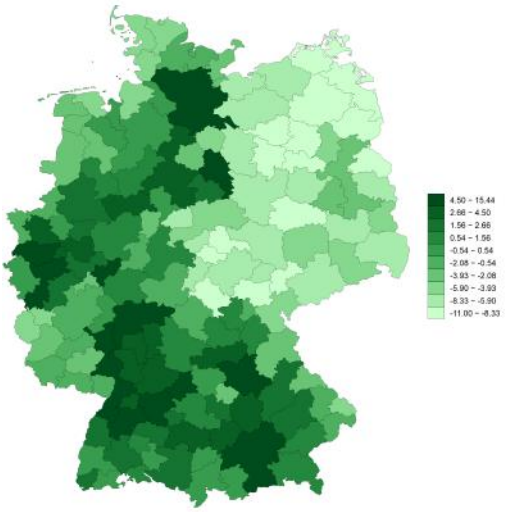
**Aggregate Effects of Optimal Policy Implementation.** In Table 2, we highlight the aggregate effects of setting taxes, subsidies and transfers according to optimal rules. We distinguish between *donor* and *recipient* regions whose consumption possibilities, $\left(I^g_{u|i,u}\right)^{1-\alpha}(E_i)^\alpha$, increased under the optimal policy by more than the median. We observe substantial in-migration into *recipient* regions, whose population increases by more than 1.6 million workers. As predicted by standard spatial economics theory, workers relocate into regions with higher real consumption possibilities, thereby congesting local labour markets and increasing (non-tradable) prices until they are indifferent between working and living in all labour markets.

The group-specific elasticity $\rho^g_{h,R}$ determines the "fiscal multipliers" size. As long as it is strictly positive, local spending and public good provision should increase labour participation rates. Similarly, workers join the labour force if the opportunity cost of not doing so has fallen, e.g., the income ratio in market sectors, relative to the home market sector, decreases (Eq. (7)). We observe a substantial increase in labour force participation of female workers due to smaller income tax rates and spatially varying non-employment benefits. Labour force participation rates increase by more in *recipient* regions.

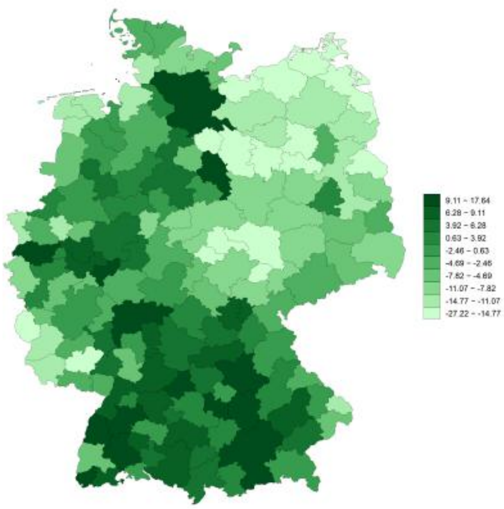
Average welfare increases by 1.27% in the counterfactual scenario (with heterogeneous effects across worker groups), while real GDP increases by a similar amount, particularly in *recipient regions*. These aggregate welfare effects arise mainly due to the increase in overall labour force participation and the relocation of workers into more productive parts of the economy. This allows for higher levels of redistribution into distressed locations as compensation.

Overall, optimally-set fiscal budgets only slightly decrease between the baseline and counterfactual scenario as the planner attempts to provide funds according to the extended

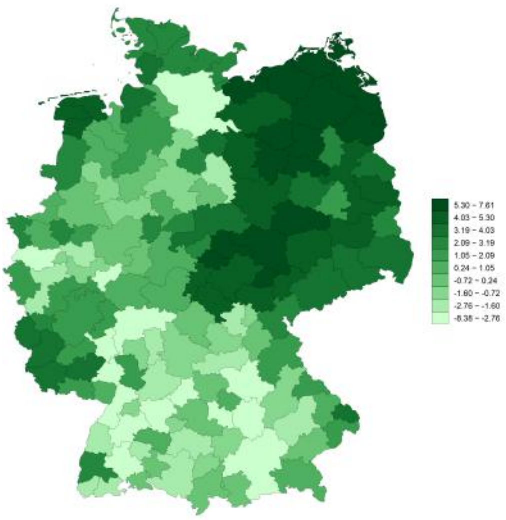
Figure 5: COUNTERFACTUAL ANALYSIS: REGIONAL EFFECTS



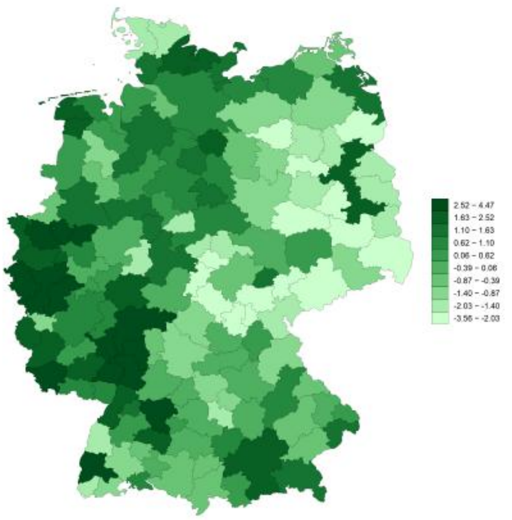

(a) Size of consumption shock




(b) Population change




(c) Real wage change




(d) Change in labour force particpation rates

*Notes:* Panel (a) displays changes in total consumption possibilities, defined as the difference of $\left(I^g_{u|i,u}\right)^{1-\alpha}(E_i)^\alpha$ between baseline scenario and when applying optimal instruments $\{\tilde{\mathcal{T}}^g_{u|i,u}, \tilde{\mathcal{S}}^g_{u|i,u}, \tilde{E}_i\}$ in the first iteration. The Panels (b) to (d) display percentage changes in total population, real wages, and labour force participation rates, respectively. Darker colours represent higher values.

Samuelson rule (see Proposition 3). Nonetheless, since average prices increase by almost two percent, we see slight decreases in per capita expenditure on public goods, which is more than compensated by increasing private good consumption possibilities.

Table 2: Optimal policy implementation: Aggregate effects

| | Overall | Recipient |
|---|---|---|
| Panel A: Population and Employment | | |
| Δ Population (Male) | 0 | 895,267 |
| Δ Population (Female) | 0 | 709,163 |
| Δ Labour force (Male) | -68,618 | 750,382 |
| Δ Labour force (Female) | 692,057 | 1,150,067 |
| Panel B: Wages | | |
| Δ Nominal wages ( Male; in €) | 597.50 | -384.76 |
| Δ Nominal wages (Female; in €) | -137.68 | -483.38 |
| Panel C: Aggregate measures | | |
| Δ Fiscal capacities (per capita; in %) | -1.10 | 2.65 |
| Δ GDP in real terms (in %) | 1.25 | 3.91 |
| Δ Welfare (in %) | 1.27 | 1.27 |

Notes: This table shows the absolute change in population and employment and percentage changes in aggregate measures, like welfare, GDP or fiscal capacities (per capita), for male and female workers under counterfactual changes in local taxes, subsidies and transfer rates that implement optimal policy instruments. Treated areas are locations where consumption possibilities increase between the baseline and counterfactual scenario. See equation (16) for a measure of localised welfare.

## 8 Conclusion

We investigate how a national planner can optimally redistribute resources across regions to account for the effects of public goods on workers' labour market participation and location choices. We estimate the impact of local public spending on workers' extensive labour supply decisions and derive an optimality rule that modifies the standard formula for a spatial framework with spillovers and sorting of heterogeneous workers. We find that optimal tax rates depend on both the intensity of migration response and the behavioural responses of workers who may exit the labour market, especially in regions with high market frictions. The planner allocates resources to regions where workers can enhance local productivity while avoiding public good congestion.

We apply our optimality rule to Germany's fiscal system. Inefficient labour force participation, spatial sorting, and sectoral selection decisions may entail significant welfare losses. Optimal policies require more funding for regions with high productivity but high non-employment and a more significant fraction of female workers. These results imply that public goods and redistribution can lower non-employment and enhance social welfare. However, they may also increase spatial or inter-group consumption inequalities.

Our study offers valuable insights into optimally redistributing resources and the influence of public goods provision on workers' decisions. Future research could use our optimality rule for other countries or regions, or investigate the precise impact of local public goods provision on labour force participation more closely. These steps could enhance our analysis and improve our understanding of the intricate link between public spending and labour market outcomes.

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# APPENDIX

This Appendix provides (1) theoretical derivations, (2) a description of the quantification of the model, (3) sensitivity checks and additional simulation results, and (4) additional empirical results supporting our findings from the main text.

Subsection A.1 and A.2 of the theoretical part of the Appendix present derivations for the main paper. Subsections A.3 and subsection A.4 summarises the spatial general equilibrium of the model. Subsection A.5 sets up the social planners problem and provides information on how to solve the planners problem.

Subsection B provides further information about the quantification of our model. Subsection B.1 supplies additional information on the sources of data used in the quantification of the model and estimation, whereas subsection B.2 highlights the steps necessary for model inversion. Section C reports the procedure for implementation of the optimal fiscal policies in general equilibrium and defines the counterfactual equilibrium.

We provide additional empirical results from estimation, inversion and counterfactual analysis in section D. Subsections D.1 - D.4 provide additional empirical results and figures related to the institutional structure of fiscal redistribution in Germany and the estimation of labour supply elasticities to public spending. Additional empirical results from counterfactual analysis can be found in subsections D.5 and **??**.

# A Theory Appendix

## A.1 Workers

**Average Local Utilities.** From the definition of the preference shifter, $\exp\left[\bar{B}^g_{h|i,u}\right]\varphi(\omega)$ the average home market preference level of workers who choose region $i \in J$ and market sector $u \in M$ in the first stage is given as

$$\frac{1}{L^g_{h|i,u}}\int_1^\infty L^g_{h|i,u}\exp\left[\bar{B}^g_{h|i,u}\right]\varphi\frac{\partial G^g(\varphi)}{\partial\varphi}d\varphi = \exp\left[\bar{B}^g_{h|i,u}\right]\int_1^\infty \varphi\frac{\partial G^g(\varphi)}{\partial\varphi}d\varphi$$
$$= \exp\left[\bar{B}^g_{h|i,u}\right]\bar{\varphi}^g,$$

where $G^g(\varphi)$ is the cumulative distribution function of workers' personal preference for non-employment and $L^g_{h|i,u} \leq L^g_{i,u}$ denotes the number of workers joining the home market sector $h$. Only those workers whose individual preference draw is above the cutoff $\tilde{\varphi}^g_{s|i,u}$, join the home market sector, such that the average home market preference level can be re-written as

$$\bar{B}^g_{s|i,u} = \frac{\exp\left[\bar{B}^g_{h|i,u}\right]}{1-G^g\left(\tilde{\varphi}^g_{s|i,u}\right)}\int_{\tilde{\varphi}^g_{s|i,u}}^\infty \varphi dG^g(\varphi),$$

with $L^g_{h|i,u}/L^g_{i,u} = 1-G^g\left(\tilde{\varphi}^g_{s|i,u}\right)$ the share of workers in the home market sector.

Assume now that the idiosyncratic component follows a Pareto distribution with the following group-specific cumulative distribution and density functions:

$$G^g(\varphi) = 1 - \varphi^{-\epsilon^g}$$

$$\frac{\partial G^g(\varphi)}{\partial \varphi} = \epsilon^g \varphi^{-\epsilon^g - 1}$$

Substituting these functional forms into the expression above yields:

$$\int_{\tilde{\varphi}^g_{s|i,u}}^{\infty} \varphi dG^g(\varphi) = \int_{\tilde{\varphi}^g_{s|i,u}}^{\infty} \varphi \left(\frac{\partial G^g(\varphi)}{\partial \varphi}\right) d\varphi = \epsilon^g \int_{\tilde{\varphi}^g_{s|i,u}}^{\infty} \varphi^{-\epsilon^g} d\varphi = \frac{\epsilon^g}{\epsilon^g - 1}\left(\tilde{\varphi}^g_{s|i,u}\right)^{1-\epsilon^g}.$$

The cutoff preference level is given by equation (6), such that we get:

$$\int_{\tilde{\varphi}^g_{s|i,u}}^{\infty} \varphi dG^g(\varphi) = \frac{\epsilon^g}{\epsilon^g - 1}\left(\left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right)\left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha}\left(\left[R_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}\right)^{1-\epsilon^g}.$$

Collecting terms, we arrive at

$$\begin{aligned}
\bar{B}^g_{s|i,u} &= L^g_{i,u}/L^g_{h|i,u} \exp\left[\bar{B}^g_{h|i,u}\right] \frac{\epsilon^g}{\epsilon^g - 1}\left(\left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right)\left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha}\left(\left[R_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}\right)^{1-\epsilon^g} \\
&= C^g\left(\mathcal{B}^g_{s|i,u}\right)^{\epsilon^g} \exp\left[-\mu^g_{u|i,u}\right]\left[\left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha}\left(\left[R_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}\right]^{(1-\epsilon^g)} \frac{1}{L^g_{h|i,u}/L^g_{i,u}},
\end{aligned}$$

where $C^g = \epsilon^g/(\epsilon^g - 1)$ is a group-specific constant.

Combining the average home market preference component with equations (2) we derive expected indirect utility in region $i$ and market sector $u$ as:

$$\begin{aligned}
\bar{V}^g_{i,u}(\omega) &= \Psi^g_{i,u}(\omega)\left(\left(1 - \xi^g_{h|i,u}\right)V^g_{u|i,u} + \xi^g_{h|i,u}V^g_{h|i,u}\right) \\
&= \Psi^g_{i,u}(\omega)\bar{A}^g_i \exp\left[-\mu^g_{u|i,u}\right]\left(\frac{I^g_{u|i,u}}{P_i}\right)^{1-\alpha}\left(\frac{R_{u|i,u}}{L^X_i}\right)^{\alpha}\left(1 + \xi^g_{h|i,u}\left[\frac{\epsilon^g}{\epsilon^g - 1} - 1\right]\right) \\
&= \Psi^g_{i,u}(\omega)V^g_{u|i,u}\left(1 + \xi^g_{h|i,u}\left[\frac{\epsilon^g}{\epsilon^g - 1} - 1\right]\right).
\end{aligned}$$

Equation (16) follows immediately.

### A.1.1 Distribution of Utilities in Market Sectors.

From (16) indirect utility from working in region $i$ and working in sector $s$ is given as:

$$\bar{V}^g_{i,u}(\omega) = \Psi^g_{i,u}(\omega)\bar{V}^g_{i,u} = \Psi^g_{i,u}(\omega)\bar{A}^g_i \exp\left[-\mu^g_{u|i,u}\right]\left(\frac{I^g_{u|i,u}}{P_i}\right)^{1-\alpha}\left(\frac{R_{u|i,u}}{L^X_i}\right)^{\alpha}\left(1 + \xi^g_{h|i,u}\left[\frac{\epsilon^g}{\epsilon^g - 1} - 1\right]\right)$$

There are $d = 1,..,D$ possible region-occupation pairs $\{i,s\}$ (with $D = JxM$) where workers can self-select and sort into. Workers choose the region-occupation pair $d$ that maximizes idiosyncratic utility.

We then define as $F^g(v_1,...,v_D)$ the cumulative distribution function of indirect utilities for workers of type $g$:

$$\begin{aligned} F^g(\mathbf{v_d}) &= \mathbb{P}\left(V_1^g(\omega) \le v_1,...,V_D^g(\omega) \le v_D\right) = \mathbb{P}\left(\Psi_1^g\left(\omega\right)\bar{V}_1^g \le v_1,...,\Psi_D^g\left(\omega\right)\bar{V}_D^g \le v_D\right) \\ &= \mathbb{P}\left(\Psi_1^g(\omega) \le \frac{v_1}{\bar{V}_1^g},...,\Psi_D^g(\omega) \le \frac{v_D}{\bar{V}_D^g}\right), \end{aligned}$$

Under the assumption of a Fréchet distribution for the idiosyncratic human capital draws, the joint distribution of utility is

$$F^g(\mathbf{v_d}) = \exp\Big\{-\Big[\sum_{u=1}^{M}\sum_{i=1}^{J}\Omega_{i,u}^g\left(v_{i,u}\right)^{-\theta^g}\Big]\Big\}, \tag{1}$$

where $\Omega_{i,u}^g = \left[\bar{V}_{i,u}^g\right]^{\theta^g}$ is a function of expected group-specific preference components and average wages, local public goods as well as regional price levels for region-occupation pair $\{i,u\}$.

### A.1.2 Expected Utility.

We are interested in the expected utility of individuals of a group $g$ if workers choose region-sector pairs $\{i,u\}$ to maximize utility. The expected utility is given as follows:

$$\begin{aligned} E^g\left[v_{i,u}\Big|_{k=v_{i,u},\forall i,u}\right] \equiv E^g[k] &= \int_0^\infty v_{i,u}\frac{\partial}{\partial v_{i,u}}\exp\Big\{-\Big[\sum_{u=1}^{M}\sum_{i=1}^{J}\Omega_{i,u}^g\left(v_{i,u}\right)^{-\theta^g}\Big]\Big\}\Big|_{k=v_{i,u},\forall i,s}dk \\ &= \int_0^\infty \theta^g k^{-\theta^g}\left[\sum_{u\in M}\sum_{i\in J}\Omega_{i,u}^g\right]\exp\Big\{-\Big[\sum_{u=1}^{M}\sum_{i=1}^{J}\Omega_{i,u}^g\Big]k^{-\theta^g}\Big\}dk. \end{aligned}$$

Re-defining variables

$$z^g = \Big[\sum_{u\in M}\sum_{i\in J}\Omega_{i,u}^g\Big]k^{-\theta^g} \quad \text{and} \quad dz^g = -\theta^g\Big[\sum_{u\in M}\sum_{i\in J}\Omega_{i,u}^g\Big]k^{-\theta^g-1}dk,$$

we get

$$\begin{aligned} E^g[k] &= \int_0^\infty \exp\Big\{-z^g\Big\}\left[\sum_{u\in M}\sum_{i\in J}\Omega_{i,u}^g\right]^{\frac{1}{\theta^g}}\left(z^g\right)^{-\frac{1}{\theta^g}}dz^g \\ &= \left[\sum_{u\in M}\sum_{i\in J}\Omega_{i,u}^g\right]^{\frac{1}{\theta^g}}\Gamma\left(\frac{\theta^g-1}{\theta^g}\right), \end{aligned}$$

where $\Gamma\left(.\right)$ denotes the Gamma function.

### A.1.3 Region-sector Shares.

We are interested in the probability that a choice of region-occupation pair $d$ is the maximum among all alternatives:

$$
\begin{aligned}
\frac{L_d^g}{L^g} &= Pr\{\bar{V}_d^g(\omega) \geq \max_{n \in D \backslash d} \bar{V}_n^g(\omega)\} \\
&= \int_0^\infty \exp\Big\{ - \Big[\sum_{u=1}^{M}\sum_{i=1}^{J} \Omega_{i,u}^g\Big] u^{-\theta^g}\Big\} \Omega_{i,u}^g \theta^g k^{-\theta^g - 1} dk \\
&= \frac{\Omega_{i,u}^g}{\sum_{u=1}^M \sum_{i=1}^J \Omega_{i,u}^g} \int_0^\infty \exp\Big\{ - \Big[\sum_{u=1}^{M}\sum_{i=1}^{J} \Omega_{i,u}^g\Big] k^{-\theta^g}\Big\} \Big[\sum_{u=1}^{M}\sum_{i=1}^{J} \Omega_{i,u}^g\Big] \theta^g k^{-\theta^g - 1} dk \\
&= \frac{\Omega_{i,u}^g}{\sum_{u=1}^M \sum_{i=1}^J \Omega_{i,u}^g}.
\end{aligned}
$$

Equation (18) follows directly.

