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ESSAYS IN ECONOMIC GEOGRAPHY AND LONG-TERM DEVELOPMENT

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Abstract

This dissertation has two main themes: first, the economic impact of tourism on cities and, secondly, the determinants of European long-run development, with a focus on the pre-Industrial era. The common thread is the attempt to develop economic geography models that incorporate spatial frictions and are liable to be given empirical content. Chapter 1, written in conjunction with G. Alfredo Minerva, provides an empirical analysis of the relationship between tourism and economic activity across Italian municipalities, and lays down the basic elements of an urban theory of tourism in an a-spatial setting. Chapter 2 extends these ideas to a quantitative urban framework to study the economic impact and the welfare consequences of tourism into the city of Venice. The model is given empirical content thanks to a large collection of data at the Census tract level for the Municipality of Venice, and then used to perform counterfactual policty analysis. In chapter 3, with Matteo Santacesaria, we consider a setting where agents are continuously distributed over a two-dimensional heterogeneous geography, and are allowed to do business at a finite set of markets. We study the equilibrium partition of the economic space into a collection of mutually-exclusive market areas, and provide condition for this equilibrium partition to exist and to be unique. Finally, chapter 4 "The rise of (urban) Europe: a Quantitative-Spatial analysis", co-authored with Matteo Cervellati and Alex Lehner, sets up a quantitative economic geography model to understand the roots of the Industrial Revolution, in an attempt to match the evolution of the European urban network, and the corresponding city-size distribution, over the period A.D. 1000-1850. It highlights the importance of agricultural trade across cities for the emergence of large manufacturing hubs.

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Chapter 1

Tourism, amenities and welfare: in an urban setting

1.1 Introduction

Tourism may be an important determinant of urban success, providing a powerful stimulus to urban growth and development. For instance, Carlino and Saiz (2008) show that the number of leisure visits to a city is one of the key predictors of its economic success. However, as tourist inflows rise, many cities are also experiencing rising land and consumption prices. In order to evaluate policies aimed at attracting tourists to certain destinations, it is therefore crucial to understand exactly the impact of tourism on local prices, nominal incomes, and, ultimately, the welfare of the resident population.

In this paper, we study how tourism affects cities through the lens of urban economics. Using data on Italian cities, we first document that, over the period $2001 - 2011$, the number of establishments and the level of employment in services are positively related to the inflow of tourists. To address these patterns, we build a model with endogenous consumption amenities, price and real income effects, and two sectors of production (a tradable intermediate sector and a non-tradable services sector).

Consumption amenities come in the form of product variety in the services sector, where horizontally differentiated firms engage in monopolistic competition. These firms are retail shops, restaurants, and other economic activities linked to a thriving services sector. Real income effects arise because residents are at the same time wage earners, land owners and consumers, and wages, land prices and consumption prices are determined endogenously through market clearing. Tourism exerts a demand pressure on the land market, on the labor market, and on the market for services, inducing general equilibrium effects on all these variables. Furthermore, when tourists are mobile across alternative destinations, spatial equilibrium effects arise. We characterize the spatial equilibrium in a simple system of two cities. First, we study the model under the assumption that the resident population is immobile, whereas tourists can freely choose between the two destinations. In a second exercise, we allow residents to relocate as well.

Our paper addresses some important issues about the impact of tourism in an urban setting. First, on the positive side, we show how tourism changes the sectoral composition of the local economy. We find that, as the number of tourists increases, the city undergoes a structural transformation away from the tradable sector, and specializes in services. Cities with a higher number of tourists have higher land prices, higher prices for services goods, and a larger number of services varieties.

As a second contribution, we determine the endogenous spatial distribution of agents between two cities, given the total number of tourists and residents. When residents are immobile, we derive a simple formula for the share of tourists in a city, as a function of the value of historical amenities, plus other characteristics, in both cities. When residents are mobile, the share of tourists and the share of residents in a city are determined jointly. In our simulations, consistently with the empirical evidence in Carlino and Saiz (2008), we find that the number of residents and the number of tourist visits in a city are positively correlated. Then, cities with rich historical amenities are predicted not only to be more specialized in services, but also to be larger in terms of population, than similar cities with poor historical amenities.

Finally, as a third contribution, we study how tourism affects the resident population in terms of welfare. We show that, if residents are immobile, they always benefit from an increase in the number of tourists, either exogenous in the single-city case, or endogenous in a system of two cities, as a consequence of richer historical amenities. When residents are mobile, the elasticity of substitution between services varieties, which governs the strength of consumption amenities, determines the welfare of residents in a two-city urban system. When consumption amenities are strong, residents are better off in an urban system where both cities receive tourists and host a large services sector; when consumption amenities are weak, residents are better off when all tourists visit one city, which therefore becomes relatively more specialized at the production of non-tradable services.

Our paper is related to the following strands of literature. First, we contribute to the economic literature on urban amenities. Glaeser et al. (2001), who introduced the concept of "consumer city", argue that two types of amenities are particularly important for urban success. On the one side, cities offer a rich variety of services and non-tradable consumer goods; on the other side, all attributes related to the aesthetics and the physical setting play an important role, since they are valued by consumers. In our terminology, the former falls in the category of endogenous amenities, whereas the latter falls in the category of exogenous amenities. Our paper builds on the importance of amenities for urban success, and presents an integrated framework to study how tourism affects urban amenities and real incomes, the implications for the welfare of residents, and how endogenous and exogenous amenities interact at the urban level. On the empirical side, there is a number of papers that study the link between the composition of local demand and product diversity. For instance, Waldfogel (2008) finds that the demographic mix of the population (i.e. ethnicity, income, education) affects the type of available restaurants across U.S. ZIP codes. Mazzolari and Neumark (2012) also find that the share of immigrants is related to the share of ethnic restaurants across Census tracts in California. Finally, Schiff (2015) finds that larger and denser markets offer both greater variety and rarer varieties of restaurants. Consistently with this literature, we document that in our data tourism and the number of restaurants and retail shops are correlated across Italian cities. Our theoretical findings are also consistent with Carlino and Saiz (2008), who show that the number of leisure visits to a city provides a good revealed-preference measure of local leisure amenities. Finally, in Lee (2010) land prices and consumption amenities shape the sorting pattern of high-skilled and low-skilled workers across cities, thus contributing to explain the urban wage premium.

Second, as far as the spatial equilibrium analysis is concerned, our model builds on the Rosen-Roback framework and on the related literature that studies the distribution of agents across cities. In the standard framework (Rosen, 1979; Roback, 1982) urban amenities affect the utility of residents directly, and residents relocate across cities to level out welfare differentials. In our model, the economic mechanism is more complex. In fact, we show that exogenous amenities may have an impact on urban outcomes and welfare even when residents are not directly interested in them; the reason is that they enter the utility function of a second class of agents, namely tourists, whose demand for land and services triggers a surge in land prices and product variety in the urban system. Extensions of the classic Rosen-Roback framework have been developed to explain the sorting of heterogeneous agents across cities (for instance Lee, 2010). We also find that residents and tourists sort between cities in the urban system, in the sense that the ratio of residents over tourists is not constant across cities. Rather, depending on exogenous parameter values, cities may become more tourist-oriented or resident-oriented.

Finally, a third strand of literature that is related to our paper is the one about the impact of tourism on the economy. Our baseline results are related to Copeland (1991), who studies a small open economy and presents two main findings: first, the welfare impact of tourism is positive, as long as it increases the relative price of non-tradables; second, under certain conditions tourism can lead to a contraction of the manufacturing sector in favour of the services sector. Chao et al. (2006) provide a similar analysis in the context of a dynamic macro model. In a recent paper, Faber and Gaubert (2018) find a positive welfare impact of tourism on the Mexican economy, using a structural spatial framework that includes productivity spillovers between the services and the manufacturing sector. We cast the discussion about the impact of tourism in an urban context that features exogenous historical amenities and endogenous consumption amenities.

The remainder of the paper is structured as follows. Section 2 presents some empirical patterns that we aim to replicate in in the model. Section 1.3 presents the baseline model. In section 1.4 we generalize the model to a system of two cities. We then present in section 1.5 some further extensions to our setting. Finally, section 1.6 concludes.

1.2 Empirical patterns

In this section, we document the empirical association between tourism and some key economic variables across Italian municipalities, over the time period 2001 – 2011. Although these patterns should not be interpreted as causal effects, they provide motivation for the theoretical analysis that we develop in the following sections. At the same time, we ground our specifications in the functional forms that we derive from the model.

Our data come from two main sources. First, we use Italian Census data for years 2001 and 2011. The Industry and Services Census provides information on the number of establishments and the number of employees in each sector for all Italian municipalities, where sectors are defined according to the NACE classification. We complement this data set with the total resident population from the Population Census. Second, data on tourism activity come from the Annual Survey of the Capacity of Tourist Accommodation Establishments. This survey provides the number of overnight stays at the province level,[1] and the number of beds (a measure of capacity) at the municipality level. First, we allocate the number of overnight stays to each municipality proportionally to its relative within-province capacity. Second, in order to provide a measure of tourism in resident-equivalent terms, we divide the number of overnight stays by 365 (assuming that each resident spends 365 nights per year in his place of residence). Then, we construct our main explanatory variable as the number of tourists per 1000 residents at the municipality level.[2]

The basic specification we run is:

$$\Delta y_{ij} = \alpha + \delta_1 \Delta \text{tourism}_{ij} + \delta_2 x_{ij} + \mu_j + \varepsilon_{ij},$$

where: Δy_{ij} is the absolute change in the dependent variable of interest from 2001 to 2011 in municipality i within province j; $\Delta \text{tourism}_{ij}$ is the main explanatory variable, the absolute change in the number of resident-equivalent tourists per 1000 residents from 2001 to 2011 in municipality i in province j; x_{ij} is a set of controls, including total municipal land area, average elevation, and a dummy for coastal towns; μ_j is a set of 103 dummies, one for each province; ε_{ij} is the error term. Note that first differences control for all time-invariant factors that affect the level of y_{ij} at the municipality level; moreover, province dummies ensure that our variation comes from comparing municipalities within narrow and homogenous spatial units. We trim our data set in order to exclude municipalities with extremely low or high values for our main regressor $\Delta \text{tourism}_{ij}$.[3] The resulting empirical density function is depicted in figure 1.1.

[Insert Figure 1.1 about here]

Table 1.1 reports the descriptive statistics for the main variables used in the analysis, for our base year (2001) and for the change over the subsequent decade (2001-2011). A first observation that emerges from the table is that the spatial distribution of tourism is uneven. In 2001, on average, there were 19 tourists per 1000 residents in Italian municipalities, whereas the median was 1.5, and the 75th percentile was 8.4. Therefore, most municipalities host a small number of tourists, while a few municipalities host a large number of tourists.

[Insert Table 1.1 about here]

[1] The province level corresponds to NUTS 3 in terms of the European geographical classification.

[2] We provide more information on the data used in Appendix A.

[3] We drop municipalities belonging to the top 1% and bottom 1% of the distribution.

Second, the number of tourists over 1000 residents increased (by 1.7 units) over our period of study; however, as shown in figure 1.2, this number masks a steep decline for the top 10% destinations (as of 2001), and a mild increase along the rest of the distribution, especially for the 8th and 9th deciles. For this reason, we run our main regressions both on the full sample and excluding the top-decile municipalities. Moreover, the number of hotels per 1000 residents and the number of restaurants and bars per 1000 residents increased, whereas the number of retail stores per 1000 residents decreased. A similar pattern emerges in terms of employment (the average change in employment in retail stores is small and positive, while the corresponding median change is small and negative).

[Insert Figure 1.2 about here]

In table 1.2 we report the results on tourism and the number of establishments for the different industries in our sample. We report in panel A the correlation between the change in the number of tourists per 1000 residents from 2001 to 2011 and the change in the number of establishments per 1000 residents over the same time period for the full sample of municipalities. We focus on industries that, in our view, represent important urban consumption amenities, both for residents and tourists: restaurants and bars (column 2), and different types of retail trade stores (columns 3-8); in the last column, we also report results for the tourist accommodation sector. The coefficients reported show that tourism is positively associated with the number of restaurants and bars, and with the total number of retail shops. For instance, in the case of Venice, back-of-the-envelope calculations predict that the increase in restaurant and bars in the 2001-2011 period that can be related to the inflow of tourists is roughly equal to 80 establishments. Census data show that the total increase of business units in industry 56 over the same period of time amounts to 374. For Florence, that experienced a much lower increase in tourism, we predict an increase of 14 restaurant and bars related to the tourist inflow, while the overall increase coming out from Census data totals 425 business units. In columns 4-8, we break down the 2-digit retail shops sector into its main 3-digit subsectors.[4] There is a positive and significant correlation for specialized food shops, books, sport, toys, and clothing and footwear. As expected, the number of accommodation establishments is also positively related to the change in the number of tourists.

[Insert Table 1.2 about here]

Panels B and C of table 1.2 check the robustness of these correlations. In panel B we show the results of the same regression, excluding the municipalities in the top decile of the tourists distribution in 2001. Results are broadly consistent. In panel C, as a second robustness check, we exclude municipalities with zero tourist density in either 2001, or 2011, or both years. Again, results are consistent, except in the regression on the number of food and beverages stores, where the coefficient is now insignificant. How can we interpret the heterogeneity across industries? Our model shows in section 1.3 that the coefficient linking the number of establishments to the tourist flow should be smaller when economies of scale are large.

[4] We exclude from the analysis gas stations, ICT retail shops, retail sale via mail orders or via Internet, and second-hand markets sales.

