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## **Impressum:**

CESifo Working Papers

ISSN 2364-1428 (electronic version)

Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH

The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute

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# On the Optimal Design of Place-Based Policies: A Structural Evaluation of EU Regional Transfers

## Abstract

We quantify general equilibrium effects of place-based policies in a multi-region framework with mobility, trade and agglomeration economies. Using detailed data on EU transfers, we infer the local effects of different transfer types on productivity, income and transportation cost. Based on these estimates and the general equilibrium model we derive the spatial distribution of economic activity and the resulting aggregate welfare effects if (i) no transfers were paid and taxes set to zero, (ii) transfers were distributed uniformly, (iii) transfers were welfare-optimally distributed. Characterizing the optimal distributions, we reveal complementarities between transfer types and between transfers and local endowments.

JEL-Codes: R100, R500, F100, F200, H200.

Keywords: economic geography, place-based policies, structural estimation subsidies, public investments, European structural funds.

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October 26, 2017

We thank David Agrawal, Gabriel Ahlfeldt, Costas Arkolakis, Fabrice Collard, David Dorn, Jordi Jofre-Monseny, Ralph Ossa and Esteban Rossi-Hansberg for their very helpful suggestions and comments. We benefited from numerous comments by participants at the CRED Seminar 2015, the Urban Economic Association's conference 2016 (Vienna), the CESifo Summer Institute 2017 (Venice), International Institute of Public Finance 2017 (Tokyo), and the Brown Bag Seminar University of Bern 2017. Support for this project from Swiss National Science Foundation with grant ref. 156186 and IMG Stiftung with grant ref. 02/2016-IMGS is gratefully acknowledged.

# 1 Introduction

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

Place-based policies cover a range of measures: The most important ones include wage subsidies, investments in local transportation infrastructure, and transfers aimed at strengthening local productivity.<sup>1</sup> In our application of EU regional policy these categories represent about 80% percent of total place-based policy expenditure. The relevance and nature of spillovers – and thus the general equilibrium effects – vary significantly across these three general types of place-based policy instruments. For instance, wage subsidies exert spillovers via market-size effects, local transportation investments have immediate consequences for the entire transportation network, and local productivity gains dissipate to non-recipient regions via the price indices of imported goods. Emphasizing the role of spillovers we identify the optimal spatial distribution of these three different transfer types and explore complementarities between transfer types as well as between transfers and local endowments.

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<sup>1</sup>We consider transfers that focus on local technological development as investments in production amenities. This includes for instance investments in local energy supply, schools or broadband telecommunication. A list of project examples financed by the EU's regional policy which we analyze in our application is documented at [http://ec.europa.eu/regional\\_policy/en/projects](http://ec.europa.eu/regional_policy/en/projects).

Our application focuses on one of the largest regional policy schemes: the European Structural & Cohesion Funds. Already since 1975 these policies are central to the process of European integration and since then the budget has grown continuously. During the budgeting period 2007 to 2013, the Structural & Cohesion Funds invested about 347.4 billion Euros in recipient regions. This accounts for approximately one third of the EU's total budget and represents 0.17% of the EU member states' total GDP (see Commission 2008). According to the Treaty on the Functioning of the European Union, the aim of the EU's regional policy is to reduce “[...] disparities between the levels of development of the various regions and the backwardness of the least favoured regions” (see Article 174, European Commission 2012) and to ensure economic progress in the member states of the EU. Hence, there is a twofold aim of reducing income inequality across regions and improving aggregate economic development. Our analysis shows that an optimal allocation of wage subsidies and investments in local production amenities could both increase efficiency and reduce disparities compared to the existing allocation. In contrast, the welfare-optimal design of transportation investments conflicts with the aim of reducing income inequality. Considering all transfer types, our analysis suggests that switching to the optimal allocation could achieve efficiency gains of about 8.36% compared to the existing scheme.

The EU recognizes the importance of spillovers and expects that “all Member States benefit from positive spillovers generated by investments in cohesion countries” (see Commission 2017). We show that partial equilibrium effects focusing on the local effects in recipient regions significantly overestimate the impact of wage subsidies and investments in production amenities. However, positive spillovers dominate for investments in transportation infrastructure.

We incorporate the main types of regional transfers into a quantitative model which captures costly inter-regional trade, factor mobility and endogenous agglomeration economies in the spirit of the new economic geography.<sup>2</sup> We fit the multi-region

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<sup>2</sup>See e.g. Baldwin et al. (2003) for an overview on the new economic geography.

model to detailed data for European NUTS2 regions and thereby recover location fundamentals reflecting regional consumption and production amenities as well as migration costs.<sup>3</sup> Our model performs well in matching empirically observed pattern across European regions. This allows to use the model structure to study the effects of different types of regional transfers on the geography of economic activity and most importantly to account for the direct cost of transfers and their spillover effects on other regions. In particular, we analyze the effects of place-based policies on aggregate efficiency and regional inequality, as measured by the Gini indices of income and population density.

We use a quasi-experimental design and detailed information about the regional distribution of EU transfers for the time period 1994-2013 jointly with data about travel times and market access to estimate the key parameters of the model. Using the estimated parameters, we solve a global optimization problem and derive the welfare optimal design of regional policy regarding the spatial distribution of transfers and across different transfer types. We compare this optimal distribution to the observed distribution as well as other counterfactual scenarios. More specifically, we show how the spatial equilibrium would change if transfers were discontinued and distributed equally according to the regional population shares.

We find that the EU place-based policy led to a positive welfare effect of 3.23% compared to a scenario without transfers. This is mainly driven by a change in the average levels of productivity and transportation costs because the existing policy does not realize the potential of distributing the investments in a welfare optimizing way. In particular, this becomes evident when comparing the current scheme to a naive rule that pays a uniform per-capita transfer to all regions. Overall, this naive rule dominates and would achieve additional efficiency gains of 0.11 percentage points but would be less effective in reducing regional inequality. Considering individual transfer types, the only instance where the current scheme is more efficient

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<sup>3</sup>Eurostat, the statistical agency of the European Union, operates a regional classification scheme (**N**omenclature des **U**nités **T**erritoriales **S**tatistiques) where NUTS2 corresponds to regional entities of 0.8m to 3m inhabitants. The current EU consists of 273 NUTS2 regions.

than the naive rule are wages subsidies. This is due to a higher marginal utility of transfers in low income regions which have been the main recipients.

The welfare optimal spatial distribution looks very different for the three transfer types: While wage subsidies should be focused on very few poor and peripheral regions, the distribution of investments in production amenities should be much less concentrated and cover regions in the core as well as in the periphery. Investments in transportation infrastructure are most efficient when focused on regions in the core of Europe. What determines how much transfers of a given type a region should receive in the welfare optimal scheme? Regarding characteristics that cannot be influenced by transfers, we show that migration costs enter negatively while a higher location attractiveness and higher supply of residential land raise the marginal welfare gain of each transfer type. Efficient investments in production amenities leverage positive spillovers on other regions such that other things equal these investments should be directed to regions with high market access. Following the same logic, investments in transportation infrastructure are most valuable when connecting highly productive places. Accordingly investments in local production amenities and local transportation infrastructure are shown to be complements. In contrast, the marginal welfare gain of wage subsidies increases in the average trade costs a region faces and decreases in its productivity. The most sizable benefit from reallocating to the optimal scheme can be realized for wage subsidies: There, the existing benefit can be tripled without an increase in regional disparities.

Below, we discuss our approach with reference to the related literature. We introduce the model in Section 3 and describe the estimation of the model parameters in Section 4. A number of counterfactual policy changes are analyzed in Section 5 and the complementarities between transfer types are explored in Section 6. Section 7 documents the importance of general equilibrium effects versus partial equilibrium effects and the last section summarizes and draws conclusions about potential reforms of regional transfers in Europe.

## 2 Literature

Our paper relates to a sizable strand of literature evaluating the effects of place-based policies (see e.g. Glaeser and Gottlieb 2008, Kline and Moretti 2014, Neumark and Simpson 2015). Boldrin and Canova (2001) initiated a number of studies focusing on place-based policies in the EU. Becker et al. (2010) address the endogeneity of transfer recipients by exploiting a discontinuity in the mechanism that determined eligibility for so-called Objective 1 transfers (the main instrument of EU regional policy) and show that the policy induced local growth and income effects beyond a simple consumption stimulus.<sup>4</sup> In order to estimate the parameters underlying the link between local characteristics and transfers we follow the quasi-experimental identification strategy by Becker et al. (2010) but apply it to outcomes that have not been studied before, i.e. measure the impact of regional transfers on local productivity amenities and transportation costs.

Most evaluations of place-based policies follow reduced-form analyses and identify the local effects in recipient regions. Hence, they mostly ignore spillovers on other regions and thus quantify only partial equilibrium effects. However, the aggregate efficiency of spatially targeted transfers depends critically on migration responses and adjustments in land rents and local prices in general (e.g. Busso et al. 2013). Migration responses and job displacement effects of place-based transfer can be substantial as documented by Einiö and Overman (2016) and Ehrlich and Seidel (2016) for regional transfers in the UK and Germany. Complex spatial interactions occur not only via relocation of households and firms but also via interregional trade and investments. For instance, an increase in local income will raise demand not only for locally produced goods but also in those regions that sustain close trade links with the transfer recipient region. Similarly, changes in productivity and transport costs will induce a reshuffling of bilateral trade shares. Accordingly, for a comprehensive evaluation of the effectiveness of place-based policies migration and trade

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<sup>4</sup>Further reduced-form evaluations of European regional policy include Midelfart-Knarvik and Overman (2002), Mohl and Hagen (2010), Pellegrini et al. (2013).



channels are relevant. Reduced-form analyses are usually not capable of identifying these interdependences. In particular as these spillovers are not constraint to neighboring regions, a structural framework is required to derive the net effect or place-based policies.<sup>5</sup>

In order to identify the general equilibrium effects of place-based policies we build upon recent work in quantitative economic-geography (e.g. Allen and Arkolakis 2014, Caliendo et al. 2016, Redding 2016, Desmet et al. 2016) and link it to data about regional transfers. The combination of model structure and quasi-experimental variation in transfer recipience allows us to identify key parameters of the model and to compute counterfactual scenarios. Hence, a key contribution of the paper is to compare the spatial equilibria that materialize under different policy schemes and to conduct welfare analyses. From a welfare perspective, a lasting impact on the spatial equilibrium is likely to dominate a policy measure's local effect on income or employment as typically identified in reduced-form analyses. Moreover, assuming that the identified parameters of the model remain constant, we can compute the effects of large-scale policy changes. The non-linearities prevalent in economic geography (both in theory and data) make it particularly relevant to go beyond marginal changes as typically obtained in empirical evaluations. Finally, we use the structural model to implement a constrained optimization approach following Su and Judd (2012) and characterize the welfare optimal design of regional transfers.

Our paper closely relates to recent contributions in the quantitative analysis of the spatial effects of public policies: Fajgelbaum et al. (2016) evaluate the degree of spatial misallocation due to taxes, Ossa (2017) analyzes welfare costs of subsidy competition in the US, and Gaubert (2017) study the effects of place-based policies on the location choice of heterogeneous firms. We deviate from these papers in a number of ways: First, we compare different channels of place-based policies

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

i.e. wage subsidies, investments in production amenities and in transport infrastructure. Second, we derive the welfare optimal distribution of different types of place-based transfers. Third, we derive the factors that determine the optimal place of investment for each type and show complementarities between different transfer types.<sup>6</sup>

Furthermore, we relate to the literature analyzing investments in transportation infrastructure. Recent papers by Alder (2016), Fajgelbaum and Schaal (2017) search for the optimal transport infrastructure network in trade models and find that investments in the core are overall beneficial. Baum-Snow et al. (2017) analyze transportation infrastructure investments in China and show that improvements in transport infrastructure can induce a loss of economic activity in the periphery. Allen and Arkolakis (2016) develop an analytical solution for how infrastructure investments between neighboring regions impact trade costs between all other region dyads. We employ this framework and highlight the interrelations between investments in local transportation infrastructure and other transfers such as wage subsidies and investments in local production amenities. Moreover, we analyze to what extent the transfer types are capable of reducing spatial inequalities and raising aggregate welfare.

### 3 Model

Our analysis builds on the framework introduced by Redding and Rossi-Hansberg (2017) featuring multiple regions, endogenous agglomeration economies, and a land market mitigating the concentration of economic activity. The economy is endowed with  $\bar{L} = \sum_n L_n$  workers in total and each worker  $L_n$  inelastically supplies one unit of labor. Every region  $n \in N$  is endowed with an exogenous quality-adjusted supply of land  $H_n$ . In equilibrium mobility of workers equalizes indirect utility up to the

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<sup>6</sup>Another related strand of literature is Albouy (2012) and Henkel et al. (2017) which consider the effects of fiscal equalization in the US and in Germany.

prevailing migration costs across regions. Trade between regions  $i$  and  $n$  is inhibited by iceberg transport cost  $d_{ni} \geq 1$ , where the first subscript refers to the place of consumption. The model allows for unbalanced trade due to regional transfers and regional imbalances in asset holdings. A central government can influence the distribution economic activity by paying regions wage subsidies or by investing in local productivity amenities and local transportation infrastructure. In equilibrium these three types of transfers are shown to exert quantitatively important spillovers on neighboring regions via trade, migration and imbalances in asset holdings. The directions of spillovers depends on the transfer type. In the following we lay out the model details and discuss how regional transfers and federal taxes are integrated.

### 3.1 Preferences and demand

Utility of an agent  $\omega$  residing in  $n$  has Cobb-Douglas form

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

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

$$G_n(b) = e^{-B_n b^{-\epsilon}}, \quad (2)$$

where the scale parameter  $B_n$  determines average amenities for location  $n$  and the shape parameter  $\epsilon$  controls the dispersion of the value of amenities across workers for each location. The composite consumption good consists of a set  $F = \sum_{n \in N} F_n$

varieties  $j$  that are aggregated according to

$$C_n = \left( \sum_{i \in N} \int_0^{F_i} c_{ni}(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \quad (3)$$

where  $\sigma = \frac{1}{1-\rho}$  refers to the elasticity of substitution. With monopolistic competition and fixed cost of production the number of varieties equals the number of firms. Maximizing (3) subject to the budget constraint delivers total demand for a variety of the differentiated good  $c_{ni}(j) = \frac{p_{ni}(j)^{-\sigma}}{P_n^{1-\sigma}} \alpha y_n L_n$  where  $y_n$  denotes region  $n$ 's per-capita income,  $L_n$  is location  $n$ 's labor force,  $P_n = \left[ \sum_{i \in N} \int_0^{F_i} p_{ni}^{1-\sigma}(j) dj \right]^{\frac{1}{1-\sigma}}$  refers to the price index and  $p_{ni} = p_i d_{ni}$  is the consumer price for a variety produced in  $i$  and consumed in region  $n$ .

Individuals are mobile across regions but face migration costs  $M_{rn}$  when migrating from  $r$  to  $n$ . These costs are measured in terms of utility such the net utility after relocation is given by  $U_n(\omega)/M_{rn}$ . To quantify the model at a fine regional scale (264 NUTS2 regions) we follow Desmet et al. (2016) and split migration cost into origin and destination specific components  $M_{rn} = o_r m_n$ .<sup>7</sup> Since individuals staying at the same place do not face these costs,  $M_{nn} = 1$ , we obtain  $m_n = \frac{1}{o_n}$ . We assume  $m_n \geq 1$  such that an individual migrating from location  $r$  to  $n$  gets a utility benefit  $o_r$  for leaving location  $r$  and pays a cost  $m_n = \frac{1}{o_n}$  for entering location  $n$ .<sup>8</sup> In the following we express everything in terms of entry costs  $m_n$ .

## 3.2 Trade Costs

Infrastructure investments represent one of the main instruments of European regional policy. Evidently these investments reduce transportation costs between two regions that are connected by a newly established or improved transportation link,

<sup>7</sup>Data on bilateral migration is not available on the regional level in Europe.

<sup>8</sup>Note that  $m_n$  may in principle also be smaller than 1 such that individuals are paid for entering region  $n$  and have to pay a fee  $o_r = 1/m_r$  for leaving region  $r$ .

say regions  $r$  and  $i$ . Moreover, these investments are expected to impact trade costs for any other region pair for which the new link is located on the least-cost path. While these groups of beneficiaries can in principle be identified, the least-cost path itself is likely to be endogenous as well which complicates the analysis.<sup>9</sup> Therefore we employ a framework recently developed by Allen and Arkolakis (2016) which assigns for a good shipped from  $r$  to  $n$  a certain probability that it passes any other region. The idea is that shipments are carried out by a continuum of traders with idiosyncratic costs of choosing different routes. Accordingly, there is a non-zero probability that shipments between two non-adjacent regions pass any transportation link. We refer to a transportation link as the direct connection between two adjacent regions  $r, i$  which incurs *direct* iceberg trade costs  $\tilde{d}_{ri}$ . For elements representing non-adjacent region pairs  $n$  and  $i$  it is assumed that  $\tilde{d}_{ni} = \infty$ . In particular, we specify direct trade costs as a function of road travel time  $TravelTime_{ri}$  between adjacent regions:

$$\tilde{d}_{ri} = e^{\beta \cdot TravelTime_{ri}}, \quad (4)$$

where  $\beta$  is estimated for European NUTS2 regions. The aggregate trade cost for shipping a good across non-adjacent locations  $r, n$  are given by the product of direct trade costs along the chosen path. We assume that path-specific trade-costs shocks occur and that traders choose the path by minimizing trade costs. In this setting Allen and Arkolakis (2016) derive the expected trade costs from  $n$  to  $i$  as:

$$d_{ni} = \Gamma\left(\frac{\theta - 1}{\theta}\right) [\mathbf{I} - \tilde{\mathbf{D}}]_{ni}^{\frac{1}{\theta}}, \quad (5)$$

where  $\theta$  denotes the shape parameter of the Fréchet distributed trade-cost shocks,  $\Gamma$  denotes the gamma distribution,  $\mathbf{I}$  is an identity matrix, and the direct iceberg trade costs enter in adjacency matrix  $\tilde{\mathbf{D}} = [\tilde{d}_{ri}^{-\theta}]$ . Due to path-specific shocks, which can also be interpreted as idiosyncratic tastes, trade between two regions can follow any route including the most indirect ones with a certain probability. However, the

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<sup>9</sup>This relates to recent papers by Alder (2016) and Fajgelbaum and Schaal (2017) which identify optimal transport networks.

probability of passing a certain link decreases with the costs of the detour that arises from the deviation from the least-cost route that would be applicable without shocks. Accordingly, a transport investment at link  $ri$  is more relevant for trade between region pairs having their least-cost route in the proximity of  $ri$  and accordingly pass the link more frequently than for those region pairs with their least-cost route being distant from link  $ri$ .<sup>10</sup> In the following we estimate the effect of transport investments on travel time between adjacent regions, which impacts direct trade costs  $\tilde{d}_{ni}$  according to (4) and affects expected trade costs between all other regions according to (5).