## A.2 Production Side

**Derivation of Unit Costs.** We derive optimal unit costs under the imperfect substitutability of labour types. Intermediate good producers minimize costs, which yields the following first-order conditions for input demand:

$$
\begin{aligned}
\delta_{i,u} \kappa_{i,u} &= \frac{r_i h_{i,u}(z_{i,u})}{\lambda_{i,u}(z_{i,u})\, y_{i,u}(z_{i,u})} \\
\delta_{i,uu'} &= \frac{P_{i,u'} M_{i,uu'}(z_{i,u})}{\lambda_{i,u}(z_{i,u})\, y_{i,u}(z_{i,u})} \\
\delta_{i,u}(1-\kappa_{i,u}) \frac{\partial l_{i,u}(z_{i,u})}{\partial L_{u|i,u}^g(z_{i,u})} &= \frac{w_{u|i,u}^g l_{i,u}(z_{i,u})}{\lambda_{i,u}(z_{i,u})\, y_{i,u}(z_{i,u})},
\end{aligned}
$$

where

$$
\frac{\partial l_{i,u}(z_{i,u})}{\partial L_{u|i,u}^g(z_{i,u})} = \left(T_{i,u}^g\right)^{\frac{\sigma^g - 1}{\sigma^g}} \left(L_{u|i,u}^g(z_{i,u})\right)^{-\frac{1}{\sigma^g}} \left(l_{i,u}(z_{i,u})\right)^{\frac{1}{\sigma^g}},
$$

and $\lambda_{i,u}(z_{i,u})$ denotes the Lagrange multiplier of the cost minimization problem, which in this framework corresponds to the price of the input bundle as well. This allows deriving type-specific labour demand as:

$$
L_{u|i,u}^g(z_{i,u}) = \frac{l_{i,u}(z_{i,u})}{T_{i,u}^g} \left( \frac{\delta_{i,u}(1-\kappa_{i,u})\lambda_{i,u}(z_{i,u})\, y_{i,u}(z_{i,u})\, T_{i,u}^g}{w_{u|i,u}^g l_{i,u}(z_{i,u})} \right)^{\sigma^g}.
$$

Substituting into $l_{i,u}$ we obtain optimal labour demand as:

$$
l_{i,u}^\star = \delta_{i,u}(1-\kappa_{i,u})\lambda_{i,u}(z_{i,u})\, y_{i,u}(z_{i,u}) \left[ \sum_{g \in G} \left( \frac{T_{i,u}^g}{w_{u|i,u}^g} \right)^{\sigma^g - 1} \right]^{\frac{1}{\sigma^g - 1}}.
$$

The first-order conditions for workers of all types are then:

$$\delta_{i,u}\left(1-\kappa_{i,u}\right)\frac{\left(\frac{T^{g}_{i,u}}{w^{g}_{u|i,u}}\right)^{\sigma^{g}-1}}{\sum_{g\in G}\left(\frac{T^{g}_{i,u}}{w^{g}_{u|i,u}}\right)^{\sigma^{g}-1}}=\frac{w^{g}_{u|i,u}L^{g}_{u|i,u}\left(z_{i,u}\right)}{\lambda_{i,u}\left(z_{i,u}\right)y_{i,u}\left(z_{i,u}\right)}.$$

Plugging the optimal input factor demands into the production function, we derive the price of the input bundle of production of intermediate goods produced in region $i$ and market sector $u$ as

$$\lambda_{i,u}\left(z_{i,u}\right)=\frac{D_{i,u}}{z_{i,u}}\left(r_{i}^{\kappa_{i,u}}\left[\sum_{g\in G}\left(\frac{T^{g}_{i,u}}{w^{g}_{u|i,u}}\right)^{\sigma^{g}-1}\right]^{\frac{1-\kappa_{i,u}}{1-\sigma^{g}}}\right)^{\delta_{i,u}}\prod_{u'\in M}\left[P_{i,u'}\right]^{\delta_{i,uu'}},$$

with $D_{i,u}\equiv\left(\delta_{i,u}\left(\kappa_{i,u}\right)^{\kappa_{i,u}}\left(1-\kappa_{i,u}\right)^{\left(1-\kappa_{i,u}\right)}\right)^{-\delta_{i,u}}\prod_{u'\in M}\left(\delta_{i,uu'}\right)^{-\delta_{i,uu'}}$ a region-sector-specific constant.

**Derivation of the Ideal Cost Index.** In this section we derive the ideal cost index $P_{i,u}$. Let $Y_{i,u}$ denote final goods quantity in region-sector pair $\{i,u\}$ and as $\tilde{y}_{i,u}\left(\mathbf{z_u}\right)=\sum_{j\in J}\tilde{y}_{ij,u}\left(\mathbf{z_u}\right)$ the demand for intermediate goods produced in all regions $j\in J$. We here denote as $\mathbf{z_u}$ the vector of idiosyncratic firm productivities in sector $u$, $\left(z_{1,u},...z_{i,u},...z_{J,u}\right)$.

Intermediate goods of a given variety, produced in the different regions $j\in J$, are perfect substitutes, such that final goods producers purchase varieties only from those locations where unit costs, inclusive of trade costs, are smallest. Therefore, it holds that

$$\tilde{y}_{ij,u}\left(\mathbf{z_u}\right)=\begin{cases}\tilde{y}_{i,u}\left(\mathbf{z_s}\right) & \text{if}\quad \tau_{ij,u}\lambda_{j,u}\left(z_{j,u}\right)<\min_{n\neq j}\tau_{in,u}\lambda_{n,u}\left(z_{n,u}\right)\\ 0 & \text{else}\end{cases}\tag{2}$$

Final good producers bundle intermediate goods into a final consumption good such that

$$Y_{i,u}=\left(\int\left(\tilde{y}_{i,u}\left(\mathbf{z_u}\right)\right)^{\frac{\sigma-1}{\sigma}}d\phi_{u}\left(\mathbf{z_u}\right)\right)^{\frac{\sigma}{\sigma-1}},\tag{3}$$

where $\phi_{u}\left(\mathbf{z_u}\right)$ denotes the joint cumulative distribution function for the vector of efficiencies $\mathbf{z_u}$ with marginal functions $\phi_{i,u}\left(z_{i,u}\right)$ and where $\sigma$ denotes the elasticity of substitution between varieties. Since there are no barriers to entry in the production of intermediate and final goods, perfect competition implies zero profits at all times.

Using the CES assumption, the corresponding demand function for a variety produced in region $i$ and occupation $u$ is

$$\tilde{y}_{i,u}\left(\mathbf{z_u}\right)=\left(p_{i,u}\left(\mathbf{z_u}\right)\right)^{-\sigma}P_{i,u}^{\sigma-1}Y_{i,u},\tag{4}$$

where $p_{i,u}(\mathbf{z_u}) = \min_{n \neq j} \tau_{in,u}\lambda_{n,u}(z_{n,u})$ equals the unit cost paid by a final good producer, and

$$P_{i,u} \equiv \left[ \int (p_{i,u}(\mathbf{z_u}))^{1-\sigma} d\phi_u(\mathbf{z_u}) \right]^{\frac{1}{1-\sigma}}$$

is the ideal cost index for final goods.

Let $G_{ij,u}(p)$ be the probability that firms located in region $j$ can offer producers in region $i$ an intermediate variety for a price lower than $p$. Under the assumptions of perfect competition and a Fréchet distribution of productivities, it then holds that:

$$\begin{aligned} G_{ij,u}(p) &= Pr\{p_{ij,u}(z_{j,u}) \leq p\} \\ &= 1 - \phi_{ij,u}\left(\frac{\lambda_{j,u}\tau_{ij,u}}{p}\right) \\ &= 1 - \exp\left\{ -\left(\frac{\lambda_{j,u}\tau_{ij,u}}{p}\right)^{-\nu_u} \right\}. \end{aligned}$$

Producers in region $i$ buy intermediate varieties from least-cost origins. The probability that producers in region $i$ end up paying the price less than $p$ for the variety is

$$\begin{aligned} G_{i,u}(p) &= 1 - \prod_{n \in J} (1 - G_{in,u}(p)) \\ &= 1 - \exp\{-p^{\nu_u}\Phi_{i,u}\}, \end{aligned}$$

where $\Phi_{i,u} = \sum_{n \in J} (\lambda_{n,u}\tau_{in,u})^{-\nu_u}$ is a function of unit prices of production, local productivity and bilateral trade costs.
Substituting the distribution of prices into the ideal cost index yields:

$$P_{i,u}^{1-\sigma} = \nu_u \Phi_{i,u} \int p^{\nu_u - \sigma} \exp\{-p^{\nu_u}\Phi_{i,u}\} dp.$$

We re-define $x_{i,u} \equiv p^{\nu_u}\Phi_{i,u}$, so with a change of variable we get:

$$\begin{aligned} P_{i,u}^{1-\sigma} &= \int \left(\frac{x_{i,u}}{\Phi_{i,u}}\right)^{\frac{1-\sigma}{\nu_u}} \exp\{-x_{i,u}\} dx_{i,u} \\ &= \Gamma\left(\frac{\nu_u + 1 - \sigma}{\nu_u}\right) (\Phi_{i,u})^{-\frac{1-\sigma}{\nu_u}}. \end{aligned}$$

The ideal cost index is therefore derived as

$$P_{i,u} = \Gamma\left(\frac{\nu_u + 1 - \sigma}{\nu_u}\right)^{\frac{1}{1-\sigma}} \left[ \sum_{j \in J} (\lambda_{j,u}\tau_{ij,u})^{-\nu_u} \right]^{-\frac{1}{\nu_u}},$$

as in equation (12).

**Trade Shares.** Let $X_{i,u}$ denote the total expenditures on final goods in region $i$, which equals the value of final goods production. As long as final goods producers make zero profits, we therefore get $X_{js} = P_{i,u}Y_{i,u} = \int p_{i,u}(\mathbf{z_u})\,\tilde{y}_{i,u}(\mathbf{z_u})\,d\phi_u(\mathbf{z_u})$. Lastly, we derive the fraction of region-$i$'s expenditure on intermediates produced in region $j$.

Define as $\pi_{ij,u}$ the probability that region $j$ is the least-cost provider of a variety for use as an intermediate input in region $i$ and sector $u$:

$$\begin{aligned}\pi_{ij,u} &= Pr\left\{p_{ij,u}(z_{j,u}) \leq \min_{n\in J\setminus j} p_{in,u}(z_{n,u})\right\}\\ &= \int \prod_{n\in J\setminus j}(1 - G_{in,u}(p))\,dG_{ij,u}(p)\end{aligned}$$

Substituting in the distribution of prices across regions yields:

$$\begin{aligned}\pi_{ij,u} &= (\lambda_{j,u}\tau_{ij,u})^{-\nu_u}\int \nu_u p^{\nu_u-1}\exp\left\{-p^{\nu_u}\Phi_{i,u}\right\}dp\\ &= \frac{(\lambda_{j,u}\tau_{ij,u})^{-\nu_u}}{\Phi_{i,u}}\left[-\exp\left\{-p^{\nu_u}\Phi_{i,u}\right\}\right]_0^{\infty}\\ &= \frac{(\lambda_{j,u}\tau_{ij,u})^{-\nu_u}}{\Phi_{i,u}}.\end{aligned}$$

The expression implies that regions with lower unit costs will comprise a larger fraction of the number of varieties sold to region $i$. Note that the fraction of *varieties* sold to region $i$ from region $j$ need not generally equal the fraction of $i$'s expenditure spent on region $j$ varieties. Nonetheless, under the assumption that efficiencies follow a Fréchet distribution, it turns out that it does, due to the fact that the distribution of prices for region $i$ is *independent of the origin* (Eaton and Kortum (2002)).

As a result, the fraction of varieties that final good producers in region $i$ and sector $u$ purchase from region $j$ equals its fraction of expenditure on goods from region $j$. Therefore it holds that

$$\pi_{ij,u} = \frac{X_{ij,u}}{X_{i,u}} = \frac{(\lambda_{j,u}\tau_{ij,u})^{-\nu_u}}{\Phi_{i,u}},$$

where we denote as $X_{ij,u} \equiv \int \frac{\lambda_{i,u}}{z_{i,u}}\tau_{ij,u}\tilde{y}_{ij,u}(\mathbf{z_u})\,d\phi_u(\mathbf{z_u})$ the expenditure spent by final good producers in region $i$ and sector $u$ on intermediates produced in region $j$ and $X_{i,u}$ are total expenditures.

## A.3 Market Clearing

A spatial general equilibrium of the economy is defined such that

1. Workers optimally choose bundles of final goods from all markets according to (1), given region-sector-specific price indices and after-tax income;

2. Workers optimally self-select into sectors and locations, given after-tax income, public expenditure, local amenities and regional price levels according to (18);

3. Workers decide on their labour force participation after their initial workplace decision according to (7);

4. Intermediate good producers demand materials, labour as well as land and structures under unit costs (10). These productive inputs are used to produce idiosyncratic intermediate good varieties according to (8) and (9);

5. Final goods producers import intermediates from the least cost intermediate producers according to equation (13);

6. Optimal price indices are given by (12);

7. Final goods market clearing implies

$$\begin{aligned} X_{i,u} =& \beta_u^R \left[ (\mathcal{T}_i + \rho_i) \left( \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} w_{s|i,u'}^g L_{s|i,u'}^g \right) \right] \\ &+ \beta_u^C \left[ \frac{L_i}{L} \left( \sum_{j \in J} \sum_{u' \in M} \left( \mathcal{H}_{j,u'} r_j - \sum_{g \in G} w_{h|j,u'}^g \xi_{h|j,u'}^g L_{j,u'}^g \right) \right) \right. \\ &\left. + (1 - \mathcal{T}_i) \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} w_{s|i,u'}^g L_{s|i,u'}^g \right] + \sum_{u' \in M} \delta_{i,u'u} \sum_{j \in J} \pi_{ji,u'} X_{j,u'} \end{aligned}$$

where the first two terms in squared brackets denote final consumption demand in region $i$ by local governments and consumers, respectively, and where the third term denotes the demand for goods produced in market $u'$ and region $i$ as material inputs in all regions and market sectors $u \in M$;

8. Labour market-clearing implies

$$L_{u|i,u}^g = \frac{\delta_{i,u} (1 - \kappa_{i,u})}{w_{u|i,u}^g} \frac{\left( \frac{T_{i,u}^g}{w_{u|i,u}^g} \right)^{\sigma^g - 1}}{\sum_{g \in G} \left( \frac{T_{i,u}^g}{w_{u|i,u}^g} \right)^{\sigma^g - 1}} \sum_{j \in J} \pi_{ji,u} X_{j,u}, \tag{5}$$

where $\sum_{j \in J} \pi_{ji,u} X_{j,u}$ are revenues from each export market. Labour market clearing for all groups $g \in G$, regions $i \in J$ and market sectors $u \in M$ ensures that labour supply equals labour demand. Aggregate labour market clearing for workers of all groups implies that workers are either in one of the $M$ market sectors or the home-market sector, such that $L^g = \sum_{i \in J} \sum_{u \in M} \left( L_{h|i,u}^g + L_{u|i,u}^g \right)$;

9. Market clearing for land and structures implies

$$h_{i,u} = \frac{\delta_{i,u} \kappa_{i,u}}{r_i} \sum_{j \in J} \pi_{ji,u} X_{j,u}. \tag{6}$$

Land and structures market clearing for all regions $i \in J$ and market sectors $u \in M$ ensures that demand for land and structures (6) equals the exogenous supply of land and structures $\bar{\mathcal{H}}_i = \sum_{u \in M} \mathcal{H}_{i,u}$.

10. Demand for materials is given by

$$M_{i,uu'} = \frac{\delta_{i,uu'}}{P_{i,u'}} \sum_{j \in J} \pi_{ji,u} X_{j,u}. \tag{7}$$

11. The local governments' budget constraint reads

$$E_i = \left( \sum_{u \in M} \sum_{g \in G} \sum_{s \in h,u} (\mathcal{T}^g_{s|i,u} + \rho_i) w^g_{s|i,u} L^g_{s|i,u} \right) \tag{8}$$

## A.4 Definition of Equilibrium

Given model primitives, a general equilibrium of the economy is referenced by a vector of the endogenous objects $\mathbf{V} = \{I^g_{s|i,u}, P_i, L^g_{i,u}, L^g_{h|i,u}, w^g_{u|i,u}, h_{i,u}, r_i, M_{i,uu'}, P_{i,u}, \pi_{ij,u}, X_{i,u}, \lambda_{i,u}, E_i\}$ and a scalar $\mathcal{V}^g$ which are jointly determined by the following equations

$$I^g_{s|i,u} = \left(1 - \mathcal{T}^g_{s|i,u}\right) w^g_{s|i,u} + \mathcal{S}^g_{s|i,u} \qquad \text{(Worker Income: G x J x 2M)} \tag{9}$$

$$P_i = \prod_{u'=1}^{M} (P_{i,u'}/\beta^C_{u'})^{\beta^C_{u'}} \qquad \text{(Regional price level: J)} \tag{10}$$

$$L^g_{i,u} = \frac{\left(\bar{V}^g_{i,u}\right)^{\theta^g}}{\sum_{u \in M} \sum_{i \in J} \left(\bar{V}^g_{i,u}\right)^{\theta^g}} L^g \qquad \text{(Labour supply: G x J x M)} \tag{11}$$

$$L^g_{h|i,u} = \left[ \left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right) \left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha} \left( \left[R_{u|i,u}\right]^{\rho^g_{h,R}} \right)^{\alpha} \right]^{-\epsilon^g} L^g_{i,u} \qquad \text{(Home market: G x J x M)} \tag{12}$$

$$L^g_{u|i,u} = \frac{\delta_{i,u}\left(1 - \kappa_{i,u}\right)}{w^g_{u|i,u}} \frac{\left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g - 1}}{\sum_{g \in G} \left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g - 1}} \sum_{j \in J} \pi_{ji,u} X_{j,u}, \qquad \text{(Labour demand: G x J x M)} \tag{13}$$

$$\sum_{u \in M} h_{i,u} = \bar{\mathcal{H}}_i \qquad \text{(Supply of land and structures: J)} \tag{14}$$

$$h_{i,u} = \frac{\delta_{i,u}\kappa_{i,u}}{r_i} \sum_{j \in J} \pi_{ji,u} X_{j,u} \qquad \text{(Demand for land and structures: J x M)} \tag{15}$$

$$M_{i,uu'} = \frac{\delta_{i,uu'}}{P_{i,u'}} \sum_{j \in J} \pi_{ji,u} X_{j,u} \qquad \text{(Demand for materials: J x } M^2\text{)} \tag{16}$$

$$P_{i,u} = \Gamma\left(\gamma_u\right)^{\frac{1}{1-\sigma}} \left[\sum_{j \in J} \left(\lambda_{j,u}\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}} \qquad \text{(Sectoral prices: J x M)} \tag{17}$$

$$\pi_{ij,u} = \frac{X_{ij,u}}{X_{i,u}} = \frac{\left(\lambda_{j,u}\tau_{ij,u}\right)^{-\nu_u}}{\sum_{n \in J}\left(\lambda_{n,u}\tau_{in,u}\right)^{-\nu_u}} \qquad \text{(Trade shares: } J^2 \text{ x M)} \tag{18}$$

$$\begin{aligned} X_{i,u} =& \beta_u^R \left[ \left(\mathcal{T}_i + \rho_i\right) \left( \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} w^g_{s|i,u'} L^g_{s|i,u'} \right) \right] \\ &+ \beta_u^C \left[ \frac{L_i}{L} \left( \sum_{j \in J} \sum_{u' \in M} \left( \mathcal{H}_{j,u'} r_j - \sum_{g \in G} w^g_{h|j,u'} \xi^g_{h|j,u'} L^g_{j,u'} \right) \right) \right. \\ &\left. + \left(1 - \mathcal{T}_i\right) \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} w^g_{s|i,u'} L^g_{s|i,u'} \right] + \sum_{u' \in M} \delta_{i,u'u} \sum_{j \in J} \pi_{ji,u'} X_{j,u'}, \quad \text{(Goods market: J x M)} \end{aligned} \tag{19}$$

$$\sum_{j \in J} \pi_{ji,u} X_{j,u} = \lambda_{i,u} \left[ \left(h_{i,u}\right)^{\kappa_{i,u}} \left(l_{i,u}\right)^{1-\kappa_{i,u}} \right]^{\delta_{i,u}} \prod_{u' \in M} \left[M_{i,uu'}\right]^{\delta_{i,uu'}} \qquad \text{(Production: J x M)} \tag{20}$$

$$E_i = \left( \sum_{u \in M} \sum_{g \in G} \sum_{s \in h,u} \left(\mathcal{T}^g_{s|i,u} + \rho_i\right) w^g_{s|i,u} L^g_{s|i,u} \right) \qquad \text{(Fiscal budgets: J )} \tag{21}$$

Finally, observe that if we substitute the production input factor demands (equations (13), (15) and (16)) into the equation detailing aggregate production of intermediate goods (20) we obtain the expression for the unit cost index in general equilibrium:

$$\lambda_{i,u} = D_{i,u} \left( r_i^{\kappa_{i,u}} \left[ \sum_{g \in G} \left( \frac{T^g_{i,u}}{w^g_{u|i,u}} \right)^{\sigma^g - 1} \right]^{\frac{1-\kappa_{i,u}}{1-\sigma^g}} \right)^{\delta_{i,u}} \prod_{u' \in M} \left[P_{i,u'}\right]^{\delta_{i,uu'}}, \tag{22}$$

Lastly, since the system of equations is over-identified (by one equation in total), we normalise prices and treat them as the numéraire in the system:

$$\sum_i P_i \equiv \bar{P} = 1. \tag{23}$$

Equation (23) similarly pins down aggregate welfare in the economy.

## A.5 The Social's Planner Problem

In this subsection of the Appendix, we set up the planner's problem and provide information on how to solve it. Further, we characterise the planner's solution.

### A.5.1 Setting up the Planner's Problem

In this subsection, we describe the planner's problem. We assume that the planner takes as given that workers can freely choose in which region-sector pair $\{i, u\}$ to live when being in the labour force while deciding on their extensive labour supply afterwards. Under this assumption, the expected utility of workers of group $g$ is given by equation (17).

Given the expected utility of workers, we can write the social welfare function as follows:

$$\begin{aligned} \mathcal{W} = \sum_{g\in G} \mu^g U \Bigg[ \Bigg( \sum_{u\in M} \sum_{i\in J} \Bigg[ \bar{A}_i^g \exp\left[-\mu^g_{u|i,u}\right] \left(C^g_{u|i,u}\right)^{1-\alpha} \left( \frac{R^g_{u|i,u}}{\left(\sum_{g\in G}\sum_{u\in M} L^g_{i,u}\right)^{\chi}} \right)^{\alpha} \\ \left( 1 + \frac{\left[ \left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right) \left(C^g_{u|i,u}/C^g_{h|i,u}\right)^{1-\alpha} \left( \left[R^g_{u|i,u}\right]^{\rho^g_{h,R}} \right)^{\alpha} \right]^{-\epsilon^g}}{\epsilon^g - 1} \right) \Bigg]^{\theta^g} \Bigg)^{\frac{1}{\theta^g}} \Gamma\left(\frac{\theta^g - 1}{\theta^g}\right) L^g \Bigg] \end{aligned} \tag{24}$$

where the $\mu^g$ are the welfare weights for each worker group, and $U(.)$ is an increasing and concave function of workers' utility.