In table 1.3 we replicate table 1.2, using as a dependent variable the change in city employment between 2001 and 2011, normalized by the resident population, for the same set of industries. The correlation is positive for restaurant and bars, and for the number of employees in retail stores, confirming that municipalities that experienced stronger tourism inflows also specialized more towards the sectors producing urban consumption amenities. The effect is statistically significant for the books, sport, toys, and clothing and footwear industries.

[Insert Table 1.3 about here]

1.3 The baseline model

In the baseline model, the city consists of a fixed resident population, n_R, and a fixed amount of land, H, which is used both for residential and for commercial purposes. Each resident supplies inelastically one unit of labor, so that total labor force is equal to n_R, and she is entitled to an equal share of the total land rents paid in the city. The number of tourists visiting the city is n_T. In this section, we take n_R and n_T as exogenously given. In section 1.4, we study how n_R and n_T are endogenously determined in a two-city system.

1.3.1 Preferences

Both residents ($i = R$) and tourists ($i = T$) have a Cobb-Douglas utility function defined over a bundle of non-tradable services and land:

$$U_i = A_i \left(\frac{C_i}{\gamma}\right)^{\gamma} \left(\frac{h_i}{1-\gamma}\right)^{1-\gamma}, \qquad 0 < \gamma < 1,$$

where A_i is a utility shifter (the amenity level provided by the city), C_i is a bundle of differentiated non-tradable services, h_i is land consumption, and γ is the share of income allocated to non-tradable services consumption. We follow the standard Dixit-Stiglitz formulation (Dixit and Stiglitz, 1977), and assume that C_i is a CES aggregate of a continuum of differentiated varieties:

$$C_i = \left(\int_0^m c_{ij}^{\varepsilon} dj\right)^{\frac{1}{\varepsilon}}, \qquad 0 < \varepsilon < 1,$$

where $1/(1-\varepsilon)$ is the elasticity of substitution between different varieties and m is the mass (hereafter, number) of varieties supplied by the non-tradable sector. We set $A_R = 1$ to simplify the model and leave only $A_T = A$ to matter in the baseline analysis.[5] A is an index broadly interpreted as those exogenous features of a city (monuments, museums, parks, etc.) that attract tourists. Let us call them historical amenities (this term may also include natural amenities). The number of varieties m of the services sector plays in our setting the role of a consumption amenity. In fact, *ceteris paribus*, under Dixit-Stiglitz preferences

[5]Tourism may affect the resident population through increased commuting times, noise, congestion on public transportation, etc. These issues represent a form of non-market congestion, and we include them into an extension to the baseline model. Our model already features some congestion effects in the form of higher prices, so we prefer to leave out of the baseline model non-market congestion.

consumers' welfare is increasing in the number of differentiated varieties supplied by the market. We think of m as the number of restaurants, retail shops, and other activities connected with a thriving services sector. This number makes a city more or less attractive, and is endogenously determined. In our model, consistently with the empirical patterns we have documented, this number is related to the number of tourists visiting the city.

Some comments are in order about the preference structure. First, we assume that residents and tourists consume the same goods.[6] Second, we assume that residents and tourists devote the same share of their budget to land consumption. Residents' budget coincides with their income, while in the case of tourists it has to be interpreted as the budget devoted to the holiday. Third, assuming that all tourists consume land, we neglect the role of day-trippers.

Residents and tourists maximize utility subject to the budget constraint, which is given by:

$$\int_0^m p_{sj} c_{ij} dj + q h_i \leq I_i = \begin{cases} w + \frac{qH}{n_R} & \text{for } i = R \\ I_T & \text{for } i = T \end{cases}$$

where p_{sj} is the price of one unit of non-tradable variety j, w is the wage rate, q is the price of one unit of land, so that qH/n_R are land rents earned by a resident. I_T is the exogenous tourist holiday budget to be spent on non-tradable services and accommodation. In our model there is a unique labor market with perfectly mobile workers, and consequently the equilibrium wage rate is unique. Taking the first-order conditions, individual demands are given by:

$$\begin{aligned} c_{ij} = &\quad p_{sj}^{-\frac{1}{1-\varepsilon}} P_s^{\frac{\varepsilon}{1-\varepsilon}} \gamma I_i, \quad j = 1, ..., m, \\ h_i = &\quad (1-\gamma)\frac{I_i}{q}, \end{aligned} \tag{1.1}$$

where P_s is the price index for the bundle of non-tradable services varieties, $P_s = \left(\int_0^m p_i^{\frac{-\varepsilon}{1-\varepsilon}} di \right)^{-\frac{1-\varepsilon}{\varepsilon}}$. Aggregate demand for non-tradable variety j is given by:

$$n_R c_{R,j} + n_T c_{T,j} = p_{js}^{-\frac{1}{1-\varepsilon}} P_s^{\frac{\varepsilon}{1-\varepsilon}} \gamma (w n_R + qH + n_T I_T). \tag{1.2}$$

As far as the price of each non-tradable services variety is the same (something that we show to be in at equilibrium) the indirect utilities of residents and tourists are:

$$V_R = m^{\frac{\gamma(1-\varepsilon)}{\varepsilon}} \frac{w + q\frac{H}{n_R}}{p_s^\gamma q^{1-\gamma}}, \tag{1.3}$$

$$V_T = A m^{\frac{\gamma(1-\varepsilon)}{\varepsilon}} \frac{I_T}{p_s^\gamma q^{1-\gamma}}, \tag{1.4}$$

where p_s is the equilibrium price of differentiated varieties. Residents and tourists welfare are linked in a positive manner to two endogenous components: first, they are linked to the number m of non-tradable

[6] It can be argued that the consumption basket of residents and tourists is actually quite different. In the polar case where residents and tourists consume two disjoint sets of differentiated varieties (so that one sector supplies differentiated varieties to residents, and another sector supplies differentiated varieties to tourists) it is possible to show that, in aggregate terms, the model keeps the same equilibrium properties as in the baseline case. We show this extension to the model in the online supplemental appendix.

services varieties, due to the *love of variety effect* embedded in the CES preference structure; second, they are linked to residents' *real income* and tourists' *real holiday budget*, respectively, since nominal quantities I_R and I_T are deflated by the price index $p_s^{\gamma} q^{1-\gamma}$. At equilibrium, the number of tourists will influence welfare through all these channels. Moreover, note that the nominal income of residents, $I_R = w + q(H/n_R)$, depends on wages and land prices. Instead, tourist nominal holiday budget, I_T, is fixed; however, in equilibrium the tourist real holiday budget does respond to the number of tourists via the effect on prices.

1.3.2 Production

In the city there are two sectors: a differentiated non-tradable sector (non-tradable services) and a homogenous intermediate sector, whose output is used in the production of non-tradable services and freely traded on world markets. We choose the homogenous good as the numeraire of the economy.

The non-tradable sector, indexed by s, is characterized by monopolistic competition. Each variety j is produced according to a Cobb-Douglas production function that combines labor, land, and the intermediate input under constant returns to scale. Therefore, output for each variety is equal to

$$y_{sj} = a_s l_{sj}^{\alpha_s} h_{sj}^{\beta_s} y_{kj}^{1-\alpha_s-\beta_s},$$

where a_s is the TFP in the non-tradable sector common to all firms, l_{sj} is labor, h_{sj} is land, and y_{kj} is the quantity of intermediate input employed by firm j. To enter the non-tradable sector, firms need a fixed requirement of η units of the intermediate input. In the absence of strategic interactions, the firm maximizes its profits subject to aggregate demand for the single variety, given by (1.2), taking the aggregate price index, P_s, as given. The first order conditions for the firm problem are:

$$\begin{aligned} \varepsilon \alpha_s p_{sj} \tfrac{y_{sj}}{l_{sj}} &= w, \\ \varepsilon \beta_s p_{sj} \tfrac{y_{sj}}{h_{sj}} &= q, \\ \varepsilon (1 - \alpha_s - \beta_s) p_{sj} \tfrac{y_{sj}}{y_{kj}} &= 1. \end{aligned} \tag{1.5}$$

Furthermore, free entry into the non-tradable sector ensures that in equilibrium all firms make zero profits:

$$\pi_{sj} = p_{sj} y_{sj} - w l_{sj} - q h_{sj} - y_{kj} - \eta = 0. \tag{1.6}$$

Clearly, given that all non-tradable firms share the same production function with the same TFP, they will charge the same price in equilibrium, $p_{sj} = p_s$ for all $j = 1, ..., m$, and demand the same amount of production factors. From the conditions in (1.5) we get that the price of a differentiated variety is equal to the marginal cost times a mark-up term,

$$p_s = \frac{w^{\alpha_s} q^{\beta_s}}{\varepsilon \kappa_s a_s},$$

where $\kappa_s < 1$ is a constant.[7] From now on we drop subscript j. Aggregate labor demand in sector s is then given by $L_s = \int_0^m l_{sj} dj = m l_s$. Aggregate land demand (H_s) and intermediate input demand (Y_k) can be expressed in a similar way.

[7]In appendix B we provide the values of the constants defined in the text; see appendix C for the derivation of p_s.

The intermediate sector, indexed by k, operates under constant returns to scale and uses labor only. The production function is $Y_k^o = a_k L_k$, where a_k is the TFP in the intermediate sector. Under our assumption of a single labor market, with workers freely mobile between sectors, and as long as $L_k > 0$, the wage rate is fixed and equal to the marginal revenue in the intermediate sector, $w = a_k$.

1.3.3 Equilibrium

There are four markets in our model: non-tradable services, land, labor, and the intermediate input. Equilibrium in each market requires:

$$n_R c_R + n_T c_T = y_s \qquad \text{(non-tradable market)} \tag{1.7}$$

$$n_R h_R + n_T h_T + m h_s = H \qquad \text{(land market)} \tag{1.8}$$

$$m l_s + L_k = n_R \qquad \text{(labor market)} \tag{1.9}$$

$$m(y_k + \eta) = Y_k^o + X \qquad \text{(intermediate input)} \tag{1.10}$$

where X are net aggregate imports of the intermediate input. In the market clearing conditions, we use the property of firm symmetry in the non-tradable sector. Equations (1.1), (1.5), (1.6), condition $w = a_k$, and equations (1.7) – (1.10) characterize the general equilibrium in the city.

Market clearing and the zero-profit condition in the non-tradable sector imply that $n_T I_T = X$.[8] This condition is a current account balance condition between the city and the rest of the world. It says that tourist expenditure that flows into the city has to be perfectly matched by payments on the intermediate input that flow out of the city, due to net imports.

In our model, the expansion of tourism causes the city to specialize more towards the services sector, at the expense of the tradable sector. To show this, we derive an expression for the share of the labor force in the services sector as a function of the number of tourists:[9]

$$\frac{L_s}{n_R} = \frac{\alpha_s \varepsilon}{1 - \beta_s \varepsilon} \left(1 + \frac{n_T I_T}{w n_R} \right). \tag{1.11}$$

As long as $L_k > 0$, so that $w = a_k$, this expression pins down L_s/n_R as a function of n_T/n_R. It says that, relative to the residents population, the labor force employed in the non-tradable sector is increasing in the number of tourists who visit the city.

Proposition 1. *The share of the labor force employed in the services sector, L_s/n_R, is increasing in the share of tourists in a city, n_T/n_R.*
When the number of tourists is greater than a threshold $\hat{n}_T$ the city becomes fully specialized in non-tradable services, that is, $L_s/n_R = 1$.

The economic intuition behind this result is simple, and it is related to the economic literature on tourism and the Dutch disease – see, for instance, Copeland (1991) and Chao et al. (2006). Since services are not

[8] See appendix C.
[9] See appendix C.

tradable, increased tourist demand pushes up revenues in the non-tradable sector, whereas the price for the intermediate input is fixed on world markets. Hence, the economy moves factors of production to the non-tradable sector and substitutes the domestic production of the intermediate input with imports. Table 1.3, in section 1.2, presents empirical evidence that is consistent with proposition 1.

When the number of tourists is greater or equal than $\hat{n}_T$, the intermediate sector disappears and the city economy becomes fully-specialized in the non-tradable sector. Setting $L_s = n_R$ in (1.11), we derive $\hat{n}_T$:

$$\hat{n}_T \equiv \frac{1-(\alpha_s+\beta_s)\varepsilon}{\alpha_s\varepsilon}\frac{a_k n_R}{I_T}.$$

This threshold is increasing in the productivity of the intermediate sector, a_k, and in the resident population, n_R. Therefore, larger cities, as well as cities where the intermediate sector is more productive, can host a larger number of tourists before full specialization is reached. To get a sense of the magnitude of this threshold, let us provide a simple parametrization. Following the estimates of Valentinyi and Herrendorf (2008) for the services sector, we set $\alpha_s = 0.65$ and $\beta_s = 0.2$. Given there is no construction sector in our model, we include both land and structures into the factor of production land. Also, we set the elasticity of substitution between services varieties, $1/(1-\varepsilon)$, equal to 4, implying $\varepsilon = 0.75$. Given these values, the share of tourists over residents such that cities become fully specialized in services, $\hat{n}_T/n_R$, is equal to a fraction 0.74 of a_k/I_T, the ratio of local wages over tourist holiday budget. Data show that the level of wages is close to annualized tourist expenditure, and this implies that the cutoff for full specialization is high. Therefore, the model suggests that only under special circumstances should we observe full specialization in the services sector at the city level.[10] In the rest of the analysis we concentrate on a partially-specialized city, assuming that $n_T < \hat{n_T}$.