In summary, using a value for  $\theta > 0$  as obtained by Allen and Arkolakis (2016) and estimating  $\beta$  based on European NUTS2 data we can reproduce the effect of a local transport-time reduction at any link  $ri$  for the aggregate European transport network. Such a modification of the transport network triggered by a local investment may result in a new spatial equilibrium with substantial relocation of economic activity far beyond the one explained by the direct effect on link  $ri$ .

An alternative approach would be to specify trade costs from a gravity model as in Anderson and Yotov (2010) or Santos Silva and Tenreyro (2006) using a pseudo-maximum-likelihood (Poisson-PML) estimator. Comparing this traditional approach with our definition of trade costs yields very similar levels of trade costs as illustrated in Appendix A.1.2. Accordingly, our analysis of wage subsidies and federal investments in production amenities is independent of whether we employ a specification with endogenous least-cost path or a traditional approach. However, the former approach allows us to study the effects of federal transport investments and their interactions with the other transfers in a more comprehensive way. In particular it accounts for transport investments altering the centrality of a region i.e. changes the number of regions dyads for which trade passes along the link.

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<sup>10</sup>More details about the specification of trade costs is presented in Appendix A.1.

### 3.3 Regional Income

Regional per-capita income  $y_n$  stems from after tax wages  $w_n(1 - \tau_n)$ , per-capita subsidies  $T_n$ , rent income  $(1 - \iota_n)H_n r_n/L_n$  and per-capita payments from a global portfolio  $\chi$ . We denote the tax rate by  $\tau_n$  and the rent per unit of land by  $r_n$ . As in Caliendo et al. (2016) and Monte et al. (2016) we assume that land is owned by locals and non-locals. Hence, individuals contribute a share  $\iota_n \in [0, 1]$  of land rents to a global portfolio which redistributes rents to workers throughout the economy and yields a per-capita payment  $\chi$ . Thereby we allow for trade deficits across regions which is empirically relevant and particularly important in the context of place-based policy. For instance, regional transfers are likely to capitalize in local asset values which benefit not only local residents but any asset holders in the recipient regions. The sum of all returns from the global portfolio is redistributed equally to the regions according to their relative population size  $\chi L_n$ . Note that even with balanced asset holdings trade imbalances apply in our model due to regional transfers. However, without taking into account imbalances in asset holdings we may overestimate the effect of transfers on trade imbalances. Aggregate regional income amounts to

$$y_n L_n = w_n L_n - \tau_n w_n L_n + L_n \mu(T_n) + (1 - \iota_n) H_n r_n + \chi L_n, \quad (6)$$

where  $\mu(\cdot)$  is a flexible function that links benefits of public per-capita wage transfers  $T_n$  to income relevant returns. This accounts for efficiency costs of public budget on the spending side, which turns out to be qualitatively equivalent to introducing a distortion of labor supply. The functional form of  $\mu(\cdot)$  and details of excess burden of taxation is specified in Section 3.5. Per-capita rents accruing from the global portfolio can be expressed as  $\chi = (1/\bar{L}) \sum_{n \in N} \iota_n H_n r_n$ . The difference between the contribution to the portfolio and the revenue out of it generates imbalances in trade accounts. Regions displaying a higher value of  $\iota_n$  than the average are characterized by a trade surplus and vice versa regions with a below average value of  $\iota_n$ . Trade

balance may be stated as

$$\Upsilon_n \equiv \iota_n H_n r_n + \tau_n w_n L_n - \chi L_n - L_n \mu(T_n). \quad (7)$$

Note, that agents do not internalize the effect of their migration decisions on the local rents distributed to other agents such that  $\chi$  remains constant. Due to Cobb-Douglas utility we can express the rental rate for land as  $r_n = [(1 - \alpha)y_n L_n] / H_n$  and reformulate per-capita income as

$$y_n = \frac{1}{\alpha + \iota_n - \alpha \iota_n} [w_n(1 - \tau_n) + \mu(T_n) + \chi] \quad (8)$$

### 3.4 Production

The production side is characterized by a technology that incurs fixed costs and region specific variable costs of labor to produce a variety. Thus, producing  $x_n(j)$  units requires  $l_n(j) = \phi + \frac{x_n(j)}{a_n}$  units of labor where  $a_n$  captures regional productivity. Profit maximizing prices  $p_{ni}(j) = \frac{\sigma}{\sigma-1} \frac{d_{ni} w_i}{a_i}$  and free-entry imply that equilibrium output is identical across all firms in a region and given by  $x_n(j) = \phi(\sigma - 1)a_n$ . Since prices and output are identical across firms within region we may drop the variety identifier in the following. From the equilibrium output it is evident that the total number of firms in each region is proportional to the number of local workers:  $F_n = \frac{L_n}{\sigma\phi}$ . Accordingly, the value of trade flows from region  $i$  to  $n$  can be stated as

$$X_{ni} = \alpha y_n L_n F_i \frac{p_{ni}^{1-\sigma}}{P_n^{1-\sigma}}. \quad (9)$$

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

$$\pi_{ni} = \frac{L_i \left( \frac{d_{ni} w_i}{a_i} \right)^{1-\sigma}}{\sum_{k \in N} L_k \left( \frac{d_{nk} w_k}{a_k} \right)^{1-\sigma}}, \quad (10)$$



as well as the price index in region  $n$

$$P_n = \frac{\sigma}{(\sigma - 1)} \left( \frac{L_n}{\sigma \phi \pi_{nn}} \right)^{1/(1-\sigma)} \frac{d_{nn} w_n}{a_n}. \quad (11)$$

A key implication of introducing agglomeration forces in the tradition of the new economic geography is that the local number of varieties produced is proportional to the local population. Moreover, the elasticity of substitution governs not only the utility attached to changes in the terms of trade but also the strengths of the agglomeration forces. Other studies such Allen and Arkolakis (2014) or Desmet et al. (2016) model agglomeration forces in a more agnostic way and introduce a further parameter that links population density to local productivity.

### 3.5 Regional and Federal Government

The national governments levies labor income taxes ( $\tau_n$ ) which are transferred to the federal budget and used to finance aggregate transfers  $T_n$ . Reflecting the most important components of European regional policy, we consider effects on local wages, local technology – which increase a region’s fundamental productivity – and investments in local infrastructure – which reduce travel-time across direct links. We denote all transfers in per-capita terms. Thus, the government budget constraint is given by:

$$\sum_{n \in N} w_n L_n \tau_n = \sum_{n \in N} L_n T_n. \quad (12)$$

Taxes in our model are locally distortive in the sense that higher labor taxes make a location less attractive for labor supply, but the tax has no effect on global labor supply. In addition we introduce an efficiency cost  $\kappa^y \in [0, 1]$  of taxation and assume that a marginal increase in per-capita transfers yields an income gain of only  $0 < \kappa^y < 1$  while the rest melts away due to potential inefficiencies in the public sector.<sup>11</sup> Accordingly, we specify the income relevant wage subsidy in the

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<sup>11</sup>This functional form has the property of a constant marginal excess burden as a marginal

benchmark model as

$$\mu(T_n) = \kappa^y \cdot T_n. \quad (13)$$

Note that a higher level of tax revenues can be raised for a given tax rate in regions where nominal wages are high. The elasticity of local labor supply with regard to the taxes and transfer is highest at places with high out-migration benefits which implies low in-migration costs

We further specify that travel time  $TravelTime_{ri}(T_i, T_r, L_i, L_r)$  can be reduced by public investments in roads and railway between regions  $n$  and  $i$  according to the following function:

$$TravelTime_{ri} = \gamma_{ri}^d - \kappa^d \cdot \frac{\ln(T_r L_r + T_i L_i)}{(L_r + L_i)^\xi}. \quad (14)$$

Per-capita investments in transportation infrastructure, thus, reduces all the travel time across all direct links which feeds back on expected trade costs across adjacent and non-adjacent regions according to Section 3.2. Similarly as in Fajgelbaum et al. (2016) we argue that investments in public transportation are rival to some extent as congestion costs increase in the local number of inhabitants and accordingly a higher investment is needed for a given travel time reduction.<sup>12</sup> The parameter  $\xi$  governs the degree of rivalry of public investments. As  $\xi \rightarrow 0$  public investment becomes fully non-rival. A link specific level of travel time  $\gamma_{ri}^d$  which is applicable in a counterfactual situation without transfers is identified empirically below.

The third effect of federal investment concerns R&D activities, universities, broadband internet access, energy supply etc. which we assume to impact local productivity. Hence, we introduce public investment in local production amenities

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unit of tax revenue only allows for a constant usage of  $\kappa^y < 1$  units of per-capita wage relevant transfers. The efficiency costs are thus constant as the level of regional transfers increases.

<sup>12</sup>Related to our specification Fajgelbaum et al. (2016) accounts for varying degree of rivalry of public goods and Fajgelbaum and Schaal (2017) integrate congestion costs in transportation networks. Edwards (1990) compares different functional forms embodying congestion of public goods.

rendering regional technology endogenous:

$$a_n = \gamma_n^a + \kappa^a \cdot \frac{\ln(T_n L_n)}{L_n^\xi}. \quad (15)$$

Again a region specific level of productivity for counterfactual situation without transfers  $\gamma_n^a$  is empirically obtained using detailed data about federal transfers. In Section 4 we describe the estimation of region- and link-specific fixed effects as well as the identification of elasticities  $\kappa^a$  and  $\kappa^d$ .

### 3.6 Residential Choice

Using the above expressions for rental rate, and price index (11) we obtain real income,

$$\frac{y_n}{P_n^\alpha r_n^{1-\alpha}} = \gamma \left( \frac{a_n y_n}{d_{nn} w_n} \right)^\alpha \left( \frac{\pi_{nn}}{L_n} \right)^{\alpha/(1-\sigma)} \left( \frac{H_n}{L_n} \right)^{1-\alpha}, \quad (16)$$

where  $\gamma = \left( \frac{\sigma-1}{\sigma} \right)^\alpha (\sigma \phi)^{\frac{\alpha}{1-\sigma}} \frac{1}{1-\alpha}^{(1-\alpha)}$ .

Indirect utility of an individual migrating from  $n$  to  $i$  depends on migration costs, real income, and a stochastic amenity term at the place of destination  $V_{ni}(\omega) = \frac{b_i(\omega)}{M_{ni}} \frac{y_i}{P_i^\alpha r_i^{1-\alpha}}$ . Since amenities follow a Fréchet distribution and indirect utility is a transformation of the random amenity draw, the cumulative distribution function of indirect utility follows again a Fréchet distribution and is given by  $G_{ni}(V) = e^{-\frac{B_i}{M_{ni}^\epsilon} \left( \frac{y_i}{P_i^\alpha r_i^{1-\alpha}} \right)^\epsilon V^{-\epsilon}}$ . The probability that an individual prefers locations  $i$  over all other locations corresponds to the share of region  $n$ 's population that relocates to region  $i$ . Using the above distributions, the share of people in location  $n$  and migrating to  $i$  corresponds to

$$\frac{L_{ni}}{L_n} = Pr(V_{ni} \geq \max\{V_{nk}\}, \forall k \in N) = \frac{\frac{B_i}{M_{ni}^\epsilon} \left( \frac{y_i}{P_i^\alpha r_i^{1-\alpha}} \right)^\epsilon}{\sum_{k \in N} \frac{B_k}{M_{nk}^\epsilon} \left( \frac{y_k}{P_k^\alpha r_k^{1-\alpha}} \right)^\epsilon}. \quad (17)$$

Note that with the specification of migration costs as outlined above the conditional migration flow is independent of the place of origin. Using  $\sum_{n \in N} L_{ni} = L_i$ , substituting origin and destination specific components of migration costs and taking the sum over all places  $n$  on both sides of (17) we derive regional population shares

$$\lambda_n = \frac{\frac{B_n}{m_n^\epsilon} \left( \frac{y_n}{P_n^\alpha r_n^{1-\alpha}} \right)^\epsilon}{\sum_{k \in N} \frac{B_k}{m_k^\epsilon} \left( \frac{y_k}{P_k^\alpha r_k^{1-\alpha}} \right)^\epsilon}, \quad (18)$$

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

From the cumulative distribution  $G_{ni}(V)$  it follows that expected indirect utility of an individual originating from  $n$  and living in  $i$  is given by

$$E[V_{ni}] = E[V_n] = \delta \left[ \sum_{k \in N} \frac{B_k}{M_{nk}^\epsilon} \left( \frac{y_k}{P_k^\alpha r_k^{1-\alpha}} \right)^\epsilon \right]^{\frac{1}{\epsilon}}, \quad (19)$$

where  $\delta = \Gamma(\frac{\epsilon-1}{\epsilon})$  is a constant term and  $\Gamma()$  refers to the Gamma function. Population mobility implies that the expected indirect utility of a person – adjusted for migration costs – has to be identical across all potential destinations such that in equilibrium locations are chosen optimally. Further substituting population share (18) and imposing symmetry of the costs of entry and exit in aggregate migration costs we obtain:

$$E[V_{ni}] = \delta (B_i)^{\frac{1}{\epsilon}} \left( \frac{y_i}{P_i^\alpha r_i^{1-\alpha}} \right) \left( \frac{1}{\lambda_i} \right)^{\frac{1}{\epsilon}} \frac{1}{M_{ni}}, \quad (20)$$

As certain locations provide more utility than others, workers move to the place which provides the highest possible utility net of migration costs. Hence, an increase

in nominal wages is *ceteris paribus* accompanied by an increase in local population share. Moreover, due to agglomeration benefits larger markets pay higher wages and are characterized by a bigger variety of local goods which reflects in a lower price index for the composite good. However, an inflow of population bids up land prices, which acts as a dispersion force in the model and reduces real wages. To ensure an unique equilibrium dispersion forces must dominate agglomeration forces in equilibrium. This leads to the following parameter restriction  $\sigma \left(1 - \frac{\alpha}{1+1/\epsilon}\right) > 1$  and rules out that the whole population is located in one region.<sup>13</sup>

### 3.7 General equilibrium

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

$$w_n \lambda_n = \alpha \sum_{k \in N} \pi_{kn} \lambda_k y_k. \quad (21)$$

Labor market clearing follows from (10) and the location choice probabilities (17) jointly with real income in (16) close the model. With 264 NUTS2 regions this yields a total of 70,224 equilibrium conditions.<sup>14</sup> Based on these conditions and data for  $\{\lambda_n, w_n, y_n, H_n, d_{ni}\}$  we can recover the location fundamentals of the model  $\{a_n, \pi_{ni}, B_n/m_n^\epsilon\}$ . All other endogenous variables can be expressed in terms of the location fundamentals and the exogenous variables. Details about inverting the model to perform overidentification checks for the location fundamentals are presented in the next section. For our counterfactual analyses we do not need the level values of location attractiveness adjusted for migration costs ( $B_n/m_n^\epsilon$ ) as we apply the exact

<sup>13</sup> For a detailed discussion see Redding and Rossi-Hansberg (2017) and our equation (24).

<sup>14</sup> Our system of equation has  $264 \times 264$  bilateral trade shares according to (10) and 264 location choice probabilities (equation (17)) as well as 264 goods market clearing conditions (equation (21)) which are sum up to 70'224 equations.

hat algebra introduced by Dekle et al. (2007) to derive welfare changes.

## 4 Estimation & calibration

In this section we discuss how we set the parameters, describe the data source of exogenous variables entering the model, outline the estimation approach for  $\{d_{ni}, \iota_n\}$  and explain how we obtain the elasticities of location amenities and trade costs with regard to transfers. As it is evident from the maps in Figure 1, our data covers almost all NUTS2 regions in the EU27 countries.<sup>15</sup> The EU administers its place-based policies according to multi-annual budgeting periods. We fit the model to data for the three most recent budgeting periods 1994-1999, 2000-2006 and 2007-2013 in order to explore the validity of our model and to obtain time variation in the location fundamentals. For the analysis of counterfactuals we focus on the most recent budgeting period 2007-2013 and perform sensitivity checks for the earlier periods. In total we observe data for 264 European NUTS2 regions which were eligible for EU transfers in the most recent period. Summary statistics of all our exogenous variables are reported in Table A.2, and Figure 1 illustrates the spatial distribution of these variables.

**Regional transfers:** The EU Commission (Directorate-General for Regional and Urban Policy) provides detailed information on regional transfers for all three budgeting periods at the NUTS2 level. The data covers regional expenditures from all three sources of regional transfers, the European Regional Development Fund (ERDF), the European Social Fund (ESF) as well as for the Cohesion Fund (CF). The transfers are classified according to 12 spending categories which we assign to the respective transfer types.<sup>16</sup> We recognize that all types of transfer categories are

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<sup>15</sup>Due to missing data our analysis excludes the remote islands Madeira, Açores, Canary Islands and the French overseas territories.

<sup>16</sup>These categories are: Business support, Energy, Environment and natural resources, Human resources, IT infrastructure and services, Research and Technology, Social infrastructure, Technical assistance, Tourism & Culture, Transport infrastructure, Urban and rural regeneration.

potentially relevant for income in the recipient regions and and sometimes it is not obvious whether a certain EU investment affected primarily local productivity or transportation costs. Accordingly, in the benchmark analysis, we sum all per-capita transfers across all categories to obtain  $T_n$  and empirically identify the effects on the productivity and transportation costs channels. We perform robustness checks to show that our results are robust to assuming that only certain categories of transfers are relevant for the respective channels.

The existing distribution of EU regional transfers is far from uniform and place-based subsidies are strongly tied to regional economic development as well as political bargaining (see e.g. Charron 2016). The highest transfer intensities were observed in the Southern and Eastern periphery of the EU as shown in panel a) of Figure 1. Notably, virtually all regions received a positive transfer from the central EU government. Yet, there is a substantial variation as per-capita transfers ranged between 34 Cents and 892 Euros.

**Population shares and regional income:** Cambridge Econometrics’ European Regional Database (ERD) provides information on population, employment and per-capita income for every NUTS2 region and the whole time period 1994-2013. Since the model assumes full employment, our benchmark simulations use employment data for  $L_n$  as well as for the shares ( $\lambda_n$ ). Note that all results are robust to using population data instead. Per-capita income ( $y_n$ ) is measured at 2005 constant price euros using a sectoral price deflator. The spatial distribution of per-capita income and population shares is depicted in panels b) and c) of Figure 1.