In maximizing the social welfare function, the social planner faces several constraints regarding public and private good consumption, production, local employment and population and goods markets, which are detailed below.
Firstly, the planner cannot choose negative values of consumption or production, such that non-negativity constraints are given as follows:

$$C^g_{s,u'|i,u}, R^g_{u,u'|i,u}, Y_{i,u'} \geq 0 \tag{25}$$

Next, when choosing consumption levels of final goods in different sectors, the planner takes into account the Cobb-Douglas utility of workers, such that

$$\prod_{u'=1}^{M} (C^g_{s,u'|i,u})^{\beta^C_{u'}} = C^g_{s|i,u} \tag{26}$$

and

$$\prod_{u'=1}^{M} \left(R^g_{s,u'|i,u}\right)^{\beta^R_{u'}} = R^g_{s|i,u}. \tag{27}$$

Final goods can used for private and public goods consumption or as materials in intermediate goods production. The resource constraints for final and intermediate goods are given as follows:[39]

$$Y_{i,u'} = \sum_{s\in h,u}\sum_{u\in M}\sum_{g\in G} C^g_{s,u'|i,u} L^g_{i,u} \xi^g_{s|i,u} + \sum_{u\in M}\sum_{g\in G}\left(\frac{L^g_{i,u}}{L_i}\right) R^g_{u,u'|i,u} + \sum_{u\in M}\int M_{i,uu'}\left(\mathbf{z}_{\mathbf{u}'}\right) d\phi\left(\mathbf{z}_{\mathbf{u}'}\right) \tag{28}$$

where we let $Y_{i,u'} \equiv \left(\int \left(\sum_{j\in J} \tilde{y}_{ij,u'}\left(\mathbf{z}_{\mathbf{u}'}\right)\right)^{\frac{\sigma-1}{\sigma}} d\phi\left(\mathbf{z}_{\mathbf{u}'}\right)\right)^{\frac{\sigma}{\sigma-1}}$ denote the quantity produced of final goods in region-sector pair $\{i,u\}$ and the intermediate goods constraint reads

$$\left[\left(h_{i,u'}\left(z_{i,u'}\right)\right)^{\kappa_{i,u'}}\left(\left[\sum_{g\in G}\left(T^g_{i,u'} L^g_{u'|i,u'}\left(z_{i,u'}\right)\right)^{\frac{\sigma^g-1}{\sigma^g}}\right]^{\frac{\sigma^g}{\sigma^g-1}}\right)^{1-\kappa_{i,u'}}\right]^{\delta_{j,u'}} \prod_{u\in M}\left[M_{i,u'u}\left(z_{i,u'}\right)\right]^{\delta_{i,u'u}}$$
$$= \sum_{j\in J} \tau_{ji,u'} \tilde{y}_{ji,u'}\left(\mathbf{z}_{\mathbf{u}'}\right) \tag{29}$$

In intermediate goods production, the social planner is constrained by the local supply of labour and land and structures such that

$$\bar{\mathcal{H}}_i = \sum_{u\in M}\int h_{i,u}\left(z_{i,u}\right) d\phi\left(z_{i,u}\right) \tag{30}$$

$$L^g_{u|i,u} = \int L_{u|i,u}\left(z_{i,u}\right) d\phi\left(z_{i,u}\right) \tag{31}$$

Local labour supply is attracted by regional real wages, public good provision and amenities, such that:

$$\frac{\left(\bar{V}^g_{i,u}\right)^{\theta^g}}{\sum_{u\in M}\sum_{i\in J}\left(\bar{V}^g_{i,u}\right)^{\theta^g}} L^g = L^g_{i,u}. \tag{32}$$

Lastly, the size of the local labour size is determined by exogenous market frictions and

[39] While, in principle, heterogeneous groups of workers could profit differently from the provision of public goods, we still impose that $R^g_{u,u'|i,u}$ is the same for all workers in all market sectors and worker groups, consistent with the framework introduced in the main part of the paper. In particular, it holds that $R^g_{u|i,u} = R_i \quad \forall u \in M, g \in G$ and similarly for the public good input from all sectors $u' \in M$. In the following we will then use $R_i$ and $R^g_{u|i,u}$ interchangeably.

Even though workers in the home market sector profit less from local public goods, e.g. $\left(R_{h|i,u}\right)^{1-\rho^g_{h,R}}$, the resource constraint still imposes that final goods must be employed in region-sector pair $\{i,u\}$ up to an aggregate level of $R^g_{u|i,u} = R_i$.

private as well as public consumption:

$$\left(1-\left[\left(\frac{1}{\mathcal{B}^g_{s|i,u}}\right)\left(C^g_{u|i,u}/C^g_{h|i,u}\right)^{1-\alpha}\left(\left[R^g_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}\right]^{-\epsilon^g}\right)L^g_{i,u}=L^g_{u|i,u}. \tag{33}$$

### A.5.2 Solving the Planner's Problem

This subsection characterises the planner's solution and the corresponding optimality conditions. To maximise the social welfare function subject to the constraints mentioned earlier, the social planner chooses the distribution of workers across locations and sectors ($L^g_{i,u}$), the size of the local labour force ($L^g_{u|i,u}$), and the consumption of public and private goods in all sectors $\{C^g_{u|i,u}, C^g_{h|i,u}, C^g_{s,u'|i,u}, R^g_{u|i,u}, R^g_{s,u'|i,u}\}$. On the production side, the social planner chooses optimal quantities of labour $L_{u|i,u}(z_{i,u})$, land and structures $h_{i,u}(z_{i,u})$ and materials $M_{i,uu'}(z_{i,u})$ as inputs into intermediate goods production. Lastly, the social planner chooses the optimal intermediate goods production in all region-sector pairs, $\tilde{y}_{ij,u}(z_{i,u})$.

The first-order conditions associated with the consumption of private goods in all sectors are given as follows:

$$(I) \qquad \frac{\partial \mathcal{W}}{\partial C^g_{s,u'|i,u}}: \quad L^g_{s|i,u}P_{i,u'}=\beta^C_{u'}\frac{C^g_{s|i,u}}{C^g_{s,u'|i,u}}P^g_{s|i,u}, \tag{34}$$

where $P_{i,u'}$ is the Lagrange multiplier corresponding to the final goods resource constraint and $P^g_{s|i,u}$ is the multiplier on the private consumption aggregation. Using equation (34) in the consumption index, the first optimality condition implies an ideal price index given by

$$P_i \equiv \frac{P^g_{s|i,u}}{L^g_{s|i,u}}=\prod_{u'=1}^{M}\left(P_{i,u'}/\beta^C_{u'}\right)^{\beta^C_{u'}}. \tag{35}$$

Similarly, we also derive the first-order conditions for public goods consumption across sectors:

$$(II) \qquad \frac{\partial \mathcal{W}}{\partial R^g_{s,u'|i,u}}: \quad P_{i,u'}\frac{L^g_{i,u}}{L_i}=\beta^R_{u'}\frac{R^g_{s|i,u}}{R^g_{s,u'|i,u}}\tilde{P}_{s|i,u}, \tag{36}$$

where $\tilde{P}_{s|i,u}$ is the Lagrange multiplier for the public good consumption aggregation, and we get an ideal price index for public goods:

$$P^R_i \equiv \tilde{P}_{s|i,u}\left(\frac{L_i}{L^g_{i,u}}\right)=\prod_{u'=1}^{M}\left(P_{i,u'}/\beta^R_{u'}\right)^{\beta^R_{u'}}. \tag{37}$$

Next, we consider the optimality conditions concerning private good levels:

$$(III) \quad \frac{\partial \mathcal{W}}{\partial C^g_{u|i,u}} : \quad \underbrace{\frac{(1-\alpha)\,\mu^g U'(\mathcal{V}^g)\,\mathcal{V}^g}{C^g_{u|i,u}}\left[\frac{\epsilon^g-1}{\epsilon^g-1+\xi^g_{h|i,u}}\right]}_{\text{marginal utility of consumption (p.c.)}}$$

$$= P_i - \underbrace{\sum_{j\in J}\sum_{u'\in M} W^g_{j,u'}\Psi^g_{j,u'}\Big/\left(1-\xi^g_{h|i,u}\right)}_{\text{sorting across region-sectors}} - \underbrace{\frac{\tilde{W}^g_{u|i,u}\left[(1-\alpha)\,\epsilon^g\right]\xi^g_{h|i,u}}{\left(1-\xi^g_{h|i,u}\right)C^g_{u|i,u}}}_{\text{selection along extensive margin}}, \tag{38}$$

where $W^g_{j,u}$ and $\tilde{W}^g_{u|i,u}$ are the Lagrange multipliers on the regional and extensive labour supply constraints, respectively, and the $\Psi^g_{j,u'}$ are given as:

$$\Psi^g_{j,u'} = \begin{cases} -\left(\frac{L^g_{j,u'}}{L^g}\right)\left(\frac{(1-\alpha)\theta^g}{C^g_{u|i,u}}\right)\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}(1-\epsilon^g)}{\epsilon^g-1+\xi^g_{h|i,u}}\right] & \text{if } \{i,u\}\neq\{j,u'\} \\ \left(1-\frac{L^g_{i,u}}{L^g}\right)\left(\frac{(1-\alpha)\theta^g}{C^g_{u|i,u}}\right)\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}(1-\epsilon^g)}{\epsilon^g-1+\xi^g_{h|i,u}}\right] & \text{if } \{i,u\}=\{j,u'\}. \end{cases}$$

The social planner equates the scaled marginal utility to the optimal regional price index after controlling for regional and sectoral sorting and selection along the extensive margin induced by rising local consumption possibilities. Specifically, these possibilities induce workers to switch places of employment and join the local labour force.

Similarly, we get the first-order conditions for the consumption possibilities of non-employed workers:

$$(IV) \quad \frac{\partial \mathcal{W}}{\partial C^g_{h|i,u}} : \quad \underbrace{\frac{(1-\alpha)\,\mu^g U'(\mathcal{V}^g)\,\mathcal{V}^g}{C^g_{h|i,u}}\left[\frac{\epsilon^g}{\epsilon^g-1+\xi^g_{h|i,u}}\right]}_{\text{Marginal utility of consumption (p.c.)}}$$

$$= P_i - \underbrace{\sum_{j\in J}\sum_{u'\in M} W^g_{j,u'}\Psi^g_{j,u',h}/\xi^g_{h|i,u}}_{\text{Sorting across region-sectors}} + \underbrace{\frac{\tilde{W}^g_{u|i,u}\left[(1-\alpha)\,\epsilon^g\right]\xi^g_{h|i,u}}{\xi^g_{h|i,u}C^g_{h|i,u}}}_{\text{Selection along extensive margin}}, \tag{39}$$

where we denote as $\Psi^g_{j,u',h}$ the following components:

$$\Psi^g_{j,u',h} = \begin{cases} -\left(\frac{L^g_{j,u'}}{L^g}\right)\left(\frac{(1-\alpha)\theta^g}{C^g_{h|i,u}}\right)\left[\frac{\epsilon^g\xi^g_{h|i,u}}{\epsilon^g-1+\xi^g_{h|i,u}}\right] & \text{if } \{i,u\}\neq\{j,u'\} \\ \left(1-\frac{L^g_{i,u}}{L^g}\right)\left(\frac{(1-\alpha)\theta^g}{C^g_{h|i,u}}\right)\left[\frac{\epsilon^g\xi^g_{h|i,u}}{\epsilon^g-1+\xi^g_{h|i,u}}\right] & \text{if } \{i,u\}=\{j,u'\}. \end{cases}$$

Similarly, the social planner maximises welfare over public good provision:

$$
\begin{aligned}
(IV) \quad \frac{\partial \mathcal{W}}{\partial R^g_{u|i,u}} : \quad & \underbrace{\alpha \mu^g U'(\mathcal{V}^g)\, \mathcal{V}^g / R^g_{u|i,u} \left[ \frac{\epsilon^g - 1 + \xi^g_{h|i,u}\left[1 - \epsilon^g \rho^g_{h,R}\right]}{\epsilon^g - 1 + \xi^g_{h|i,u}} \right]}_{\text{Marginal utility of consumption}} \\
& = \frac{P^R_i}{L_i} - \underbrace{\sum_{j \in J} \sum_{u' \in M} W^g_{j,u} \Psi^{g,R}_{j,u'}}_{\text{Sorting across region-sectors}} - \underbrace{\tilde{W}^g_{u|i,u} \left[\alpha \epsilon^g \rho^g_{h,R}\right] \xi^g_{h|i,u} / R^g_{u|i,u}}_{\text{Selection along extensive margin}},
\end{aligned} \tag{40}
$$

and the $\Psi^{g,R}_{j,u'}$ are given as:

$$
\Psi^{g,R}_{j,u'} = \begin{cases} -\left(\frac{L^g_{j,u'}}{L^g}\right)\left(\frac{\alpha\theta^g}{R^g_{u|i,u}}\right)\left[\frac{\epsilon^g - 1 + \xi^g_{h|i,u}\left[1-\epsilon^g \rho^g_{h,R}\right]}{\epsilon^g - 1 + \xi^g_{h|i,u}}\right] & \text{if } \{i,u\} \neq \{j,u'\} \\ \left(1 - \frac{L^g_{i,u}}{L^g}\right)\left(\frac{\alpha\theta^g}{R^g_{u|i,u}}\right)\left[\frac{\epsilon^g - 1 + \xi^g_{h|i,u}\left[1-\epsilon^g \rho^g_{h,R}\right]}{\epsilon^g - 1 + \xi^g_{h|i,u}}\right] & \text{if } \{i,u\} = \{j,u'\}. \end{cases}
$$

On the production side, the social planner optimally chooses the number of productive inputs into intermediate goods production and distributes production across regions and sectors:

$$
\begin{aligned}
(V) \quad \frac{\partial \mathcal{W}}{\partial L^g_{u|i,u}(z_{i,u})} : \quad & \tilde{\lambda}_{i,u}(z_{i,u})\, \delta_{i,u} (1 - \kappa_{i,u}) \frac{\left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g - 1}}{\sum_{g \in G} \left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g - 1}} \frac{\sum_{j \in J} \tau_{ji,u} \tilde{y}_{ji,u}(z_{i,u})}{L^g_{u|i,u}(z_{i,u})} \\
& = w^g_{u|i,u} d\phi(z_{i,u})
\end{aligned} \tag{41}
$$

where $\tilde{\lambda}_{i,u}(z_{i,u})$ and $w^g_{u|i,u}$ are the Lagrange multipliers on the intermediate goods constraint and resource constraint for local labour respectively. Also,

$$
(VI) \quad \frac{\partial \mathcal{W}}{\partial h_{i,u}(z_{i,u})} : \quad \tilde{\lambda}_{i,u}(z_{i,u})\, \delta_{i,u} \kappa_{i,u} \frac{\sum_{j \in J} \pi_{ji,u} \tilde{y}_{ji,u}(z_{i,u})}{h_{i,u}(z_{i,u})} = r_i d\phi(z_{i,u}), \tag{42}
$$

where we denote as $r_i$ the Lagrange multiplier on the resource constraint for land and structures. Similarly, the materials input is derived as follows:

$$
(VII) \quad \frac{\partial \mathcal{W}}{\partial M_{i,uu'}(z_{i,u})} : \quad \tilde{\lambda}_{i,u}(z_{i,u})\, \delta_{i,uu'} \frac{\sum_{j \in J} \pi_{ji,u} \tilde{y}_{ji,u}(z_{i,u})}{M_{i,uu'}(z_{i,u})} = P_{i,u'} d\phi(z_{i,u}). \tag{43}
$$

Using the first-order conditions (41) - (43) in the intermediate goods resource constraint, we derive the optimal region-sector-specific unit cost index:

$$\tilde{\lambda}_{i,u}\left(z_{i,u}\right) \equiv \frac{\lambda_{i,u} d\phi(z_{i,u})}{z_{i,u}} = \frac{D_{i,u}}{z_{i,u}} \left( r_i^{\kappa_{i,u}} \left[ \sum_{g\in G} \left( \frac{T_{i,u}^g}{w_{u|i,u}^g} \right)^{\sigma^g - 1} \right]^{\frac{1-\kappa_{i,u}}{1-\sigma^g}} \right)^{\delta_{i,u}} \prod_{u'\in M} \left[P_{i,u'}\right]^{\delta_{i,uu'}} d\phi(z_{i,u}), \tag{44}$$

with $D_{i,u} \equiv \left(\delta_{i,u}\left(\kappa_{i,u}\right)^{\kappa_{i,u}}\left(1-\kappa_{i,u}\right)^{(1-\kappa_{i,u})}\right)^{-\delta_{i,u}} \prod_{u'\in M}\left(\delta_{i,uu'}\right)^{-\delta_{i,uu'}}$ a region-sector-specific constant. The social planner similarly optimises with respect to intermediate goods production and consumption in region-sector pair $\{i,u\}$ :

$$(VIII) \quad \frac{\partial \mathcal{W}}{\partial \tilde{y}_{ji,u'}\left(\mathbf{z_{u'}}\right)} : \begin{cases} \tilde{y}_{ji,u'}\left(\mathbf{z_{u'}}\right) > 0 \text{ if } \tilde{\lambda}_{j,u}\left(z_{j,u}\right)\tau_{ij,u} = P_{i,u}\left(Y_{i,u}\right)^{\frac{1}{\sigma}}\left(\sum_{j\in J}\tilde{y}_{ij,u'}\left(\mathbf{z_u}\right)\right)^{-\frac{1}{\sigma}} d\phi\left(z_{j,u}\right) \\ \tilde{y}_{ji,u'}\left(\mathbf{z_{u'}}\right) = 0 \text{ if } \tilde{\lambda}_{j,u}\left(z_{j,u}\right)\tau_{ij,u} > P_{i,u}\left(Y_{i,u}\right)^{\frac{1}{\sigma}}\left(\sum_{j\in J}\tilde{y}_{ij,u'}\left(\mathbf{z_u}\right)\right)^{-\frac{1}{\sigma}} d\phi\left(z_{j,u}\right) \end{cases}$$

This first-order condition can be re-written as $\tilde{y}_{i,u}\left(\mathbf{z_u}\right) = \left(\frac{p_{i,u}(\mathbf{z_u})}{P_{i,u}}\right)^{-\sigma} Y_{i,u}$, using the fact that prices equal unit costs under perfect competition and with $\tilde{\lambda}_{i,u}\left(z_{i,u}\right) \equiv p_{i,u}(z_{i,u})d\phi(z_{i,u})$. Given the derivations and discussions in section A.2, it is then easily seen that this first-order condition leads to the same trade shares and price levels as in the competitive equilibrium. On the production side, the planner would then choose the same allocation as in the competitive equilibrium.