We can now complete the description of the equilibrium. The equilibrium number of firms in the non-tradable sector is:

$$m = \kappa_m \frac{a_k n_R + n_T I_T}{\eta}, \tag{1.12}$$

with κ_m being a constant. The equilibrium land price is:

$$q = \kappa_q \frac{a_k n_R + n_T I_T}{H}, \tag{1.13}$$

with κ_q being a constant.[11] Given the Cobb-Douglas assumption imposed on both utility and production, the non-tradable sector always employs a constant fraction of the city land, regardless of the number of tourists in the city:

$$H_s = \frac{\beta_s\varepsilon\gamma}{1-\gamma+\beta_s\varepsilon\gamma}H.$$

[10] According to Istat (2017a) median disposable income in Italy was 16,115 euros in 2015 for a single person. According to Istat (2017b) average daily expenditure by Italian tourists for a holiday in Italy was 78 euros in 2015, which corresponds to an annual equivalent of 28,470 euros. Back-of-the-envelope calculations show that in this case a share equal at least to 0.42 tourists per resident is needed to get full specialization. In our sample of roughly 8,000 Italian municipalities, in year 2001 the ratio $\frac{n_T}{n_R}$ has a mean of 0.03, and exceeds 0.42 in about 100 municipalities, being mostly seaside and mountain resorts.

[11] See appendix C.

Finally, the equilibrium price for non-tradable services varieties is:

$$p_s = \kappa_p \frac{a_k^{\alpha_s}}{a_s} \left(\frac{a_k n_R + n_T I_T}{H} \right)^{\beta_s}, \tag{1.14}$$

where κ_p is a constant. Let us make some comments about the relationships we derived so far. First, note that the variables m, q and p_s are strictly increasing in n_T. Second, note that whereas m and q are linear in the number of tourists, p_s is a concave function. This has implications when we evaluate the welfare impact of tourism. Finally, as far as m is concerned, table 1.2 in section 1.2 presents empirical evidence that is consistent with equation (1.12).

1.3.4 Welfare

What is the impact of tourism on the welfare of residents? The number of tourists affects the welfare of residents through the level of consumption amenities and the change in real income. The effect on consumption amenities is always positive – see equation (1.12): tourism boosts growth in services, increasing the number of available varieties. In contrast, the sign of the real income effect is not obvious: as tourists flow into the city, the resident population earns better rents (wages are fixed under partial specialization), but also faces higher consumption prices. The following proposition characterizes the impact of tourism on the welfare of residents.

Proposition 2. *The welfare of residents, V_R, is always increasing in the number of tourists, n_T.*

Proof. See Appendix D. □

Residents welfare depends on consumption amenities and real income. In turn, real income depends on real wages and real land income. Resident nominal wages are fixed, so that the impact of tourism runs through land prices only. The effect of tourism on real land income is always positive: nominal land income rises linearly with the number of tourists, whereas the price index $p_s^{\gamma} q^{1-\gamma}$ is concave. The effect of tourism on real wages is always negative, but the positive real land income and consumption amenity effects prevail. Therefore, the total welfare effect of tourism on residents is positive.[12]

Let us now turn to the welfare of tourists. Again, the effect on consumption amenities is positive. In contrast, the real income effect is always negative, as tourist budget is fixed at I_T and doesn't adjust to the tourism-related hike in prices. Which of the two effects prevails? The following proposition shows that tourists are worse off in tourism-crowded cities as long as the services sector is weakly differentiated.

Proposition 3. *The welfare of tourists, V_T, is decreasing in the number of tourists, n_T, if and only if*

$$\varepsilon > \frac{\gamma}{1 + \beta_s \gamma} \equiv \hat{\varepsilon}.$$

[12] Proposition 2 is related to the result in Copeland (1991), that tourism improves welfare, since an increase in the price of non-tradables amounts to a terms-of-trade improvement. In our setting tourism increases the price of land with respect to the price of the tradable intermediate input, which is fixed on international markets. However, our model also features monopolistic competition in the services sector; thus, it allows to shed light on endogenous consumption amenities.

Proof. See Appendix D. □

The economic intuition behind this result is simple. When services varieties are not too differentiated (that is, when ε is sufficiently high) the gains from variety are low and the negative real income effect prevails. In this case, the impact of tourism on the welfare of tourists is negative. However, provided that ε is sufficiently low, the gains from variety overcome the real income losses, and an increase in the number of tourists, n_T, brings a positive effect on the welfare of tourists. In the remainder of the paper, we say that consumption amenities are *weak* when $\varepsilon > \hat{\varepsilon}$ (poorly differentiated services sector), and that consumption amenities are *strong* when $\varepsilon \leq \hat{\varepsilon}$ (strongly differentiated services sector).

1.4 Amenities and welfare in a system of two cities

In this section, we study the spatial equilibrium of tourists across alternative destinations. The parameter A, the level of historical amenities, is going to play a role in this section: since A enters the welfare of tourists, tourists' mobility creates a link between local historical amenities and the endogenous variables of the model, including consumption amenities and the welfare of residents. Cities with a rich historical heritage attract more tourists, and therefore have higher land prices, consumption prices, and a larger services sector, with a higher number of varieties. We focus on a simple system of two cities that differ in terms of four exogenous parameters: the level of historical amenities enjoyed by tourists, the TFP of the tradable and non-tradable services sectors, and the stock of land. Both cities are small open economies that can freely trade with each other and with the rest of the world. Thus, as in the baseline case, the price of the tradable good is fixed on international markets and normalized to 1. Concerning the resident population, we consider two polar assumptions. First, we assume that residents are immobile. Second, we assume they are freely mobile between the two cities, with the total number of residents in the urban system being exogenous and equal to N_R. Our approach is in the spirit of the Rosen-Roback classic framework (Rosen 1979; Roback 1982), with the difference that, in our model, there are two groups of mobile agents: tourists and residents. Our model is also related to Anas and Pines (2008), who study the consequences of congestion in a system of two cities; however, whereas they model a *closed* urban system, we consider an *open* urban system, where a tradable good may be exchanged with an outer economy. In fact, given that tourist expenditure is exogenous in our setting, we require cities to import goods from the rest of the world in order to maintain the equilibrium on the balance of payments. We focus on the case where both cities are partially specialized in non-tradables, even when all tourists head to the same city, and consumption amenities are weak.[13]

[13] In formal terms we are assuming that $N_T < min[\widehat{n}_{T,1}, \widehat{n}_{T,2}]$ and $\varepsilon > \hat{\varepsilon}$. In the Online supplemental appendix we present the results for strong consumption amenities and immobile residents: in this case, apart from a knife-edge situation, the spatial equilibrium encompasses the full agglomeration of tourists in one destination, even when the two cities are identical in terms of the exogenous parameters.

1.4.1 Spatial equilibrium with immobile residents

Let ϕ_T denote the fraction of the total tourist population choosing city 1, $n_{T,1} = \phi_T N_T$. Tourists are freely mobile between the two destinations, whereas residents are immobile. We may have either an interior equilibrium where tourists visit both cities, or corner solutions where all tourists agglomerate in one of the two cities. Therefore, the spatial equilibrium requires:

$$\begin{aligned} & \Delta V(\phi_T) \equiv V_{T,1}(\phi_T) - V_{T,2}(\phi_T) = 0, \quad \text{and} \quad 0 < \phi_T < 1 \qquad (1.15) \\ \text{or} \qquad & \Delta V_T(\phi_T) \leq 0, \quad \text{and} \quad \phi_T = 0 \\ \text{or} \qquad & \Delta V_T(\phi_T) \geq 0, \quad \text{and} \quad \phi_T = 1 \end{aligned}$$

meaning that no tourist has an incentive to change his choice of destination. This first condition characterizes the interior equilibrium, and the latter two the corner solutions. The interior equilibrium exists and is unique if and only if

$$\frac{\partial \Delta V_T(\phi_T)}{\partial \phi_T} < 0 \quad \text{for} \quad 0 < \phi_T < 1, \qquad (1.16)$$

$$\Delta V_T(0) > 0, \qquad (1.17)$$

$$\Delta V_T(1) < 0. \qquad (1.18)$$

When the non-tradable sector supplies poorly differentiated varieties ($\varepsilon > \hat{\varepsilon}$) the effect of consumption amenities on welfare is weak. In this case, we know from proposition 3 that tourist welfare is decreasing with the number of tourists visiting the city. As a result, ΔV_T is decreasing in ϕ_T, and condition (1.16) is verified. The closed-form expression for ϕ_T at the interior equilibrium is:

$$\phi_T = \frac{TP_1}{TP_1 + TP_2} + \frac{TP_1 a_{k,2} n_{R,2} - TP_2 a_{k,1} n_{R,1}}{(TP_1 + TP_2) N_T I_T}, \qquad (1.19)$$

where the two terms, labeled TP_1 and TP_2, can be interpreted as the *tourist potential* of a city in terms of historical amenities, tradable and non-tradable sectors productivity, and total land stock:

$$TP_1 \equiv \left(\frac{A_1 a_{s,1}^{\gamma} H_1^{1-\gamma+\beta_s\gamma}}{a_{k,1}^{\alpha_s\gamma}} \right)^{1/\delta},$$

$$TP_2 \equiv \left(\frac{A_2 a_{s,2}^{\gamma} H_2^{1-\gamma+\beta_s\gamma}}{a_{k,2}^{\alpha_s\gamma}} \right)^{1/\delta},$$

where $\delta \equiv (1-\gamma+\beta_s\gamma) - \frac{\gamma(1-\varepsilon)}{\varepsilon} > 0$ since consumption amenities are weak. The tourist potential of a city is positively related to the level of the historical amenity, the productivity of the non-tradable sector, the land stock, and it is inversely related to the productivity of the tradable sector. The effect of A is obvious, since it is a parameter that enters directly into the utility function of tourists. The effect of H works through a reduction in the price of land, see equation (1.13), and in the price of non-tradable services, see equation (1.14). The parameter a_s makes a city more attractive through a reduction in p_s again. A rise in a_k (and in the city's wage rate) makes it less attractive through a corresponding rise in q and p_s.

We still have to characterize the corner solutions. Intuitively, an interior equilibrium exists as long as none of the two cities is overwhelmingly more attractive than the other, from the tourist's point of view.

Merging (1.17) and (1.18), we obtain the following restriction on the ratio of the tourist potential of the two cities:

$$\frac{a_{k,1}n_{R,1}}{a_{k,2}n_{R,2}+N_TI_T} < \frac{TP_1}{TP_2} < \frac{a_{k,1}n_{R,1}+N_TI_T}{a_{k,2}n_{R,2}}. \tag{1.20}$$

When these inequalities do not hold, tourists concentrate in a single city, that we label *tourist hub*. Two possible cases - interior equilibrium and a tourist hub in city 2 - are depicted in figure 1.3. Condition (1.20) also shows that, in general, when the total number of tourists N_T is high, a tourist hub never emerges under weak consumption amenities.

[Insert Figure 1.3 about here]

We now discuss the implications of the two-city structure for residents welfare, with a special emphasis on the role of historical amenities, A. When residents are immobile, we can go back to equations (1.11) – (1.14) and obtain the endogenous variables of the model in terms of the tourism potential in both cities. Let us focus on city 1. We find that the the share of the labor force employed in the non-tradable sector, $L_{s,1}/n_{R,1}$, the number of firms in the non-tradable sector, m_1, the price of land, q_1, and the price of non-tradable goods, $p_{s,1}$, are positively related the level of historical amenities A_1. Cities with more historical amenities have, on one hand, higher consumption amenities and higher land income; on the other hand, they have higher prices for the two consumption goods, namely non-tradable services and land itself. Given proposition 2, historical amenities raise the welfare of residents unambiguously: even though they do not have a direct impact on residents welfare, they attract more tourists to the city and affect the endogenous variables of the model.

Proposition 4. *The welfare of residents in city 1, $V_{R,1}$, is always increasing in the level of local historical amenities, A_1.*

The important implication of this result is that, *ceteris paribus*, for residents it is better to live in a city with higher historical amenities than in a city with lower historical amenities, thanks to the economic consequences of tourism on the urban economy. The higher is the historical amenity advantage of, say, city 1 over city 2, the higher is the share of tourists ϕ_T, and, therefore, the higher is the welfare of residents in city 1 as compared to city 2.