**Residential land supply:** Information about residential land-use stems from the dataset “Ecosystem types of Europe” published by the European Environment Agency (EEA). This data provides habitat information for every 100x100m cell according to the European nature information system (EUNIS) habitat classification. For residential land-use ( $H_n$ ) we sum up all constructed, industrial and other artifi-

cial habitats for every NUTS2 region.<sup>17</sup> Regional levels of  $H_n$  are shown in panel d) of Figure 1.

**Price of land and shares to global portfolio:** We compute the price of the immobile factor – land – using the condition  $r_n = (1-\alpha)L_n y_n / H_n$  jointly with data on regional per-capita income ( $y_n$ ), population ( $L_n$ ) and residential supply of land ( $H_n$ ) as described above. For the consumer’s expenditure share in goods consumption we follow Davis and Ortalo-Magne (2011) and assume  $\alpha = 0.75$ . Note that this corresponds very well with Eurostat data about household expenditure allocated to housing.<sup>18</sup>

The trade balance is calculated by calibrating each region’s share of the immobile sector paid into the international portfolio  $\iota_n$ . We solve for  $\iota_n$  by minimizing the sum of squared errors between the observed trade balance  $\Upsilon_n^{Data}$  and the model’s trade balance as defined in (7):

$$\min_{\iota_n} (\Upsilon_n^{Data} + L_n \mu(T_n) - \tau_n w_n L_n - \iota_n H_n r_n + \chi L_n)^2. \quad (22)$$

Note that per-capita rents from the international portfolio are defined as  $\chi = \frac{\sum_{i \in N} \iota_i H_i r_i}{\sum_{n \in N} L_n}$ . Data for annual trade balance  $\Upsilon_n^{Data}$  stems from Eurostat and is only available at country level. To obtain region  $n$ ’s trade balance we weight the country’s trade balance GDP. Thus, we divide the trade balance by GDP data from Eurostat and take averages over the respective budgeting periods. To correct trade balance for imbalances in the EU fiscal and place-based policy we use information about financial contribution to the EU budget ( $\tau_n w_n L_n$ ) and revenues from the EU budget ( $L_n \mu(T_n)$ ). Figure A.2 in Appendix A depicts the high correlation of 0.994 between the data and the model’s trade balance.

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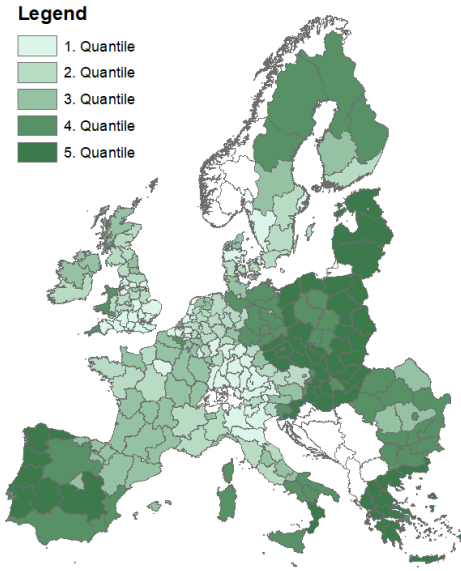
<sup>17</sup>This corresponds to the EUNIS habitat classification J which captures: Buildings of cities, towns and villages, low density buildings, extractive industrial sites, transport networks and other constructed hard-surfaced areas, highly artificial man-made waters and associated structures and waste deposits.

<sup>18</sup>According to Eurostat (2016) households in the EU spent nearly 25% of their income on housing.

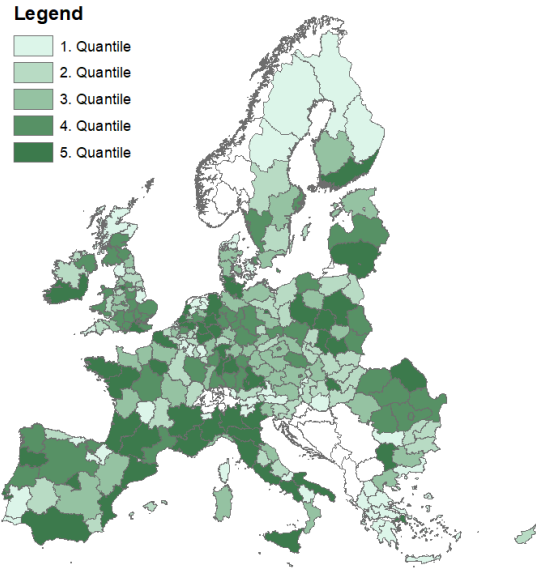


Figure 1: Overview of exogenous variables

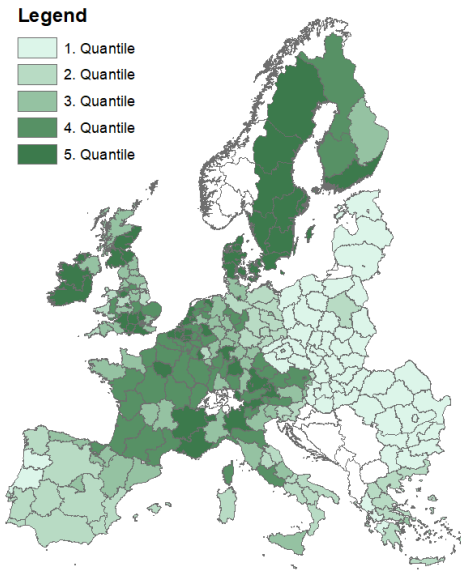
(a) Transfers per capita ( $T_n$ )



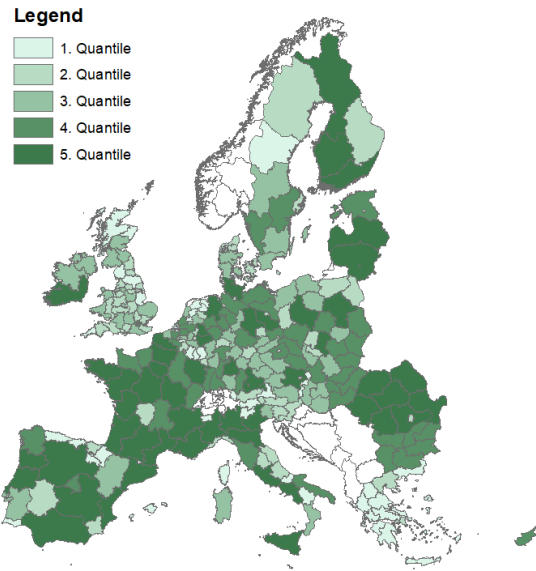
(b) Population share ( $\lambda_n$ )



(c) Regional income ( $y_n$ )



(d) Residential land supply ( $H_n$ )



Note: The figures depict quantiles of the reported variables. A darker shading in the map indicates a higher value. Data on transfers bases on the budgeting period 2007-13. Per-capita income and population shares are measured as averages over the years 2007- 13. Residential land supply refers to the year 2012.

**Wages:** We obtain region  $n$ 's wages  $w_n$  from equation (8) where we specify the income relevant wage subsidy according to (13) and set the efficiency of wage subsidies ( $\kappa^y$ ) in the benchmark analysis equal to 0.975 as suggested by Harberger (1964).<sup>19</sup> Note that welfare effects of adjusting the distributions of transfer are qualitatively not affected by the choice of the excess burden parameter.

In our main analysis we set tax rates ( $\tau_n$ ) constant across regions and thus tax revenue proportional to regional wages. This seems legitimate as the two main sources of the EU budget are proportional to local income. By far the most important part of a country's contribution to the EU budget bases on a uniform rate applied to the gross national income (GNI) of each member state. In 2012 the EU-27 countries contributed 86.8% to the EU budget according to their GNI based valuation. The second most important component refers to contributions according to a harmonised VAT of 0.3%. The value added tax contributed about 13.1% to the total budget and the remaining difference is accounted for by correction mechanisms. Accordingly, the countries' financial contributions to the EU budget relative to their income display very little heterogeneity.<sup>20</sup> Hence, in our main analysis we abstract from the relatively minor differences on the financing side to isolate the effects of place-based policies in the counterfactual analyses. The tax rate  $\tau_n = \tau$  is obtained from the government budget (12) constraint equating transfer expenditure and total tax revenue:

$$\tau \sum_{n \in N} w_n L_n = \sum_{n \in N} L_n T_n. \quad (23)$$

As a robustness check we collected information about the financial contributions to

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<sup>19</sup>The classical reference for an efficiency loss of taxation is Harberger (1964), which estimated that tax revenue decreases by 2.5% in presence of a labor income tax instead of a lump-sum tax. Feldstein (1999) argues that this is heavily underestimated and provides himself an excess burden of 30%, which we see as a lower bound. Thus, we run our simulations with values  $\kappa^y = \{0.7, 0.975\}$  and interpret the corners as high vs. low excess burden.

<sup>20</sup>Correction mechanisms have been applied for United Kingdom, Netherlands, Sweden, Denmark and Ireland. Information about specific contributions to the regional policy budget is not available, but the EU discloses countries' overall payments to the EU budget which are very similar when weighted by the countries' income. In contrast, the share of regional transfers in local GDP (at NUTS2 level) ranged from 0.0004 percent (UK, London) to 4.6 percent (Hungary, Northern Great Plain).

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

**Transportation costs:** We use equation (5) and information on  $TravelTime_{ri}$  together with parameter estimates for  $\theta$  and  $\beta$  to obtain expected transportation costs ( $d_{ni}$ ). Using GIS software we identify adjacent NUTS2 regions and compute the elements of the adjacency matrix ( $\tilde{\mathbf{D}}$ ) based on road  $TravelTime_{ri}$  between the centroids of the respective regions which is provided by the RRG Database. The latter contains detailed information on different speed limits, slope gradients, congestion etc..<sup>21</sup> The variable  $TravelTime_{ri}$  is measured in hours travelled on roads in the years 1999, 2006, and 2013 for the respective periods. By minimizing the sum of squared errors between observed freight and gravity equation (9), we estimate the factor converting travel time to trade cost  $\beta$ . For this we need data on bilateral road freight among NUTS2 regions and set parameter values for the trade elasticity  $\sigma = 5$  and heterogeneity of traders  $\theta = 136.13$ .<sup>22</sup> The former stems from the European Transport Policy Information System (ETIS) for the year 2010 and we parameterize the elasticity of substitution ( $\sigma$ ) and trade heterogeneity ( $\theta$ ) according to estimations obtained by Simonovska and Waugh (2014) and Allen and Arkolakis (2016).

The non-linear least square estimates of our gravity equation provides a value

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<sup>21</sup>Note that we assume regions maintaining a ferry connection to be adjacent in order to ensure a comprehensive transport network and trade between the EU continent and the islands. Information about ferry connections is obtained from openstreetmap.org. We exclude the following remote islands (NUTS2 codes in parentheses): Madeira (PT30), Açores (PT20), Canary Islands (ES70) and French overseas territories (FR91, FR92, FR93, FR94).

<sup>22</sup>The elasticity of substitution is within the range of accepted parameter values in the trade literature and equivalent to Redding and Rossi-Hansberg (2017). Simonovska and Waugh (2014) estimated a trade elasticity of  $-4$  which yields  $\sigma = 5$ . Desmet et al. (2016) and Redding and Rossi-Hansberg (2017) consider trade across countries and use  $\sigma = 4$  as estimated by Bernard et al. (2003) on the basis of plant-level data in the U.S. manufacturing sector. In contrast, Allen and Arkolakis (2014) focus on trade within a country and use  $\sigma = 9$ . Evidence on the trader's heterogeneity  $\theta$  is scarce and only estimates of Allen and Arkolakis (2016) exists.

of  $\beta = 0.068$ . Figure A.1 in the appendix depicts a strong correlation of -0.709 between demeaned freight data and trade costs with estimated  $\beta$ .<sup>23</sup> Our estimate is slightly higher compared to the results of Allen and Arkolakis (2016) which likely due differences in the institutions and geography of our setting. First, trade and geographic barriers might be higher compared to the US which would result in a higher factor converting travel time to trade costs. Second, transportation links are much shorter for NUTS2 regions than for major cities located at the US Interstate Highway System in Allen and Arkolakis (2016). We refer to our Section A.1.1 in the appendix for a more detailed discussion of the estimation of  $\beta$ .

**Location fundamentals:** Equations (10), (16), (17), and (21) characterize the equilibrium. We substitute the data described above, set the Fréchet parameter of idiosyncratic location tastes to  $\epsilon = 3$  and invert the model to recover the location fundamental of the model  $\{a_n, \pi_{ni}, B_n/m_n^\epsilon\}$ . The latter parameterization is in accordance with Bryan and Morten (2015) and Redding and Rossi-Hansberg (2017). Finally, in order to separate local amenities from migration costs, we use information about local life satisfaction provided by the OECD. Note that the counterfactual simulations are independent from the quantification of life satisfaction as this data is only used to disentangle the role of migration costs from local consumption amenities. A detailed discussion of the derivation of location fundamentals and data sources is presented in Appendix A.4 and A.5.

**Transfer elasticity of production amenities and travel time:** We estimate transfer elasticities based on fixed effects regressions and a regression discontinuity design. In the latter case we exploit the fact that a substantial share of regional transfers (Objective 1 transfers) are paid according to an allocation rule that gives rise to a discontinuity: Regions are eligible for the highest transfer intensity if their per-capita GDP falls below 75% of the EU average in some well defined years prior to the respective budgeting period (see Becker et al. 2010). We estimate these

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<sup>23</sup>We demean both variables to absorb importer and exporter fixed effects as shown in gravity equation (9).

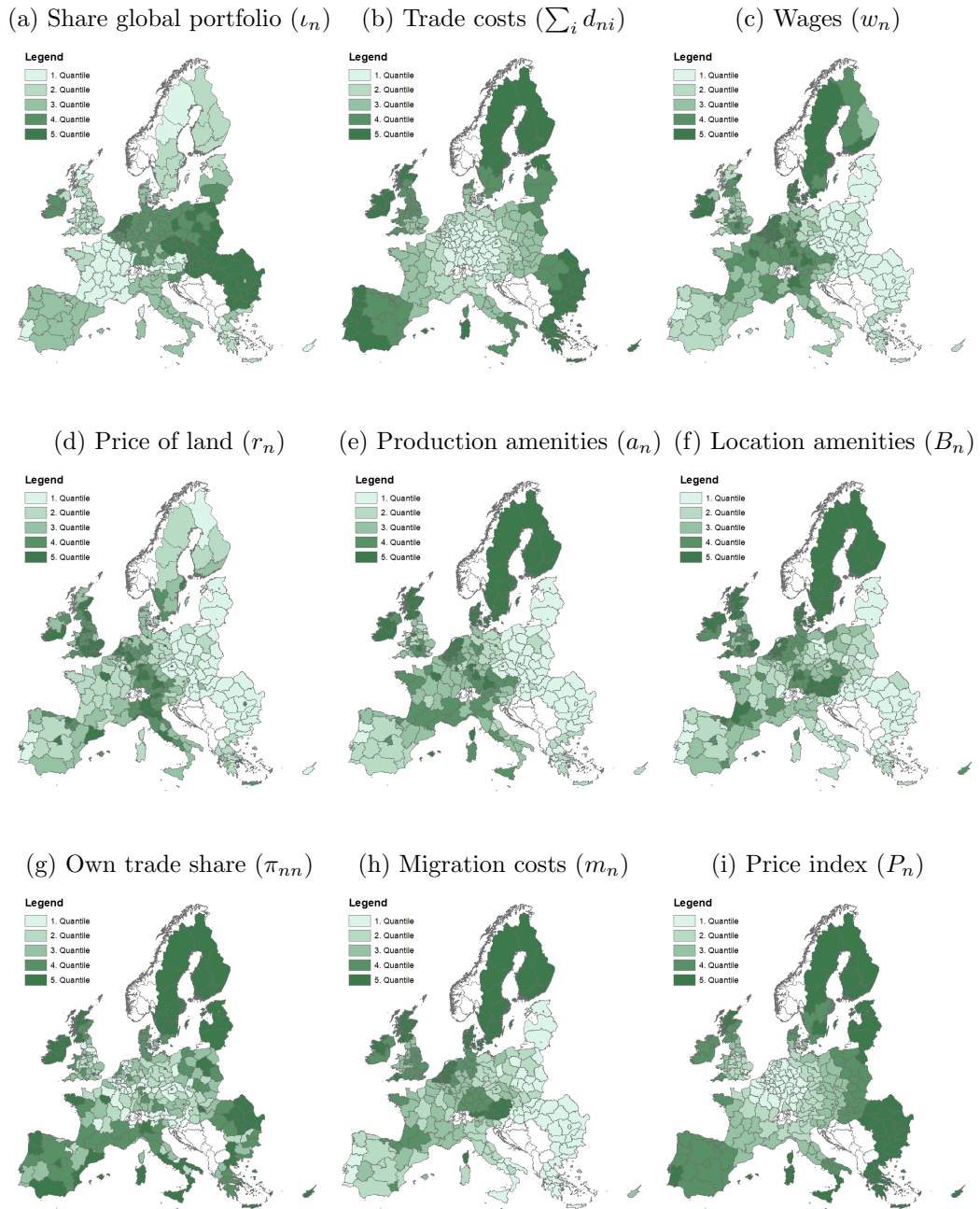
elasticities based on data for all three budgeting periods. Accordingly, we recover regions' production amenities for 1993-99, 1999-06, 2007-13 separately and estimate  $\kappa^a$  based on the pooled data. This allows us to exploit changes in transfer intensities over time in addition to the cross-sectional variation and improve the causal identification of the transfer elasticities. Note that when considering periods prior to 2007-13 we set tax rates to zero for observations that were then not a member of the EU. In the benchmark specification we assume full rivalry of public investments in production amenities,  $\xi = 1$ . In contrast, for the transfer elasticity of transport costs we use non-rivalry ( $\xi = 0$ ) as the benchmark. We choose these two corner cases as per-capita transfers are mostly relevant for production enhancing capital investments which tend to be rival, whereas newly built transport infrastructure reduces the costs of transportation independently of the number of users as long as a certain threshold of usage is not reached. While we cannot directly test these assumption, we estimate the elasticities  $\kappa^a$  and  $\kappa^d$  for varying values of  $\xi \in \{0, \dots, 1\}$  and perform model selection based on the Akaike information criterion which supports our assumptions. The benchmark results for the estimates of both transfer elasticities are displayed in Table A.1 in Appendix A. It is evident that higher regional transfer intensities increase production amenities and decrease road travel time. For our quantitative analysis we employ the benchmark estimates of the fixed-effects model and set  $\kappa^a = 0.763$  and  $\kappa^d = 0.00605$ .<sup>24</sup>

An overview of our recovered variables is depicted in Figure 2. A number of observations stand out: First, wages are lowest in the east and south of Europe, whereas production amenities are highest in the core, also in Scandinavia and generally in cities. Second, land rents are evidently highest in cities and tend to be relatively high in the UK, northern Italy and southern Germany compared to areas with low land prices in Central and Eastern Europe. Third, Germany and Eastern Europe display a high share of contributions to the global portfolio indicating a trade surplus while low shares of global investments in Greece and Portugal result in

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<sup>24</sup>Note that these elasticities for production amenities and travel time are not directly comparable with prior estimates in the literature focusing on aggregate GDP or employment.