The social planner also chooses the optimal allocation of workers across regions and sectors:

$$\begin{aligned} (IX) \quad \frac{\partial \mathcal{W}}{\partial L_{i,u}^g} : \quad & \underbrace{W_{i,u}^g}_{\text{opportunity cost}} + \underbrace{\sum_{u'\in M} P_{i,u'}\left[\xi_{h|i,u}^g C_{h,u'|i,u}^g + \left(1-\xi_{h|i,u}^g\right) C_{u,u'|i,u}^g\right]}_{\text{consumption cost (private)}} \\ & = \underbrace{-\alpha\chi\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g \frac{L_{i,u}^g}{\sum_{g\in G}\sum_{u\in M} L_{i,u}^g}}_{\text{marginal public goods (spillovers)}} + \underbrace{\left(1-\xi_{h|i,u}^g\right)\tilde{W}_{u|i,u}^g}_{\text{marginal product of labour (private)}} \\ & + \underbrace{\tilde{w}_i}_{\text{spillover on local firm productivity}}, \end{aligned} \tag{45}$$

where the total productivity spillovers ("agglomeration economies") are given as

$$\tilde{w}_i \equiv \sum_{u\in M}\sum_{g\in G}\int \zeta^g \delta_{i,u}\left(1-\kappa_{i,u}\right) \frac{\left(\frac{T_{i,u}^g}{w_{u|i,u}^g}\right)^{\sigma^g-1}}{\sum_{g\in G}\left(\frac{T_{i,u}^g}{w_{u|i,u}^g}\right)^{\sigma^g-1}} \frac{\sum_{j\in J}\tau_{ji,u}\tilde{y}_{ji,u}\left(z_{i,u}\right)}{\sum_{u\in M}\sum_{g\in G} L_{i,u}^g} p_{i,u}(z_{i,u}) d\phi\left(z_{i,u}\right) \tag{46}$$

Finally, the social planner optimally allocates workers across the extensive margin,

$L^g_{u|i,u}$. The corresponding first-order condition states:

$$(X) \qquad \frac{\partial \mathcal{W}}{\partial L^g_{u|i,u}} : \; w^g_{u|i,u} = \tilde{W}^g_{u|i,u}. \tag{47}$$

### A.5.3 Characterisation of the Planner's Solution

In this Online Appendix, we show how to derive the optimal taxes and transfers that implement the socially optimal levels of private and public good consumption in several steps:

1. Solve for the optimal private goods consumption of employed and non-employed workers in all regions, sectors and groups, combining equations (38), (39), (47) and the planner's first-order condition on local population (45)
2. Derive optimal consumption levels as a function of two policy instruments: region-sector-group-specific tax rates on local labour income as well as additive wage subsidies
3. Show that both policy instruments can be implemented using solely information on observable variables at the regional level, structural parameters and the optimal level of local public good provision
4. Derive the optimal level of public good consumption, using equations (40), (47), the planner's first-order condition on local population (45) as well as the solutions for private good consumption from step 2
5. Solve for local public good levels solely as a function of economic variables at the local level (wages, rents, population, labour force participation rates) as well as structural parameters of the model
6. Determine private good consumption expenditures $P_i C^g_{s|i,u}$ using the previously solved levels of public good expenditure

**Steps 1 & 2: Optimal Private Good Consumption.** We first derive the optimal private good consumption levels of workers from the planner's problem. By using the first-order condition on the local labour force, we can re-write the first-order conditions on local consumption, equation (38), as follows:

$$\begin{aligned}&(1-\alpha)\left[\frac{\epsilon^g - 1 + \xi^g_{h|i,u}\left[1-\epsilon^g\right]}{\epsilon^g - 1 + \xi^g_{h|i,u}}\right]\left(\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g + \theta^g W^g_{i,u} - \theta^g \sum_{j\in J}\sum_{u'\in M} W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)\right)\\ &= \left(1-\xi^g_{h|i,u}\right) P_i C^g_{u|i,u} - w^g_{u|i,u}\left[(1-\alpha)\,\epsilon^g\right]\xi^g_{h|i,u}.\end{aligned}$$

Substituting in the first-order conditions on local population yields

$$\left(1-\xi^g_{h|i,u}\right) P_i C^g_{u|i,u} \left[\frac{\epsilon^g - 1 + \xi^g_{h|i,u}}{\epsilon^g - 1 + \xi^g_{h|i,u}\left[1-\epsilon^g\right]} + (1-\alpha)\,\theta^g\right] = -\,(1-\alpha)\,\theta^g P_i \xi^g_{h|i,u} C^g_{h|i,u}$$
$$+\,(1-\alpha)\left(\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g - \theta^g \sum_{j\in J}\sum_{u'\in M} W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)\right)$$
$$+\,w^g_{u|i,u}\,(1-\alpha)\left[\theta^g - \xi^g_{h|i,u}\left(\theta^g - \frac{\epsilon^g\left(\epsilon^g - 1 + \xi^g_{h|i,u}\right)}{\epsilon^g - 1 + \xi^g_{h|i,u}\left[1-\epsilon^g\right]}\right)\right]$$
$$-\,(1-\alpha)\,\theta^g\left[\alpha\chi\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g L^g_{i,u}\left(\sum_{g\in G}\sum_{u\in M} L^g_{i,u}\right)^{-1} - \tilde{w}^g_{i,u}\right]$$

Note that the private goods consumption still depends on the consumption level of non-employed workers at this point. We, therefore, also derive the consumption levels of non-employed workers:

$$(1-\alpha)\left[\frac{\epsilon^g \xi^g_{h|i,u}}{\epsilon^g - 1 + \xi^g_{h|i,u}}\right]\left(\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g + \theta^g W^g_{i,u} - \theta^g \sum_{j\in J}\sum_{u'\in M} W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)\right)$$
$$= \xi^g_{h|i,u} P_i C^g_{h|i,u} + w^g_{u|i,u}\left[(1-\alpha)\,\epsilon^g\right]\xi^g_{h|i,u}.$$

Once again substituting in the first-order conditions on local population yields

$$\xi^g_{h|i,u} P_i C^g_{h|i,u} = \left[\frac{\epsilon^g - 1 + \xi^g_{h|i,u}}{\epsilon^g \xi^g_{h|i,u}} + (1-\alpha)\,\theta^g\right]^{-1}\left[-\,(1-\alpha)\,\theta^g P_i\left(1-\xi^g_{h|i,u}\right) C^g_{u|i,u}\right.$$
$$+\,(1-\alpha)\left(\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g - \theta^g \sum_{j\in J}\sum_{u'\in M} W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)\right)$$
$$+\,w^g_{u|i,u}\,(1-\alpha)\left[\theta^g - \xi^g_{h|i,u}\left(\theta^g + \frac{\epsilon^g - 1 + \xi^g_{h|i,u}}{\xi^g_{h|i,u}}\right)\right]$$
$$\left.-\,(1-\alpha)\,\theta^g\left[\alpha\chi\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g L^g_{i,u}\left(\sum_{g\in G}\sum_{u\in M} L^g_{i,u}\right)^{-1} - \tilde{w}_i\right]\right]$$

Combining these last three equations and after a bit of algebra, we derive the optimal consumption levels of employed workers, as a function of the market wage, and two policy instruments $\tilde{\mathcal{T}}^g_{u|i,u}$ and $\tilde{\mathcal{S}}^g_{u|i,u}$:

$$P_i C^g_{u|i,u} = \left(1-\tilde{\mathcal{T}}^g_{u|i,u}\right) w^g_{u|i,u} + \tilde{\mathcal{S}}^g_{u|i,u} \tag{48}$$

where we define

$$1-\tilde{\mathcal{T}}^{g}_{u|i,u}=\frac{\epsilon^{g}(1-\alpha)}{1-\xi^{g}_{h|i,u}}+\frac{(1-\alpha)\left(\epsilon^{g}-1\right)\epsilon^{g}\theta^{g}}{(1+(1-\alpha)\theta)\left(\epsilon^{g}-1+\xi^{g}_{h|i,u}\right)}-\frac{(1-\alpha)\left(\epsilon^{g}+\theta^{g}\left(\epsilon^{g}-1\right)+(1-\alpha)\theta^{g}\epsilon^{g}\right)}{(1-\alpha)\theta^{g}+1}$$

$$\tilde{\mathcal{S}}^{g}_{u|i,u}=\frac{\left(\epsilon^{g}-1\right)\left[(1-\alpha)\left(\mu^{g}U'\left(\mathcal{V}^{g}\right)\mathcal{V}^{g}\left(1-\theta^{g}\alpha\chi\frac{L^{g}_{i,u}}{L_{i}}\right)-\theta^{g}\sum_{j\in J}\sum_{u'\in M}W^{g}_{j,u'}\left(\frac{L^{g}_{j,u'}}{L^{g}}\right)+\theta^{g}\tilde{w}_{i}\right)\right]}{\left(\epsilon^{g}-1+\xi^{g}_{h|i,u}\right)\left(1+(1-\alpha)\theta^{g}\right)}$$

Similarly, we also derive the consumption possibilities of non-employed workers

$$P_{i}C^{g}_{h|i,u}=\left(1-\tilde{\mathcal{T}}^{g}_{h|i,u}\right)w^{g}_{u|i,u}+\tilde{\mathcal{S}}^{g}_{h|i,u} \tag{49}$$

where we define

$$1-\tilde{\mathcal{T}}^{g}_{h|i,u}=\epsilon^{g}\left(\frac{\epsilon^{g}}{\epsilon^{g}-1+\xi^{g}_{h|i,u}}-(1+(1-\alpha))-\frac{\left(1-\xi^{g}_{h|i,u}\right)}{\left(\epsilon^{g}-1+\xi^{g}_{h|i,u}\right)\left(1+(1-\alpha)\theta^{g}\right)}\right)$$

$$\tilde{\mathcal{S}}^{g}_{h|i,u}=\frac{\epsilon^{g}\left[(1-\alpha)\left(\mu^{g}U'\left(\mathcal{V}^{g}\right)\mathcal{V}^{g}\left(1-\theta^{g}\alpha\chi\frac{L^{g}_{i,u}}{L_{i}}\right)-\theta^{g}\sum_{j\in J}\sum_{u'\in M}W^{g}_{j,u'}\left(\frac{L^{g}_{j,u'}}{L^{g}}\right)+\theta^{g}\tilde{w}_{i}\right)\right]}{\left(\epsilon^{g}-1+\xi^{g}_{h|i,u}\right)\left(1+(1-\alpha)\theta^{g}\right)}$$

Relative to the competitive equilibrium the social planner will distribute consumption levels differently across groups, regions and sectors in order to achieve the optimal distribution of workers across space and the optimal local labour force participation. Note further that optimal taxes are solely a function of structural parameters and observable non-employment rates. On the other hand, the additive wage subsidies take care of local externalities (agglomeration economies and public good congestion).

**Step 3: Optimal Private Goods Consumption Levels as a Function of Observables.** To show how the additive wage subsidies can be implemented as a policy instrument, we again use the first-order condition on local population to re-write additive wage subsidies as follows:

$$\tilde{\mathcal{S}}_{u|i,u}^{g}=\frac{\left(\epsilon^{g}-1\right)\left(1-\alpha\right)\mu^{g}U'\left(\mathcal{V}^{g}\right)\mathcal{V}^{g}\left(1-\alpha\chi\theta^{g}\left(\frac{L_{i,u}^{g}}{L_{i}}-\frac{1}{L^{g}}\sum_{j\in J}\sum_{u'\in M}\left(\frac{L_{j,u'}^{g}}{L_{j}}\right)L_{j,u'}^{g}\right)\right)}{\left(\epsilon^{g}-1+\xi_{h|i,u}^{g}\right)\left(1+\left(1-\alpha\right)\theta^{g}\right)}$$
$$+\frac{\frac{(\epsilon^{g}-1)(1-\alpha)\theta^{g}}{L^{g}}\sum_{j\in J}\sum_{u'\in M}L_{j,u'}^{g}\left[P_{j}\sum_{s\in h,u'}\xi_{s|j,u'}^{g}C_{s|j,u'}^{g}-\left(1-\xi_{h|j,u'}^{g}\right)w_{u'|j,u'}^{g}-\tilde{w}_{j,u'}^{g}\right]}{\left(\epsilon^{g}-1+\xi_{h|i,u}^{g}\right)\left(1+\left(1-\alpha\right)\theta^{g}\right)}$$
$$+\frac{\left(\epsilon^{g}-1\right)\left(1-\alpha\right)\theta^{g}\tilde{w}_{i}}{\left(\epsilon^{g}-1+\xi_{h|j,u'}^{g}\right)\left(1+\left(1-\alpha\right)\theta^{g}\right)}$$

The weighted average of aggregate private good consumption is given as:

$$\sum_{i\in J}\sum_{u\in M}P_{i}L_{i,u}^{g}\sum_{s\in h,u}\xi_{s|i,u}^{g}C_{s|i,u}^{g}=\sum_{i\in J}\sum_{u\in M}\left[L_{i,u}^{g}w_{u|i,u}^{g}\sum_{s\in h,u}\xi_{s|i,u}^{g}\left(1-\tilde{\mathcal{T}}_{s|i,u}^{g}\right)+L_{i,u}^{g}\sum_{s\in h,u}\xi_{s|i,u}^{g}\tilde{\mathcal{S}}_{s|i,u}^{g}\right]$$

Using the expressions for weighted additive wage subsidies and taxes yields

$$\left(1-\alpha\right)\mu^{g}U'\left(\mathcal{V}^{g}\right)\mathcal{V}^{g}=\frac{1}{L_{g}}\sum_{i\in J}\sum_{u\in M}L_{i,u}^{g}\left[P_{i}\sum_{s\in h,u}\xi_{s|i,u}^{g}C_{s|i,u}^{g}\right]$$

Substituting the expression for marginal utilities $\left(1-\alpha\right)\mu^{g}U'\left(\mathcal{V}^{g}\right)\mathcal{V}^{g}$ back into the additive wage subsidies yields

$$\tilde{\mathcal{S}}_{u|i,u}^{g}=\frac{\epsilon^{g}-1}{L^{g}\left(\epsilon^{g}-1+\xi_{h|i,u}^{g}\right)\left(1+\left(1-\alpha\right)\theta^{g}\right)}\left(\left(\tilde{\mathcal{L}}_{i,u}^{g}+\left(1-\alpha\right)\theta^{g}\right)\left(\sum_{j\in J}\sum_{u'\in M}L_{j,u'}^{g}P_{j}\sum_{s\in h,u}\xi_{s|j,u'}^{g}C_{s|j,u'}^{g}\right)\right.$$
$$\left.-\left(1-\alpha\right)\theta^{g}\sum_{j\in J}\sum_{u'\in M}L_{j,u'}^{g}w_{u|i,u}^{g}\left(1-\xi_{h|i,u}^{g}\right)+\left(1-\alpha\right)\theta^{g}\left(L^{g}\tilde{w}_{i}-\sum_{j\in J}\sum_{u'\in M}L_{j,u'}^{g}\tilde{w}_{j,u'}^{g}\right)\right)$$

where

$$\tilde{\mathcal{L}}_{i,u}^{g}=1-\alpha\chi\theta^{g}\left(\left(\frac{L_{i,u}^{g}}{L_{i}}\right)-\frac{1}{L^{g}}\sum_{j\in J}\sum_{u'\in M}L_{j,u'}\left(\frac{L_{j,u'}^{g}}{L_{j}}\right)\right)$$

Finally note that total consumption expenditures (on private and public goods) in the economy have to equal total incomes from working and land rents, such that

$$\sum_{g\in G}\sum_{j\in J}\sum_{u'\in M}L_{j,u'}^{g}P_{j}\sum_{s\in h,u}\xi_{s|j,u'}^{g}C_{s|j,u'}^{g}+\sum_{j\in J}P_{j}^{R}R_{j}$$
$$=\sum_{g\in G}\sum_{j\in J}\sum_{u'\in M}L_{j,u'}^{g}\left(1-\xi_{h|j,u'}^{g}\right)w_{u|j,u'}^{g}+\sum_{j\in J}\sum_{u'\in M}h_{j,u'}r_{j} \tag{50}$$

Substituting back in, it follows that the additive wage subsidies can be characterised only by observable variables at the regional level (e.g. wages, rents, local population, employment rates as well as structural parameters) and the (to be determined) levels of optimal public good provision :

$$\begin{aligned}
&\tilde{\mathcal{S}}_{u|i,u}\sum_{g\in G}\frac{L^g\left(\epsilon^g-1+\xi^g_{h|i,u}\right)\left(1+(1-\alpha)\,\theta^g\right)}{\left(\epsilon^g-1\right)\left(\tilde{\mathcal{L}}^g_{i,u}+(1-\alpha)\,\theta^g\right)}=\\
&\sum_{g\in G}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}\left(1-\xi^g_{h|j,u'}\right)w^g_{u|j,u'}+\sum_{j\in J}\sum_{u'\in M}\mathcal{H}_{j,u'}r_j-\sum_{j\in J}P^R_jR_j\\
&-\sum_{g\in G}\frac{(1-\alpha)\,\theta^g}{\tilde{\mathcal{L}}^g_{i,u}+(1-\alpha)\,\theta^g}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}w^g_{u'|i,u'}\left(1-\xi^g_{h|i,u}\right)\\
&+\sum_{g\in G}\frac{(1-\alpha)\,\theta^gL^g}{\tilde{\mathcal{L}}^g_{i,u}+(1-\alpha)\,\theta^g}\left(\tilde{w}_i-\frac{1}{L^g}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}\tilde{w}^g_{j,u'}\right)
\end{aligned}\tag{51}$$

as well as

$$\begin{aligned}
&\tilde{\mathcal{S}}_{h|i,u}\sum_{g\in G}\frac{L^g\left(\epsilon^g-1+\xi^g_{h|i,u}\right)\left(1+(1-\alpha)\,\theta^g\right)}{\epsilon^g\left(\tilde{\mathcal{L}}^g_{i,u}+(1-\alpha)\,\theta^g\right)}=\\
&\sum_{g\in G}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}\left(1-\xi^g_{h|j,u'}\right)w^g_{u|j,u'}+\sum_{j\in J}\sum_{u'\in M}\mathcal{H}_{j,u'}r_j-\sum_{j\in J}P^R_jR_j\\
&-\sum_{g\in G}\frac{(1-\alpha)\,\theta^g}{\tilde{\mathcal{L}}^g_{i,u}+(1-\alpha)\,\theta^g}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}w^g_{u'|i,u'}\left(1-\xi^g_{h|i,u}\right)\\
&+\sum_{g\in G}\frac{(1-\alpha)\,\theta^gL^g}{\tilde{\mathcal{L}}^g_{i,u}+(1-\alpha)\,\theta^g}\left(\tilde{w}_i-\frac{1}{L^g}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}\tilde{w}^g_{j,u'}\right)
\end{aligned}\tag{52}$$

where we assume that additive wage subsidies do not differ by worker group as in the framework in the main part of the paper, such that $\tilde{\mathcal{S}}^g_{s|i,u}=\tilde{\mathcal{S}}_{s|i,u}\quad\forall g\in G$.

In comparison to the competitive equilibrium, the social planner implements additive wage subsidies $\tilde{\mathcal{S}}^g_{s|i,u}$ to address externalities related to production and public good congestion. Intuitively, the social planner will allocate higher wage subsidies for regions with high potential for agglomeration economies but minor initial public good congestion (relative to other regions). However, these subsidies will be lower in regions with high non-employment regions, as attracting workers to these areas decreases the aggregate labour force.

**Step 4: Optimal Public Good Provision.** In this section, we derive the optimal regional public good provision, given the optimal consumption possibilities for all worker groups and the optimal tax system.

First, we re-write the first-order conditions on local public good consumption (equation

(40)) as follows:

$$\alpha\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]}{\epsilon^g-1+\xi^g_{h|i,u}}\right]\left(\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g+\theta^g W^g_{i,u}-\theta^g\sum_{j\in J}\sum_{u'\in M}W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)\right)$$
$$=P^R_i\tilde{R}_i/L_i-\alpha\epsilon^g\rho^g_{h,R}\xi^g_{h|i,u}w^g_{u|i,u}.$$

Substituting in the first-order conditions on local population $L^g_{i,u}$ as well as the optimal consumption levels yields

$$\frac{P^R_i\tilde{R}_i}{L_i}=\alpha\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]}{\epsilon^g-1+\xi^g_{h|i,u}}\right]$$
$$\Bigg(-\left[\xi^g_{h|i,u}\left(\left(1-\tilde{\mathcal{T}}^g_{h|i,u}\right)w^g_{u|i,u}+\tilde{\mathcal{S}}^g_{h|i,u}\right)+\left(1-\xi^g_{h|i,u}\right)\left(\left(1-\tilde{\mathcal{T}}^g_{u|i,u}\right)w^g_{u|i,u}+\tilde{\mathcal{S}}^g_{u|i,u}\right)\right]\theta^g$$
$$+\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g-\theta^g\sum_{j\in J}\sum_{u'\in M}W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)$$
$$+\left(\left(1-\xi^g_{h|i,u}\right)\theta^g+\epsilon^g\rho^g_{h,R}\xi^g_{h|i,u}\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}}{\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]}\right]\right)w^g_{u|i,u}$$
$$-\theta^g\left[\alpha\chi\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g L^g_{i,u}\left(\sum_{g\in G}\sum_{u\in M}L^g_{i,u}\right)^{-1}-\tilde{w}_i\right]\Bigg)$$

with $P_iC^g_{h|i,u}$ and $P_iC^g_{u|i,u}$ as defined above. Substituting in their expressions from above yields

$$\frac{P^R_i\tilde{R}_i}{L_i}=\alpha\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]}{\epsilon^g-1+\xi^g_{h|i,u}}\right]$$
$$\Bigg(\frac{\mu^g U'\left(\mathcal{V}^g\right)\mathcal{V}^g\left(1-\theta^g\alpha\chi\frac{L^g_{i,u}}{L_i}\right)-\theta^g\sum_{j\in J}\sum_{u'\in M}W^g_{j,u'}\left(\frac{L^g_{j,u'}}{L^g}\right)+\theta^g\tilde{w}_i}{1+(1-\alpha)\theta^g}$$
$$-\theta^g\left(\frac{(1-\alpha)\theta^g\left(1-\xi^g_{h|i,u}\right)}{1+(1-\alpha)\theta^g}\right)w^g_{u|i,u}$$
$$+\left(\theta^g\left(1-\xi^g_{h|i,u}\right)+\epsilon^g\rho^g_{h,R}\xi^g_{h|i,u}\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}}{\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]}\right]\right)w^g_{u|i,u}\Bigg)$$

We then use, once again, the first-order condition on local population to finally get

$$\frac{P_i^R \tilde{R}_i}{L_i} = \alpha \left[ \frac{\epsilon^g - 1 + \xi^g_{h|i,u} \left[ 1 - \epsilon^g \rho^g_{h,R} \right]}{\epsilon^g - 1 + \xi^g_{h|i,u}} \right]$$

$$\left( \frac{\mu^g U' \left( \mathcal{V}^g \right) \mathcal{V}^g \left( 1 - \alpha \chi \theta^g \left( \frac{L^g_{i,u}}{L_i} - \frac{1}{L^g} \sum_{j \in J} \sum_{u' \in M} L_{j,u'} \left( \frac{L^g_{j,u'}}{L_j} \right) \right) \right)}{1 + (1-\alpha)\theta^g} \right.$$

$$+ \frac{\frac{\theta^g}{L^g} \sum_{j \in J} \sum_{u' \in M} L^g_{j,u'} \left[ P_j \sum_{s \in h,u'} \xi^g_{s|j,u'} C^g_{s|j,u'} - \left( 1 - \xi^g_{h|j,u'} \right) w^g_{u'|j,u'} - \tilde{w}^g_{j,u'} \right]}{(1 + (1-\alpha)\theta^g)} + \frac{\theta^g \tilde{w}_i}{(1 + (1-\alpha)\theta^g)}$$

$$- \theta^g \left( \frac{(1-\alpha)\theta^g \left( 1 - \xi^g_{h|i,u} \right)}{1 + (1-\alpha)\theta^g} \right) w^g_{u|i,u}$$

$$\left. + \left( \theta^g \left( 1 - \xi^g_{h|i,u} \right) + \epsilon^g \rho^g_{h,R} \xi^g_{h|i,u} \left[ \frac{\epsilon^g - 1 + \xi^g_{h|i,u}}{\epsilon^g - 1 + \xi^g_{h|i,u} \left[ 1 - \epsilon^g \rho^g_{h,R} \right]} \right] \right) w^g_{u|i,u} \right)$$