1.4.2 Spatial equilibrium with mobile residents

We now allow the resident population to relocate between the two cities to take advantage on any welfare differentials that may arise, including those induced by tourism. Thus, the spatial distribution of residents in the urban system is now determined in the spatial equilibrium together with the distribution of tourists. We still assume that consumption amenities are weak ($\varepsilon > \hat{\varepsilon}$) and treat the total number of tourists in the urban system, N_T, as exogenous. Let ϕ_R denote the share of residents who live in city 1, $\phi_R = n_{r,1}/N_R$. To characterize the spatial equilibrium, we take into account two facts. First, the welfare of tourists in both cities now depends on ϕ_R, besides ϕ_T; thus, we rewrite (1.15) as:

$$\begin{aligned} & \Delta V(\phi_T, \phi_R) \equiv V_{T,1}(\phi_T, \phi_R) - V_{T,2}(\phi_T, \phi_R) = 0 \quad \text{and} \quad 0 < \phi_T < 1, \\ \text{or} \quad & \Delta V_T(\phi_T, \phi_R) \leq 0 \quad \text{and} \quad \phi_T = 0, \\ \text{or} \quad & \Delta V_T(\phi_T, \phi_R) \geq 0 \quad \text{and} \quad \phi_T = 1, \end{aligned} \tag{1.21}$$

where the first condition describes an interior solution and the second and third conditions describe the corner solutions where tourists cluster in one city. Second, we need a condition to describe the spatial equilibrium for residents. Under weak consumption amenities ($\varepsilon > \hat{\varepsilon}$ and $\delta < 0$) we can rule out the existence of corner solutions for residents (either $\phi_R = 0$ or $\phi_R = 1$) for any value of ϕ_T, because their indirect utility becomes very large as the number of residents approaches zero. Thus, at the spatial equilibrium the welfare of residents must be equal in the two cities:

$$\Delta V(\phi_T, \phi_R) \equiv V_{R,1}(\phi_T, \phi_R) - V_{R,2}(\phi_T, \phi_R) = 0, \quad \text{and} \quad 0 < \phi_R < 1. \tag{1.22}$$

The system of equations (1.21) and (1.22) is non-linear and cannot be fully solved in closed form. To further illustrate the properties of the model, we run a simple simulation exercise. Specifically, we consider two symmetrical cities in terms of land endowments, and tradable and non-tradable sectors TFP, and we compute the equilibrium distribution of tourists and residents in the two cities for different values of relative tourist amenities. We fix the parameter A_2 to the value of 1 in city 2, and let the corresponding parameter in city 1, A_1, vary from 0.9 to 1.1. We base our simulation on the average values for roughly 800 cities in the top 9th decile of the tourist/resident ratio in 2001 in our Italian data. On average, these municipalities host 9,550 residents and 260 tourists;[14] multiplying by 2 to mimic a two-city system, we obtain $N_R = 19,100$ and $N_T = 520$. The average land area is 46 squared kilometres, thus we set $H = 46$ in both cities. We set a_k, the TFP in the intermediate sector, equal to $16,115$ to match the median value of disposable income in Italy for a single person, and we assume the same value for the TFP in the services sector, a_s. For the parameters α_s, β_s, and ε we use the values reported in section 1.3.3; in addition, we set $1 - \gamma$, the share of land expenditure in consumer's budget, equal to 0.3. Finally, we use equation (1.12) and the total number of food-services establishments and retail stores in our tourist-intensive municipalities to calibrate a value for the fixed cost in the services sector, η; since $m = 140$ in our sample, a back-of-the-envelope calculation gives $\eta = 229,770$.

Figure 1.4a shows that in the value range $0.9 < A_1 < 1.1$, the share of city 1's labor force employed in the services sector increases by roughly 5 percentage points, remaining well below the full specialization cutoff. In figure 1.4b we illustrate our main simulation results. A 4% difference in the relative value of amenities is enough to attract all tourists in one of the two cities: when $A_1 < 0.96$, roughly, all tourists go to city 2, whereas when $A_1 > 1.04$ all tourists go to city 1. Within this range, we get an interior equilibrium where tourists visit both cities. The share of tourists in city 1 goes up as A_1 increases. Furthermore, the increasing tourist population raises the welfare of residents in city 1, and therefore entices more residents to

[14] As in the empirical analysis, the tourist population equals the number of overnight stays divided by 365.

relocate there from city 2 until indirect utilities are again equalized in the two cities. From roughly 0.475, when there are no tourists around, the share of the total resident population who lives in city 1 goes up to roughly 0.525, when all tourists visit that city. Moreover, the figure shows that the share of tourists increases more rapidly than the share of residents as historical amenities in city 1 rise. In other terms, as a tourist destination becomes more attractive, the spatial sorting of tourists is more intense than the sorting of residents. This is to be expected, since historical amenities affect tourists' utility in a direct fashion, while residents are affected only indirectly through the mechanisms at work in our model (i.e., real land income and endogenous consumption amenities).

[Insert Figure 1.4 about here]

It is interesting to note how the spatial sorting of residents and tourists in the two cities is in fact driven by a sort of comparative advantage. Let us add some analytical derivations. When we are at an interior spatial equilibrium ($0 < \phi_T < 1$) using (1.21) and (1.22) we get that

$$\frac{1}{A_2}\frac{1-\phi_T}{1-\phi_R} - \frac{1}{A_1}\frac{\phi_T}{\phi_R} = \frac{1}{1-\gamma+\beta_s\gamma\varepsilon}\left(\frac{a_{k,1}}{A_1} - \frac{a_{k,2}}{A_2}\right)\frac{N_R}{N_T I_T},$$

where the right-hand side of this expression can be interpreted as a measure of the comparative advantage of city 1 at attracting residents through high wages ($w = a_k$ under partial specialization) over attracting tourists through high historical attractions. Accordingly, when city 1 has a comparative advantage at attracting residents and city 2 at attracting tourists,

$$\frac{a_{k,1}}{A_1} > \frac{a_{k,2}}{A_2}, \tag{1.23}$$

we get

$$\frac{\phi_T}{\phi_R} < \frac{A_1}{A_2}\frac{1-\phi_T}{1-\phi_R}, \tag{1.24}$$

which says that the share of tourists over the share of residents in city 1 is smaller than the share of tourists over the share of residents in city 2, net of relative historical amenities. Going back to our simulation exercise, tradable sector's TFP and wages are equal in the two cities ($a_{k,1} = a_{k,2}$) and $A_2 = 1$. When $A_1 < 1$ in the simulations, (1.23) is still verified so that city 1 has a comparative advantage at attracting residents, and city 2 at attracting tourists. From (1.24) we easily derive that the share of tourists hosted in city 1 is smaller than the share of residents, $\phi_T < \phi_R$. Along the same line of reasoning, for $A_1 = 1$ we get that $\phi_T = \phi_R$, while for $A_1 > 1$ city 1 has a comparative advantage at attracting tourists over residents, and then $\phi_T > \phi_R$. These patterns are exactly matched by figure 1.4b.

The role of historical amenities in attracting residents to the city is amplified by the strength of endogenous consumption amenities: stronger product differentiation in services strengthens the pull of residents exerted by the expanding services sector. To show this, we re-run the previous exercise for 10 different values of ε, ranging from 0.65 to 0.95. A lower value of this parameter corresponds to stronger consumption amenities. Figure 1.5 shows the increase in the share of residents living in city 1, ϕ_R, corresponding to the increase in historical amenities from 0.9 to 1.1, such that the whole tourist population moves from city 2 to city 1, for different values of ε. The rise in the resident population due to increasing historical amenities ranges from below 1%, when consumption amenities are very weak ($\varepsilon = 0.95$) to more than 20%, when consumptions amenities are moderate ($\varepsilon = 0.65$). With a vertical line we indicate the benchmark value for ε, that was set at $\varepsilon = 0.75$.

[Insert Figure 1.5 about here]

We now investigate the relationship between historical amenities, tourism and the welfare of residents. Varying the relative value of amenities, we study the indirect utility of a resident in the urban system (since residents are free to move, their welfare in the two cities is equalized). Our results are reported in figure 1.6. On the vertical axis we show the indirect utility of any resident in the urban system, V_R, for three different values of ε. Since we are interested, for a given ε, in studying the welfare of residents associated to a specific spatial distribution of tourists, we have normalized welfare to one in the baseline scenario where no tourist goes to city 1 ($A_1 = 0.9$).[15] Two points stand out in figure 1.6. First, the welfare of residents is not monotone in the relative value of historical amenities and, thus, in the number of tourists who visit the city. This contrasts with the scenario where residents are immobile. Second, the shape of the welfare schedule depends crucially on the strength of consumption amenities. When consumption amenities are not too weak (low ε) welfare reaches a maximum at $A_1/A_2 = 1$, when tourists are equally spread between the two cities. In our baseline parametrization, with $\varepsilon = 0.75$, the welfare gain associated to having two equally attractive cities with equal historical amenities is tiny, roughly 0.02%, as compared to a scenario where tourist attractions are concentrated in a single destination (where all tourists cluster). In contrast, when consumption amenities are very weak (high ε) the reversed pattern obtains; in this case, residents are best off when A_1/A_2 is either very low or very high, and all tourists agglomerate in one city. In the former case (low ε) when both cities are similar and receive tourists they develop a thriving services sectors, which is valuable to consumers given that product varieties are well differentiated. In the latter case (high ε) where product varieties are poorly differentiated, the best option from the residents' point of view is to live in an asymmetric urban system, where one city is relatively specialized in retail services, hosts a larger resident population, and has a rich pool of historical amenities which attract all tourists, and the other city remains a smaller manufacturing town, relatively specialized in the production of tradable goods, and with little historical amenities to amuse tourists.

[Insert Figure 1.6 about here]

In appendix F we show that the basic mechanisms are the same when we allow the tradable sector productivity, in addition to historical amenities, to differ across cities.

[15] Without normalization, V_R is strictly higher for a lower ε, for any value of A_1.

1.5 Extensions

1.5.1 Congestion effects

In our model with a fixed resident population, tourism improves the welfare of residents at the city level, even as the number of tourists becomes very large. However, excessive tourism may cause a number of problems such as increased commuting times, noise, congestion on public transports, etc.[16] These issues represent a form of non-market congestion. To introduce them we develop a simple extension of our framework. Let us bring back into the model the parameter A_R, indexing the value of local amenities for residents, such that the utility of residents is:

$$U_R = A_R \left(\frac{C_R}{\gamma}\right)^{\gamma} \left(\frac{h_R}{1-\gamma}\right)^{1-\gamma}, \qquad 0 < \gamma < 1.$$

We assume that the amenity A_R is subject to non-market congestion; that is, it depreciates as the number of tourists in the city n_T increases, $\partial A_R/\partial n_T < 0$. Since A_R doesn't enter the maximization problem, the equilibrium allocation is the same as before. Thus, we can write the indirect utility of residents as $\tilde{V}_R \equiv A_R V_R$, where V_R is the equilibrium welfare of residents in the baseline case – see section 1.3.

As an illustration, suppose that $A_R(n_T) = e^{-\rho n_T}$. Then,

$$\frac{\partial \tilde{V}_R}{\partial n_T} < 0 \iff -\frac{\partial A_R}{\partial n_T}\frac{n_T}{A_R} > \frac{\partial V_R}{\partial n_T}\frac{n_T}{V_R}$$

where we are comparing two elasticities with respect to the number of tourists: the elasticity of non-market congestion, and the elasticity of V_R (which combines the elasticity of consumption amenities and real land income). We then get the condition

$$\rho > \frac{\partial V_R}{\partial n_T}\frac{1}{V_R}. \tag{1.25}$$

The optimal number of tourists, n_T^*, that maximizes residents welfare is the one implicitly defined by the following condition:

$$\rho = \frac{\partial V_R}{\partial n_T}\frac{1}{V_R}.$$

If we assume that ρ is not too large, $\rho < \frac{\partial V_R}{\partial n_T}\frac{1}{V_R}$ for n_T close to zero, a sufficient condition for the existence of an optimal level of tourists that maximizes resident welfare $\tilde{V}_R$ is that the right-hand side of (1.25) is monotonically decreasing in n_T. In Appendix E we provide it, and show that, basically, it entails that consumption amenities are not too weak. For low levels of tourism ($n_T < n_T^*$) the combination of increasing real incomes and increasing consumption amenities prevail over non-market congestion forces; for high levels of tourism ($n_T > n_T^*$), the opposite is true. Consequently, the welfare of residents is hump-shaped in the number of tourists, with a bliss point at n_T^*.

1.5.2 Higher substitutability between labor and the intermediate input

In this section, we develop a simple extension of the production function in the services sector, such that the elasticity of substitution between labor and the intermediate input can be greater than one. This implies

[16] See, for instance, the report by McKinsey&Company and World Travel and Tourism Council (2017).

that it takes a larger number of tourists for cities to reach full specialization. This result reinforces our conclusion that the partial specialization scenario is the most relevant to analyze: beforehand we made this point on empirical grounds, given that full specialization is hard to observe in real world – we now add a theoretical argument.

In practice, we assume that labor and the intermediate input are combined according to a CES structure, with elasticity of substitution $\theta \geq 1$; this structure is then nested into a Cobb-Douglas production function that includes land. Therefore, all the results that follow subsume our baseline results as a special case in which $\theta = 1$. Formally, let the production function for the non-tradable good be:

$$y_s = a_s h_s^{\beta_s} \left[(\alpha_s)^{\frac{1}{\theta}} l_s^{\frac{\theta-1}{\theta}} + (1-\alpha_s-\beta_s)^{\frac{1}{\theta}} y_k^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}(1-\beta_s)}, \quad \text{with} \quad \theta \geq 1,$$

while the production function for the intermediate good is the same as in the baseline case. Combining the first-order conditions for l_s and y_k, and summing over all firms we obtain:

$$wL_s = \frac{\alpha_s}{(1-\alpha_s-\beta_s)} w^{1-\theta} Y_k.$$

Using the market clearing condition for the intermediate good and for labor, and following the same steps as in section 1.3.3, we can write:

$$wL_s = \frac{\alpha_s w^{1-\theta}}{\alpha_s w^{1-\theta} + (1-\alpha_s-\beta_s)} (wn_R + n_T I_T - m\eta).$$

Using the zero profit condition we get

$$\frac{L_s}{n_R} = f(\theta) \left(1 + \frac{n_T I_T}{wn_R} \right), \tag{1.26}$$

where $f(\theta) = \frac{\varepsilon(1-\beta_s)}{1-\beta_s\varepsilon} \frac{\alpha_s w^{1-\theta}}{\alpha_s w^{1-\theta}+(1-\alpha_s-\beta_s)}$. Equation (1.26) is a generalization of equation (1.11). The wage is pinned down in the intermediate sector ($w = a_k$) under partial specialization, and the share of residents employed in services still increases linearly with the number of tourists. However, given that $f(1) = \alpha_s\varepsilon/(1-\beta_s\varepsilon)$ and $f'(\theta) < 0$ for $\theta \geq 1$, the slope of $\frac{L_s}{n_R}$ with respect to n_T is now flatter than in (1.11). As a result, the threshold $\hat{n}_T$ is larger than in the baseline case. In particular, it is possible to show that $\hat{n}_T$ is increasing in θ, and tends to infinity as $\theta \to \infty$. Thus, the scope of partial specialization increases the more substitutable are labor and the intermediate input.