Figure 2: Overview of estimated and recovered variables



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

a trade deficit. Fourth, migration entry costs are highest in the Netherlands, Scandinavia, Austria, and parts of Germany whereas workers find it relatively easy to emigrate to the South and East of Europe. Fifth, the price index strongly correlates with the geographical market access as measured by the sum of trade costs. These patterns are well in line with stylized facts about economic geography in Europe and suggest that the model performs well in matching the distribution of economic activity.

Table 1 provides information on all parameters entering our Model. For parameters that we cannot estimate based on our data we refer to conventional values from the existing literature. Note that we perform numerous sensitivity checks running our simulations with different parameter constellations and conclude that our qualitative results are robust to the choice of parameters within the usual range reported in the literature.

Table 1: Estimation and calibration of parameters

Description	Par.	Value	Reference
Efficiency of wage subsidies	$\kappa^y$	{0.7, 0.975}	Harberger (1964), Feldstein (1999)
Elasticity of prod. amenities	$\kappa^a$	0.397	own estimation
Elasticity of transport infrastructure	$\kappa^d$	0.006	own estimation
Rivalry of public investment	$\xi$	{0,1}	-
Share of consumption expenditure	$\alpha$	0.75	Davis and Ortalo-Magne (2011)
Elasticity of substitution	$\sigma$	5	Simonovska and Waugh (2014)
Heterogeneity of preferences	$\epsilon$	3	Monte et al. (2016)
Factor converting $TT_{ri}$ to $\tilde{a}_{ri}$	$\beta$	0.068	own estimation
Heterogeneity of traders	$\theta$	136.13	Allen and Arkolakis (2016)

The table reports estimated and calibrated parameters entering our model. Values specified in curly brackets are assumed to be lower or upper bounds.

## 5 Simulation and counterfactual analysis

We use the equilibrium system to undertake model based counterfactual analyses of EU regional policy.<sup>25</sup> We derive counterfactual changes in wages, trade shares and

<sup>25</sup>The equilibrium is characterized by (10), (16), (17), and (21).

population shares which provide – jointly with direct effects of transfers on productivity and income – sufficient statistics of the welfare effects of regional policy. A counterfactual change is denoted as  $\hat{x} = \frac{x'}{x}$ , where  $x$  is the observed variable and  $x'$  is the unobserved counterfactual value of  $x$ . We discuss counterfactual simulations where transfers enter in three ways. First, transfers influence the equilibrium via nominal wage subsidies raising income ( $\hat{y}_n$ ). Second, transfers impact transportation costs and thereby alter trade costs ( $\hat{d}_{ni}$ ) and regions' market access. Third, investments in production amenities yield a shift in production amenities ( $\hat{a}_n$ ) which reduce prices of varieties produced in recipient regions. According to expected utility equation (20) the change in welfare across regions is given by:

$$\widehat{E[V]} = \left( \frac{1}{\hat{\pi}_{nn}} \right)^{\frac{\alpha}{\sigma-1}} \left( \frac{\hat{y}_n \hat{a}_n}{\hat{w}_n \hat{d}_{nn}} \right)^{\alpha} \left( \hat{\lambda}_n \right)^{\frac{\alpha}{\sigma-1} - (1-\alpha) - \frac{1}{\epsilon}}. \quad (24)$$

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

We isolate effects of different transfer mechanisms by studying three counterfactual situations: First, we analyze the effect of abandoning EU regional transfers altogether and set the corresponding tax rates to zero. The resulting outcome provides a welfare measure of EU regional policy. In a second counterfactual analysis we show how the spatial equilibrium would change if per-capita transfers were distributed equally. In this case, the level of transfers is comparable to the observed one and deviations in welfare are attributed to the unequal distribution of transfers across regions. Hence, this counterfactual provides a measurement of how efficiently the EU distributes transfers compared to a naive rule that gives everybody the same. Third, we derive the optimal allocation of transfers for each type of transfer separately as well as for the sum of transfer channels. This allows us to quantify potential efficiency gains from redistribution and to derive the factors that render



a type of transfer efficient in some regions and inefficient in others. In all our simulations we keep tax rates constant such that the optimality criterion focuses on the distribution and design of transfers rather than the size of the program. Before we discuss the counterfactual experiments in detail it is instructive to analyze the marginal welfare effects of different transfer types across regions.

## 5.1 Marginal welfare effects of transfers

We decompose the marginal welfare effects of transfers in four components: the direct effect of transfers, the price index effect through adjustment in wages and the effects via changes in own trade shares and local population shares. Totally differentiating expected welfare ( $E[V]$ ) with respect to transfers illustrates the weights put on these components:

$$\begin{aligned}
d \ln E[V_n] = & -\frac{\alpha}{\sigma-1} \underbrace{d \ln \pi_{nn}}_{\substack{\text{Adjustment} \\ \text{own trade share}}} + \alpha \underbrace{(d \ln y_n + d \ln a_n - d \ln d_{nn})}_{\text{Direct effects}} - \alpha \underbrace{d \ln w_n}_{\substack{\text{Price index} \\ \text{effect}}} \\
& + \left( \underbrace{\frac{\alpha}{\sigma-1}}_{\substack{\text{Agglomeration} \\ \text{force}}} - \underbrace{(1-\alpha)}_{\substack{\text{Dispersion} \\ \text{force}}} - \underbrace{\frac{1}{\epsilon}}_{\substack{\text{Taste} \\ \text{heterogeneity}}} \right) \underbrace{d \ln \lambda_n}_{\substack{\text{Change in} \\ \text{population}}} .
\end{aligned} \tag{25}$$

The first welfare implication is common across a wide range of trade models and is due to changes in terms of trade which result in adjustments in own trade share as described in Arkolakis et al. (2012). Transfers affect local prices leading to a deterioration in terms of trade. This effect on welfare increases with the weight people put on consumption of the composite good (higher  $\alpha$ ) and decreases with the substitutability of foreign goods by local varieties (higher  $\sigma$ ).

Second, direct effects of transfers are unambiguously positive as they raise local income, productivity or reduce local trade costs. This part of the marginal welfare effect is characterized by decreasing marginal returns of transfers which is reflected in the fact that percentage changes of per-capita income, productivity or trade costs

enter the equation. For instance, a unit increase of transfers results in a higher percentage gain in local income if the prevailing income level is low. Similarly, regions contributing a high share of the local rent income to the global portfolio display a smaller direct effect of transfers because a share  $\iota_n$  of the increase in land values will be passed over to residents of other regions.

Third, as local income increases, local production expands, pays higher wages which in turn translates into increases in the price index of this region. Thus, this negatively affects welfare as local goods become relatively more expensive. This negative effect amplifies with the weight people assign to the composite consumption good (high  $\alpha$ ).

Fourth, changes in population affect welfare through agglomeration forces, dispersion forces and heterogeneity of location tastes. As population concentrates in a location the measure of local varieties expands which in the presence of trade costs makes the location more attractive. The effect attenuates the lower the elasticity of substitution (low  $\sigma$ ) and it amplifies the higher the weight on the composite consumption good (high  $\alpha$ ). A population inflow in a location is accompanied by an increase in land prices which in turn leads to less housing consumption. This effect on welfare is amplified the higher people weight the non-tradable housing good (low  $\alpha$ ). If workers have relatively heterogeneous tastes for regions (low  $\epsilon$ ) it is more likely that a large fraction of the individuals entering the regions have a low amenity draw and therefore face a reduction in indirect utility. In the extreme case with homogeneous tastes ( $\epsilon \rightarrow \infty$ ) there are no costs in terms of amenity mismatch. In accordance with the literature on quantitative economic geography we restrict the parameter space to ensure that the agglomeration force is dominated by the dispersion forces i.e. that the last channel is always negative.<sup>26</sup>

In the following we conduct simulation experiments to quantify the spatial distribution of marginal welfare effects for each type of transfer. In particular we shock every region separately with a marginal transfer unit and obtain welfare changes

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<sup>26</sup>As discussed in Section 3.6 this implies  $\frac{\alpha}{\sigma-1} < (1-\alpha) + \frac{1}{\epsilon}$ .

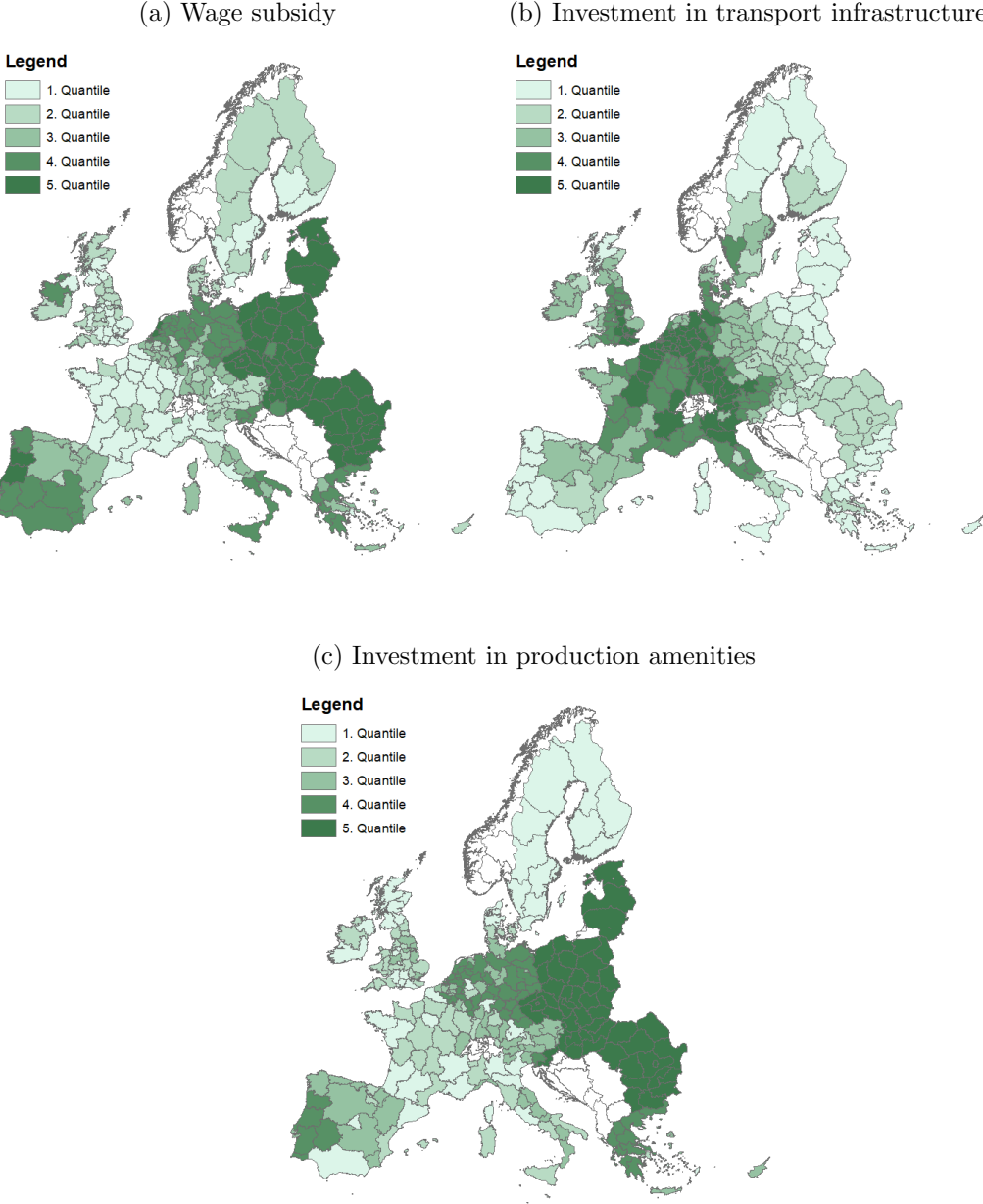
relative to the situation without transfers. The government budget necessary for this experiment is negligible and we ensure that the relative per-capita tax burden remains constant across regions. To isolate the marginal utility gain by transfer type we eliminate the potential responses of the respective other transfer types by alternately setting two out of the three transfer elasticity parameters ( $\kappa^y$ ,  $\kappa^a$ ,  $\kappa^d$ ) to zero.

Figure 3 illustrates the heterogenous distribution of welfare changes for the three transfer types and reveals the characteristics that determine the utility gain from transfers. In panel a) we consider wage subsidies and observe a strong positive effect on welfare in peripheral and relatively poor regions. Overall, the welfare change of a wage subsidy is highest in Eastern European regions and lowest for French, British and Nordic regions. In contrast, in panel b) it is evident that investments in transportation infrastructure are most effective in the core. Panel c) displays the effectiveness of investments in production amenities and shows a mixed pattern of local marginal welfare effects. In this case some relatively poor regions but also some central regions exhibit high welfare gains. This reflects the fact that the marginal gain from an investment in production amenities is higher at low productivity places but positive spillovers via the price index are more pronounced in central regions. While this analysis is providing first insights into the optimal distribution of transfers, non-linearities in the model may imply that a mechanism allocating transfers sequentially to the region that just exhibits the highest marginal welfare gain may not necessarily deliver the welfare optimal distribution.

## 5.2 No-transfer scenario

Next, we evaluate the welfare effects in a no-transfer scenario which would apply if the European Union abandoned it's place-based policy scheme all together. Hence, we set both transfers and tax rates to zero. Figure B.1 in the Appendix illustrates the changes in the four components of the marginal welfare effect as derived in equation (25). Expectedly, we find that productivity and income losses would be

Figure 3: Marginal welfare effect of transfers



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

most pronounced in Southern and Eastern Europe where the per-capita transfers are the highest. In contrast the change in transportation costs due to suspending transfers would be most pronounced in the Benelux countries, England, and some parts of Germany and Austria. These direct effects would translate into changes in wages, own trade shares and population shares. In particular, our simulation suggests that substantially more workers would relocate from Southern and Eastern European regions to the Center and North of Europe. Overall, our model predicts for the ten countries with the highest net emigration that they would lose about 7% of their population when moving from the observed equilibrium to a situation without transfers.<sup>27</sup> At the same time average nominal per-capita income in the considered regions of these ten countries would be about 4% lower than in the observed equilibrium. Accordingly, our findings suggest that EU regional transfers were quite effective in reducing migration from new member states in the East to the center. On average, abolishing transfers would also significantly reduce trade and increases own trade shares by 5 percentage points. Summing up over all welfare components we find that this policy change would yield a significant welfare loss compared to the observed distribution of transfers.

How did the individual types of transfers contribute to the welfare gain and the reduction in inequality compared to a non-transfer scenario? In Table 2 we summarize the effects of individual transfer types on welfare and regional inequality as measured by Gini indices. Panel a) isolates the wage subsidies as a mechanism of regional transfers, panels b) and c) isolate the effects via production amenity gains and changes in transportation costs while panel d) considers all three transfer channels simultaneously. In columns (2) we report the change in welfare and inequality obtained with the observed spatial distribution of transfers relative to the counterfactual without transfers. Assuming that productivity and transportation costs remain unaffected by transfers, we find that the observed distribution of transfers raised welfare by 0.15%. Reductions in regional inequality concern the second ob-

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<sup>27</sup>These countries are BG, RO, MT, HU, LV, EE, SK, CZ, GR, PL. The share of population of these 10 countries in the total European population is currently about 9.5%.

jective of regional policy. In this regard it turns out that the observed distribution of wage subsidies has in fact reduced inequality in terms of population distribution, nominal income and wages as well as real income.

Analogously, assuming that the only direct effect of transfers is to raise local productivity, we find that the welfare gain due to the observed allocation of transfers amounts to 1.20%. A significant reduction in inequality is obtained as the production enhancing effects of transfers are concentrated in the periphery.

Finally, panel c) of Table 2 isolates the effects of transport infrastructure investments. Transport infrastructure represents not only a major part of expenditure but also contributed to the largest welfare gain which amounts to about 1.52%.<sup>28</sup> However, transportation infrastructure investments have increased regional inequality in terms of nominal and real income compared to the counterfactual without transfers while they have decreased inequality in the population distribution. The reason is that observed transportation investments were primarily directed to cities in the poor and peripheral countries. Accordingly, dispersion in population distribution was reduced as less cross-country emigration from South and Eastern European countries occurred as a result of the transfers. Neglecting productivity and direct income effects, these transfers have increased income inequality within countries as some more accessible regions have gained disproportionately.

Considering the total effect of transfers via all three channels (panel d) of Table 2) we obtain a welfare increase of about 3% and an unambiguous reduction in regional inequality compared to the no-transfer scenario.

### 5.3 Uniform distribution of transfers

Another natural candidate for a policy experiment is to fix tax rates and distribute the government budget uniformly across regions. This naive distribution allows

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<sup>28</sup>In the programming period considered, investments in transport infrastructure amounted to about 14% of total expenditure.