**Step 5: Public Good Provision as a Function of Observables.** At this point, we again make use of the fact that

$$\mu^g U' \left( \mathcal{V}^g \right) \mathcal{V}^g = \frac{1}{(1-\alpha) L^g} \sum_{i \in J} \sum_{u \in M} L^g_{i,u} \left[ P_i \sum_{s \in h,u} \xi^g_{s|i,u} C^g_{s|i,u} \right] \tag{53}$$

Plugging in, we can the re-write the last equation as follows

$$\frac{P_i^R \tilde{R}_i}{L_i} = \alpha \left[ \frac{\epsilon^g - 1 + \xi^g_{h|i,u} \left[ 1 - \epsilon^g \rho^g_{h,R} \right]}{\epsilon^g - 1 + \xi^g_{h|i,u}} \right]$$

$$\left( \frac{1}{L^g (1-\alpha)(1 + (1-\alpha)\theta^g)} \left[ \left( \tilde{\mathcal{L}}^g_{i,u} + (1-\alpha)\theta^g \right) \sum_{j \in J} \sum_{u' \in M} L^g_{j,u'} P_j \sum_{s \in h,u} \xi^g_{s|j,u'} C^g_{s|j,u'} \right. \right.$$

$$- (1-\alpha)\theta^g \sum_{j \in J} \sum_{u' \in M} L^g_{j,u'} w^g_{u'|j,u'} \left( 1 - \xi^g_{h|i,u} \right)$$

$$\left. + (1-\alpha)\theta^g \left( L^g \tilde{w}_i - \sum_{j \in J} \sum_{u' \in M} L^g_{j,u'} \tilde{w}^g_{j,u'} - (1-\alpha)\theta^g \left( 1 - \xi^g_{h|i,u} \right) L^g w^g_{u|i,u} \right) \right]$$

$$\left. + \left( \theta^g \left( 1 - \xi^g_{h|i,u} \right) + \epsilon^g \rho^g_{h,R} \xi^g_{h|i,u} \left[ \frac{\epsilon^g - 1 + \xi^g_{h|i,u}}{\epsilon^g - 1 + \xi^g_{h|i,u} \left[ 1 - \epsilon^g \rho^g_{h,R} \right]} \right] \right) w^g_{u|i,u} \right)$$

Putting everything together, we get a solution for the optimal levels of local public good provision $\tilde{R}_i$ that solely depends on observable variables at the region-gender-sector level (e.g. employment, wages, rents, labour force participation rates, price levels) as well as structural parameters:

$$
\begin{aligned}
&\frac{P_i^R\tilde{R}_i}{L_i}\sum_{u\in M}\sum_{g\in G}\frac{\left(\epsilon^g-1+\xi^g_{h|i,u}\right)\left(1+\left(1-\alpha\right)\theta^g\right)L^g}{\left(\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]\right)\left(\tilde{\mathcal{L}}^g_{i,u}+\left(1-\alpha\right)\theta^g\right)}=\frac{\alpha}{1-\alpha}\\
&\left(M\times\left(\sum_{j\in J}\sum_{u'\in M}\sum_{g\in G}L^g_{j,u'}\left(1-\xi^g_{h|j,u'}\right)w^g_{u'|j,u'}+\sum_{j\in J}\sum_{u'\in M}\mathcal{H}_{j,u'}r_j-\sum_{j\in J}P_j^RR_j\right)\right.\\
&-\sum_{u\in M}\sum_{g\in G}\frac{\left(1-\alpha\right)\theta^g}{\tilde{\mathcal{L}}^g_{i,u}+\left(1-\alpha\right)\theta^g}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}\left(1-\xi^g_{h|j,u'}\right)w^g_{u'|j,u'}\\
&+\sum_{u\in M}\sum_{g\in G}\frac{\left(1-\alpha\right)\theta^gL^g\tilde{w}_i}{\tilde{\mathcal{L}}^g_{i,u}+\left(1-\alpha\right)\theta^g}-\sum_{u\in M}\sum_{g\in G}\frac{\left(1-\alpha\right)\theta^g}{\tilde{\mathcal{L}}^g_{i,u}+\left(1-\alpha\right)\theta^g}\sum_{j\in J}\sum_{u'\in M}L^g_{j,u'}\tilde{w}^g_{j,u'}\\
&-\sum_{u\in M}\sum_{g\in G}\frac{\left(\left(1-\alpha\right)\theta^g\right)^2\left(1-\xi^g_{h|i,u}\right)L^gw^g_{u|i,u}}{\tilde{\mathcal{L}}^g_{i,u}+\left(1-\alpha\right)\theta^g}\\
&+\sum_{u\in M}\sum_{g\in G}\frac{L^g\left(1-\alpha\right)\left(1+\left(1-\alpha\right)\theta^g\right)}{\tilde{\mathcal{L}}^g_{i,u}+\left(1-\alpha\right)\theta^g}\\
&\left.*\left(\theta^g\left(1-\xi^g_{h|i,u}\right)+\epsilon^g\rho^g_{h,R}\xi^g_{h|i,u}\left[\frac{\epsilon^g-1+\xi^g_{h|i,u}}{\epsilon^g-1+\xi^g_{h|i,u}\left[1-\epsilon^g\rho^g_{h,R}\right]}\right]\right)w^g_{u|i,u}\right)
\end{aligned}
\tag{54}
$$

where

$$
\tilde{\mathcal{L}}^g_{i,u}=1-\alpha\chi\theta^g\left(\frac{L^g_{i,u}}{L_i}-\frac{1}{L^g}\sum_{j\in J}\sum_{u'\in M}L_{j,u'}\left(\frac{L^g_{j,u'}}{L_j}\right)\right)
$$

and we used the fact that aggregate expenditures on private and public goods consumption equals total labour and rent income in the economy.

Finally, we show how the agglomeration benefits $\tilde{w}_i$ in each region-sector pair are determined. Note first that the integration of equation (41) yields

$$
\delta_{i,u}\left(1-\kappa_{i,u}\right)\frac{\left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g-1}}{\sum_{g\in G}\left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g-1}}\int p_{i,u}(z_{i,u})\sum_{j\in J}\tau_{ji,u}\tilde{y}_{ji,u}\left(z_{i,u}\right)d\phi(z_{i,u})=w^g_{u|i,u}L^g_{u|i,u}
$$

with $\tilde{\lambda}_{i,u}\left(z_{i,u}\right)=p_{i,u}(z_{i,u})d\phi(z_{i,u})$, since prices equal unit costs under perfect competition.

Combining with the definition of $\tilde{w}_i$ in equation (46) yields aggregate agglomeration benefits as a function of wages, employment as well as the agglomeration elasticities:

$$
\tilde{w}_i=\sum_{u\in M}\sum_{g\in G}\zeta^g\left(1-\xi^g_{h|i,u}\right)w^g_{u|i,u}\left(\frac{L^g_{i,u}}{L_i}\right)
\tag{55}
$$

**Step 6: Optimal Private Goods Consumption.** Given the optimal amount of local public goods $P_i^R\tilde{R}_i$ and our results from steps 1-3, it is straightforward to also solve for the optimal wage subsidies $\tilde{\mathcal{S}}^{g}_{s|i,u}$ and thus the optimal private goods consumption levels of all workers, solely as a function of observable variables at the local level and structural parameters.

# B Quantifying the Model

In this subsection of the Appendix, we discuss the data used for the quantification of the model as discussed in Section 5 of the main paper. We provide further information on how we recover the amenities, preferences, and productivity levels from our general equilibrium model.

## B.1 Data

For the model quantification, we require data on employment, non-employment, wages, tax revenues and fiscal transfers, bilateral trade flows, and value-added for each region-sector pair. Additionally, we use data on region-specific land rents and aggregate price levels to derive prices and unit costs of non-tradable sectors. We focus on 141 commuting zones as the empirical equivalent to the regions of the model framework (Kosfeld and Werner, 2012) and use the Standard Classification of all Economic Activities (ISIC, Rev. 4) to construct six sectors. Table B.1 summarizes how we aggregate the ISIC 4 Sectors into our six "market sectors". Sectors 1-4 are tradable, whereas sectors 5 and 6 consist of non-tradable goods. We consider two non-tradable sectors: Construction and non-tradable services (for example, Finance and Insurance, Public Administration, and Education).

Table B.1: ISIC Revision 4 Sector Classification

| Description | Sector | Classification ISIC Revision 4 |
|---|---|---|
| Agriculture, Forestry and Fishing | Agriculture | A |
| Mining and Quarrying<br>Electricity, gas, steam and air conditioning supply<br>Water supply; sewerage, waste management and remediation activities | Mining and Quarrying | B,D,E |
| Manufacturing | Manufacturing | C |
| Wholesale and retail trade; repair of motor vehicles and motorcycles<br>Transportation and Storage<br>Accommodation and food service activities<br>Information and communication | Wholesale/ Retail Trade | G-J |
| Construction | Construction | F |
| Financial and insurance activities<br>Real estate activities<br>Professional, scientific and technical activities<br>Administrative and support service activities<br>Public administration and defence; compulsory social security<br>Education<br>Human health and social work activities<br>Arts, entertainment and recreation<br>Other service activities<br>Activities of households as employers<br>Activities of extraterritorial organizations and bodies | Non-tradable and Non-market Services | K-U |

Notes: This table displays the six sectors: Agriculture (A), Mining (B/D/E), Manufacturing (C) Wholesale/Retail Trade (G - J), Construction (F) and Non-tradable and non-market services(K - U). Sectors 1 - 4 are tradable sectors, sectors 5 & 6 are non-tradable sectors.

**Wages.** To calculate the total wage bill per region and sector, we interact average wages per worker type and industry from the National Accounts (EU KLEMS, see Stehrer et al. (2018)) with region-sector-specific fixed effects. We extract these fixed effects from a standard AKM (Abowd et al., 1999) earnings function (with dummies for three education levels, part-time employment, a cubic age and experience term, and person fixed effects) in an approach similar to Card et al. (2013) using the Weakly anonymous Version of the Sample of Integrated Labour Market Biographies (SIAB).[40]

**Employment.** We use data from the Federal Employment Agency ("Bundesagentur für Arbeit") to obtain information on the number of workers $L_{i,s}^{g}$ of group $g$ employed in labour market $i$ and sector $s$ Statistische Ämter des Bundes und der Länder (2021b).

**Material Inputs.** Data on gross output and value-added comes from the Growth and Productivity Accounts (EU KLEMS, see Stehrer et al. (2018)) and regional economic accounts provided by the Statistical Office of the European Union (Eurostat). To calculate local levels of gross output, we allocate sector-specific gross output across regions according to region-specific value-added shares. Information on input-output linkages between sectors comes from the World Input-Output Tables (WIOD, see Timmer et al. (2015)).

**Trade Flows.** To identify bilateral trade costs and regional gross output, we require information on interregional trade flows for all tradable sectors to match the expenditures in the model, $\sum_{j \in J} \pi_{ji,u} X_{j,u}$. We use observed bilateral trade shares to allocate the region-sector-specific gross output from the EU KLEMS database across trading pairs. The Clearing House of Transport Data at the Institute of Transport Research of the German Aerospace Center provides information on bilateral trade that went through German territory in 2010. See their final report for the Forecast of Nationwide Transport Relations in Germany 2030 ('Verkehrsverflechtungsprognose 2030', henceforth VVP, Schubert et al. (2014)). It provides information on interregional trade volumes in metric tons between German districts in 2010. To match our empirical equivalents of regions and sectors, we aggregate trade flows to the commuting zone and sector level. As an input to the theoretical model, we require trade *values* rather than volumes, so we convert the data using appropriate unit values. We base our measure of region-sector-specific unit values on actual output data, such that the information on the volume of bilateral trade flows obtained from the VVP directly matches the aggregate region-sector-specific output. We aggregate trade data to the level of local labour market regions and ISIC Revision 4 sectors to resemble our classification of region-sector pairs.

**Price Levels of Non-Tradables.** We use mix-adjusted regional real estate price indices from Ahlfeldt et al. (2020) as a proxy for local price levels in the construction sector.[41]

[40] For each individual we collect information on wages, education, gender, age, occupation, sector, workplace, location of residence, and employment status. To address the censoring of wages at the social security maximum, we apply the imputation method proposed by Card et al. (2013).

[41] The computation of the regional real estate price indices follows the methodology outlined in Combes et al. (2019). Ahlfeldt et al. (2020) rely on the micro data set "Real-Estate Data for Germany", which is

For price levels of non-tradable services, we rely on estimates of price level differences by sector in Weinand and Auer (2020). We control for tradable service prices and aggregate them to the regional level. Since unit costs can only be identified up-to-scale, we finally re-scale all price indices $P_{i,ntM}$ such that their output-weighted average sums to unity for all sectors.

## B.2 Identification steps for model fundamentals and additional endogenous variables

Our strategy for identifying amenities, preferences, and productivity involves several steps:[42]

1. **Use data on value-added, gross output and input-output linkages to derive model-consistent values $\delta_{i,u}$, $\delta_{i,uu'}$, $\kappa_{i,u}$ for all region-sector pairs**

   (a) **Share of value added for all region-sector pairs**

   Expenditures on wages, as well as land and structures in region-sector pair {i,u}, are a fixed share of total expenditures by equations (13) and (15)

$$\delta_{i,u} = \frac{\sum_{g \in G} w^g_{u|i,u} L^g_{u|i,u} + r_i h_{i,u}}{\sum_{j \in J} \pi_{ji,u} X_{j,u}}, \tag{56}$$

   such that the parameters $\delta_{i,u}$ can be identified by the fraction of value added over gross regional output in each region-sector pair.

   (b) **Shares of material inputs $\delta_{i,uu'}$ for all regions and sectors**

   Note that in the aggregate economy, total trade flows equal aggregate expenditures, such that

$$\sum_{i \in J} \sum_{j \in J} \pi_{ji,u} X_{j,u} = \sum_{i \in J} X_{i,u}.$$

   Summing the demand for materials (16) over all regions yields then

$$\delta_{uu'} = \frac{\sum_{i \in J} M_{i,uu'} P_{i,u'}}{\sum_{i \in J} X_{i,u}},$$

   where we define as $\delta_{uu'}$ the share of economy-wide material inputs of goods from sector $u'$ used in the production of goods from sector $u$. We observe material inputs in the production of goods from each sector from the World Input-Output Tables (Timmer et al. (2015)) at the aggregate level. We, however, cannot observe material inputs by sectors separately for each region. We, therefore, assume that in all regions, the value of materials $u' \in M$ used as inputs, relative

described in great detail in Boelmann and Schaffner (2019) and originally comes from the internet platform Immobilien Scout 24. See the Online Appendix of Ahlfeldt et al. (2020) for more details.

[42] We build upon the identification strategies outlined in Caliendo et al. (2018) and Rossi-Hansberg et al. (2019).

to total material inputs, is constant, such that:

$$\delta_{uu'} = \frac{\delta_{i,uu'}}{\sum_{u' \in M} \delta_{i,uu'}} \quad \forall i \in J.$$

The regional share of material inputs is, therefore, determined as follows:

$$\delta_{i,uu'} = (1 - \delta_{i,u})\, \delta_{uu'}.$$

(c) **Share of value-added accruing to workers** Lastly, we calibrate the share of value added accruing to workers for each region-sector pair as

$$1 - \kappa_{i,u} = \frac{\sum_{g \in G} w^g_{u|i,u} L^g_{u|i,u}}{\delta_{i,u} \sum_{j \in J} \pi_{ji,u} X_{j,u}}. \tag{57}$$

2. **Derive expenditures on land and structures and trade imbalances for all regions**

Expenditures on land and structures are a fixed share of total wage expenditures in all region-sector pairs:

$$r_i h_{i,u} = \frac{\kappa_{i,u}}{1 - \kappa_{i,u}} \sum_{g \in G} w^g_{u|i,u} L^g_{u|i,u}, \tag{58}$$

such that the total income of rentiers in region $i \in J$ is given by:

$$\sum_{u \in M} r_i h_{i,u} = \sum_{u \in M} \frac{\kappa_{i,u}}{1 - \kappa_{i,u}} \sum_{g \in G} w^g_{u|i,u} L^g_{u|i,u}.$$

3. **Calculate model-consistent expenditure shares $\beta^C_{u'}$ and $\beta^R_{u'}$ for all sectors**

Aggregate goods markets clear for all sectors, which, jointly with the definition of $\mathcal{K}$, implies that

$$\begin{aligned}\sum_{i \in J} X_{i,u} =& \beta^R_{u'} \left( \sum_{i \in J} \sum_{s \in h,u} \sum_{g \in G} \sum_{u' \in M} (\mathcal{T}_i + \rho_i) \left( w^g_{s|i,u'} L^g_{s|i,u'} \right) \right) \\ & + \beta^C_{u'} \left( \sum_{i \in J} \sum_{s \in h,u} \sum_{g \in G} \sum_{u' \in M} (1 - \mathcal{T}_i)\, w^g_{s|i,u'} L^g_{s|i,u'} + \mathcal{K} \right) \\ & + \sum_{i \in J} \sum_{u' \in M} \frac{\delta_{i,u'u}}{\delta_{i,u'} \left(1 - \kappa_{i,u'}\right)} \sum_{g \in G} w^g_{u|i,u'} L^g_{u|i,u'},\end{aligned} \tag{59}$$

Given aggregate wage data, employment data and parameter values for $\rho_i$ and $\mathcal{T}_i$ as well as for $\delta_{i,u}$,$\kappa_{i,u}$ and $\delta_{i,uu'}$ obtained from identification step 1 we solve for model-consistent expenditure shares $\{\beta^C_{u'}, \beta^R_{u'}\}$ which imply aggregate sector-specific goods market clearing. We assume that local governments do not consume housing but otherwise distribute expenditures like workers across the remaining sectors. This assumption allows us to fit private expenditure shares better to observable housing expenditure shares in Germany, under the restriction that goods markets clear in all regions and sectors (59).

4. **Calculate total expenditures**
Goods market clearing in all regions and sectors implies that,

$$\begin{aligned} X_{i,u} =& \beta_u^R \left[ (\mathcal{T}_i + \rho_i) \left( \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} w^g_{s|i,u'} L^g_{s|i,u'} \right) \right] \\ &+ \beta_u^C \left[ \frac{L_i}{L} \left( \sum_{j \in J} \sum_{u' \in M} \left( \mathcal{H}_{j,u'} r_j - \sum_{g \in G} w^g_{h|j,u'} \xi^g_{h|j,u'} L^g_{j,u'} \right) \right) \right. \\ &\left. + (1 - \mathcal{T}_i) \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} w^g_{s|i,u'} L^g_{s|i,u'} \right] + \sum_{u' \in M} \delta_{i,u'u} \sum_{j \in J} \pi_{ji,u'} X_{j,u'}, \end{aligned}$$

which we solve for using the model-consistent expenditure shares $\{\beta_u^C, \beta_u^R\}$ from identification step 4.

5. **Calculate relative unit cost shares $\tilde{\lambda}_{i,u}$ for all tradable goods**
Substituting the expressions for trade shares (18) as well as the calculated values for total expenditure from above into equations (57) yields

$$\sum_{j \in J} X_{j,u} \frac{(\lambda_{i,u} \tau_{ji,u})^{-\nu_u}}{\sum_{n \in J} (\lambda_{n,u} \tau_{jn,u})^{-\nu_u}} = \frac{\sum_{g \in G} w^g_{u|i,u} L^g_{u|i,u}}{\delta_{i,u} (1 - \kappa_{i,u})}. \tag{60}$$

For all pairs $\{i, u\}$ we solve for the relative unit costs $\tilde{\lambda}_{i,u} \equiv \frac{(\lambda_{i,u})^{\nu_u}}{\sum_{n \in J} (\lambda_{n,u})^{\nu_u}}$ that are implied by the structure of trade flows. The unit costs can be identified from equations (60) as smaller relative unit costs imply that a region $i$ is the least-cost producer for a larger number of varieties, which increases trade shares towards all regions $j \in J$.
In all sectors where goods are non-tradable, it holds that $\pi_{ji,u} = 0$ as long as $j \neq i$, such that

$$X_{i,nt} = \frac{\sum_{g \in G} w^g_{nt|i,nt} L^g_{nt|i,nt}}{\delta_{i,nt} (1 - \kappa_{i,nt})}.$$

where $nt \subset M$ denotes sectors from the subset of market sectors that are non-tradable.