1.6 Conclusions

In this paper we have shown that the number of establishments and employment in non-tradable services industries that are related to consumption amenities react to the inflow of tourists at the city level in Italy. Consistently with these findings, we set up a general equilibrium model of small open cities that are tourist destinations, to study the impact of tourism on endogenous amenities, factors' allocations across sectors, prices, and welfare.

The model uncovers new normative implications about tourism and residents' welfare. An interesting message of our paper concerns whether it is better for a resident to live in a city with more historical amenities and hence more tourism than other cities. We show why and when this is the case, and we also show that when residents are mobile the strength of consumption amenities can make an urban system where cities are similar in terms of historical amenities the best possible configuration. In other terms, our model sheds light on the welfare consequences of the interaction of historical (exogenous) amenities and consumption (endogenous) amenities at the urban level.

Our model also contributes to the literature on the economic consequences of tourism, which is a fast-growing sector all over the world. An interesting direction for future research would be to increase the scope of the empirical analysis, by examining the reaction of prices to tourism, and by thoroughly investigating the causal link between tourism and the endogenous variables of our model.

Appendix

A Description of the main variables used in the empirical analysis

Tourism. Our data provide the total number of overnight stays in tourist accommodation establishments at the province level and the total number of beds in tourist accommodation establishments at the municipality level - a measure of capacity. We compute the share of beds in each municipality over its province total; then, we allocate overnight stays to each municipality based on this capacity weight. Finally, we divide the number of overnight stays by 365: in this way, we construct a "resident-equivalent" measure of the number of tourists. Source: *Annual Survey of Capacity of Tourist Accommodation Establishments* (Istat), years 2001 and 2011.

Resident population. The resident population is taken from Census, and it is expressed in thousands of units. Source: *Population Census* (Istat), years 2001 and 2011.

Establishments. Hotels per 1000 residents is the number of local business units in the tourist accommodation sector (NACE Rev. 2 industry 55, therefore it includes hostels, campings, etc.) divided by the resident population expressed in thousands. Restaurants and bars per 1000 residents is the number of local units in the restaurants and food services sector (NACE industry 56) divided by the resident population expressed in thousands. Retail shops per 1000 residents is the number of local units in the retail shop sector (3-digit NACE industries 471, 472, 475, 476, 477) divided by the resident population expressed in thousands. Source: *Industry and Services Census* (Istat), years 2001 and 2011.

Employment. Employment is the sum of workers employed in the local business units in the relevant sectors, divided by the total resident population in the municipality expressed in thousands. Source: *Industry and Services Census* (Istat), years 2001 and 2011.

B Exact values of the constants

These are the exact values of some of the constants that appear in the paper:

$$\kappa_s = \alpha_s^{\alpha_s}\beta_s^{\beta_s}(1-\alpha_s-\beta_s)^{(1-\alpha_s-\beta_s)},$$
$$\kappa_m = \frac{1-\varepsilon}{1-\beta_s\varepsilon},$$
$$\kappa_q = \frac{1-\gamma+\beta_s\varepsilon\gamma}{\gamma(1-\beta_s\varepsilon)},$$
$$\kappa_p = \frac{\kappa_q^{\beta_s}}{\varepsilon\kappa_s}.$$

C Analytical derivations for the baseline model

Optimal price p_s

Rewrite the first order conditions in the non-tradable sector (1.5) as:

$$\begin{aligned} l_{sj} &= \tfrac{\alpha_s}{1-\alpha_s-\beta_s}\tfrac{y_k}{w}, \\ h_{sj} &= \tfrac{\beta_s}{1-\alpha_s-\beta_s}\tfrac{y_k}{q}, \\ p_{sj} &= \tfrac{1}{\varepsilon(1-\alpha_s-\beta_s)}\tfrac{y_{kj}^{\alpha+\beta}}{a_s l_s^{\alpha_s} h_s^{\beta_s}}, \end{aligned} \tag{1.27}$$

where we have divided the first and the second condition by the third, and rearranged the third in terms of p_{sj}. Now plug the first and the second equation into the third of (1.27) to obtain $p_s = \frac{w^{\alpha_s}q^{\beta_s}}{\varepsilon\kappa_s a_s}$.

Current account balance equation

As a preliminary step, note that total residents' expenditure can be expressed as $n_R I_R$, because all residents earn the same income (the wage is equalized in the two sectors) and the labor market clears. With this in mind, plug the first order conditions for consumers (1.1) into the market clearing conditions for the non-tradable goods (1.7) and land (1.8):

$$\gamma w n_R + \gamma q H + \gamma n_T I_T = m p_s y_s,$$
$$(1-\gamma) w n_R + (1-\gamma) q H + (1-\gamma) n_T I_T + q m h_s = qH.$$

Then, use the zero profit condition in the first equation ($p_s y_s = w l_s + q h_s + y_k + \eta$), and sum the two equations to get:

$$w n_R + qH + n_T I_T + q m h_s = w m l_s + q m h_s + m y_k + m\eta + qH,$$

where we expressed the firm variables on the right-hand side in aggregate terms. Note that the qmh_s and the qH terms cancel out. Now, plug into this expression the market clearing condition for the intermediate input (1.10):

$$w n_R + n_T I_T = w m l_s + Y_k^o + X.$$

Finally, plug in the zero profit condition in the intermediate sector, $Y_k^o = wL_k$, and note that $w(ml_s + L_K)$ cancels out with wn_R on the left-hand side by labor market clearing. We are left with:

$$n_T I_T = X.$$

Share of the labor force employed in the services sector

Optimal firm behavior in both sectors allows us to write:

$$\begin{aligned} wL_s &= \alpha_s \varepsilon p_s Y_s \\ &= \frac{\alpha_s}{1-\alpha_s-\beta_s} Y_k \\ &= \frac{\alpha_s}{1-\alpha_s-\beta_s} (Y_k^o + X - m\eta) \\ &= \frac{\alpha_s}{1-\alpha_s-\beta_s} (wL_k + n_T I_T - m\eta), \end{aligned}$$

where we have also used the market clearing condition (1.10) in the third equality, and the current account balance condition in the fourth equality. Second, using the labor market clearing condition (1.9), we obtain:

$$wL_s = \frac{\alpha_s}{1-\beta_s}(wn_R + n_T I_T - m\eta),$$

which depends on the wage rate and on the number of firms. Finally, we can write the zero profit condition in sector s (1.6) in terms of wL_s as

$$\pi_s = 0 \iff \frac{1-\varepsilon}{\varepsilon} \frac{wL_s}{\alpha_s} = m\eta, \tag{1.28}$$

and substitute it back into the previous expression to obtain

$$\frac{L_s}{n_R} = \frac{\alpha_s \varepsilon}{1-\beta_s \varepsilon} \left(1 + \frac{n_T I_T}{wn_R}\right).$$

Equilibrium number of firms, m and land price, q

The zero profit condition (1.6), given constant factor shares and constant mark-up, can be written as

$$\frac{1-\varepsilon}{\varepsilon} \frac{w_s L_s}{\alpha_s} = m\eta$$

Substituting equation (1.11) in the main text with $w = a_k$, we obtain the number of firms in the non-tradable sector as given by expression (1.12).

Let us turn to the land price q. First, total expenditure by residents and tourists on land is:

$$(1-\gamma)[wn_R + qH + n_T I_T].$$

Second, total firms' expenditure on land is:

$$qH_s = \frac{\beta_s}{\alpha_s} wL_s = \frac{\beta_s \varepsilon}{1-\beta_s \varepsilon}(wn_R + n_T I_T).$$

Equating the sum of these expressions to total land revenue qH, for the case where $w = a_k$, and isolating q, we obtain expression (1.13) for the land price.

D Proofs of propositions

Proof of proposition 2

Substitute the wage rate $w = a_k$, the land price (1.13), and the price of non-tradable services (1.14) into the expression for V_R given by equation (1.3). We obtain:

$$V_R = \frac{K}{n_R} \frac{(1+\kappa_q)a_k n_R + \kappa_q n_T I_T}{(a_k n_R + n_T I_T)^{1-\gamma+\beta_s\gamma} - \frac{\gamma(1-\varepsilon)}{\varepsilon}}$$

where $K \equiv (\frac{\kappa_m}{\eta})^{\frac{\gamma(1-\varepsilon)}{\varepsilon}} \frac{(\varepsilon\kappa_s)^\gamma}{(\kappa_q)^{1-\gamma+\beta_s\gamma}} \frac{a_s^\gamma H^{1-\gamma+\beta_s\gamma}}{a_k^{\alpha_s\gamma}}$. The numerator of V_R represents the nominal income of residents as a function of tourists, whereas the denominator combines the land price component, $(1-\gamma+\beta_s\gamma)$, and the love of variety component, $\frac{\gamma(1-\varepsilon)}{\varepsilon}$. Note that land price has a direct effect on the aggregate price index $(1-\gamma)$ and an indirect effect, since it is part of the marginal cost for firms in the services sector $(\beta_s\gamma)$. Take the derivative with respect to n_T:

$$\frac{\partial V_R}{\partial n_T} = \frac{K I_T}{n_R(a_k n_R + n_T I_T)^{2-\gamma+\beta_s\gamma-\frac{\gamma(1-\varepsilon)}{\varepsilon}}} \times$$
$$\left\{\kappa_q(a_k n_R + n_T I_T) - \left[1-\gamma+\beta_s\gamma - \frac{\gamma(1-\varepsilon)}{\varepsilon}\right][(1+\kappa_q)a_k n_R + \kappa_q n_T I_T]\right\}.$$

Collect terms:

$$\frac{\partial V_R}{\partial n_T} = \frac{K I_T}{n_R(a_k n_R + n_T I_T)^{2-\gamma+\beta_s\gamma-\frac{\gamma(1-\varepsilon)}{\varepsilon}}} \times$$
$$\left\{\left(\gamma(1-\beta_s) + \frac{\gamma(1-\varepsilon)}{\varepsilon}\right)\kappa_q n_T I_T + \left[\kappa_q - \left(1-\gamma+\beta_s\gamma - \frac{\gamma(1-\varepsilon)}{\varepsilon}\right)(1+\kappa_q)\right] a_k n_R\right\}.$$

Now plug in the expression for κ_q and do the remaining simplifications:

$$\frac{\partial V_R}{\partial n_T} = \frac{K I_T}{n_R(a_k n_R + n_T I_T)^{2-\gamma+\beta_s\gamma} - \frac{\gamma(1-\varepsilon)}{\varepsilon}} \left\{\frac{1-\gamma+\beta_s\gamma\varepsilon}{\varepsilon} n_T I_T + \frac{(1-\varepsilon)}{\varepsilon} a_k n_R\right\},$$

which is always positive.

Proof of proposition 3

Substitute the equilibrium expressions for the number of firms (1.12), the land price (1.13), and the price of non-tradables (1.14) into the indirect utility of tourists (1.4). For $n_T < \hat{n}_T$, we get:

$$V_T = \frac{K A_T I_T}{(a_k n_R + n_T I_T)^{1-\gamma+\beta_s\gamma-\frac{\gamma(1-\varepsilon)}{\varepsilon}}},$$

where K is a constant term, as defined above. The partial derivative with respect to the number of tourists can be written as:

$$\frac{\partial V_T}{\partial n_T} = \left[\frac{\gamma(1-\varepsilon)}{\varepsilon} - (1-\gamma+\beta_s\gamma)\right] \frac{V_T}{a_k n_R + n_T I_T}.$$

This expression is less than zero for $\varepsilon > \frac{\gamma}{1+\beta_s\gamma}$.

E Sign of the derivative of $\frac{\partial V_R}{\partial n_T}\frac{1}{V_R}$ with respect to n_T

In this section we provide a sufficient condition for the term

$$\frac{\partial V_R}{\partial n_T}\frac{1}{V_R} \tag{1.29}$$

to be monotonically decreasing in n_T. The sign of the derivative of (1.29) with respect to n_T is equal to the sign of the following binary quadratic form:

$$[\varepsilon(2-\gamma+\beta_s\gamma\varepsilon)-1](a_k n_R)^2 - 2(1-\gamma+\beta_s\gamma\varepsilon)(1-\varepsilon)a_k n_R n_T I_T - (1-\gamma+\beta_s\gamma\varepsilon)^2(n_T I_T)^2,$$

which is quadratic with respect to the two terms $a_k n_R$ and $n_T I_T$. A sufficient condition for the quadratic form to be negative is that

$$\varepsilon(2-\gamma+\beta_s\gamma\varepsilon) < 1$$

which can be written as

$$\varepsilon - \gamma + \beta_s\gamma\varepsilon < \frac{(1-\varepsilon)^2}{\varepsilon}. \tag{1.30}$$

When consumption amenities are strong ($\varepsilon \leq \hat{\varepsilon}$) the sufficient condition (1.30) is satisfied, and then (1.29) is decreasing in n_T. When consumption amenities are weak, the left-hand side of (1.30) is positive: this condition is still satisfied if ε is not too large (consumption amenities are not too weak). We call the value of ε such that $\varepsilon - \gamma + \beta_s\gamma\varepsilon = \frac{(1-\varepsilon)^2}{\varepsilon}$ as $\hat{\hat{\varepsilon}}$. Then, (1.29) is decreasing in n_T also for the case $\hat{\varepsilon} < \varepsilon \leq \hat{\hat{\varepsilon}}$. We give a graphical representation of this condition in the figure that follows.