Table 2: Welfare and inequality effects of transfers

	(a) Wage subsidies			(b) Production amenities		
	Equal (1)	Observed (2)	Optimal (3)	Equal (1)	Observed (2)	Optimal (3)
Welfare ( $\widehat{V}_n$ )	0.05%	0.15%	0.45%	1.23%	1.20%	1.26%
$\widehat{Gini}(L_n)$	-0.12%	-0.48%	-0.43%	-2.35%	-2.40%	-2.49%
$\widehat{Gini}(y_n)$	-0.36%	-1.46%	-1.66%	-3.19%	-3.48%	-3.37%
$\widehat{Gini}(w_n)$	-0.11%	-0.37%	-0.81%	-3.57%	-3.86%	-3.78%
$\widehat{Gini}(y_n/P_n^\alpha r_n^{1-\alpha})$	-0.16%	-0.66%	-0.68%	-1.55%	-1.71%	-1.65%
	(c) Transportation infrastructure			(d) All transfers		
	Equal (1)	Observed (2)	Optimal (3)	Equal (1)	Observed (2)	Optimal (3)
Welfare ( $\widehat{V}_n$ )	1.68%	1.52%	1.72%	3.34%	3.23%	3.50%
$\widehat{Gini}(L_n)$	-0.31%	-0.34%	-0.32%	-2.69%	-3.03%	-2.89%
$\widehat{Gini}(y_n)$	0.27%	0.16%	0.30%	-3.21%	-4.55%	-3.96%
$\widehat{Gini}(w_n)$	0.40%	0.27%	0.44%	-3.24%	-3.84%	-3.58%
$\widehat{Gini}(y_n/P_n^\alpha r_n^{1-\alpha})$	0.21%	0.08%	0.27%	-1.45%	-2.16%	-1.75%

The table compares outcomes relative to the no transfer equilibrium. Columns 1 refer to an equal distribution of per-capita transfers, columns 2 refer to the observed distribution of transfers, and columns 3 refer to the optimal distribution of total transfers (panel d) and individual transfer types (panels a, b, c). Panel a) considers transfer effects only via wage subsidies, panel b) considers transfer effects only via production amenities and panel c) considers only effects via investments in transport infrastructure. The first line shows the welfare changes in general equilibrium. Lines 2 to 5 show the changes in regional inequality as measured by the Gini indices. In all counterfactual experiments we keep the tax rates constant at the observed level.

us to isolate the welfare implications of the regional distribution of transfers while keeping the level of taxes and thus regional policy interventions constant. While we are confident to identify the causal effect of transfers on the level of production amenities and travel time based on our quasi-experimental design, we have no empirical information about the distortions that arise from raising the budget. Thus, we assume a constant marginal excess burden of taxation in accordance with previous literature (see Section 4). Accordingly, we stress in our analysis to compare the quantitative implications of different distributions of transfers and put less weight on the interpretation of the welfare effect obtained for different levels of transfers.

We focus on a long-run equilibrium where government spending and expenditures have to be balanced. Even though tax rates remain constant at the observed level in this experiment, the total transfer budget may differ somewhat between the observed and equal distribution of transfers. This happens since changes in population and wages influence tax payments to the government budget. An alternative approach that yields similar results would be to fix the budget and adjust the tax rates accordingly. The counterfactual changes in local outcomes of this experiment are depicted in Figure B.2 in the Appendix and the consequences for welfare and regional inequality are reported in column (1) of Table 2.

Moving from the observed to a uniform distribution of transfers, our model again predicts significant immigration from Eastern and Southern European countries to the Core and Northern parts of Europe. Yet, the migration response would be less pronounced than in the case without transfers as the ten countries with the highest emigration would lose only about 2% of their population compared to the observed equilibrium. The reduction in nominal per-capita income across regions in these countries would be about 2.1% compared to the observed equilibrium. From an aggregate welfare perspective the naive policy scheme dominates the observed one. By summing up all welfare components we estimate an increase in welfare of about 3.4% when moving from the observed to a uniform distribution of transfers (see panel d) of Table 2). This increase in welfare is obtained via production increases and



reductions in transportation costs. A uniform per-capita distribution of transfers would allocate more funds to the center and thereby reach an increase in welfare of 0.16 percentage points via the trade costs channel (see panel c) of Table 2) and a small increase of 0.03 percentage points via the productivity channel (see panel b) of Table 2). Only with regard to wage subsidies the existing distribution is more efficient than a uniform distribution as is evident from panel a) of Table 2. Overall, the comparison of columns (1) and (2) in Table 2 illustrates that the existing distribution goes further in reducing regional inequalities than an equal distribution but at the costs of lower efficiency. Hence, we conclude that the distribution of transfers in the EU is overall less efficient than a naive approach that distributes transfers equally across Europe while it reaches significantly lower inequality. From a policy makers point of view the crucial question is whether there are efficiency gains to be reached without compromising on the degree of regional cohesion.

## 5.4 Optimal distribution of transfers

In this section we derive the welfare optimal distribution of transfers and reveal further welfare gains compared to the existing allocation of transfers. We refrain from computing the optimal size of the transfer budget as this would be an immediate consequence of our assumption about the efficiency parameter of transfers  $\kappa^y$  which cannot be identified empirically with the data at hand.

The distribution of the marginal welfare effects presented in Section 5.1 already reveal some general pattern of an optimal distribution, but non-linearities in the model urge us to use a solver searching for the global solution. To maximize aggregate welfare we use a “Mathematical Programming With Equilibrium Constraints” (MPEC) approach as introduced by Su and Judd (2012) and applied by Ossa (2014) and Ossa (2017) for optimal tariffs and subsidies. This numerical optimization routine maximizes regions’ welfare and uses the model’s equilibrium equations as constraints. For a detailed documentation of our numerical optimization approach we refer to Section C in the appendix.

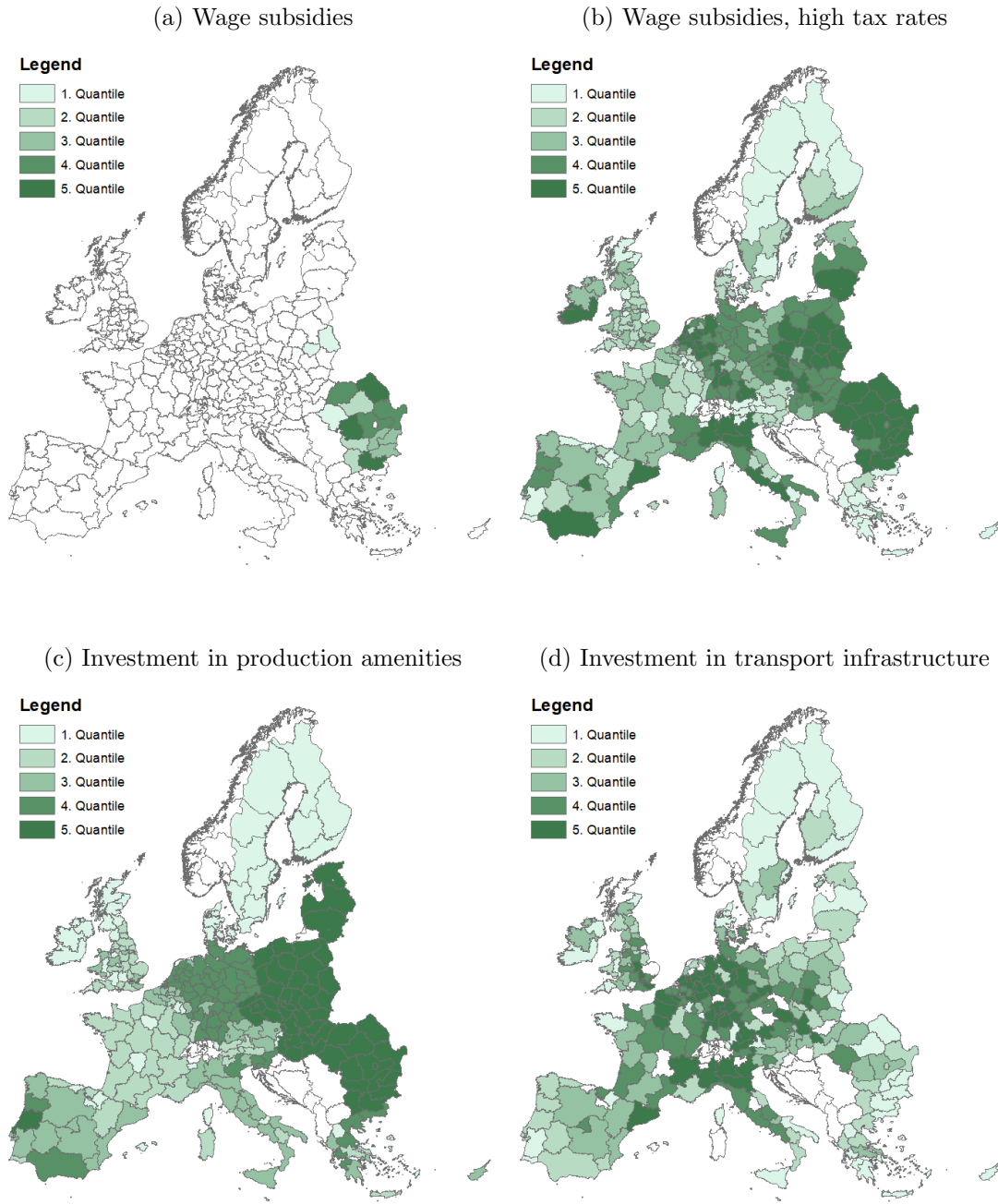
We derive the optimal distributions of transfers for each type separately and report the corresponding optimal welfare changes and impacts on regional inequality in columns (3) of Table 2. Figure 4 shows the share of the total transfer budget a regions should receive according to the welfare optimizing algorithm. From panel a) it is evident that the optimal distribution of wage subsidies deviates significantly from the observed one (see Figure 1). In particular, the welfare optimal policy issues transfers to only a few regions in Eastern Europe while cutting subsidies in most other recipient regions. A redistribution of wage subsidies according to our optimal allocation yields a welfare gain of 0.45% compared to the no-transfer scenario which is three times the gain achieved by the observed distribution. Importantly, the efficiency gain can be achieved at an even lower degree of regional inequality in terms of (real) income and population density. Focusing on transfers that operate via wage subsidies to a small set of regions allows for an unambiguous welfare increase without compromising regional inequality. Note that an increase in the budget would clearly expand the number of recipient regions according to the welfare optimal policy. For instance, we show in panel b) the resulting distribution that would apply if we drastically increase tax rates by a factor of 50. In this case almost all regions would receive some transfers but the optimal transfer intensity would still be the highest in the periphery.

The optimal distribution of investments in transportation infrastructure is presented in panel d) and indicates a very different pattern. The highest shares of the transfer budget are allocated to central regions in northern Italy, the Benelux countries, Germany, and France. In order to maximize aggregate welfare, a transfer scheme focusing on transport costs reductions exert the most significant spillover effects at central places. This implies a substantial reallocation of transfers compared to the current scheme: The correlation coefficient between the regional distribution according to the optimal scheme and the one of observed transfers under the official heading ‘Transport infrastructure’ is only 0.13.<sup>29</sup> Such a reallocation could

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<sup>29</sup>Comparisons with the distributions of other transfers types yield similar correlations: 0.11 for total transfers; 0.11 for wage subsidies; 0.4 for investments in production amenities.

Figure 4: Optimal distribution of transfers



Note: Panel a) shows the optimal distribution of wage subsidies at the observed tax rates. Panel b) also focuses on the optimal distribution of wage subsidies but is calculated according to a much higher budget where tax rates are multiplied by 50. Panel c) and d) show the optimal distributions of investments in production amenities and transportation infrastructure, respectively. In these cases we hold tax rates constant at the observed level. The figures depict local shares of the total transfer volume according to quantiles where a darker shading represents a higher transfer share.

achieve an efficiency gain of about 0.2 percentage points compared to the existing distribution. However, this welfare gain would come at a higher regional inequality.

With regard to investments in local production amenities the optimal pattern is again more in line with the observed one. The maximization routine suggests the highest transfer shares in Central and Eastern Europe, but also advises a broad dispersion of transfers across European regions. The optimum is characterized by a welfare gain of 0.06 percentage points compared to the observed one and reaches a lower degree of regional inequality in terms of population density. However, the resulting inequalities in terms of income are slightly higher than in the observed distribution of transfers.

Finally, considering all transfer types, the welfare optimal scheme could realize an efficiency gain of 0.27 percentage points compared to the observed one while keeping tax rates constant. Hence, this mere improvement of the distribution of transfers raises the welfare gain of the EU regional policy by about 8.36%. Notably this comes at the costs of somewhat higher regional inequality.

## **6 Complementarity of transfer types**

A conceptual understanding of the welfare effects of different regional transfer types would allow for a superior design of place-based policies. However, explaining the underlying forces is difficult as the model implies a complex mapping from location fundamentals to welfare effects. A simple regression analysis aiming to explain the role of location fundamentals for the marginal welfare effects in regional transfers fails in our context. This is because location fundamentals enter in a highly non-linear way and thus are likely to confound other coefficients in a linear regression. Therefore, we conduct a simulation exercise, where we homogenize regions in terms of all location fundamentals such that general equilibrium outcomes of marginal wel-

fare effects of transfers are ex-ante identical across regions.<sup>30</sup> Then, we alternately set one of the location fundamentals to its recovered or observed value while keeping all others constant and calculate the marginal welfare effects of transfer.<sup>31</sup> This procedure allows us to make ceteribus paribus statements of how location fundamentals impact the marginal welfare effects of regional transfers.

Before providing evidence on the role of location fundamental, it is instructive to discuss opposing properties of our transfer types on price indexes. Recall that wage subsidies raise local income directly, and local wages to a lower extent, as a certain share of increases in nominal income is passed over to trading partners or to the global portfolio. This ‘second-round’ increase of local wages impacts other regions (neighbors) negatively because all varieties imported from the transfer recipient regions become relatively more expensive. In contrast, gains in production amenities or transportation infrastructure affect local price indexes directly and influence welfare of other regions positively. In these cases income and wages only change in a ‘second-round’ such that overall positive spillovers dominate. Thus, wage subsidies are more efficient when spent in low income regions where the marginal return of consumption is high and in low accessibility regions where the negative spillovers via price indices are less pronounced. Investments in production amenities and transportation infrastructure are spent more efficiently in highly accessible regions as these locations maximize the dispersion of the gains from such investments.

In Figure 5 we reveal important complementarities between the three investment

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<sup>30</sup>We set all location fundamentals to the average values. In the case of trade costs this is not possible as geography (i.e. location and the number of neighbors) matters for the calculation of trade costs. This limitation results in a scattered pattern in Figure 5 panels b), d), and f) instead of an exact relationship. However, the correlations are unambiguous such that this limitation is not problematic for our simulation experiment.

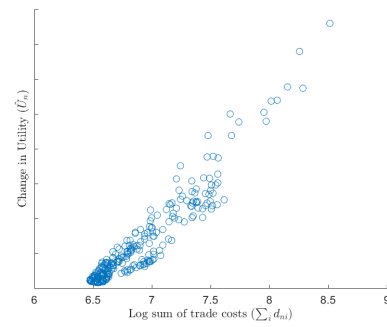
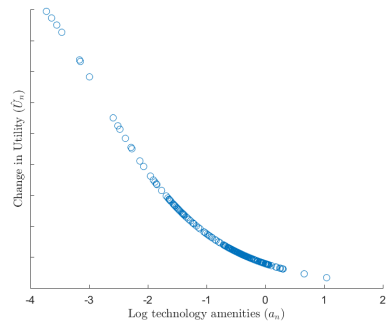
<sup>31</sup>This exercise can also be interpreted as a difference-in-difference estimation of regional transfers, where the first difference is the same for all regions. The average treatment effect in a difference-in-difference estimation in our case is  $E[\hat{U}_{n,T,A}|T = 1, A = 1] - E[\hat{U}_{n,T,A}|T = 0, A = 1] - (E[\hat{U}_{n,T,A}|T = 1, A = 0] - E[\hat{U}_{n,T,A}|T = 0, A = 0])$ , where  $T = 1$  indicates that region  $n$  got a marginal amount of transfers and  $A = 1$  denotes that all location fundamental are set to its average value for all regions and  $A = 0$  denotes that one specific location fundamental is set to its observed value.

Figure 5: Complementarities of regional transfers

Marginal welfare effect of wage subsidies

(a) Production amenity ( $a_n$ )

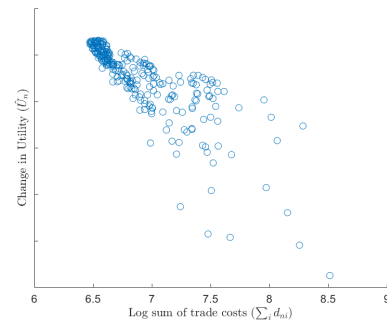
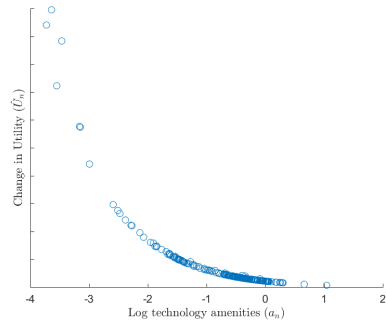
(b) Sum of trade costs ( $\sum_i d_{ni}$ )



Marginal welfare effect of investments in production amenities

(c) Production amenity ( $a_n$ )

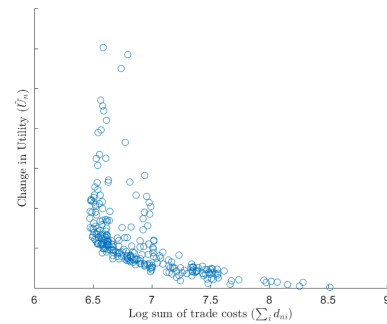
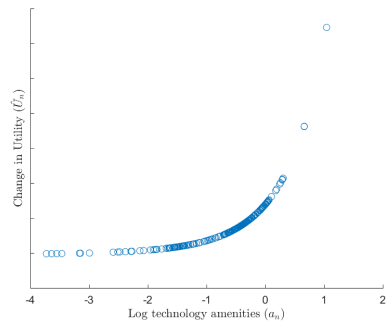
(d) Sum of trade costs ( $\sum_i d_{ni}$ )



Marginal welfare effect of investments in transportation infrastructure

(e) Production amenity ( $a_n$ )

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



Note: The scale change in utility is normalized and utility differences can be compared. Increases or decrease in utility are not relevant in this figure.

types. The figures depict the respective marginal welfare effects against the distributions of production amenities and geographical accessibility (e.g. sum of trade costs). The correlations in panels a) and b) show that wage subsidies are most effective in regions with low productivity and low accessibility. These pattern are due to decreasing marginal returns of consumption and negative spillovers dominating for wage subsidies. Panels c) and d), show that investments in production amenities reach the highest welfare gains in fact in regions with low productivity and low accessibility. The first result is due to decreasing marginal efficiency of transfers as defined in equation (15). The latter result materializes because production amenity gains should be directed to regions where the diffusion of positive spillovers is maximized. Considering investments in transportation infrastructure (panels e) and f)) we find the highest welfare gains in high productivity and high accessibility regions. The first result is due to agglomeration economies – a high productivity leads to dense population and a sizable home market which raises the benefits of market integration. The latter is due to the positive spillovers via the transportation network: Central, highly accessible regions are relevant for trade between many region pairs which have their least cost route in the proximity. Accordingly, an improvement of the infrastructure in central regions will be passed over to the effective trade costs for a large share of other region pairs. Moreover, according to (14) the percentage reduction of travel time following a marginal investment is higher for adjacent region pairs with low travel time.