6. **Compute sector-specific price levels for all tradable goods**
Substituting relative unit costs $\tilde{\lambda}_{j,u}$ into price equations (17) allows solving for the

ideal region-sector-specific cost indices $P_{i,u}$:

$$P_{i,u} = \Gamma\left(\gamma_u\right)^{\frac{1}{1-\sigma}} \left[\sum_{j\in J} \left(\tilde{\lambda}_{j,u}\right)^{-1} \left(\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}} * \left(\sum_{n\in J} \left(\lambda_{n,u}\right)^{\nu_u}\right)^{\frac{1}{\nu_u}}, \tag{61}$$

where $\sum_{n\in J} \left(\lambda_{n,u}\right)^{\nu_u}$ are sector-specific constants to be determined by normalization. We choose a model-consistent normalization on aggregate sector-specific cost indices: $P_u \equiv \sum_{i\in J} P_{i,u}\pi_{i,u} = 1 \quad \forall u \in TR \subset M$, that is we define sector-specific cost aggregates as a weighted average of region-sector-specific costs and normalize them to unity. The weights $\pi_{i,u} = \frac{X_{i,u}}{\sum_{n\in J} X_{n,u}}$ are the share of total spending in sector $s$, that accrues to region-i expenditures. Applying the normalization, we solve for the sector-specific constants, such that

$$\left(\sum_{n\in J} \left(\lambda_{n,u}\right)^{\nu_u}\right)^{\frac{1}{\nu_u}} = \frac{1}{\Gamma\left(\gamma_u\right)^{\frac{1}{1-\sigma}} \sum_{i\in J} \pi_{i,u} \left[\sum_{j\in J} \left(\tilde{\lambda}_{j,u}\right)^{-1} \left(\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}}}.$$

We subsequently calculate ideal cost indices relative to a weighted average of costs across all regions, that is

$$P_{i,u} = \frac{\left[\sum_{j\in J} \left(\tilde{\lambda}_{j,u}\right)^{-1} \left(\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}}}{\sum_{i\in J} \pi_{i,u} \left[\sum_{j\in J} \left(\tilde{\lambda}_{j,u}\right)^{-1} \left(\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}}}. \tag{62}$$

Using the normalization for aggregate sector-specific cost indices once again, we solve for unit costs in levels:

$$\lambda_{i,u} = \frac{\left(\tilde{\lambda}_{i,u}\right)^{\frac{1}{\nu_u}}}{\Gamma\left(\gamma_u\right)^{\frac{1}{1-\sigma}} \sum_{i\in J} \pi_{i,u} \left[\sum_{j\in J} \left(\tilde{\lambda}_{j,u}\right)^{-1} \left(\tau_{ij,u}\right)^{-\nu_u}\right]^{-\frac{1}{\nu_u}}}.$$

7. **Compute price levels in all regions for all non-tradable goods**
The price levels of non-tradable services are defined as

$$P_{i,ntS} = \beta_{ntS} \left(\frac{P_{i,S}}{\left(P_{i,tS}/\beta_{tS}\right)^{\beta_{tS}}}\right)^{\frac{1}{\beta_{ntS}}},$$

where the price level of tradable services $P_{i,tS}$ and the consumption shares of tradable and non-tradable services $\{\beta_{tS}, \beta_{ntS}\}$ follow from the previous steps. In all non-tradable sectors it holds that $\tau_{ij,u} \to \infty$ for all regions $j \neq i$, such that price levels simplify to:

$$P_{i,nt} = \Gamma\left(\gamma_{nt}\right)^{\frac{1}{1-\sigma}} \lambda_{i,nt}.$$

Using regional price data for our choice of non-tradable sectors, we subsequently solve also for unit costs in these sectors.

Finally, we normalise aggregate price levels and units costs to the numéraire such that

$$\sum_i P_i \equiv \bar{P} = 1.$$

8. **Compute productivity as compensating differential to unit costs**
Group-specific labour demand (13) can be re-written in terms of the aggregate wage sum:

$$\frac{w^g_{u|i,u} L^g_{u|i,u}}{\sum_{g\in G} w^g_{u|i,u} L^g_{u|i,u}} = \frac{\left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g-1}}{\sum_{g\in G}\left(\frac{T^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g-1}}$$

Substituting relative productivity $\tilde{T}^g_{i,u} \equiv \frac{T^g_{i,u}}{\sum_{g\in G} T^g_{i,u}}$ and rearranging terms yields

$$\frac{\left(w^g_{u|i,u}\right)^{\sigma^g} L^g_{u|i,u}}{\sum_{g\in G} w^g_{u|i,u} L^g_{u|i,u}} = \frac{\left(\tilde{T}^g_{i,u}\right)^{\sigma^g-1}}{\sum_{g\in G}\left(\tilde{T}^g_{i,u}\right)^{\sigma^g-1}\left(w^g_{u|i,u}\right)^{1-\sigma^g}}$$

Applying the fact that relative productivity $\tilde{T}^g_{i,u}$ sums to unity in all region-sector pairs by construction allows identifying them solely in terms of observable average wages and market employment:

$$\tilde{T}^g_{i,u} = \frac{\left(w^g_{u|i,u}\right)^{\frac{\sigma^g}{\sigma^g-1}}\left(L^g_{u|i,u}\right)^{\frac{1}{\sigma^g-1}}}{\sum_{g\in G}\left(w^g_{u|i,u}\right)^{\frac{\sigma^g}{\sigma^g-1}}\left(L^g_{u|i,u}\right)^{\frac{1}{\sigma^g-1}}}$$

Intuitively, relative productivity is larger, the higher the demand for group-specific employment, given group-specific wage differences. From equations (20) as well as group-specific labour demand, demand for land and structures and material demand, we finally arrive at

$$\sum_{g\in G}\left(T^g_{i,u}\right)^{\delta_{i,u}(1-\kappa_{i,u})} = \frac{D_{i,u}}{\lambda_{i,u}}\left(r_i^{\kappa_{i,u}}\left[\sum_{g\in G}\left(\frac{\tilde{T}^g_{i,u}}{w^g_{u|i,u}}\right)^{\sigma^g-1}\right]^{\frac{1-\kappa_{i,u}}{1-\sigma^g}}\right)^{\delta_{i,u}} \prod_{u'\in M}\left[P_{i,u'}\right]^{\delta_{i,uu'}}$$

Given unit cost estimates, higher local unit prices (e.g. wages, rent, intermediate goods prices) imply larger regional productivity in sector $u$:

$$T^g_{i,u} = \tilde{T}^g_{i,u} \left[ \frac{D_{i,u}}{\lambda_{i,u}} \left( r_i^{\kappa_{i,u}} \left[ \sum_{g \in G} \left( \frac{\tilde{T}^g_{i,u}}{w^g_{u|i,u}} \right)^{\sigma^g - 1} \right]^{\frac{1-\kappa_{i,u}}{1-\sigma^g}} \right)^{\delta_{i,u}} \prod_{u' \in M} \left[ P_{i,u'} \right]^{\delta_{i,uu'}} \right]^{\frac{1}{\delta_{i,u}\left(1-\kappa_{i,u}\right)}}.$$

9. **Ensure goods market clearing in non-tradable sectors**
Identification step 5 ensures goods market clearing in all regions and tradable sectors since unit costs are identified from trade flows and the definition of final goods demand.

In non-tradables sectors, in contrast, we use observable price levels to identify unit costs. These are unlikely to initially ensure goods market clearing, as defined in equation (19). We, therefore, gradually adjust the parameters $\delta_{i,u}, \delta_{i,uu'}$ across regions and non-tradable sectors such that they ensure goods market clearing, together with observable sectoral price levels. The loop works as follows:

 - Follow identification steps 1-8, given initial guesses for $\delta_{i,u}, \delta_{i,uu'}$ in all regions and sectors
 - Calculate total trade flows implied by guesses of unit costs, $X_{i,u}$ and trade costs
 - Use guesses for unit costs and intermediate cost inputs to compute the total value of intermediate goods production (the right-hand side of goods market clearing equation (19))
 - Evaluate whether local production equals total demand ( calculated trade flows from the step above)
 - Adjust the parameters $\delta_{i,u}, \delta_{i,uu'}$, re-do all the steps above, until goods market clearing is ensured

10. **Compute preferences as compensating differentials to labour supply**
Regional price levels are a Cobb-Douglas aggregate of sector-specific prices by equation (10). Given sector-specific unit cost levels (62), as well as data on wages $w^g_{u|i,u}$, tax rates, public expenditure and employment rates, overall amenities $\bar{A}^g_i \exp\left[-\mu^g_{u|i,u}\right]$ are recovered as the residual to observable labour supply:

$$L^g_{i,u} = \frac{\left(\bar{V}^g_{i,u}\right)^{\theta^g}}{\sum_{u \in M} \sum_{i \in J} \left(\bar{V}^g_{i,u}\right)^{\theta^g}} L^g,$$

Spatial variation in after-tax real income and public expenditure identifies average group-specific overall amenities up to a group-specific constant for each region-sector pair $\{i, u\}$. Perfect worker mobility across regions and sectors ensures that the worker-group-specific utility levels will be equalised. We, lastly, normalise overall amenities to a group-specific mean of 1 and regress the compound component $\bar{A}_i^g \exp\left[-\mu^g_{u|i,u}\right]$ on region fixed effects for all worker groups to separately identify amenities and region-sector-specific participation costs.

11. **Compute preference shifters for the home market**
We use the structural parameter estimates $\{\epsilon^g, \rho^g_{h,C}, \rho^g_{h,R}, \alpha\}$ and non-employment rates to recover the home-market-specific preference shifters from equations (12):

$$\mathcal{B}^g_{s|i,u} = \left(\xi^g_{h|i,u}\right)^{\frac{1}{\epsilon^g}} \left(\frac{I^g_{u|i,u}}{I^g_{h|i,u}}\right)^{1-\alpha} \left(\left[R_{u|i,u}\right]^{\rho^g_{h,R}}\right)^{\alpha}$$

Finally, we split preference shifters into participation costs and home-market-preferences, such that

$$\exp\left[\bar{B}^g_{h|i,u}\right] = \mathcal{B}^g_{s|i,u} \exp\left[-\mu^g_{u|i,u}\right].$$

# C Counterfactual Implementation

In this part of the appendix, we report the procedure for our counterfactual analysis from Section 7 of the paper.

To implement the counterfactual, we first invert the model for the year 2014, using the inversion steps outlined in section B.2. Next, we calculate the optimal policy instruments according to equations ((48), (49), (51), (52), (54)) and as detailed in section A.5.3. We then solve for the vector of counterfactual equilibrium values for all endogenous variables $\{I^g_{s|i,u}, P_i, L^g_{i,u}, L^g_{h|i,u}, w^g_{u|i,u}, h_{i,u}, r_i, P_{i,u}, M_{i,uu'}, \pi_{ij,u}, X_{i,u}, \lambda_{i,u}, E_i\}$ with an iterative loop. Since the optimal policies are a function of all endogenous variables, we adjust them according to rules ((48) - (54)) after having solved for new variables values in each iteration. The loop works as follows:

1. Keep all model fundamentals constant and start the loop with first guesses for local population, price levels and wages, $\mathcal{V}_0 = \{L^g_{i,u}, P_{i,u}, w^g_{u|i,u}\}$, as well as policy instruments $\mathcal{V}^P_0 = \{\tilde{\mathcal{T}}^g_{s|i,u}, \tilde{\mathcal{S}}^g_{s|i,u}, \tilde{E}_i\}$.

2. Solve for income levels:

$$I^g_{s|i,u} = \left(1 - \tilde{\mathcal{T}}^g_{s|i,u}\right) w^g_{s|i,u} + \tilde{\mathcal{S}}^g_{s|i,u}$$

3. Solve for budgets of local governments: $E_i = \tilde{E}_i$

4. Solve for regional price levels (Eq. (10))

5. Solve for non-employment rates (Eq. (12))

6. Solve for aggregate trade flows $\sum_{j\in J} \pi_{ji,u} X_{j,u}$ (Eq. (13))

7. Solve for rent income from land and structures, $r_i h_{i,u}$ (Eq. (15))

8. Solve for interest rates (Eq. (15) and (14))

9. Solve for expenditures on materials (Eq. (16))

10. Solve for total expenditures:

$$X_{i,u} = \beta_u^R \tilde{E}_i + \beta_u^C \Big[ \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} I^g_{s|i,u'} \Big] + \sum_{u' \in M} \delta_{i,u'u} \sum_{j \in J} \pi_{ji,u'} X_{j,u'}$$

11. Solve for unit costs (Eq. (22))

12. Solve for trade shares ((18))

13. Update guesses for prices $P_{i,u}$ (Eq. (17) ) and normalise updated price levels (Eq. (23))

14. Update guesses for local labour supply (Eq. (11))

15. Update guesses for wages (Eq. (13))

16. Update optimal policy rule (Eq. (48), (49), (51), (52), (54))

17. Stop loop when guesses for the vector $\mathcal{V}_0$ and updated values align

**Counterfactual equilibrium** Given model primitives, the counterfactual general equilibrium of the economy is referenced by a vector of the endogenous objects $\mathbf{V} = \{I^g_{s|i,u}, P_i, L^g_{i,u}, L^g_{h|i,u}, w^g_{u|i,u}, h_{i,u}, r_i, M_{i,uu'}, P_{i,u}, \pi_{ij,u}, X_{i,u}, \lambda_{i,u}, E_i\}$ and a scalar $\mathcal{V}^g$ which are jointly determined by equations {(10), (11), (12), (13), (14), (15), (16), (17), (18), (22), (23) } as well as the income of workers and local governments as well as total expenditures under optimally-chosen policy instruments:

$$I^g_{s|i,u} = \left(1 - \tilde{\mathcal{T}}^g_{s|i,u}\right) w^g_{s|i,u} + \tilde{\mathcal{S}}^g_{s|i,u} \tag{63}$$

$$E_i = \tilde{E}_i \tag{64}$$

$$X_{i,u} = \beta_u^R \tilde{E}_i + \beta_u^C \Big[ \sum_{s \in h,u} \sum_{u' \in M} \sum_{g \in G} I^g_{s|i,u'} \Big] + \sum_{u' \in M} \delta_{i,u'u} \sum_{j \in J} \pi_{ji,u'} X_{j,u'} \tag{65}$$

and where optimal policy instruments are implemented according to equations {((48) - (54)) }.

# D Additional Empirical Results

Subsection D.1 of this empirical part of the Appendix examines the institutional structure of fiscal resource allocation and the provision of public goods in Germany, providing essential background information for our analysis. Subsection D.2 shows that the 2011 Census shock induced a one-off but permanent shock to fiscal transfers and local government budgets. Finally, Subsection D.3 uses triple difference-in-difference regressions to investigate whether female workers in treated regions experienced significantly different local employment effects following the Census shock.

## D.1 Institutional Structure of Fiscal Resource Allocation and the Provision of Local Public Goods in Germany

This subsection describes the the structure of fiscal resource allocation and provision of public goods in the German federation of states.

**Fiscal Revenues Redistribution.** We examine the spatial distribution of tax revenues in Germany, guided by Article 72 of the German constitution, which aims to ensure equivalent living conditions across all regions. To achieve this goal, the federal government and states share and redistribute tax revenue across cities and towns according to a complex set of rules that includes population and income shares, as well as various other federal grants, public budgets, and financial assistance for investments.[43]

On average, 74.9 billion Euros is redistributed annually, primarily from more affluent regions in Southern and Western Germany to East Germany. These transfers from the federal government and states to local governments amount to approximately 2.7% of the country's GDP or 12.4% of the aggregate tax revenue (see Statistisches Bundesamt (2021b); Statistisches Bundesamt (2021a); Statistische Ämter des Bundes und der Länder (2021a)).[44] Panel (a) of Figure D.3 represents the average annual distribution of fiscal transfers across regions from 2008 to 2014, illustrating the significant reliance on the redistribution scheme, with some districts in East Germany receiving more than 60% of their total income.

Overall, the spatial redistribution of tax revenues and transfers has profound implications for the local spending capacity and potential of municipalities to provide local public goods, directly influencing the allocation of economic activity and welfare outcomes

[43] Identifying the total flow of fiscal funds from federal to sub-federal jurisdictions is difficult due to a lack of publicly accessible data on specific investments (see, for example, Buchheim and Watzinger (2022)). For instance, Germany introduced the "Kinderförderungsgesetz" (KiföG) in 2008 to provide public childcare for all children over one. The local childcare investments were mainly financed by intergovernmental transfers from a federal fund (the "Sondervermögen Kinderbetreuungsausbau"). This special fund provided 5.4 billion euros for investments in daycare facilities and daycare for children under three between 2008 and 2021. Despite numerous efforts to obtain the information on the regional allocation of fiscal funds, the states' corresponding statistical offices could not provide us with detailed data.

[44] It is essential to note that this analysis considers the 401 German NUTS3 regions (Landkreise) as the spatial units. However, it should still be acknowledged as a conservative estimate as it does not account for transfers across municipalities within NUTS3 regions.

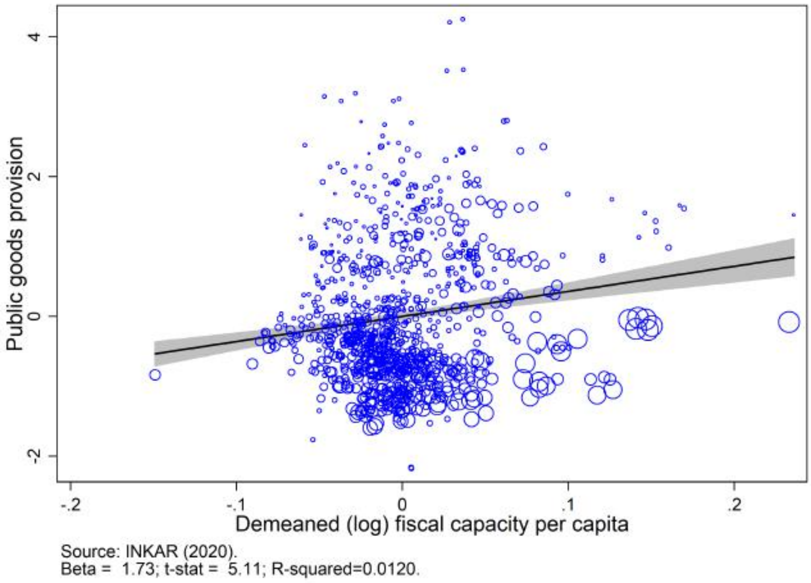
(Fajgelbaum and Gaubert, 2020; Henkel et al., 2021). In the main text, we demonstrate that fiscal budget shocks can adversely impact public goods provision, which, in turn, can affect local employment and labour force participation decisions.

**Local Government's Public Goods Provision.** Understanding the underlying institutional structure that governs the provision of public goods at the local level is crucial, as it shapes the dynamics of local economies and the relative attractiveness of different locations. Article 28 of the German constitution serves as the foundational framework for regulating the provision of local public goods in Germany, guaranteeing cities, municipalities, and districts the right to local self-government. However, federal and state laws dictate that municipalities must provide specific public goods to their residents, encompassing essential services such as childcare, elementary schools, drinking water and sewage systems, energy and waste management, fire departments, municipal elections, and social institutions. Municipalities have the discretion to fulfil these requirements according to their unique circumstances. Local governments represent approximately 21.5% of total government spending or 111.2 billion Euros annually between 2008 and 2014 (see Statistisches Bundesamt (2021b); Statistisches Bundesamt (2021a); Statistische Ämter des Bundes und der Länder (2021a)). The financial needs of municipalities are shaped by factors such as population size and demographic composition, which further influence their capacity to provide these essential public goods.

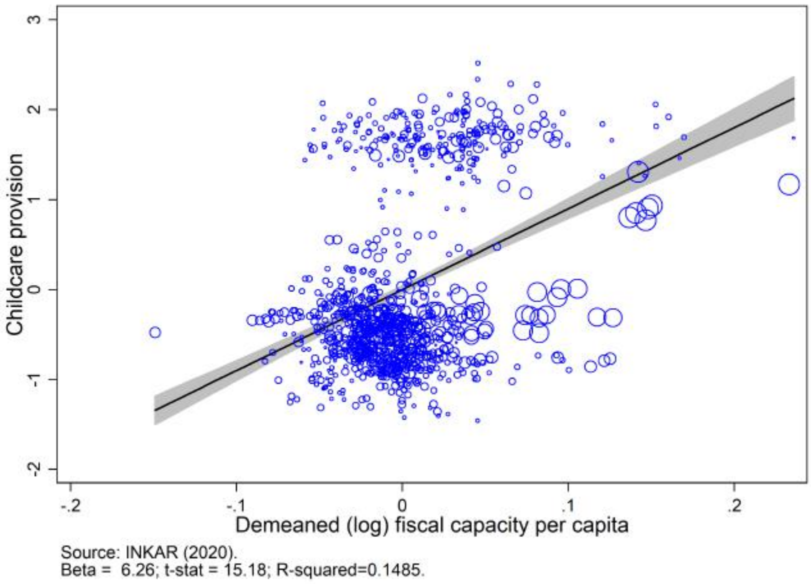
Measuring local public goods provision is complex due to its multifaceted and nonmarketable nature. To capture this complexity, we employ a first principal component analysis to convert various indicators of public goods provision into a single measure. We gather information on local public goods, including childcare provision, accessibility of elementary schools, public transportation, infrastructure, such as motorways, airports, and train stations, household broadband internet access, drinking water and sewage supply, energy and waste management, as well as publicly financed recreational areas from the INKAR (2020) database. We then standardize to give this variable a zero mean and unit standard deviation.

Limited fiscal revenues impose constraints on municipalities in delivering local public goods. In contrast, greater fiscal capacities enable communities to allocate more resources in this regard (see Panel (a) of Figure D.1). Fiscal capacities per capita, normalized by the working-age population in 2008 and demeaned by their yearly average, exhibit a positive relationship, indicating that higher local government budgets facilitate the increased provision of public goods. Tight fiscal budgets necessitate cost-saving measures in maintaining and providing local public goods.[45] As illustrated in Panel (b) of Figure D.1, adequate fiscal capacities play a significant role in enabling local governments to provide public childcare services.