[Insert Figure 1.7 about here]

F Further simulations for the two cities system with mobile residents

The qualitative results of our simulations are confirmed when we introduce more asymmetry between cities. As a further step, we repeat our analysis setting $a_{k,1} = 16,920$ and $a_{k,2} = 15,310$, respectively 5% above and below the median value of median disposable income in Italy in 2015. Thus, we let city 1 be more productive than city 2 at the production of the tradable intermediate inputs, which translates into higher wages for residents.

We report the spatial distribution of tourists in figure 1.8a, and the welfare schedule in figure 1.8b.

[Insert Figure 1.8 about here]

Since the interior equilibrium now obtains in the range 1.06 to 1.14, on the horizontal axis we plot A_1/A_2 ranging from 1 to 1.2. As expected, it takes a higher value of A_1 to shift the tourist population from city 2 to city 1, given the productivity advantage of city 1, which makes it more apt to be a resident-city. The share of residents, ϕ_R, is still positively related to the share of tourists, ϕ_T.

When it comes to welfare, we observe the same reversal as before. For low values of ε, residents are better off when the two cities in the urban system are relatively similar in terms of historical amenities, such that tourists split between them; note, however, that the peak now occurs when $A_1 = 1.09$ and the share of tourists in city 1 is 0.45, that is, lower than one half as in the symmetric case in the main text. For high values of ε residents are better off when the two cities are heterogeneous in terms of historical amenities, so that city 2 receives the whole tourists population. Furthermore, when cities have a different productivity in the tradable sector, another noteworthy pattern emerges. When ε is high, such that product varieties are poorly differentiated, residents are better off when tourists concentrate in city 2, and city 1, where the tradable sector is more productive (and wages are higher), remains a resident-city. In other words, welfare is maximized when the historical amenities are relatively low in the more productive city, such that the pattern of comparative advantage in the two cities is as heterogeneous as possible. In contrast, our results suggest that, under moderate product differentiation (i.e., $\varepsilon = 0.65$) residents are better off when the pattern of comparative advantage is similar in the two cities.

Table 1.1: Descriptive statistics

	Obs	Mean	S.D.	Min	1st quartile	Median	3rd quartile	Max
Residents (1000)	7873	7.19	39.88	0.03	1.07	2.40	5.79	2546.80
Tourists per 1000 residents	7873	18.93	61.03	0.00	0.00	1.45	8.43	1471.81
Hotels, etc. per 1000 residents	7873	1.23	3.73	0.00	0.00	0.15	0.80	74.26
Restaurants and bars per 1000 residents	7873	4.45	3.65	0.00	2.61	3.57	5.09	79.21
Retail stores per 1000 residents	7873	9.87	5.12	0.00	6.63	9.27	12.28	97.97
Employment in hotels, etc. per 1000 residents	7873	3.79	10.98	0.00	0.00	0.35	2.67	257.09
Employment in restaurants and bars per 1000 residents	7873	10.36	10.17	0.00	4.90	7.87	12.56	196.60
Employment in retail stores per 1000 residents	7873	19.00	18.43	0.00	10.83	15.87	22.44	744.41
Land area (squared km)	7873	37.19	50.21	0.15	11.25	21.77	42.96	1307.71
Δ tourists per 1000 residents	7873	1.74	13.71	-87.77	0.00	0.57	3.15	89.27
Δ hotels, etc. per 1000 residents	7873	0.04	2.06	-39.04	-0.03	0.00	0.23	71.43
Δ restaurants and bars per 1000 residents	7873	0.86	2.36	-26.32	-0.03	0.75	1.59	55.18
Δ retail stores per 1000 residents	7873	-1.55	2.72	-29.41	-2.82	-1.54	-0.25	83.22
Δ employment in hotels, etc. per 1000 residents	7873	0.54	12.45	-182.84	-0.40	0.00	0.50	349.88
Δ employment in restaurants and bars per 1000 residents	7873	4.56	10.12	-147.62	0.78	3.63	6.84	223.78
Δ employment in retail stores per 1000 residents	7873	0.28	12.10	-134.42	-3.45	-0.38	2.69	474.48

Notes: The table provides descriptive statistics for the variables used in the regressions. The first set of variables shown are computed with respect to the year 2001. *Residents (1000)* is the number of residents at the city level expressed in thousands. *Tourists per 1000 residents* is the number of tourists normalized by the resident population expressed in thousands. We then report statistics for the total number of establishments and total employment normalized by thousands of residents at the municipality level for some NACE Rev. 2 industries: *Hotels, etc.* is industry 55, *Restaurants and bars* is industry 56, *Retail stores* is the sum of 3-digit industries 471, 472, 475, 476, 477. *Land area* is total urban land area. In the bottom part of the table, we report the change between 2001 and 2011 for the same set of variables.

Table 1.2: Tourism and number of establishments

	Restaurant and bars	Retail trade						Accommodation
		All	Non-spec. stores	Food, beverages	Household equip.	Books, sport, toys	Clothing, footwear	
NACE Rev. 2	56		471	472	475	476	477	55
Panel A: All municipalities								
Δ tourism	0.018***	0.013***	-0.002	0.003**	0.001	0.003**	0.008***	0.038***
	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.005)
R^2	0.057	0.051	0.032	0.032	0.035	0.048	0.053	0.216
Obs.	7,873	7,873	7,873	7,873	7,873	7,873	7,873	7,873
Panel B: Without top decile of 2001 tourist density municipalities								
Δ tourism	0.025***	0.017***	-0.004	0.005**	0.001	0.003***	0.012***	0.046***
	(0.006)	(0.005)	(0.003)	(0.002)	(0.002)	(0.001)	(0.003)	(0.006)
R^2	0.049	0.053	0.038	0.035	0.038	0.021	0.048	0.169
Obs.	7,216	7,216	7,216	7,216	7,216	7,216	7,216	7,216
Panel C: Without municipalities with zero tourist density in either 2001 or 2011								
Δ tourism	0.018***	0.012***	-0.001	0.002	0.001	0.003*	0.007***	0.037***
	(0.004)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.005)
R^2	0.072	0.077	0.040	0.041	0.049	0.071	0.079	0.226
Obs.	4,951	4,951	4,951	4,951	4,951	4,951	4,951	4,951

Notes: In all columns, the dependent variable is the change in the number of establishments per 1000 residents between 2001 and 2011. Each column represents a different industry. In panel A we use the full sample of municipalities; in panel B we exclude the municipalities in the top decile of the tourists per 1000 residents distribution in 2001; in panel C we exclude municipalities with zero tourist density in either 2001 or 2011. All regressions include as controls total municipal land area, average elevation, a dummy variable for coastal towns, and dummy variables for each province. ***,**,* denote significance at the 1%, 5%, 10% level, respectively. Robust standard errors are reported in parenthesis.

Table 1.3: Tourism and employment

	Restaurant and bars	Retail trade						Accommodation
		All	Non-spec. stores	Food, beverages	Household equip.	Books, sport, toys	Clothing, footwear	
NACE Rev. 2	56		471	472	475	476	477	55
Panel A: All municipalities								
Δ tourism	0.048***	0.026***	0.000	0.004	-0.001	0.007**	0.016***	0.117***
	(0.016)	(0.009)	(0.006)	(0.003)	(0.003)	(0.003)	(0.005)	(0.029)
R^2	0.088	0.023	0.013	0.033	0.017	0.036	0.017	0.121
Obs.	7,873	7,873	7,873	7,873	7,873	7,873	7,873	7,873
Panel B: Without top decile of 2001 tourist density municipalities								
Δ tourism	0.063***	0.015	-0.011	0.001	-0.004	0.006	0.024**	0.110***
	(0.017)	(0.018)	(0.013)	(0.004)	(0.005)	(0.004)	(0.011)	(0.016)
R^2	0.038	0.022	0.015	0.034	0.018	0.014	0.017	0.064
Obs.	7,216	7,216	7,216	7,216	7,216	7,216	7,216	7,216
Panel C: Without municipalities with zero tourist density in either 2001 or 2011								
Δ tourism	0.041**	0.023***	0.001	0.004	0.001	0.006*	0.011**	0.117***
	(0.018)	(0.009)	(0.005)	(0.004)	(0.002)	(0.003)	(0.004)	(0.032)
R^2	0.112	0.046	0.023	0.044	0.028	0.057	0.033	0.149
Obs.	4,952	4,952	4,952	4,952	4,952	4,952	4,952	4,952

Notes: In all columns, the dependent variable is the change in employment per 1000 residents between 2001 and 2011. Each column represents a different industry. In panel A we use the full sample of municipalities; in panel B we exclude the municipalities in the top decile of the tourists per 1000 residents distribution in 2001; in panel C we exclude municipalities with zero tourist density in either 2001 or 2011. All regressions include as controls total municipal land area, average elevation, a dummy variable for coastal towns, and dummy variables for each province. ***,**,* denote significance at the 1%, 5%, 10% level, respectively. Robust standard errors are reported in parenthesis.

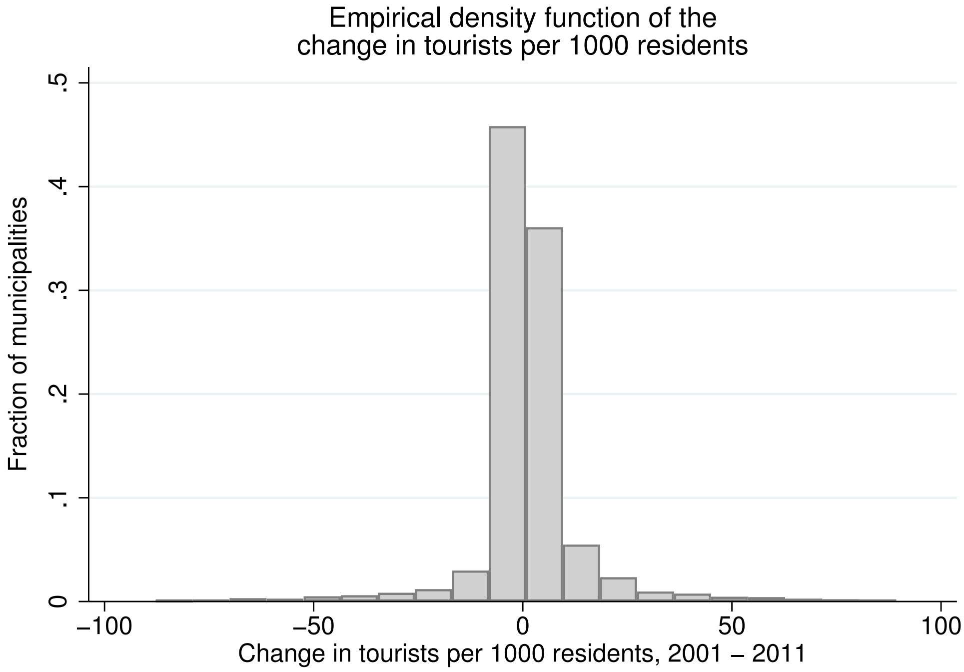


Figure 1.1: Empirical density function of the change in the number of tourists (in terms of resident-equivalent) per 1000 residents over the period 2001 − 2011, after having dropped municipalities at the top 1% and bottom 1% of the distribution.

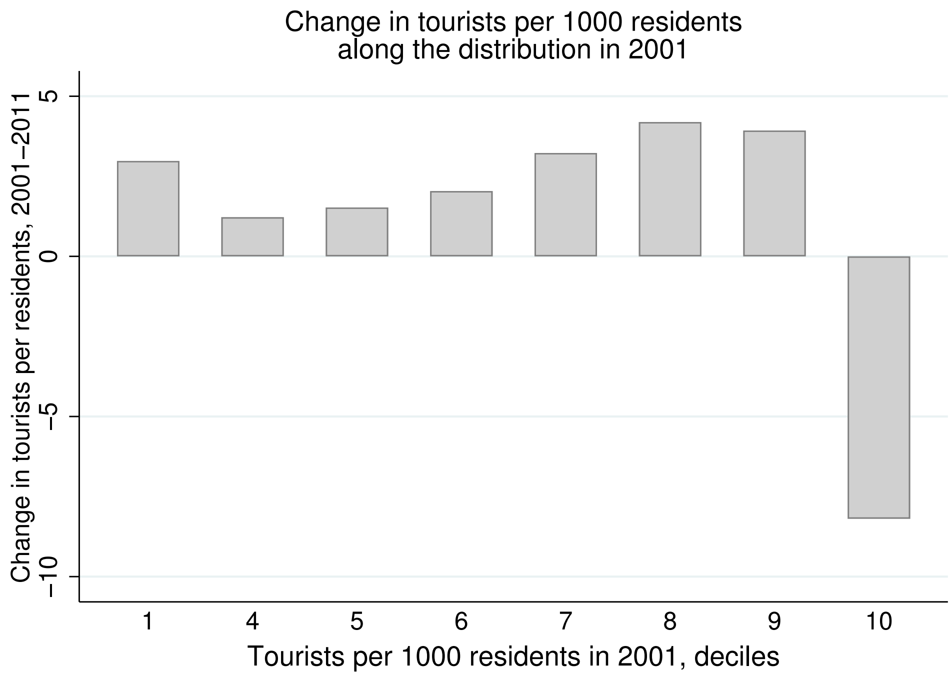
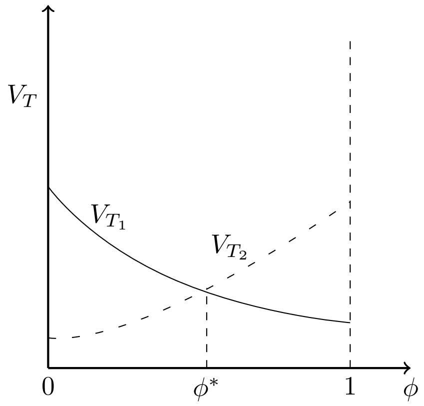
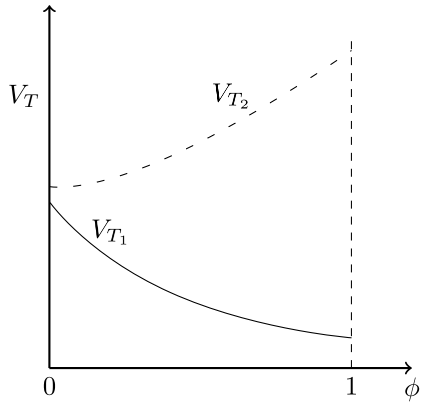


Figure 1.2: Average change in the number of tourists (in terms of resident-equivalent) per 1000 residents over the period 2001 − 2011. Municipalities are ranked in terms of deciles of the distribution of the number of tourists per residents in 2001.