We report the role of the remaining location fundamentals that cannot be influenced by regional transfers in Figures B.3, B.4, and B.5 in the Appendix. Location attractiveness, residential land supply, and the share paid to global portfolio enter positively into the marginal welfare effects of all three transfer types. The reasons are intuitive as a social planner would aim to allocate individuals to places with high consumption amenities and plenty of land available such as to leverage the fundamental merits of locations and minimize congestion costs. A higher share of contributions to the global portfolio implies that the income gains from transfers are spread broader across regions. If regions are *ceteris paribus* identical a broad

distribution generates a higher marginal welfare effect than a concentrated distribution due to decreasing marginal utility. Migration entry costs imply that a fraction of utility melts away when entering a region. Thus, transfers should not attract individual to regions with high migration entry costs as movers would experience a significant utility reduction. These migration entry costs may for instance be interpreted as the adjustment costs due to a different language or climate. Put differently our formulation of bilateral migration costs, implies that the marginal welfare effect of transfers is higher at places with low emigration benefits that is at the places where individuals are relatively immobile.

Table 3: Optimal investment location by transfer type

	Local productivity (1)	Sum of trade costs (2)	Location of optimal investment (3)
Wage subsidies	low	high	periphery
Production amenities	low	low	mixed
Transport infrastructure	high	low	core

The table shows which location characteristics are beneficial for welfare by our different transfer types. The results are a summary of Figure 4 and 5.

The location characteristics that render transfers or different type most efficient are summarized in Table 3 and related to the observed geography of economic activity in the European Union. Wage subsidies would be most efficient in peripheral regions of Europe that are on average characterized by lower productivity and accessibility. This fits relatively well with the observed distribution of transfers as illustrated in Figure 1. Focusing on projects that aim at increasing productivity and improving transportation infrastructure we conclude that the observed expenditure distribution does not coincide with the optimal one. Transport infrastructure should clearly focus on the core and the optimal location of investment in production amenities is somewhat mixed between the core and periphery of the EU but less focused on the periphery than the observed one.



## 7 Comparison between the general and partial equilibrium responses to transfers

The model presented in this paper allows us to isolate different channels of a place-based policy. A simple cost-benefit analysis capturing only direct effects of transfers in recipient regions could lead to a significant misinterpretation of the welfare effects. According to (25) we define direct effects of transfers as changes in local income, production amenities and own trade costs which can be identified by econometric methods. However, changes in location fundamentals induce adjustments in migration, trade and wages as captured by our general equilibrium model.

Table 4: General vs. partial equilibrium effects

	GE Welfare ( $\hat{V}_n$ ) – PE Welfare ( $\hat{V}_n$ )		
	Equal	Observed	Optimal
Wage subsidies	-0.01	-0.02	-0.63
Production amenities	-0.52	-0.54	-0.63
Transport infrastructure	1.81	1.66	1.84
All transfers	1.24	1.00	0.51

The table compares welfare changes as computed from our general equilibrium analysis to the corresponding partial equilibrium welfare changes (see (25)). The differences are reported in percentage points. The partial equilibrium changes exclude adjustments via migration, trade, and local wages (price index) and are weighted by regions' population shares.

Table 4 quantifies the differences between general and partial equilibrium responses to transfers. The results show that a policy-maker taking only partial equilibrium effects into consideration, overestimates the welfare effects in case of wage subsidies and production amenities. In case of investments in transportation infrastructure the partial equilibrium in fact underestimates the aggregate welfare change. These opposite assessments arises due to investments in transportation infrastructure affecting the general equilibrium not only via own trade costs but also via reductions in travel time for other region pairs.<sup>32</sup> This implies a further welfare

<sup>32</sup>Note that the adjustments in own trade costs are relatively minor because they are only caused

gains that are not accounted for in partial equilibrium. In our application the latter category of transfers turns out relatively important and accordingly changes in trade costs are sizable. Thus, considering the welfare effects across all transfer types we find that a partial equilibrium approach would underestimate the aggregate gains.

## 8 Conclusion

In this paper we present a novel quantitative analysis of the general equilibrium effects of place-based policies in Europe. We integrate the three major types of regional transfers, i.e. wage subsidies, investments in local production amenities and investments in transportation infrastructure, into a rich economic geography framework. The model performs well in matching important pattern of the distribution of economic activity in Europe. Applying it to two decades of regional data, we estimate the key parameters of the model and recover cross-sectional as well as time variation in location fundamentals. In particular, for the causal identification of the elasticities of local production amenities and trade costs with regard to transfers, we exploit changes in the regional eligibility for EU transfers.

We then perform counterfactual experiments where we abandon transfers or redistribute them uniformly across regions. Overall, we find that the EU place-based policy led to a positive welfare effect of 3.23% compared to a scenario without transfers. However, the policy does not realize the potential of distributing the investments in a welfare optimizing way: A uniform distribution turns out to reach a higher welfare level for two out of three transfer types than the EU's current scheme.

A further contribution concerns the derivation of the welfare optimal distribution of transfers. Contrasting the optimal distributions with the observed ones provides us with a quantification of the potential welfare gains that could be realized. In total, switching to the optimal distribution could achieve efficiency gains of about

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by traders having a taste for non-optimal routes, i.e. detours bypassing the own region.

8.36%. Regarding the type of transfers, there is not one size fits all approach for optimal distribution: While wage subsidies should be limited to the few poorest regions, infrastructure investment should rather focus on the core regions. This serves as a basis for our detailed derivation of the determinants for an optimal transfer scheme and the complementarities of different transfer types. We show that the investments in local production amenities and transportation infrastructure can be leveraged by allocating them such as to maximize positive spillovers. This implies a complementarity between these two transfer types. In contrast for wage subsidies we show that negative spillovers dominate. Another dimension of heterogeneity in the regional effectiveness of transfers might stem from variations in the quality of local institution which is not accounted for in our current framework. Nevertheless we believe that our systematic approach for an optimal transfer scheme may serve as serve as guidelines for policy makers.

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# Appendix

## A Estimation and calibration

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

Trade costs are based on a framework developed in Allen and Arkolakis (2016). In the following we describe how we derive expected trade costs (5) and discuss how we adapt their approach for the EU. In Section A.1.1 we discuss how we convert travel time into trade costs and in Section A.1.2 we compare our results to the ones obtained from an alternative approach to estimate trade costs.

Trade is undertaken by a continuum of heterogeneous agents  $v$  who endogenously choose a path  $p$  with length  $K$  to get from  $n$  to  $i$ . We specify cost of shipping a good from adjacent locations  $r$  to  $i$  as a function of road travel time measured in hours<sup>33</sup>

$$\tilde{d}_{ri} = e^{\beta \cdot TravelTime_{ri}}, \quad (\text{A.1})$$

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

$$\check{d}_{ni}(p) = \prod_{k=1}^K \tilde{d}_{p_{k-1}, p_k}. \quad (\text{A.2})$$

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

$$d_{ni}(v) = \min_{p \in P_k, K \geq 0} \check{d}_{ni}(p)\epsilon_{ni}(p, v). \quad (\text{A.3})$$

We allow traders to choose any possible path to ship a good from  $n$  to  $i$ . The extent of mistakes traders incur is governed by the shape parameter  $\theta$ . The calibration of  $\theta$  determines the possibility of mistakes and randomness in the choice of routes. A higher value of  $\theta$  indicates greater agreement across traders, where in the limit case of no heterogeneity  $\theta \rightarrow \infty$  all traders choose the least-cost route. Thus, the framework we described is a generalization of the least-costs approach used in the previous literature and allows a trader to ship a good on second best routes.<sup>34</sup> By using the properties of the Fréchet distribution as described in Eaton and Kortum (2002), expected trade costs  $d_{ni}$  consist of trade costs realized on all possible paths

$$d_{ni} \equiv E_v[d_{ni}(v)] = c \left( \sum_{K=0}^{\infty} \sum_{p \in P_K} \check{d}_{ni}(p)^{-\theta} \right)^{-\frac{1}{\theta}}, \quad (\text{A.4})$$

<sup>33</sup>If  $n$  and  $i$  are not adjacent, then  $t_{ni} = \infty$  indicating that there is no direct connection. We also assume that  $t_{nn} = \infty$  and exclude outgoing paths starting and ending in the same location. However, traders can ship goods from  $n$  to  $n$  with no trade costs. With our definition of  $t_{nn} = \infty$  this is the only path of length zero.

<sup>34</sup>Studies modeling trade costs by using a fast marching algorithm or least costs approaches are Donaldson (2017), Donaldson and Hornbeck (2016) or Allen and Arkolakis (2014).

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

$$\pi_{ni}^d(p) = Pr(\check{d}_{ni}(p) \leq \min\{\check{d}_{ni}(p)\}, \forall p \in P_K, K \geq 0) = \frac{d_{ni}(p)^{-\theta}}{\sum_{K=0}^{\infty} \sum_{p' \in P_{ij,K}} d_{ni}(p')^{-\theta}}. \quad (\text{A.5})$$

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

$$d_{ni}^{-\theta} = c^{-\theta} \sum_{K=0}^{\infty} \tilde{\mathbf{D}}_{ni}^K, \quad (\text{A.6})$$

where  $\tilde{\mathbf{D}}_{ni}^K$  is the  $(n, i)$ 's element of adjacency matrix  $\tilde{\mathbf{D}}$  to the power of  $K$ .<sup>35</sup> The Neumann series converges. Reformulating the above equation we yield an analytical relationship between the transport infrastructure matrix and expected trade cost

$$d_{ni} = cb_{ni}^{-\frac{1}{\theta}}. \quad (\text{A.7})$$

This expression accounts that traders are minimizing heterogenous trader- and path-specific trade costs. By applying the matrix calculus described in Allen and Arkolakis (2016) we derive from equation (A.5) the probability of using link  $t_{kl}$  when shipping a good from  $i$  to  $n$

$$\pi_{ni}^{kl} = \left( \frac{1}{c} \frac{d_{ni}}{d_{nk} \tilde{d}_{kl} d_{li}} \right)^{\theta}. \quad (\text{A.8})$$

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

### A.1.1 Estimation of trade costs

In the following we describe how we use the framework described above in order to compute expected trade costs  $d_{ni}$  according to equation (A.7). First, we describe how we derive direct transport costs  $\tilde{d}_{ni}$  from (4). With GIS software we identify adjacent NUTS2 regions. Then, we assume regions maintaining a ferry connection are also adjacent to each other. From openstreet map we take ferry connections in order to ensure a comprehensive transport network and connect the EU continent with the islands.<sup>36</sup> Data on  $TravelTime_{ni}$  sources from the RRG GIS Database,

<sup>35</sup>Note,  $\tilde{\mathbf{D}}_{ni} = 0$  indicates no connections between  $n$  and  $i$ ,  $\tilde{\mathbf{D}}_{ni} = 1$  indicates a costs-less connection and  $\tilde{\mathbf{D}}_{ni} \in (0, 1)$  indicates a costly connection.

<sup>36</sup>We connect the EU continent with Islands such as British, Nordic, Spanish or Italian Islands. This leaves us with one region which is not connected to the network and for which we assume a ferry connection to the closest region. This connection in fact exist, but is not reported in openstreetmap. We also exclude remote islands such as Madeira PT30, Açores PT20, Canary Islands ES70 or French overseas territories FR91,FR92, FR93, FR94.



which contains detailed information on different speed limits, slope gradients, congestion etc.. The variable  $TravelTime_{ni}$  measures time (in hours) travelled on roads from centroid of  $n$  to centroid of  $i$  and is obtain at the NUTS2 level. To proceed and obtain trade costs  $d_{ni}$ , we use equation (A.7) as well as information on TravelTime  $\tilde{d}_{ni}$  and parameters  $\theta$  and  $\beta$ .

As Truck-specific trade data does not exist for Europe we set the Fréchet parameter governing heterogeneity of traders  $\theta = 136.13$  according to the estimates by Allen and Arkolakis (2016). With this information and the data on  $TravelTime_{ni}$  we can specificity adjacency matrix  $\tilde{\mathbf{D}}$ . Gravity equation (9) and the definition of trade cost (A.7) can be used to estimate the factor converting travel time to trade cost  $\beta$ . We perform a non-linear least squares estimation and minimize the sum of squared residuals between observed and implied trade by the model

$$\min_{\beta} \sum_{n,i \in N} \left( \log(X_{ni}^{Data}) - \beta_0 - \frac{\sigma - 1}{\theta} \log([I - \tilde{\mathbf{D}}]_{ni}^{-1}) - \log(\delta_n) - \log(\eta_i) \right)^2. \quad (\text{A.9})$$

In order to get rid of the constant  $\beta_0$  and dummies  $\delta_n$  and  $\eta_n$  capturing importer and exporter fixed effects, we demean trade and trade costs accordingly. Data on bilateral road freight  $X_{ni}^{DATA}$  among NUTS2 regions stem from the European Transport Policy Information System (ETIS). We estimate a value of  $\beta = 0.068$ . This estimate is higher compared to Allen and Arkolakis (2016), which we can be explained by shorter transport links in our study resulting in wider detours and a higher factor converting travel time to trade costs. Figure A.1, panel a) depicts a strong correlation of -0.709 between the freight data and the values of trade costs obtained from the estimation approach described above. In the figure we demean the freight data and the values for trade costs in order to correct for origin and destination specific fixed effects.

### A.1.2 Estimation of trade costs based on Poisson-PML ( $d_{ni}^{PPML}$ )

As an alternative approach we follow Santos Silva and Tenreyro (2006) and use a poisson pseudo-maximum-likelihood (Poisson-PML) estimator to estimate the gravity equation (9). This approach controls for heteroscedasticity in the estimation of the parameters in log-linearized models. By substituting the solution for goods prices  $p_{ni}$  and collecting exporter and importer specific terms in respective fixed effects ( $\xi$  and  $\zeta$ ) our estimated equation writes:

$$X_{ni} = (\xi_n d_{ni}^{1-\sigma} \zeta_i) \epsilon_{ni}, \quad (\text{A.10})$$

where  $\epsilon_{ni}$  denotes the error term which enters multiplicatively. Moreover, Fally (2015) show that an Poisson-PML estimation of a gravity equation with exporter and importer fixed effects of the form above is consistent with a structural approach that imposes further restrictions on exporter and importer terms. Similar as in Anderson and Yotov (2010) we assume that the unobserved trade costs are a function of the following observables

$$d_{ni}^{1-\sigma} = e^{\beta_1 \ln(TravelTime_{ni}) + \beta_2 CB_{ni} + \beta_3 CIB_{ni} + \beta_4 SC_{ni} + \beta_5 TWI_{ni}} \quad (\text{A.11})$$

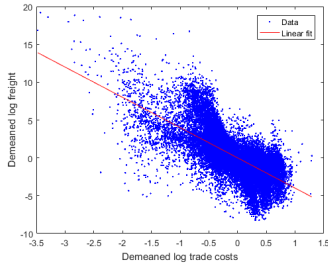
where  $\ln(TravelTime_{ni})$  measures logarithmic road travel-time between a region dyad,  $CB_{ni}$  and  $CIB_{ni}$  capture the presence of common border and common international border between the regions  $n$  and  $i$ ,  $SC_{ni}$  indicates whether regions  $n$  and  $i$  belong to the same country and  $TWI_{ni}$  is unity for internal trades i.e. when  $i = n$ . Data on bilateral freight and road travel time among NUTS2 regions stem from the same source as described above.

Panels b) and c) compare our benchmark estimated for trade costs  $d_{ni}$  with the ones obtained from more traditional PPML or purely distance based approaches. Overall, the measured seem to

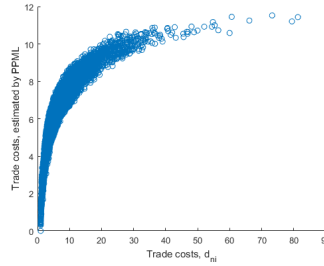
capture relatively similar information as is evident from the high correlations between the trade costs obtained from the different approaches.

Figure A.1: Comparison of trade cost

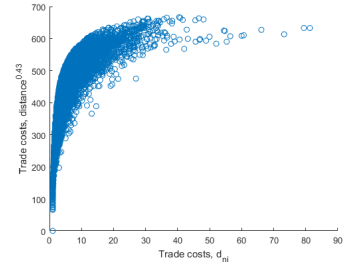
(a) Modeled trade costs and observed freight



(b) PPML estimates



(c) Distance based



Note: We use our estimates of  $\beta = 0.068$  for the factor converting travel time to trade costs. This estimate minimizes sum of square residuals between demeaned log freight and demeaned log trade costs data. Correlation between modeled trade costs and traditional approaches in panel (b) is 0.8 and in panel (c) is equal to 0.7.

## A.2 Estimation of transfer elasticities ( $\kappa^a$ , $\kappa^d$ )

In Table A.1 we report the results of the regression described in Section 4. We estimate equations (14) and (15) employing recovered data for production amenities and information about regional transfers from the central EU budget. Our counterfactual simulations are based on the elasticities of transfers ( $\kappa^a$  and  $\kappa^d$ ) obtained from the fixed effects specifications reported in columns (1) and (3). The specifications based on the regression discontinuity design (RDD) in columns (2) and (4) exploit the fact that only regions with a per-capita income of less than 75% of the EU average (measured in well specified years prior to the begin of the respective budgeting period and in PPP terms) are eligible for the highest transfer intensity referred to as Objective 1 funds. Intuitively, identification rests on the idea that focusing on regions on both sides but at close proximity of the threshold generates quasi-random assignment of transfers. Applying the estimates obtained by the RDD to the average transfer intensities of Objective 1 regions yields transfer elasticities of productivity and travel time that are well in line with those obtained from the fixed effects specifications.