[45] It is worth noting that the financial situation of certain municipalities worsened with the introduction of the "Schuldenbremse" (debt brake) in 2009, which mandated a balanced budget without net borrowing for federal and state governments each year. Additionally, Article 115 of the German constitution limits




(a) Public goods provision




(b) Childcare provision

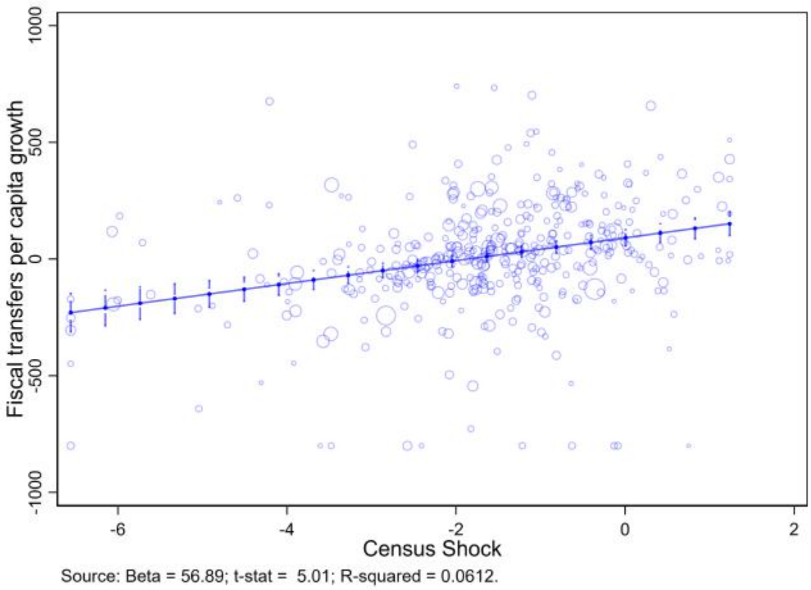
Figure D.1: Public goods provision and local fiscal capacities per capita

*Notes:* Panel (a) compares local public goods provision to fiscal capacity per capita, normalized by working-age population and adjusted for yearly averages. Panel (b) examines the relationship between fiscal capacities and childcare provision. Fiscal capacities are calculated using available tax revenues after redistribution, incorporating local tax revenues and transfer payments. Public goods and childcare provision are derived from a principal component analysis of various indicators, including childcare services, broadband access, transportation, retirement homes, recreational areas, and waste management. The size of the marker is proportional to the regional population size in 2008. Data comes from INKAR (2020) and Statistisches Bundesamt (2021b,a); Statistische Ämter des Bundes und der Länder (2021a).

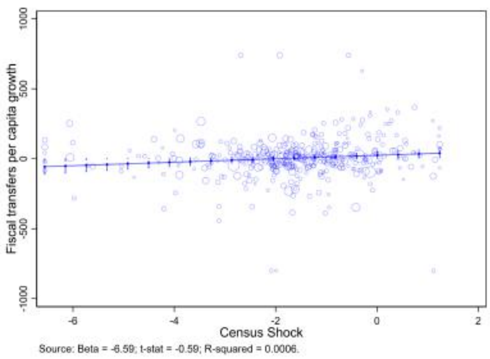
## D.2 First-Stage of the 2011 Census Shock

The 2011 Census shock induced a permanent shock to fiscal transfers and local government budgets. Our analysis shows that higher levels of the Census shock are associated with significantly larger fiscal per capita transfer growth in 2012, the first year when updated population counts were used for the calculation of fiscal transfers (see Panel (a) of Figure D.2). At the same time, we do not observe a significant impact of the Census on transfers and fiscal budgets in the pre-shock or post-shock periods in Panels (b) and (c), respectively.

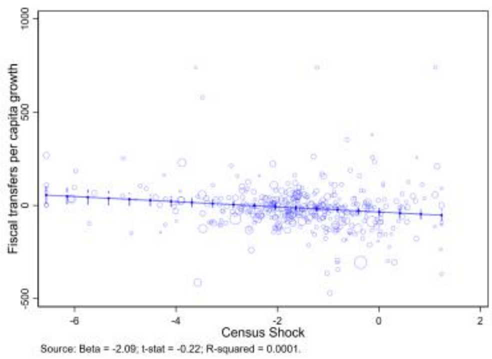
Figure D.2: The 2011 Census shock and fiscal transfers




(a) Fiscal transfer shock period




(b) Pre-shock period




(c) Post-shock period

Note: This figure plots demeaned fiscal transfer growth per capita (relative to the state-specific mean) against the identically demeaned Census shock. Panel (a) plots the correlation for 2012, the year of the "fiscal transfer shock" (e.g. the year when population re-counts were first incorporated into the calculation of fiscal transfers). Panel (b) and Panel (c) plot the same correlation for two years before and one period after the fiscal transfer shock. The size of the marker is proportional to the regional population size in 2010.

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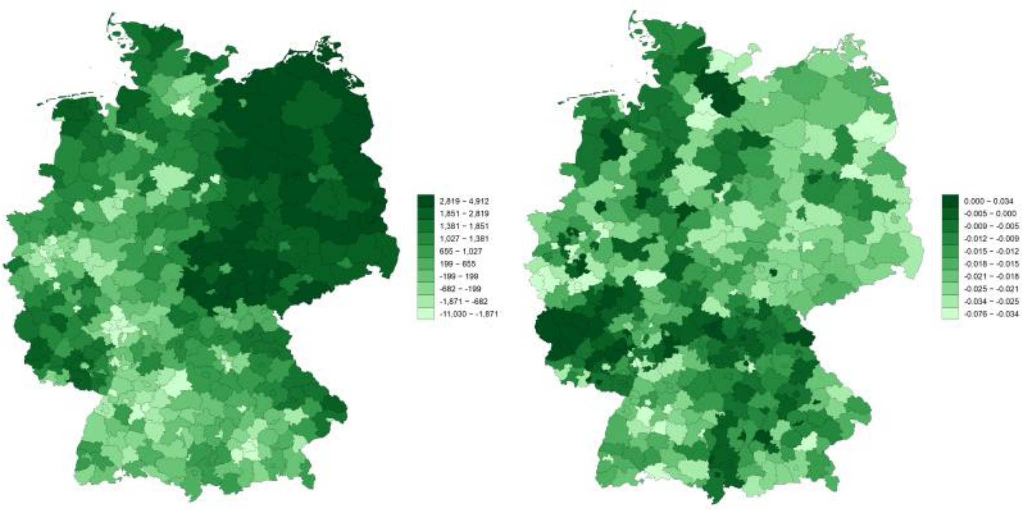
net borrowing at the federal level to 0.35 % of national GDP (see Busch and Strehl (2019) for an overview).

We estimate the dynamic effect of the Census shock on per capita growth of fiscal transfers in an event-study approach, where we run the following regression in first differences:

$$\Delta \text{Transferpc}_{i,t} = c_t + c_{j,t} + \sum_{s=T+k} \beta_s \Delta \ln \text{Census}_{i,2011} \times \mathbb{1}\left[t = s\right] + u_{i,t}. \qquad (66)$$

Here $\Delta\text{Transferpc}_{i,t}$ refers to the per capita growth of fiscal transfers between subsequent years[46], $c_t$ and $c_{j,t}$ are time and state-time fixed effects and $\Delta \ln \text{Census}_{i,2011}$ is the Census shock as defined above. We define all event periods relative to the event year $T - 1$ in which the Census shock occurred, which we take as the reference period. The regression coefficients for $k \in [-8; 7]$ are shown in column (1) of Table 4 and displayed graphically in Panel (a) of Figure D.4. Our results show no statistically significant impact on fiscal transfer growth in pre-periods and no distinguishable trends before 2011. Reassuringly, this implies that the Census shock is unlikely to correlate with shocks to local economic activity that determine the allocation of fiscal transfers.

Figure D.3: Spatial disparities in fiscal transfers and the 2011 Census shock




(a) Fiscal transfers per capita (b) 2011 Census shock

*Notes:* Panel (a) of this figure plots the geographical pattern of fiscal transfers per capita at the end of the year 2010 across the 401 German counties ("Kreise und kreisfreie Städte). Legend labels are in 2010 Euros. Panel (b) plots the geographical pattern of the Census shock (the difference between (log) population counts at the end of the year 2010 and the results of the Census in May 2011) across the 401 German counties ("Kreise und kreisfreie Städte). Darker shading indicates higher values.

However, the coefficient for the year of the fiscal transfer shock is positive, statistically

[46] To limit reverse causality concerns, we use the pre-Census 2010 population count throughout to calculate fiscal transfers per capita.

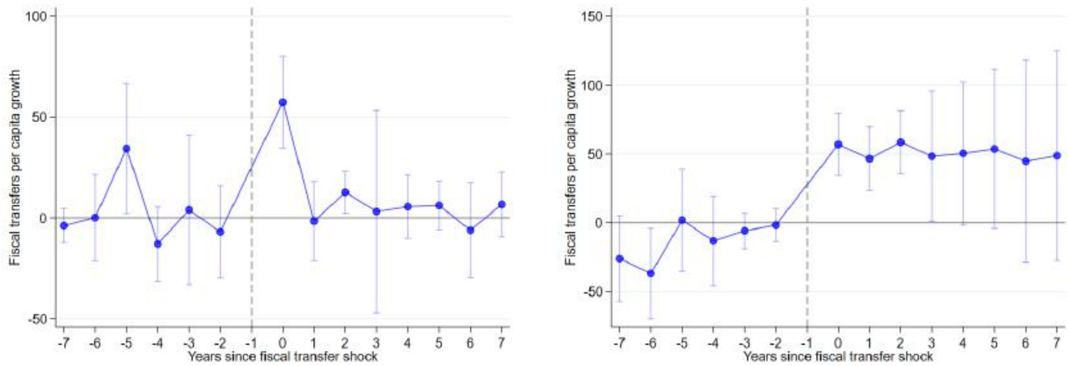
significant, and economically meaningful: A one percent larger shock to local population counts increased fiscal transfer growth by approximately 57 EUR. Put differently, an increase of the Census shock by one standard deviation led, on average, to 15% higher fiscal transfers per capita in 2012.[47] The Census shock permanently shifts the size of fiscal transfers since future extrapolations of population counts use official population numbers from the Census.

To assess the aggregate effect of the Census shock, we first define the cumulative change in fiscal transfers relative to the reference period 2011 as

$$\Delta \text{Transferpc}_{i,t}^{\text{cum}} \equiv \frac{\text{Transfer}_{i,t} - \text{Transfer}_{i,2011}}{L_{i,2010}}.$$

Subsequently, we re-run regression equations (66) with $\Delta \text{Transferpc}_{i,t}^{\text{cum}}$ as the dependent variable. We display the coefficients from this regression in column (2) of Table 4 and Panel (b) of Figure D.4. Reassuringly, the cumulative effect on fiscal transfers is constant over the post-treatment periods, while none of the coefficients significantly differ from zero. Thus, the Census shock induced a one-off permanent shock to fiscal transfers that were both unexpected and exogenous to local economic activity.

Figure D.4: Impact of 2011 Census shock on fiscal transfers




(a) Yearly effect

(b) Cumulative effect

Note: Panel (a) plots the coefficients and 95% confidence intervals of regressing yearly per capita growth of fiscal transfers on an interaction of the Census shock and a year dummy (controlling for state-year fixed effects). Event periods are defined relative to the year of the Census shock (e.g., $t = -1$ in 2011). In Panel (b), the dependent variable is the cumulative per capita growth in fiscal transfers relative to the year of the Census shock. Standard errors are clustered on the level of regions.

## D.3 Difference-in-Difference Analysis

We employ triple difference-in-difference regressions to examine the local employment effects of the 2011 Census shock on female workers in treated regions. Our specification is as follows:

[47] This equals an increase of the Census shock by 1.3 percentage points. See Panel (b) of Table 2 for summary statistics of the Census shock.

$$\begin{aligned} Y^g_{i,t} = a_0 + a_1 * \text{Female} + a_2 * \text{Post} + a_3 * (\text{Post} \times \text{Female}) + a_4 * \text{Treat} \\ + a_5 * (\text{Treat} \times \text{Female}) + a_6 * \text{DiD} + a_7 * (\text{DiD} \times \text{Female}) + \beta' X^g_{i,t} + u^g_{i,t}, \end{aligned} \tag{67}$$

where Female, Post and Treat are dummies for workers being female, living in treated regions and post-treatment periods (years after 2011), respectively. The variables DiD and (DiD $\times$ Female) are our main outcome variables and refer to the interaction (Post $\times$ Treat) and the female-specific component of it (when applicable). We use various measures of public good provision, as well as the measures of non-employment defined in section 2.1, as outcome variables either in levels or logs. Finally, $X^g_{i,t}$ is a vector of control variables, including wages, and $u^g_{i,t}$ is a residual. In more demanding specifications, we estimate a fully-fledged two-way fixed effects model with region-gender and year-gender fixed effects.

Our findings indicate that increases in public debt were not significantly larger in treated than control regions, as shown by the difference-in-difference and two-way fixed effects estimates in columns (1) and (2) of Table 6. Local jurisdictions did not compensate for decreasing tax and transfer revenues through increased public debt uptake but suffered a permanent decrease in fiscal budgets. Unfortunately, detailed expenditure data for local governments are unavailable at the county level. Instead, we approximate spending on public goods provision with their local supply and find that daycare rates of toddlers (column (3)) and available places in nursing homes (column(4)) experienced significantly smaller increases in treated regions following the Census shock.

Column (1) of Table 1 displays the non-employment estimates of regression (67). Non-employment rates were more pronounced in treated regions than control regions, even in pre-treatment periods. Furthermore, across all treatment groups, non-employment rates decreased by approximately 60% points since 2011. However, the reduction in non-employment was significantly smaller in treated regions: non-employment rate decreases of male workers were approximately 10% smaller in those jurisdictions which experienced the most significant population decreases and, consequently, permanent adverse shocks to fiscal budgets. Additionally, the negative Census-induced fiscal budget shock increased local gender employment gaps by around five per cent since the labour supply of female workers is impacted more strongly.

Using only within-state ("Bundesland") variation over time (column (2)) barely changes the estimated coefficients. In column (3), we estimate a fully-fledged two-way fixed effects model with region-gender and year-gender fixed effects. Reassuringly, our DiD estimates are barely affected by this more demanding specification. Finally, we show that changes in the public employment payroll do not explain the employment effects. Column (4) displays the estimated coefficients: there is no statistically significant effect on per-capita public employment.

Table 1: Triple difference-in-difference approach

| | Non-employment (1) | Non-employment (2) | Non-employment (3) | Public employment (4) |
|---|---|---|---|---|
| Female | 0.187*** | | | |
| | (0.009) | | | |
| Post-treatment | -0.603*** | -0.579*** | | |
| | (0.018) | (0.018) | | |
| Post-treatment * Female | 0.008 | -0.012 | | |
| | (0.008) | (0.009) | | |
| Treated | 0.240*** | 0.231*** | | |
| | (0.050) | (0.039) | | |
| Treated*Female | -0.106*** | -0.098*** | | |
| | (0.024) | (0.023) | | |
| DiD | 0.119*** | 0.101** | 0.099** | 0.011 |
| | (0.042) | (0.041) | (0.041) | (0.008) |
| DiD*Female | 0.037* | 0.054*** | 0.055*** | |
| | (0.019) | (0.021) | (0.021) | |
| Constant | -2.282*** | | | |
| | (0.024) | | | |
| Region-gender fixed effects | no | no | yes | yes |
| Year-gender fixed effects | no | no | yes | yes |
| State-gender fixed effects | no | yes | no | no |
| Controls | no | yes | yes | no |
| Observations | 13338 | 13338 | 13338 | 3123 |

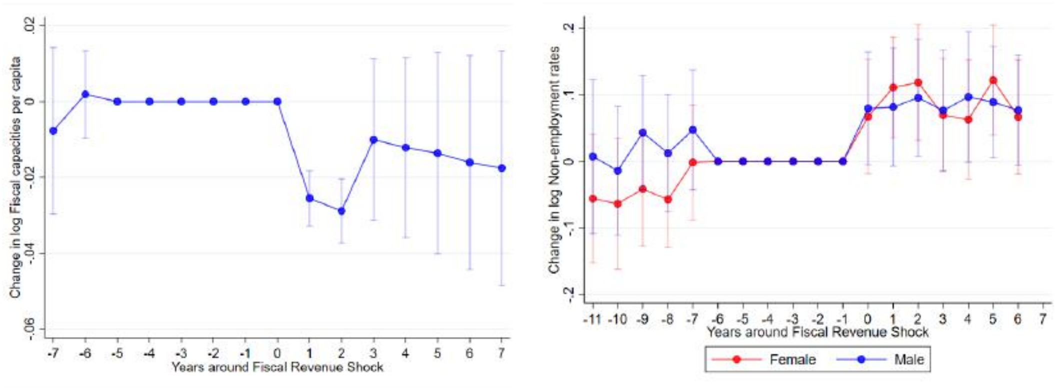
Notes: This table shows the estimates of the triple difference-in-difference regressions outlined in equation (67) on the natural logarithm of non-employment probabilities in columns (1) - (3) and on the natural logarithm of per-capita public employment in column (4). Instead of dummies for treatment and post-treatment we employ the full set of region-gender and time-gender fixed effects in columns (3) and (4).For the calculation of per-capita public employment we hold regional population counts constant at their pre-Census level in 2010. Standard errors clustered on the level of regions. $^{+}$ $p < 0.15$, $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

## D.4 Additional Figures and Tables for estimation and inversion

Table 2: Summary Statistics

| | Treated | | Control | | Total | |
|---|---|---|---|---|---|---|
| | Mean | Std | Mean | Std | Mean | Std |
| Panel A: Labour Force Participation | | | | | | |
| Δ Labour force participation rate (Female) | 0.003 | 0.006 | 0.005 | 0.008 | 0.005 | 0.008 |
| Δ Labour force participation rate (Male) | -0.001 | 0.006 | 0.001 | 0.007 | 0.001 | 0.007 |
| Δ Relative labour force participation rate | 0.004 | 0.008 | 0.005 | 0.007 | 0.005 | 0.007 |
| Panel B: Population and Population Growth | | | | | | |
| Yearly (Log) Population Growth (2010) | 0.001 | 0.006 | -0.003 | 0.006 | -0.002 | 0.006 |
| Yearly (Log) Population Growth (Census Year) | -0.041 | 0.012 | -0.014 | 0.009 | -0.018 | 0.014 |
| Yearly (Log) Population Growth (2013) | 0.004 | 0.007 | 0.001 | 0.006 | 0.001 | 0.006 |
| Census shock (May 2011) | -0.045 | 0.012 | -0.015 | 0.008 | -0.019 | 0.013 |
| Panel C: Fiscal Capacities and Transfers | | | | | | |
| Δ (Log) Fiscal capacities (per capita) | 0.119 | 0.176 | 0.115 | 0.177 | 0.115 | 0.177 |
| Δ (Log) Fiscal transfers (per capita) | 0.022 | 0.709 | 0.066 | 0.615 | 0.062 | 0.625 |
| Δ (Log) Public Debt (per capita) | 0.317 | 0.743 | 0.189 | 0.560 | 0.206 | 0.590 |
| Panel D: Supply of public childcare | | | | | | |
| Δ Childcare rate (toddlers) | 0.029 | 0.059 | 0.031 | 0.052 | 0.031 | 0.053 |
| Δ Childcare rate (3-5 yrs) | -0.045 | 0.012 | -0.015 | 0.008 | -0.019 | 0.013 |

Notes: Panel A reports the mean and standard deviation (Std) of time changes in labour force participation rates for all German counties and workers of both genders, separately for treated and non-treated regions. Panel B reports the mean and standard deviation of log population growth and the 2011 Census shock for all German counties, separately for treated and non-treated regions. Panel C reports the mean and standard deviation of log growth in fiscal capacities per capita (local tax revenues after fiscal re-distribution), fiscal transfers per capita, and public debt, separately for treated and non-treated regions. Time changes are relative to the pre-Census year 2010, and we hold population counts constant at their 2010 level. Panel D reports the mean and standard deviation of time changes in childcare rates relative to their 2010 pre-Census level. Childcare rates are defined as the share of toddlers (< 3 years) and children aged 3-5 years in daycare institutions relative to the total number of children in the age group in a region.




(c) Fiscal capacities per capita

(d) Non-employment

Figure D.5: Treatment Effect of 2011 Census shock on Local Public Finance and Non-employment

*Notes:* This Figure plots the event study coefficients using a doubly robust estimator (IPWRA) that combines IPW with a probit treatment model and a linear outcome model and 95% confidence intervals for the Treatment Effect framework regressions. Panel (a) shows the event study coefficients on fiscal capacities growth. Panel (b) shows the coefficients on non-employment. Lags of the outcome variable and period effects are used as explanatory variables. Event periods are defined relative to the year of the Census shock. Standard errors are bootstrapped and clustered at the regional level.