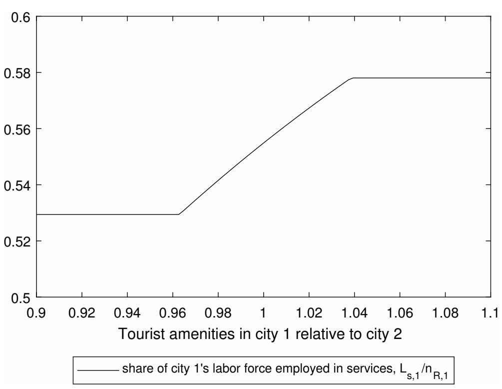


(a) The interior equilibrium

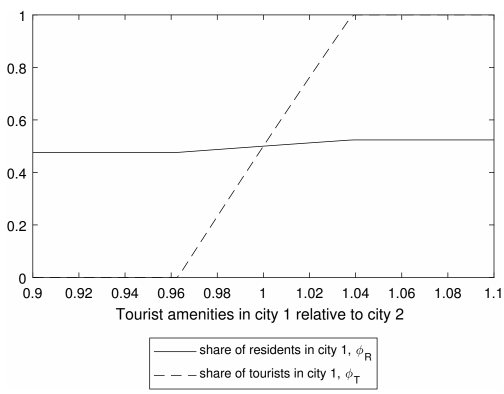


(b) Equilibrium with a tourist hub in city 2

Figure 1.3: Spatial equilibrium with weak consumption amenities and immobile residents



(a) Equilibrium share of city 1's employment in the non-tradable sector with respect to total employment in the city



(b) Equilibrium share of residents and tourists in city 1 with respect to the total number of residents and tourists in the system of cities

Figure 1.4: Increasing historical amenties: Simulation for the two city model with mobile residents ($\varepsilon = 0.75$)

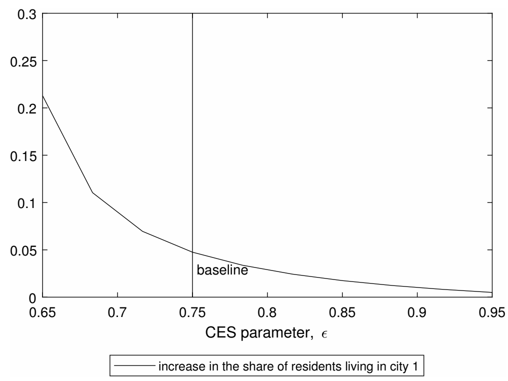


Figure 1.5: Large increase of historical amenities in city 1 (from $A_1 = 0.9$ to $A_1 = 1.1$) and increase in the share of residents, for different values of ε

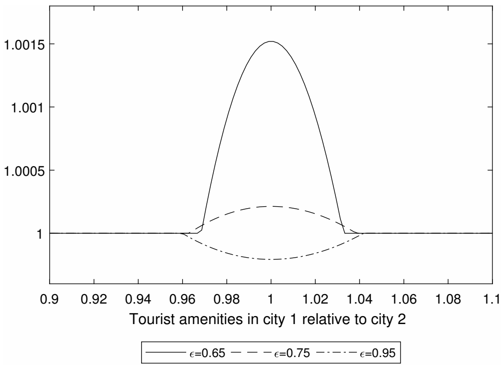


Figure 1.6: Individual welfare of residents in city 1

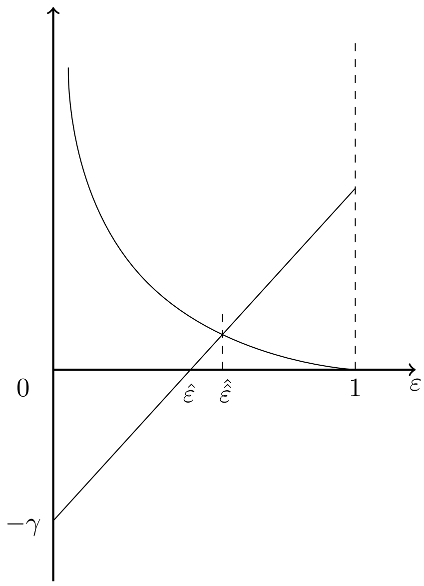
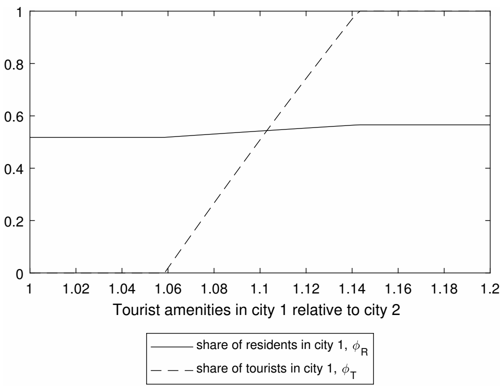
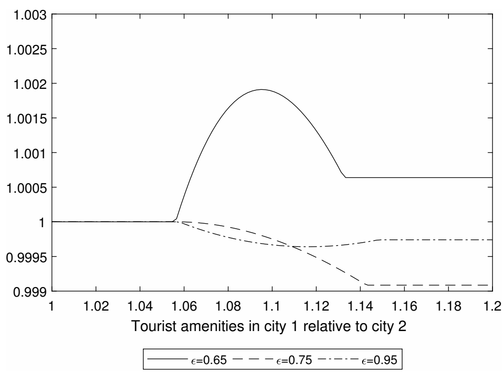


Figure 1.7: Graphical representation of the sufficient condition



(a) Equilibrium share of residents and tourists in city 1



(b) Individual welfare of residents in city 1

Figure 1.8: Spatial equilibrium and welfare for two cities with mobile residents and different productivity in tradables

Chapter 2

Tourism and urban structure: evidence from Venice

2.1 Introduction

Tourism allows local economies to export non-tradable goods, and as such, it can be an important driver of urban growth. However, as a consequence of the large increases in tourist flows in recent years, many popular urban destinations are debating the pros and cons of tourism for local residents. One frequent concern is that rising consumption prices, noise pollution, and other congestion effects which are associated with high levels of tourist demand may entail large costs for the resident population, at least partially offsetting its benefits in terms of higher labor demand and land income.

At the same time, many cities are debating and/or adopting policies designed to mitigate the perceived negative effects of tourism. Such policies include, for instance, entrance fees, tourist taxes (extra-charges on overnight stays which are collected by the Municipality), as well as policies targeted to the spatial distribution of tourism within the urban area, with the aim of either restricting or encouraging the inflow of tourists into specific neighborhoods.

Despite its economic importance, and its prominence in the public debate, though, research on the economic impact of tourism on cities is surprisingly scant. We still lack systematic empirical evidence on the impact of tourism on urban structure, as well as an analytical framework that is suitable, first, to understand the economic consequences of tourism and, second, to evaluate the effects of urban policies on the welfare of residents.

In order to fill this gap, this paper studies the impact of tourism on the distribution of economic activity within the city of Venice. It offers four main contributions. First, I assemble a rich data set with information on residential population, employment, commuting flows, housing stock characteristics, as well as a number of geographical features for small spatial units within the city of Venice. In order to build a spatially disaggregated measure of tourism intensity that also varies at such a fine level of spatial disaggregation, this paper uses information on a sample of +150k geolocalized photos downloaded from the Flickr website. On top of the geographic coordinates, I observe the unique user ID and the date of the shot. I also collect data for the other Municipalities of the Veneto Region. Section 2.2 describes the main datasets used in the analysis.

Second, in section 2.4, I develop a quantitative model of urban structure that incorporates tourism. The model builds on Ahlfeldt *et al.* (2015), and introduces three key modifications that make it suitable to study tourism at the urban level. First, besides residents, the model features a second class of agents, tourists, whose income is determined exogenously, and who enjoy tourist-specific amenities, i.e. tourist attractions. Second, there are two sectors of production: non-tradable (retail) services, which are purchased by residents and tourists alike, and an intermediate sector that produces a tradable good, used as an input in the production of retail services. Agents, both residents and tourists, also consume floorspace which are available in fixed supply.

Tourist demand drives up consumption prices for residents in areas that are rich with tourist attractions, thereby reducing their utility relative to other areas. Furthermore, the demand for retail services also shifts the composition of the local labor force towards the retail sector and increases overall employment in Census tracts with high tourist attractions. Since the traded good is homogenous, some tracts may fully specialize in the production of retail services, thus exchanging tourism-related exports with imports of the intermediate traded good.

Crucially, the incidence of tourism is not uniform over the urban area, as tourist attractions are clustered in the historical centre, the impact of tourism on housing and labor markets is unequally distributed in space. As residents take into account wages and housing costs in making their commuting decisions, tourism has the potential to reshape how cities are spatially organized. This illustrates the importance of studying the urban consequences of tourism within a spatial general equilibrium framework.

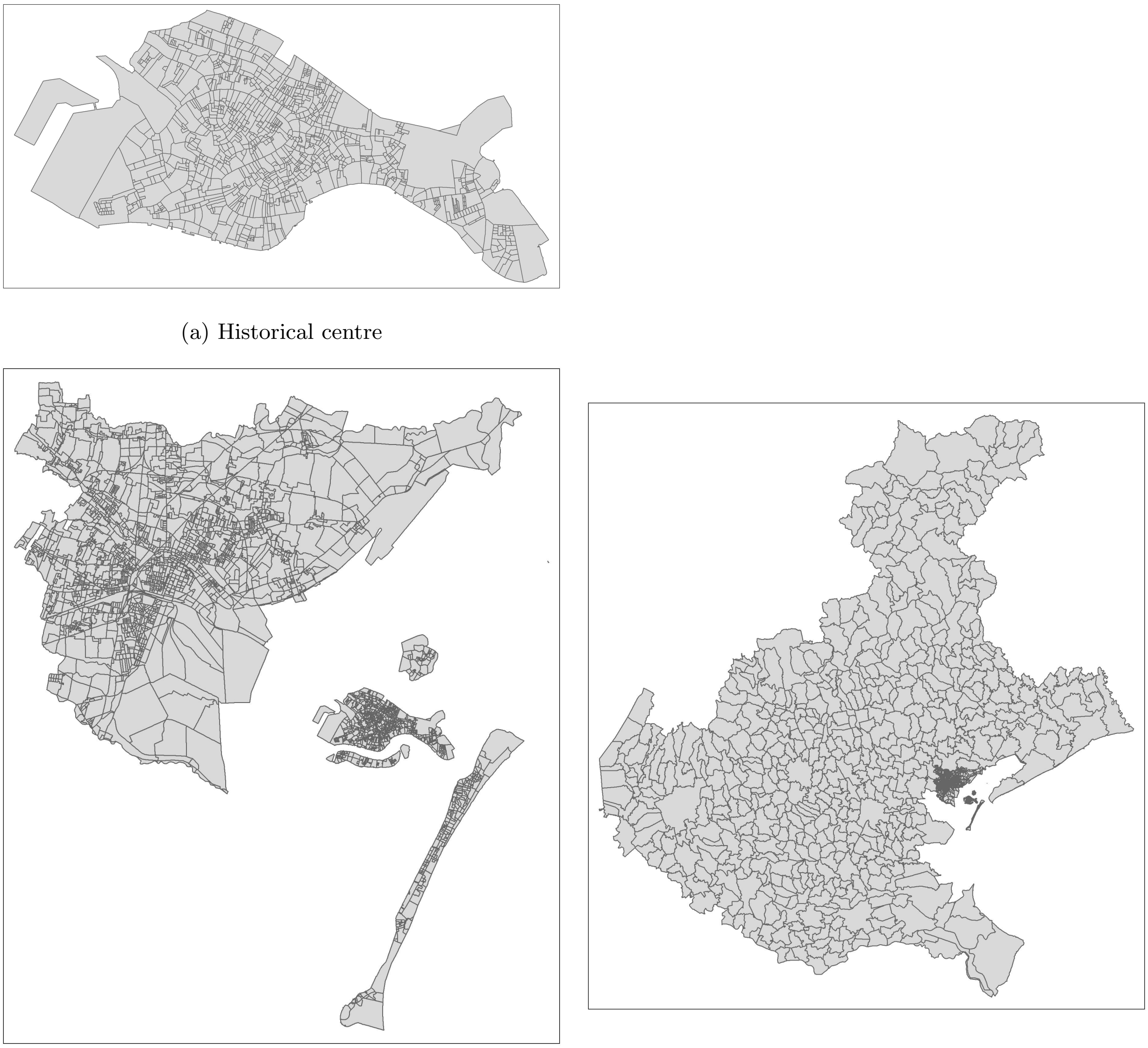
Third, I show how to use the structure of the model to back out the unobserved vectors of residential amenities, tourist amenities, and traded sector productivities for each unit of observation. The methodology requires data on floorspace, commuting shares for residents, as well as bilateral travel distances between each pair of spatial units in the data. Crucially, the methodology also requires data on the share of tourists who lodge or consume in each tract: I use the number of beds in Tourist Accommodation activities as a proxy for tourist demand for accommodation services, and the share of Flickr photos in each tract as a proxy for tourist non-land consumption demand.