## A.3 Trade balance

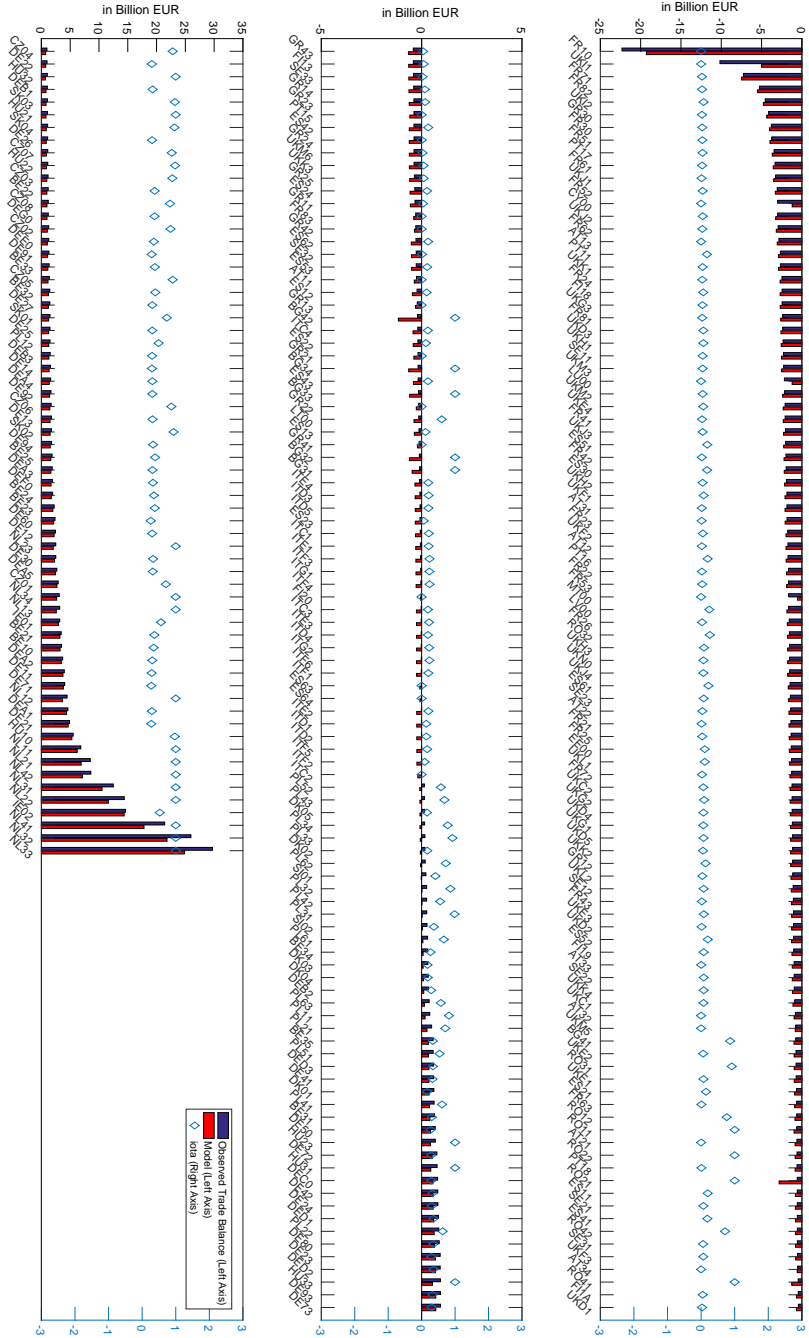
Figure A.2 presents the calibration of the share of payments to the global portfolio ( $\iota$ ) discussed in Section 4 as well as observed and predicted trade balances. Regions characterized by high trade surpluses as for instance North and South Holland (NL32 and NL33) contribute most of their land rents to the global portfolio. We observe some small deviations between the observed and predicted trade balances which is due to the bounds of  $\iota_n \in (0, 1)$ . An example where this parametric restriction is biding concerns regions with a substantial trade surplus which should spend more than their returns from land to the global portfolio. Overall we capture most of the heterogeneity of trade imbalances as is evident from the high correlation of 0.99 between modeled and predicted trade balances.

Table A.1: Effect of place-based transfers on bilateral adjacent travel time and production amenity

	Trans. infrastructure $\kappa^d$		Production amenities $\kappa^a$	
	FE (1)	RDD (2)	FE (3)	RDD (4)
Ln(Transfers)	-0.006*** (0.002)	-0.033** (0.013)		
Ln(Transfers)/Capita			0.397** (0.185)	2.078** (0.826)
Observations	1,884	1,884	708	674
No. regions	244	244	264	245
F first-stage	.	2495.016	.	9.973
AIC	-7190.101	5113.467	-2376.733	-270.943
R <sup>2</sup>	0.329	0.153	0.536	0.558
Time FE	Yes	Yes	Yes	Yes
Region FE	Yes	No	Yes	No
Polynomial	.	2	.	2

Covariates include a dummy indicating new member countries of the European Union as well as a dummy for membership in the Schengen area (which abolished border controls). The RDD specifications generally include asymmetric second order polynomial functions of the forcing variable which determined eligibility for Objective 1 transfers, i.e. per-capita GDP relative to the EU average in the relevant years. Robust standard errors in brackets, \* p<0.10, \*\* p<0.05, \*\*\* p<0.01

Figure A.2: Comparison between modeled and observed trade balance and contribution to global portfolio  $\iota_n$



Note: Blue and red bars illustrate the observed  $\Upsilon^{Data}$  and solved trade balance  $\Upsilon^{Model} = \iota_n H_n r_n + \chi L_n$ , respectively. Diamonds show the contribution to the global portfolio  $\iota_n$  that minimize the least square deviations between the modelled and observed values.

## A.4 Production amenity ( $a_n$ ) and trade shares ( $\pi_{ni}$ )

Substituting equilibrium equations (10) in (21) yields

$$a_i^{1-\sigma} = \alpha w_i^{-\sigma} \sum_{n \in N} \frac{d_{ni}^{1-\sigma} \lambda_n y_n}{\sum_{k \in N} \lambda_k \left( \frac{d_{nk} w_k}{a_k} \right)^{1-\sigma}}. \quad (\text{A.12})$$

By using equation (A.12) we can recover location  $i$ 's production amenity  $a_n$ , given data for  $\{\lambda_n, y_n\}$  and substituting parameters  $\{\sigma, \alpha\}$ , estimates  $\{d_{ni}\}$  as well as the already recovered information on  $\{w_n\}$ . The solution to this equation is unique (up to scale) as follows immediately from Proposition 6 in Redding (2016). Once we know regions' production amenity we can recover bilateral trade shares according to (10). Again we substitute data for  $\{\lambda_n\}$ , estimates  $\{d_{ni}\}$  as well as recovered information on  $\{w_n, a_n\}$ . The solution to this equation is unique (up to scale) as follows from the theorems of Fujimoto and Krause (1985) for this type of equation.

## A.5 Location amenities ( $B_n$ ) and migration costs ( $m_n$ )

According to equation (18) location amenities and migration costs prevent people from consuming the highest attainable real income. In order to disentangle these two factors we substitute real income in (20) and obtain utility for stayers which is independent of migration costs

$$E[V_{nn}] = \bar{L}^{\frac{1}{\epsilon}} \gamma \delta (B_n)^{\frac{1}{\epsilon}} \left( \frac{a_n y_n}{d_{nn} w_n} \right)^{\alpha} \pi_{nn}^{\alpha/(1-\sigma)} H_n^{1-\alpha} L_n^{-\eta}, \quad (\text{A.13})$$

where  $\eta = \frac{\alpha\epsilon + (1-\alpha)(1-\sigma)\epsilon + (1-\sigma)}{(1-\sigma)\epsilon} > 0$  in order to guarantee a stable unique equilibrium. Solving for population shares the last expression writes

$$\lambda_n^{-1} \Phi_n^{\frac{1}{\eta}} \left( \frac{B_n^{\frac{1}{\epsilon}}}{E[V_{nn}]} \right)^{\frac{1}{\eta}} = \sum_{k \in N} \left( \frac{B_k^{\frac{1}{\epsilon}}}{E[V_{kk}]} \right)^{\frac{1}{\eta}} \Phi_k^{\frac{1}{\eta}}, \quad (\text{A.14})$$

where  $\Phi_n = \left( \frac{a_n y_n}{d_{nn} w_n} \right)^{\alpha} \pi_{nn}^{\alpha/(1-\sigma)} H_n^{1-\alpha}$ . Using equation (A.14) we can recover  $\frac{B_n^{\frac{1}{\epsilon}}}{E[V_{nn}]}$  given data for  $\{\lambda_n, y_n, H_n\}$  and using parameters  $\{\sigma, \alpha, \epsilon\}$ , estimates  $\{d_{nn}\}$  and already recovered information on  $\{w_n, a_n, \pi_{nn}\}$ . Again the theorems by Fujimoto and Krause (1985) apply to this type of equation and proof uniqueness of the solution. In a next step we make use of subjective well-being data as a measure for regions' utility levels (see also Desmet et al. 2016). We resort to self-evaluation of life satisfaction data provided by the OECD for European NUTS2 and NUTS1 regions. The OECD indicators on regional life satisfaction are calculated using microdata from Gallup world poll. Since our life satisfaction data bases on the so-called Cantril scale ranging from zero to ten, we transform the data. Using individual income data jointly with the same source of information on wellbeing Deaton and Stone (2013) find a robust correlation between subjective well-being and log real income with a point estimate of  $\rho = 0.55$ .<sup>37</sup> We apply their point estimate of a linear-log specification and transform the subjective well-being data  $E[\tilde{V}_n]$  such that we obtain real income/indirect utility as it enters our model

$$E[V_{nn}] = e^{\frac{1}{\rho} E[\tilde{V}_n]}. \quad (\text{A.15})$$

<sup>37</sup>In particular, Deaton and Stone (2013) estimate a linear-log model with region fixed-effects that absorb location-specific amenities.

This measurement allows us to recover location amenities. Finally we plug in real income (16) in (18) and solve for migration entry costs

$$m_n^{-\epsilon} \lambda_n^{-1} \phi_k = \sum_{k \in N} m_k^{-\epsilon} \phi_k, \quad (\text{A.16})$$

where  $\phi_n = B_n \left( \frac{a_n y_n}{d_{nn} w_n} \right)^{\alpha \epsilon} \left( \frac{\pi_{nn}}{L_n} \right)^{\alpha \epsilon / (1-\sigma)} \left( \frac{H_n}{L_n} \right)^{(1-\alpha)}$ . Given data for  $\{L_n, y_n, H_n\}$ , estimates for  $\{d_{nn}\}$  and already recovered information on  $\{w_n, a_n, \pi_{nn}, B_n\}$  we can use equation (A.16) to recover migration entry costs  $m_n$ . The uniqueness proof follows from the theorems by Fujimoto and Krause (1985). Note, that utility measures do not enter in the counterfactual simulation exercises. They are used here only in order to separate migration costs from location amenities.

## A.6 Summary statistics of exogenous and recovered variables

We present summary statistics of all our variables in Table A.2. Table A.3 shows that our recovered variables do not exhibit obvious correlations and are sufficiently independent of each other.

## B Counterfactual analysis

In the following we derive a system of equations that allows us to undertake a model based counterfactual analysis of EU regional policy. Following Dekle et al. (2007) we denote a counterfactual change as  $\hat{x} = \frac{x'}{x}$ , where  $x$  is the observed variable and  $x'$  is the unobserved counterfactual value of  $x$ . Given the model's parameters  $\{\alpha, \sigma, \epsilon, \iota_n, \kappa^y, \kappa^a, \kappa^d, \beta, \theta, \xi\}$  and the variables  $\{\lambda_n, w_n, \pi_{ni}, y_n, \tau_n, T_n\}$  we use the following system of equations to solve for counterfactual changes in the model's endogenous variables  $\{\hat{w}_n, \hat{y}_n, \hat{\lambda}_n, \hat{\pi}_{ni}, \hat{a}_n, \hat{d}_{ni}\}$  which determine changes in aggregate welfare. Wage adjustments follow directly from equation (21):

$$\hat{w}_i w_i \hat{\lambda}_i \lambda_i = \alpha \sum_{k \in N} \hat{\pi}_{ki} \pi_{ki} \hat{y}_k y_k \hat{\lambda}_k \lambda_k. \quad (\text{B.1})$$

Next, we divide the counterfactual by the equilibrium trade share using (10) and obtain

$$\hat{\pi}_{ni} = \frac{\hat{\lambda}_i \left( \frac{\hat{d}_{ni} \hat{w}_i}{\hat{a}_i} \right)^{1-\sigma}}{\sum_{k \in N} \hat{\lambda}_k \left( \frac{\hat{d}_{nk} \hat{w}_k}{\hat{a}_k} \right)^{1-\sigma} \pi_{nk}}. \quad (\text{B.2})$$

Similarly, we can express the change in counterfactual population by dividing the counterfactual population mobility condition by the equilibrium mobility conditions (18) and (16)

$$\hat{\lambda}_n = \frac{\left( \frac{\hat{B}_n}{\hat{m}_n^\epsilon} \right) \left( \frac{\hat{\pi}_{nn}}{\lambda_n} \right)^{\frac{\alpha \epsilon}{1-\sigma}} \left( \frac{\hat{a}_n \hat{y}_n}{\hat{d}_{nn} \hat{w}_n} \right)^{\alpha \epsilon} \left( \frac{1}{\lambda_n} \right)^{(1-\alpha) \epsilon}}{\sum_{k \in N} \left( \frac{\hat{B}_k}{\hat{m}_k^\epsilon} \right) \left( \frac{\hat{\pi}_{kk}}{\lambda_k} \right)^{\frac{\alpha \epsilon}{1-\sigma}} \left( \frac{\hat{a}_k \hat{y}_k}{\hat{d}_{kk} \hat{w}_k} \right)^{\alpha \epsilon} \left( \frac{1}{\lambda_k} \right)^{(1-\alpha) \epsilon} \lambda_k}. \quad (\text{B.3})$$

Using equation (8) we can express per-capita income in the counterfactual equilibrium

$$\hat{y}_n y_n = \frac{1}{\alpha + \iota_n - \alpha \iota_n} \left( \hat{w}_n w_n (1 - \hat{\tau}_n \tau_n) + \kappa^y \hat{T}_n T_n + \hat{\chi} \chi \right), \quad (\text{B.4})$$

Table A.2: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.
Own trade share ( $\pi_{nn}$ )	0.09	0.13	0.00	0.89
Population ( $L_n$ )	840.70	717.91	18.11	6055.46
Wages per capita ( $w_n$ )	38.48	17.58	2.44	146.04
Income per capita ( $y_n$ )	51.48	22.13	5.74	198.50
Transfers per capita ( $T_n$ )	136.84	190.34	0.34	891.56
Transfers ( $T_n L_n$ )	84.19	129.72	0.25	808.98
Objective 1 regions	0.30	0.46	0.00	1.00
Transfers in Obj. 1 regions	218.82	156.93	7.57	808.98
Transfers in non-Obj. 1 regions	25.66	46.71	0.25	422.04
Transfers per capita in Obj. 1 regions	366.55	184.54	55.00	891.56
Transfers per capita in non-Obj. 1 regions	36.97	65.35	0.34	630.22
Production amenity ( $a_n$ )	0.62	0.33	0.02	2.84
Own trade costs ( $d_{nn}$ )	1.00	0.00	1.00	1.00
Migration costs ( $m_n$ )	214.62	220.47	1.08	1205.71
Location amenity ( $B_n$ )	3.18	9.37	0.00	80.64
Land supply ( $H_n$ )	828.46	599.13	7.53	3366.19
Share global portfolio ( $\iota_n$ )	0.32	0.34	0.00	1.00
Tax rates ( $t_n$ )	0.25	0.00	0.25	0.25
Global portfolio return $\chi$	3185.93	0.00	3185.93	3185.93

Note: Population is measured in thousand inhabitants, per-capita wages and per-capita income in thousand Euros, transfer levels in million Euros, tax rates in percent, in migration costs in  $10^3$  units, and location amenity in  $10^{16}$  units.

Table A.3: Correlation matrix of recovered variables

	$a_n$	$B_n$	$\pi_{nn}$	$m_n$
$a_n$	1	0.357	0.171	0.641
$B_n$		1	0.131	0.684
$\pi_{nn}$			1	0.024
$m_n$				1

where returns from global portfolio change due to adjustments in income and population  $\hat{\chi}\chi = (1 - \alpha) \sum_n \iota_n \hat{y}_n y_n \hat{\lambda}_n \lambda_n$ . Tax rates are kept constant in our main analysis but we allow for changes  $\hat{\tau}_n \tau_n$  in robustness checks where we instead fix the total budget. The governments decision about how to allocate the place-based policy budget feeds back on to the total tax revenue and thus on to the budget for transfers  $\hat{T}_n T_n$ . This is because the regional allocations of transfers impacts the level of nominal wages which are proportional to the tax revenue. We run simulations for each investment type separately and alternately set two out of the three transfer elasticities ( $\kappa^y, \kappa^a, \kappa^d$ ) to zero. Thus, local investments affect production amenities or travel time

$$a'_n = \gamma_n^a + \kappa^a \cdot \frac{\ln(\hat{T}_n T_n \hat{\lambda}_n \lambda_n \bar{L})}{(\hat{\lambda}_n \lambda_n \bar{L})^\xi}, \quad (\text{B.5})$$

and

$$TravelTime'_{ri} = \gamma_{ri}^d - \kappa^d \cdot \frac{\ln(\hat{T}_r T_r \hat{\lambda}_r \lambda_r \bar{L} + \hat{T}_i T_i \hat{\lambda}_i \lambda_i \bar{L})}{(\hat{\lambda}_r \lambda_r \bar{L} + \hat{\lambda}_i \lambda_i \bar{L})^\xi}, \quad (\text{B.6})$$

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

$$\sum_{n \in N} \hat{w}_n w_n \hat{\lambda}_n \lambda_n \hat{\tau}_n \tau_n = \sum_{n \in N} \hat{\lambda}_n \lambda_n \hat{T}_n T_n. \quad (\text{B.7})$$

Equations (B.1)-(B.7) enable us to solve for counterfactual changes in wages  $\hat{w}_n$ , trade shares  $\hat{\pi}_n$  and population shares  $\hat{\lambda}_n$  for all regions  $n$ . We obtain the change in aggregate welfare from expected utility (20):

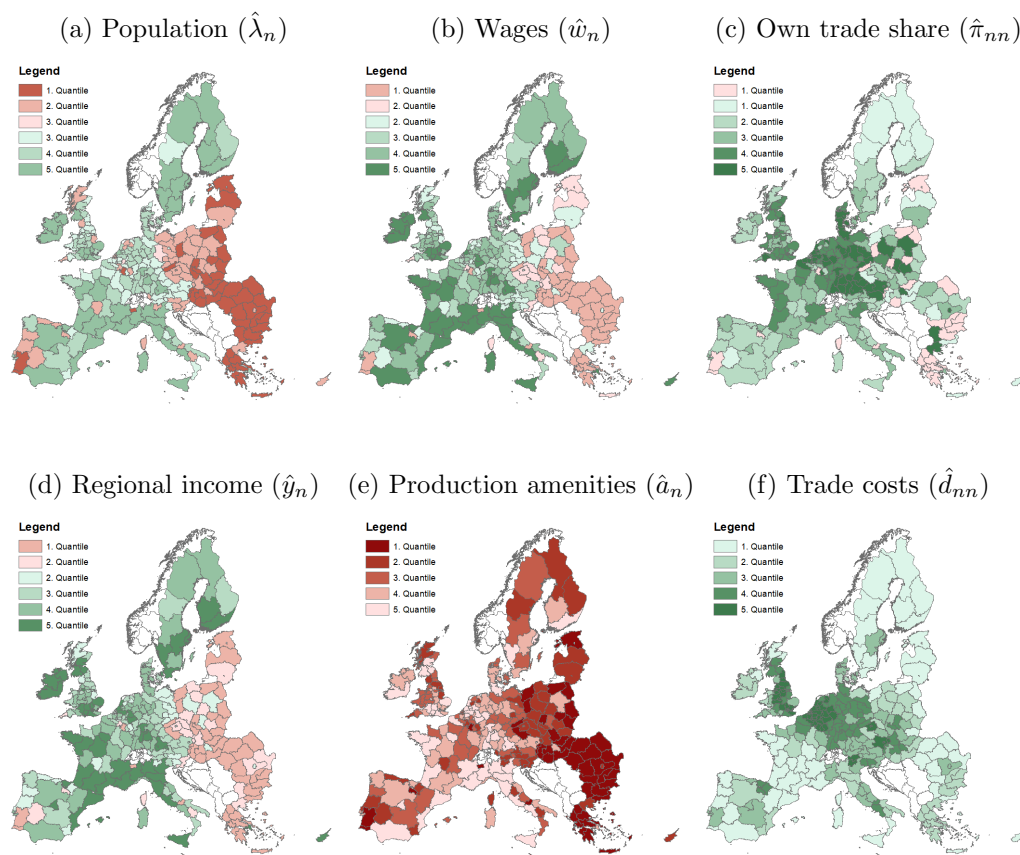
$$\widehat{E[V]} = \left( \frac{1}{\hat{\pi}_{nn}} \right)^{\frac{\alpha}{\sigma-1}} \left( \frac{1}{\hat{w}_n} \right)^\alpha \left( \hat{\lambda}_n \right)^{\frac{\alpha}{\sigma-1} - (1-\alpha) - \frac{1}{\epsilon}} \left( \frac{\hat{y}_n \hat{a}_n}{\hat{a}_{nn}} \right)^\alpha. \quad (\text{B.8})$$

The first, second and third terms capture general equilibrium effects via trade, migration and the price index. The last term reflects direct effects (partial equilibrium) of transfers on local income, production amenities, and intra-regional trade costs.