Table 3: THE EFFECT OF THE 2011 CENSUS SHOCK ON NON-EMPLOYMENT

| | Δ Non-employment share (Female) (1) | Δ Non-employment share (Male) (2) | ΔNon-employment share (Female) (3) | Δ Non-employment share (Male) (4) |
|---|---|---|---|---|
| Years: -11 to -10 | -0.065 | -0.005 | -0.060 | -0.003 |
| | (0.071) | (0.048) | (0.050) | (0.054) |
| Years: -9 to -8 | -0.056 | 0.027 | -0.049 | 0.028 |
| | (0.054) | (0.042) | (0.040) | (0.044) |
| Years: -7 to -6 | -0.006 | 0.020 | -0.001 | 0.024 |
| | (0.029) | (0.029) | (0.022) | (0.023) |
| Years: -5 to -4 | -0.003 | 0.006 | - | - |
| | (0.012) | (0.009) | - | - |
| Years: -3 to -2 | -0.009 | 0.005 | - | - |
| | (0.010) | (0.008) | - | - |
| Year: -1 | - | - | - | - |
| Year: 1 | $0.064^{+}$ | $0.082^{*}$ | $0.067^{+}$ | $0.080^{*}$ |
| | (0.048) | (0.044) | (0.044) | (0.043) |
| Years: 2 to 3 | $0.111^{**}$ | $0.090^{+}$ | $0.115^{***}$ | $0.089^{**}$ |
| | (0.045) | (0.056) | (0.041) | (0.045) |
| Years: 4 to 5 | 0.063 | $0.090^{+}$ | $0.066^{+}$ | $0.087^{*}$ |
| | (0.044) | (0.055) | (0.045) | (0.048) |
| Years: 5 to 6 | $0.090^{**}$ | $0.087^{+}$ | $0.094^{**}$ | $0.083^{**}$ |
| | (0.045) | (0.056) | (0.043) | (0.042) |
| Year fixed effects | yes | yes | yes | yes |
| IPW | yes | yes | yes | yes |
| RA | no | no | yes | yes |
| Lags used | 1 | 1 | 5 | 5 |
| Observations | 11,936 | 11,936 | 11,936 | 11,936 |

Notes: This table shows the estimates of the Treatment Effect framework regressions on the natural logarithm of the growth in non-employment probabilities. We use inverse probability weighting (IPW) with a probit treatment model in columns (1) and (2). Columns (3) and (4) show the coefficients of a "doubly robust" estimator (IPWRA) which combines inverse probability weighting with a probit treament model and a linear outcome model. We use lags of the outcome variable as well as period effects as explanatory variables for the treatment and outcome models. Event periods are defined relative to the year of the Census shock (e.g., $t = -1$ in 2011). Standard errors are bootstrapped and clustered on the level of regions. $^{+}$ $p < 0.15$, $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

Table 4: THE EFFECT OF THE 2011 CENSUS SHOCK ON TRANSFER AND CAPACITY GROWTH

| | Yearly Growth Transfers (1) | Cumulative Growth Transfers (2) | Yearly Growth Capacities (3) | Cumulative Growth Capacities (4) |
|---|---|---|---|---|
| $k = -7$ | -3.845 | -26.044$^{+}$ | -9.910$^{+}$ | 19.944$^{*}$ |
| | (4.295) | (15.819) | (6.253) | (10.380) |
| $k = -6$ | 0.103 | -36.836$^{**}$ | 4.418 | 23.267$^{**}$ |
| | (10.920) | (16.755) | (4.394) | (10.806) |
| $k = -5$ | 34.404$^{**}$ | 1.502 | 1.895 | 18.366$^{**}$ |
| | (16.469) | (18.939) | (8.701) | (9.318) |
| $k = -4$ | -12.928 | -13.222 | 5.502 | 24.184$^{**}$ |
| | (9.434) | (16.572) | (6.556) | (9.926) |
| $k = -3$ | 3.952 | -5.881 | -14.486$^{*}$ | 9.700 |
| | (18.904) | (6.634) | (8.684) | (8.134) |
| $k = -2$ | -6.942 | -1.711 | -1.211 | 10.602$^{*}$ |
| | (11.686) | (6.065) | (5.980) | (6.278) |
| $k = -1$ | . | . | . | . |
| $k = 0$ | 57.259$^{***}$ | 56.891$^{***}$ | 63.398$^{***}$ | 62.183$^{***}$ |
| | (11.588) | (11.570) | (7.462) | (6.115) |
| $k = 1$ | -1.615 | 46.544$^{***}$ | -1.532 | 62.232$^{***}$ |
| | (10.021) | (11.789) | (5.164) | (7.085) |
| $k = 2$ | 12.655$^{**}$ | 58.489$^{***}$ | 10.593$^{***}$ | 70.440$^{***}$ |
| | (5.313) | (11.668) | (3.736) | (7.370) |
| $k = 3$ | 3.114 | 48.253$^{**}$ | -8.783 | 57.198$^{***}$ |
| | (25.594) | (24.131) | (19.864) | (18.995) |
| $k = 4$ | 5.562 | 50.404$^{*}$ | 11.638$^{**}$ | 64.713$^{***}$ |
| | (8.048) | (26.506) | (5.082) | (22.613) |
| $k = 5$ | 6.161 | 53.652$^{*}$ | 11.740$^{**}$ | 72.050$^{***}$ |
| | (6.138) | (29.483) | (4.657) | (26.180) |
| $k = 6$ | -6.153 | 44.666 | 11.607$^{**}$ | 78.634$^{**}$ |
| | (12.047) | (37.426) | (4.451) | (29.976) |
| $k = 7$ | 6.646 | 48.681 | 10.422$^{**}$ | 85.147$^{**}$ |
| | (8.189) | (38.859) | (4.565) | (33.331) |
| Period fixed effects | yes | yes | yes | yes |
| State × Period fixed effects | yes | yes | yes | yes |
| Observations | 5,969 | 6,384 | 5,969 | 6,384 |

Notes: This table reports the effect of Census shock on fiscal transfers (columns (1)-(2)) and fiscal capacities (columns (3)-(4)) according to equation (66). Event periods are defined relative to the timing of the Census (e.g. $k = -1$ in 2011). Standard errors (in parentheses) are clustered at the level of German counties. $^{+}$ $p < 0.15$, $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

Table 5: The effect of the 2011 Census shock on (log) fiscal capacity growth

| | (Log) Yearly Growth Capacities (1) | (Log) Cumulative Growth Capacities (2) |
|---|---|---|
| $k = -7$ | -0.001 | -0.001 |
| | (0.002) | (0.002) |
| $k = -6$ | 0.002$^{*}$ | 0.000 |
| | (0.001) | (0.002) |
| $k = -5$ | 0.001 | 0.001 |
| | (0.002) | (0.002) |
| $k = -4$ | 0.001$^{*}$ | 0.002$^{+}$ |
| | (0.001) | (0.001) |
| $k = -3$ | -0.001 | 0.001 |
| | (0.001) | (0.001) |
| $k = -2$ | -0.001 | 0.001 |
| | (0.001) | (0.001) |
| $k = -1$ | . | . |
| $k = 0$ | 0.006$^{***}$ | 0.006$^{***}$ |
| | (0.001) | (0.001) |
| $k = 1$ | -0.001 | 0.005$^{***}$ |
| | (0.001) | (0.001) |
| $k = 2$ | 0.001 | 0.006$^{***}$ |
| | (0.001) | (0.001) |
| $k = 3$ | 0.001 | 0.006$^{***}$ |
| | (0.001) | (0.002) |
| $k = 4$ | 0.001$^{*}$ | 0.007$^{***}$ |
| | (0.001) | (0.002) |
| $k = 5$ | 0.001$^{**}$ | 0.008$^{***}$ |
| | (0.000) | (0.002) |
| $k = 6$ | 0.001$^{**}$ | 0.009$^{***}$ |
| | (0.000) | (0.003) |
| $k = 7$ | 0.001$^{**}$ | 0.010$^{***}$ |
| | (0.000) | (0.003) |
| Period fixed effects | yes | yes |
| State × Period fixed effects | yes | yes |
| Observations | 6,384 | 6,384 |

Notes: This table reports the effect of Census shock on fiscal capacities (columns (1)-(2)) according to equation (66). Event periods are defined relative to the timing of the Census (e.g. $k = -1$ in 2011). Standard errors (in parentheses) are clustered at the level of German counties. $^{+}$ $p < 0.15$, $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

Table 6: THE EFFECT OF THE 2011 CENSUS SHOCK ON PUBLIC GOOD PROVISION

| | Public debt (1) | Public Debt (2) | Childcare rate (3) | Nursing home places (4) |
|---|---|---|---|---|
| Post-treatment | $0.167^{***}$ | | | |
| | (0.026) | | | |
| Treated | 0.111 | | | |
| | (0.089) | | | |
| DiD | 0.087 | 0.104 | $-1.066^{**}$ | $-0.030^{**}$ |
| | (0.077) | (0.081) | (0.420) | (0.014) |
| Constant | $6.885^{***}$ | | | |
| | (0.828) | | | |
| Region fixed effects | no | yes | yes | yes |
| Year fixed effects | no | yes | yes | yes |
| State fixed effects | no | no | no | no |
| Observations | 3454 | 3454 | 3159 | 1755 |

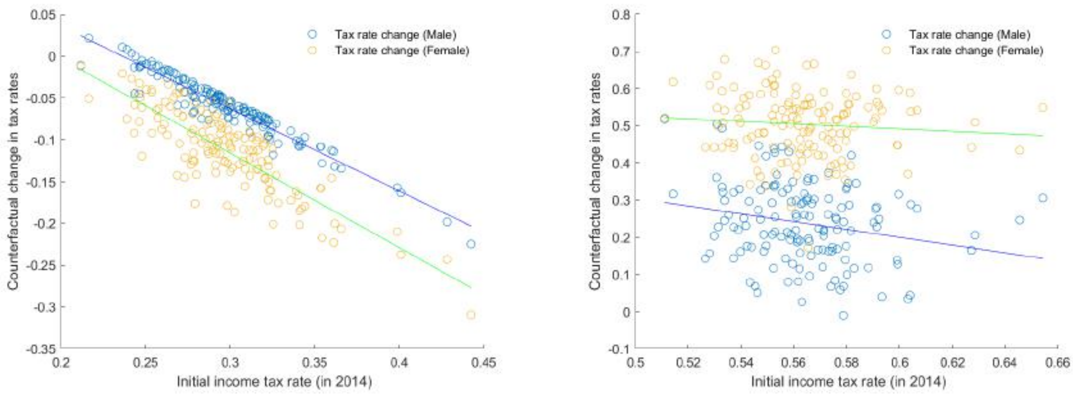
Notes: This table shows the estimates of the triple difference-in-difference regressions outlined in equation (67) on the natural logarithm of per-capita public debt (columns (1)- (2)), childcare rates (column(3)) and the natural logarithm of per-capita nursing home places (column(4)). Childcare rates are defined as the share of toddles ($<$ 3 years) in daycare institutions. For the calculation of per capita public debt and nursing home places we hold regional population counts constant at their pre-Census level in 2010.Standard errors clustered on the level of regions. Data comes from INKAR (2020). $^{+}$ $p < 0.15$, $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

## D.5 Additional Figures to illustrate optimal fiscal instruments

In sub-section D.5 we show additional graphs and maps, that highlight the spatial distribution of the optimal fiscal instruments.

**Optimal taxes** In Figure D.6 we plot observable tax rates in the year 2014 against the tax rate change induced by the implementation of optimal taxes according to the planner's policy rules (equations (48) and (49)). We observe a harmonisation of tax rates across the economy, as decreases tend to be largest in locations with high initial taxes. This holds especially true for taxes on employed workers (Panel (a)), and to lesser degree for taxes levied on non-employed workers.

Optimally-set tax rates on workers' wage income are smaller in the largest urbanised areas of the economy (Panel (a) of figure D.7), consistent with the planner's policy rule and a rural labour force participation premium (see also Figures 1 and 3 in the main paper). To induce higher labour force participation in urban areas, the planner furthermore allocates smaller non-employment benefits (that is higher taxes on non-employment workers' income) in the most populous labour markets of Germany (Panel (b)).

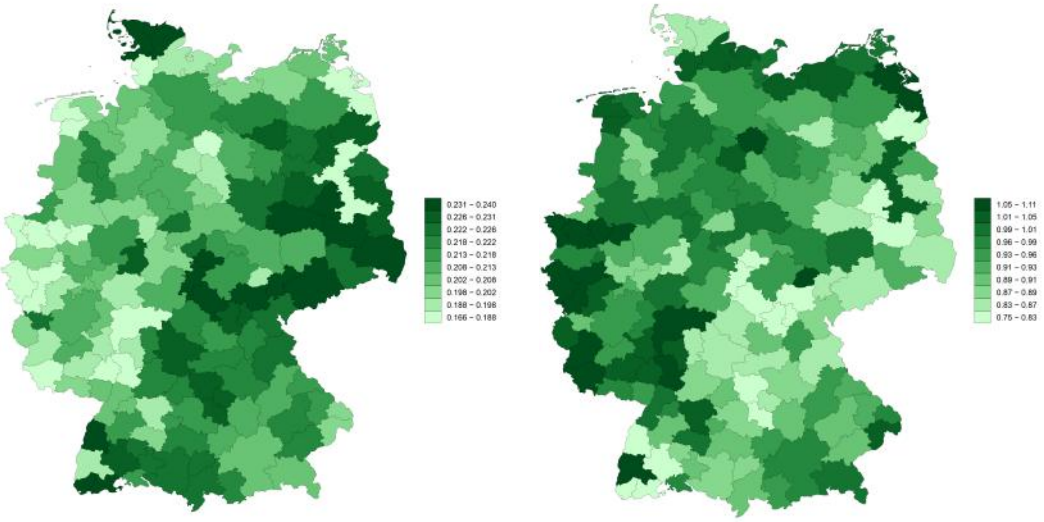



(a) Employed Workers (b) Non-employed workers

Figure D.6: Optimal taxes

*Notes:* This figure plots the local tax rates (in 2014) against the change in tax rates to the optimally-chosen rates by the social planner for employed workers (Panel (a)) as well as non-employed workers (Panel (b)). Optimal taxes are calculated according to equations (48) and (49). Given that non-employed workers only receive 62% of nominal wages initially, we calculate their tax rates as $1-0.62(1-\mathcal{T}_i)$ in the initial scenario. Tax rate changes are denoted as percentage point changes.

**Externalities** In Figure D.8 we display the spatial distribution of localized externalities. Agglomeration economies, $\tilde{w}_i$, are the aggregate effect of additional workers on other workers' productivity, along the whole distribution of firms. From equation (46) they are




(a) Employed workers (b) Non-employed workers

Figure D.7: Map of optimal taxes

*Notes:* Panel (a) displays a map of the tax rates on employed workers' income chosen by the social planner and Panel (b) maps the optimal tax rates levied on non-employed workers. Darker colours represent higher values.

determined as

$$\tilde{w}_i = \sum_{u \in M} \sum_{g \in G} \int \frac{\partial \left[\sum_{j \in J} \tau_{ji,u} \tilde{y}_{ji,u}\left(z_{i,u}\right)\right]}{\partial T^g_{i,u}} \frac{\partial T^g_{i,u}}{\partial L^g_{i,u}} d\phi(z_{i,u}) = \sum_{u \in M} \sum_{g \in G} \zeta^g \left(1 - \xi^g_{h|i,u}\right) w^g_{u|i,u} \left(\frac{L^g_{i,u}}{L_i}\right).$$

From these agglomeration benefits, we subtract the marginal effect additional workers have on the congestion of public goods to get the total size ofr localized externalities. Combining equations (45) and (53) we get

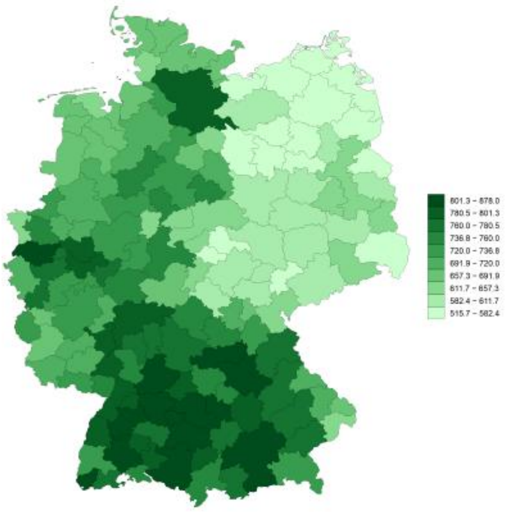
$$\frac{\partial \mathcal{W}}{\partial \left(R_i / L^{\chi}_i\right)} \frac{\partial R_i / L^{\chi}_i}{\partial L^g_{i,u}} = -\frac{\alpha}{1-\alpha} \frac{\chi}{L^g} \frac{L^g_{i,u}}{\sum_{u \in M} \sum_{g \in G} L^g_{i,u}} \sum_{i \in J} \sum_{u \in M} L^g_{i,u} P_i \sum_{s \in h,u} \xi^g_{s|i,u} C^g_{s|i,u}$$

See Online Appendix A.5.3 for technical details and derivations.

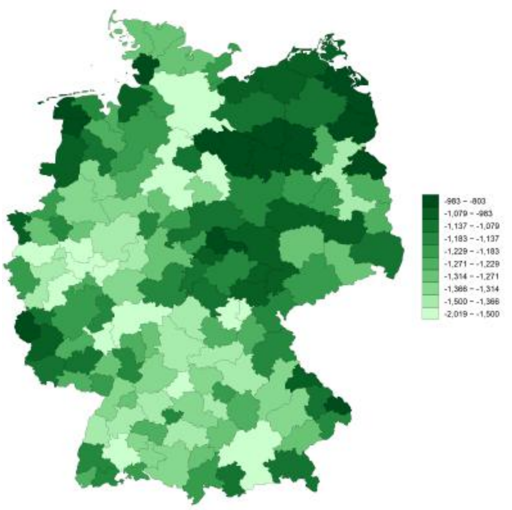
Agglomeration economies are larger in the most urbanised areas of West Germany (Panel (a)), which is also reflected in persistent wage differences between former Eastern and Western Germany (e.g. Heise & Porzio, 2022 ). Yet, net of congestion costs on public goods, this relationship reverses (Panel (b)) and even increases between initial and counterfactual equilibrium (Panel (c)).

**Optimal public goods provision** The planner (partly) reverses the existing fiscal redistribution scheme and reallocates funds into (rural) parts of West Germany where their consumption benefit is highest (see also Panel (b) of Figure 1).

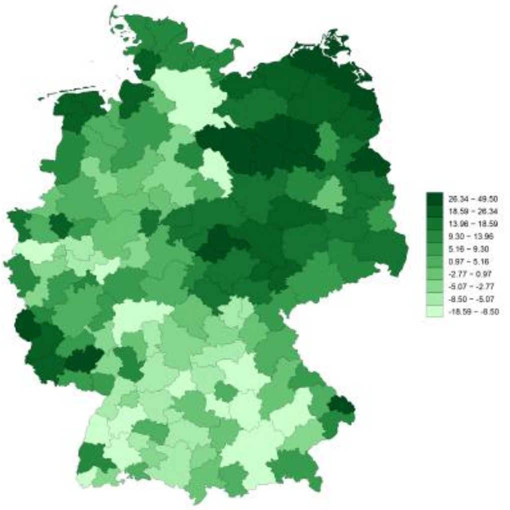
**Private versus public goods consumption** The planner's choice of policy instruments affects both private and public goods consumption possibilities. Panel (a) of Figure D.9 shows that they are, nonetheless, highly correlated. Yet, non-employment individuals in locations, which profit most significantly from increased in private and public consumption possibilities, see their income cut more strongly (Panel (b)). This creates incentives for workers to join the labour force according to equation (7).



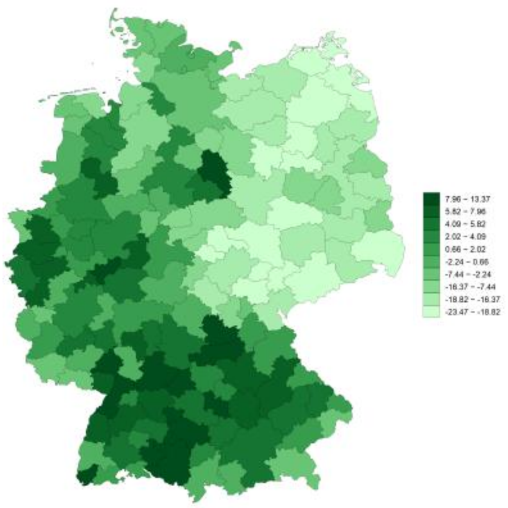

(a) Agglomeration Economies




(b) Total size of localised externalities



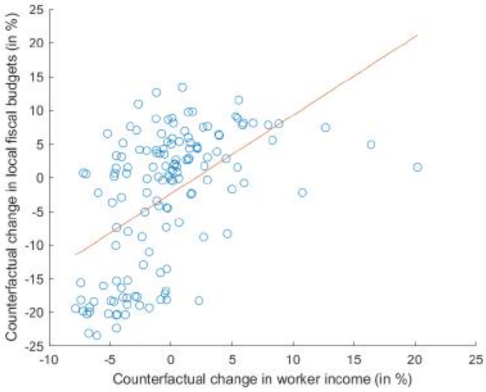

(c) Counterfactual change in localised externalities



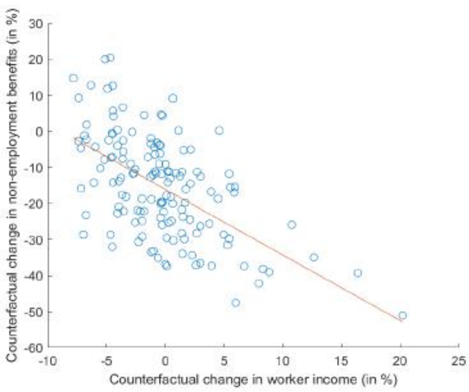

(d) Counterfactual change in local fiscal budgets

Figure D.8: Spatial distribution of localised externalities

*Notes:* Panel (a) displays a map of local agglomeration economies $\tilde{w}_i$ for the year 2014 and Panel (b) maps the total size of localized externalities (agglomeration economies, net of public good congestion) for the same year. Panel (c) displays the percentage change in localized externalities between initial and counterfactual equilibrium, while Panel (d) shows the percentage change in total fiscal budgets used for public goods provision. Darker colours represent higher values.




(a) Public goods consumption




(b) Non-employment benefits

Figure D.9: Private and public goods consumption

*Notes:* Panel (a) plots the counterfactual change in worker income against changes in fiscal budgets when optimal policies are implemented. Panel (b) plots the change in income of employed workers against changes in income of non-employed workers. Worker income under optimal policy for workers of different employment groups is defined as $I^g_{s|i,u} = \left(1 - \tilde{\mathcal{T}}^g_{s|i,u}\right) w^g_{s|i,u} + \tilde{\mathcal{S}}^g_{s|i,u}$.

## D.6 Additional Figures from the Counterfactual Analysis

In this appendix we display additional material from the counterfactual analysis.

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