## B.1 Counterfactual analysis: No transfers

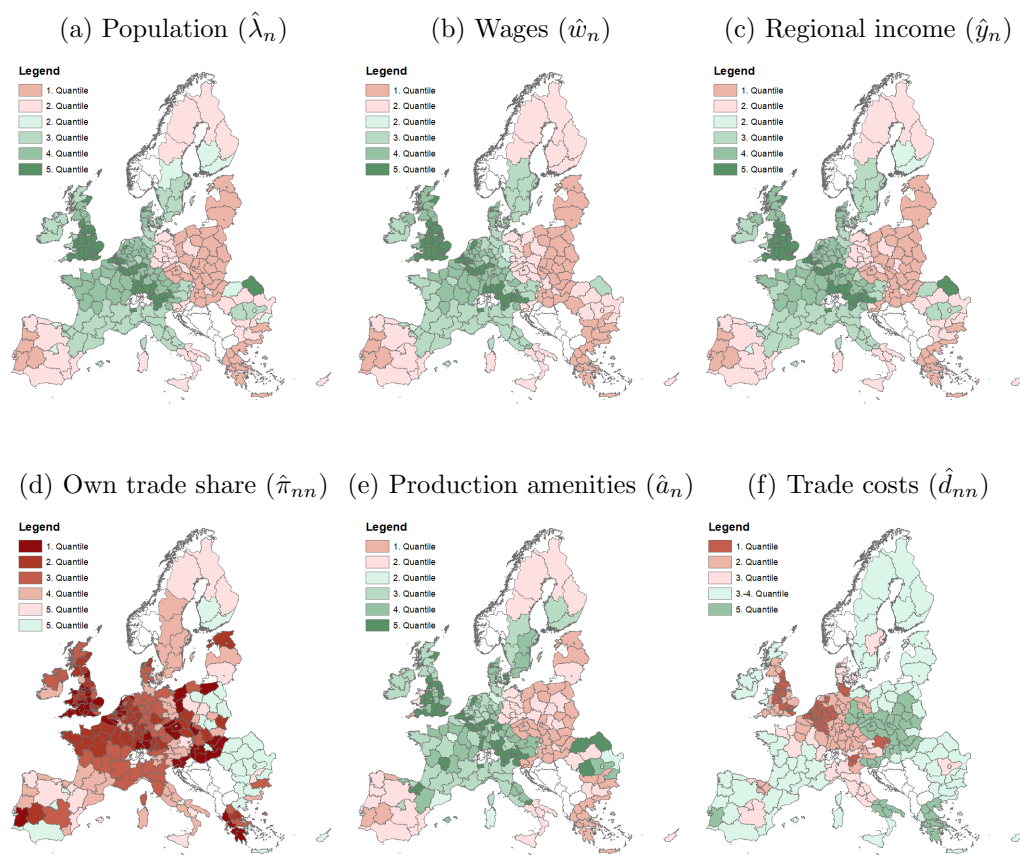
Figure B.1: Counterfactual analysis: No transfers scenario compared to observed distribution of transfers



Note: Transfers act through wage subsidies and investments in production amenities and transport infrastructure. The figure depicts changes in the particular variable reported by quantiles. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect.

## B.2 Counterfactual analysis: Equal distribution of transfers

Figure B.2: Counterfactual analysis: Equal distribution of transfers compared to observed scenario

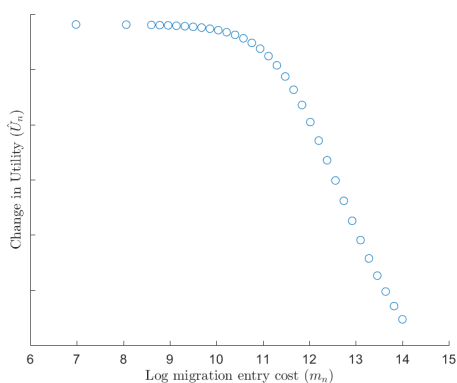


Note: Transfers act through wage subsidies and investments in production amenities and transport infrastructure. The figure depicts changes in the particular variable reported by quantiles. A darker shading represents a stronger effect, where a green (red) color illustrates a positive (negative) effect.

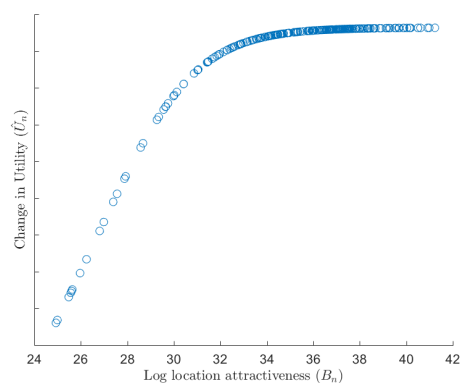
### B.3 Counterfactual analysis: Explaining marginal welfare effects

Figure B.3: Explaining marginal welfare effects of wage subsidies

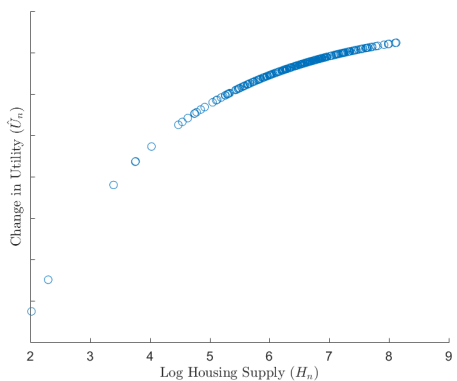
(a) Migration entry costs ( $m_n$ )



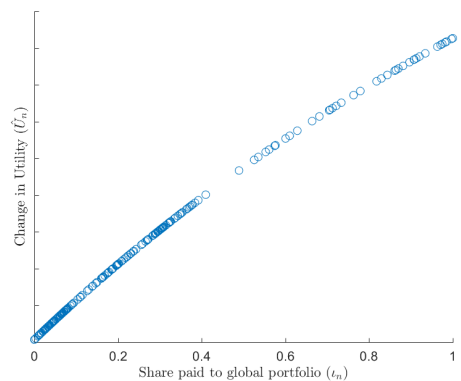
(b) Location attractiveness ( $B_n$ )



(c) Resid. land supply ( $H_n$ )

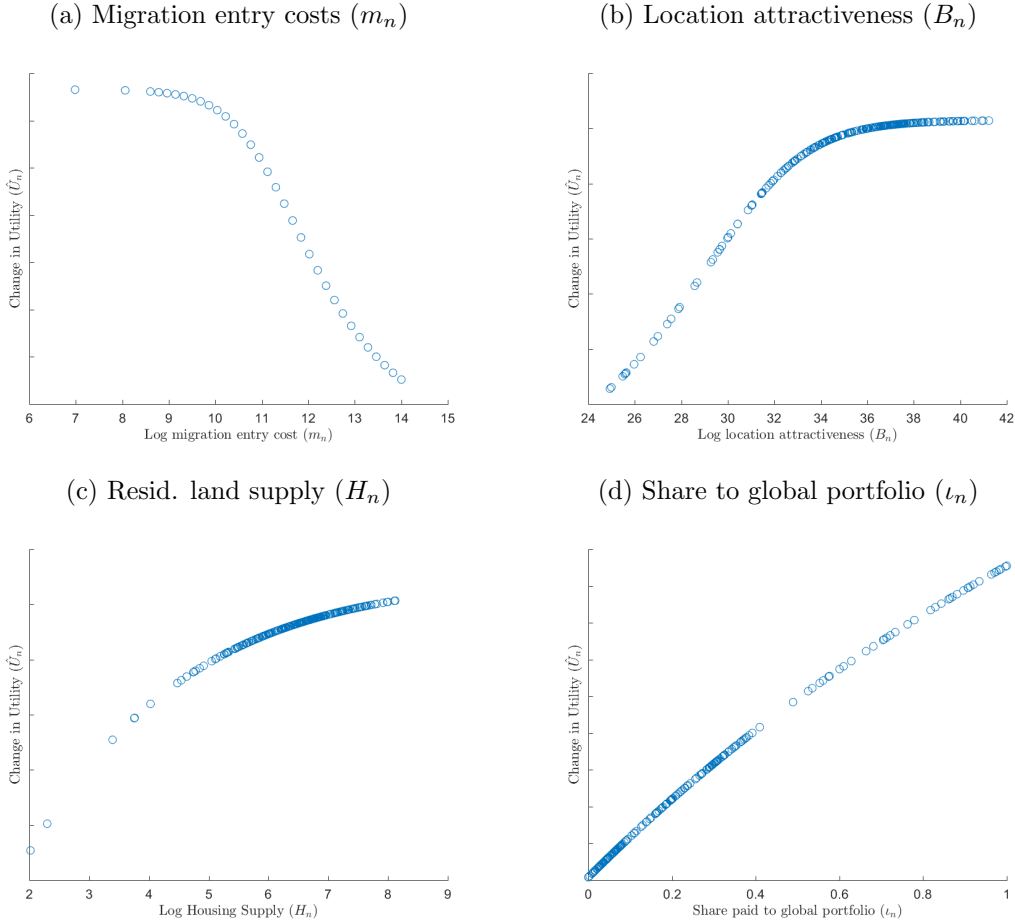


(d) Share to global portfolio ( $l_n$ )



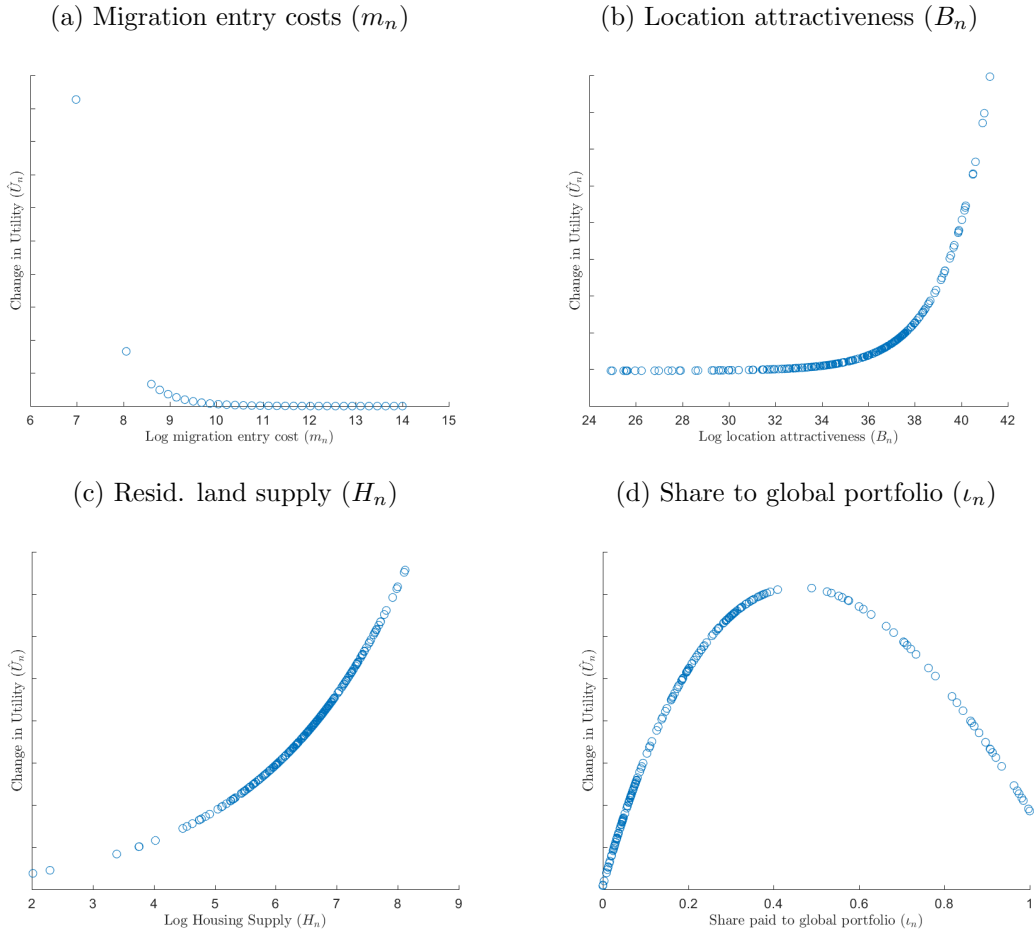
Note: The scale change in utility is normalized and utility differences can be compared. Increases or decrease in utility are not relevant in this figure.

Figure B.4: Explaining marginal welfare effects of investments in production amenities



Note: The scale change in utility is normalized and utility differences can be compared. Increases or decrease in utility are not relevant in this figure.

Figure B.5: Explaining marginal welfare effects of investments in transport infrastructure



Note: The scale change in utility is normalized and utility differences can be compared. Increases or decrease in utility are not relevant in this figure.

## C Optimal Transfers

In this section we describe our numerical optimization routine with a government choosing the welfare optimal transfer scheme. We use the Mathematical Programs With Equilibrium Constraints (MPEC) approach described in Su and Judd (2012) for economic models and in particular applied to trade models in Ossa (2014). Following their approach we maximize indirect utility of one arbitrary region and take the model's equilibrium conditions as constraints. Given this nonlinear constrained optimization procedure the solution characterizes a spatial equilibrium as described in

Section 3.7. Hence, our maximization problem writes

$$\max_{\hat{T}_n, \hat{\pi}_{nn}, \hat{y}_n, \hat{w}_n, \hat{\lambda}_n} \widehat{E[V]} = \left( \frac{1}{\hat{\pi}_{nn}} \right)^{\frac{\alpha}{\sigma-1}} \left( \frac{\hat{y}_n \hat{a}_n}{\hat{w}_n \hat{a}_{nn}} \right)^\alpha \left( \hat{\lambda}_n \right)^{\frac{\alpha}{\sigma-1} - (1-\alpha) - \frac{1}{\epsilon}} \quad (\text{C.1})$$

*s.t.* all equilibrium conditions (B.1)-(B.7).

We either allow the government to make a lump sum wage subsidy or investments in production amenities or investments in transport infrastructure or altogether. Accordingly, equations (B.4), (B.5), and (B.6) apply in the optimization routine. For all our optimizations we hold tax rates constant such that a shift in the transfer budget may only be generated by different distributions of transfers.

## C.1 Solving Approach

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

1. From a normal distribution with mean zero and variance  $10^9$  we form a random initial guess for transfer shares ( $T_n$ ). We take absolute values to ensure the guess is positive and normalize the guess such that the sum is equal to 1.
2. Based on random transfer share draws we compute the equilibrium values for changes in wages ( $\hat{w}_n$ ), population shares ( $\hat{\lambda}_n$ ), own trade shares ( $\hat{\pi}_{nn}$ ), indirect utility of region 1 ( $\hat{V}_1$ ) and total transfers paid ( $\hat{T}$ ) satisfying equilibrium constraints (B.1)-(B.7). We take these values as an initial guess for our optimization routine.
3. We maximize welfare subject to equilibrium constraints by numerically running an interior point algorithm in Artely's Knitro solver. For any random initial guess our problem converges to the same solution and this makes us confident that we have reached a global optimum. In this global optimum migration cost adjusted utility is equalized, government budget is balanced and all equilibrium conditions (as described in Section 3.7) are fulfilled up to a small epsilon  $\epsilon < 1^{-10}$ .

In the following we describe the optimization specification in more detail. The main challenge for such an optimization is to make the numerical routine feasible for our  $4 \cdot 240 + 3 = 963$  endogenous variables with  $3 \cdot 240 + 4 = 724$  equilibrium constraints and one objective function as described in the previous section. First, in order to increase the convergence it is necessary to scale all variables to a similar magnitude and bound these in the solver accordingly. Second, we supply gradients of our objective function and equilibrium constraints and form a jacobian matrix. Both adjustments result in a considerable speed gain and enable us to solve the optimization problem in appropriate time ( $\sim 14$  hours) on a high-end workstation. The matrix  $J_{B,\lambda}$  shows the jacobian matrix of constraint  $B$  with respect to variable  $\lambda$ .

$$J_{B,\lambda} = \begin{bmatrix} \frac{\partial B_1}{\partial \lambda_1} & \cdots & \frac{\partial B_n}{\partial \lambda_1} & \cdots & \frac{\partial B_N}{\partial \lambda_1} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial B_1}{\partial \lambda_n} & \cdots & \frac{\partial B_n}{\partial \lambda_n} & \cdots & \frac{\partial B_N}{\partial \lambda_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial B_1}{\partial \lambda_N} & \cdots & \frac{\partial B_n}{\partial \lambda_N} & \cdots & \frac{\partial B_N}{\partial \lambda_N} \end{bmatrix}. \quad (\text{C.2})$$