Finally, the paper uses the model to evaluate the impact of counterfactual tourism policies. Examples of such policies. This step is to be completed in the near future, As convergence algorithm used to solve the model is still not working as well as desired. Some examples of tourism policies that the model allows to study, as well as a description of the main convergence issues, is provided in section 2.6.

Relation to the literature. There are two main themes in the paper, which contribute to shed light on some broad questions in the economic literature. The first theme is the impact of globalization on local economies. In particular, Faber and Gaubert (2019) study the impact of tourism across Mexican regions within a quantitative spatial framework. This paper complements their cross-regional evidence with within-region and within-city evidence. The second theme is how the spatial organization of cities responds to external shocks. This paper builds on Ahlfeldt et al. (2015), and extends their quantitative urban model to incorporatate tourism. A closely-related paper in this field is Allen et al. (2020), who focus on very similar questions for the city of Barcelona. Almagro and Domìnguez-Iino (2020) also look at the impact of tourism, in the form of AirBnb listing, on the city of Amsterdam: in their approach, tourism is modelled as a congestion shock on the residential market, and commuting across locations is not allowed. By contrast, I also consider tourist expenditure on services goods, whose spatial distribution can differ from their residential expenditure because of commuting.

2.2 Data sources

This research is based on the collection of a large amount of data on population, employment, commuting flows, tourism intensity, and housing stock characteristics for 3637 Census tracts within the Municipality of Venice, as well as for all other 577 Municipalities included in the Veneto region. The historical center of Venice comprises 1122 tracts, other minor islands of the lagoon comprise 344 tracts, while all other locations, both in the Municipality of Venice and in the Veneto region, are mainland locations. Focusing on a broader region is important, because the Venice labor market is highly integrated with the labor markets of the surrounding municipalities. By including the Veneto region in the analysis, we capture 99 per cent of the commuting to, as well as from, the Municipality of Venice. Figure 2.1 shows the spatial units of the analysis for the historical centre of Venice (2.1a), the Municipality of Venice (2.1b) and the Veneto region (2.1c). In the remainder of this section, I describe the various data sources used in the analysis.



(a) Historical centre

(b) The Municipality of Venice

(c) The Region of Veneto

Figure 2.1: The spatial units of analysis

Census data First, I use the 2011 Italian Population and Housing Census to obtain data on resident population at the Census tract level. For municipalities other than Venice, I aggregte this information at the Municipality level. The Census file also contains important information on housing stock characteriscs, such as the number of buildings built during ten-year brackets, starting from 1920 or earlier, and the number of buildings with 1, 2, 3, and 4 or more floors. Second, the Industry and Services Census (CIS) contains information on the number of employees at the Census tract level broken down by 3-digit NACE sector. Finally, Istat provides the commuting matrix at the tract level, based on all respondents who declared to commute daily from their employment location to their residence location, and to return home on the same day. The Census questionnaire asks them to report their workplace address, which is then used to locate their employment tract. I focus on work-related commuters, although the data set also includes the number of education-related commuters.

Flickr data A necessary condition to study the impact of tourism on urban structure is to construct a measure of tourism intensity that varies within cities. This is challenging, as tourism statistics are usually collected at the Municipal level (as is the case for Italy). To overcome this challenge, I assembled a dataset of geotagged photos downaloaded from Flickr, a popular image hosting website launched in 2004 by Ludicorp and later acquired by Yahoo![1]. Overall, the dataset contains 168769 photos, 75% of which taken in the Municipality of Venice. Besides the geographic coordinates[2], I also observe the unique user id and the date that the shot was taken. This information is crucial, as it allows me to reasonably identify tourists in the Flickr sample. I define as tourists all users who took photos in Venice over a time period shorter than 21 days, and only retain photos taken by these group.

Tourist accommodation services The list of Tourist Accommodation services is compiled and updated yearly by the Chamber of Commerce and available on the Venice Open Data portal (`dati.venezia.it`). Then, I geocoded each tourist accommodation by matching its address with a shapefile of all Venetian addresses provided by the Municipality. This register also contains information on the number of stars, the number of rooms, and the number of beds for each room for all tourist accommodation activities that regularly filed the registration form to the Chamber of Commerce. Data on the number of beds for the other Veneto Municipalities comes from the Capacity of tourist accommodation estabilishments, an annual Census Survey that collects information regarding accommodation estabilishements in Italy.

OMI data Information on housing prices is available from the *Osservatorio del Mercato immobiliare* (OMI), a branch of the Italian Tax Agency that collects and publishes data on real estate quotations. The OMI breaks the national territory into homogenous market areas, i.e. OMI zones. Then, quotations are estimated based on a sample of observed market transactions in each zone, for different building typologies. In particular, the data allows the researcher to distinguish between houses, shops, offices. While extremely rich, the OMI zones are larger spatial units than the Census tracts I use in the main analysis. These data will turn out to be useful in validating the model.

Land use The Municipality of Venice provides a shapefile with the universe of 40074 buildings in the Municipality. This allows me to construct a measure of developed area for each tract. Furthemore, buildings are coded by main use (e.g. residential, church, industrial, etc.). I complement this data with the Land Use Survey (*Indagine sul consumo del suolo*) carried out by the Veneto region in year 2012.
Transport Network I combine the road networks for the Municipality of Venice and the for the Veneto region. Furthermore, I manually coded the main public ferry lines (*vaporetto*) using the QGIS software. Then, I compute commuting distances using the GRASS modules for network analysis available in QGIS, allowing for multi-modal transport. The *vaporetto* is an important means of public transport, both for

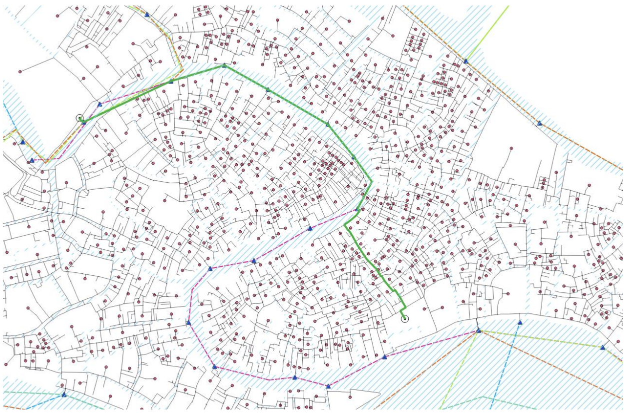
[1]Flickr photos have been previously used in the economic literature by Ahlfeldt (2013)

[2]Flickr users can equip their uploaded photos with geographic information in three ways: first, if the photos is taken using a GPS device, the geographic metadata might be attached automatically to the picture; second, the picture may be geocoded using third-party software before being uploaded to Flickr; third, since 2006, users can locate their pictures after uploading them to Flickr, by dragging them on a digital map [3]. I only download photos with the maximum level of reported accuracy, meaning that the photo is either geocoded automatically, or that the user zoomed down to closest permitted level (street level) when manually locating the photo on the map.

residents and tourists, in Venice's historical centre. Failing to take into account the *vaporetto* option would lead to overestimating travel times for certain commutes, notably, for instance, to *Piazza San Marco*, which attracts a large number of workers. This said, in the Veneto region as a whole, only 6.6 percent of workers rely on public transport to go to work. This motivates leaving out train connections from the transport network. Figure 2.2 gives an illustration of the construction of the transport network, zooming on the historical centre of Venice: figure 2.2a shows the street network, as provided by the Municipality; in figure 2.2b the street network is connected to the centroids of each tract, to the *vaporetto* stops, and the *vaporetto* lines (the colored dashed lines) have been added; figure 2.2c shows the network fastest path from *Santa Lucia* train station to *San Marco* square, which takes 33 minutes and consists in taking the ferry right in front of the station, getting of at the Rialto bridge and continuing on foot to the destination. More details on the construction of the network are given in the appendix.

(a) The street network

(b) The street network, the location centroids, and the ferry connections



(c) The shortest route from the train station to *San Marco* square (green line)

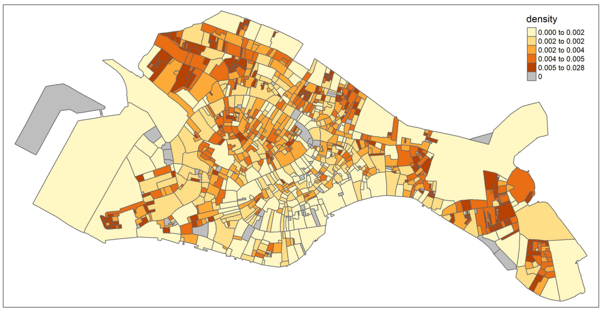
Figure 2.2: The transport network: an illustration

Other geographic information I collected a wealth of administrative geographic information publicly available on the Municipality of Venice's Open Data web portal. Other available shapefiles include the entire canal network, green area polygons, and altimetry measured at 76032 points in the historical center of Venice, which provides a good measure of the exposure to the flooding (*acqua alta*) phenomenon.

All the details concerning the construction of the dataset, plus further information about the main variables used in the analysis is provided in the Data appendix, in section A.

2.3 Descriptive evidence

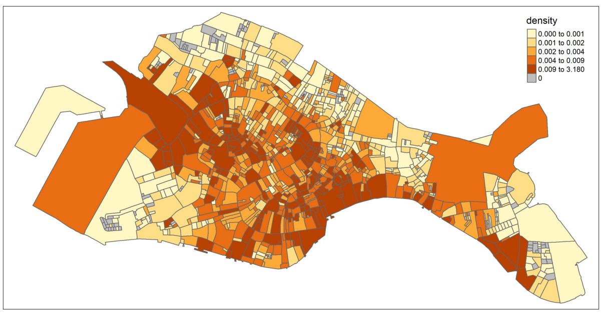
To get a preliminary overview of the empirical setting, figure 2.3 shows the densities (taken over total floorspace) of four main variables of the analysis, for all Census tracts on the historical centre of Venice: the number of (employed) residents (2.3a), the number of employees, (2.3b), the number of residents in tourists accommodation activities, and the number of Flickr photos. The color scale shows the quantiles of the density distribution, excluding zeros. Two features of the data emerge from these maps. First, there is a negative correlation between the density of residents and the density of employment. Tracing an ideal line from the *Santa Lucia* train station to *Piazza San Marco*, the resident population appears to be concentrated above the line, along the northern seaboard, while employment is concentrated below the line, with two main agglomerations around the train station and San Marco square. Second, the spatial distribution of tourist accommodation capacity (2.3c) and Flickr photos (2.3d) closely matches the spatial distribution of employment.



(a) Density of employed resident population

(b) Density of employment

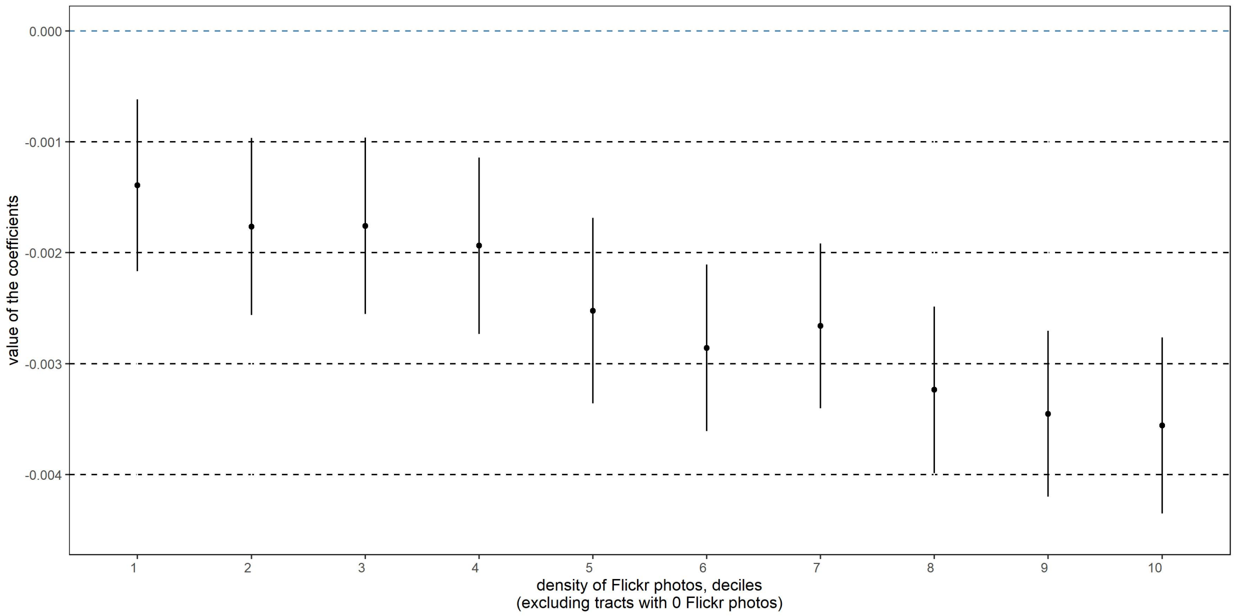
(c) Density of beds in Tourist Accommodation Services



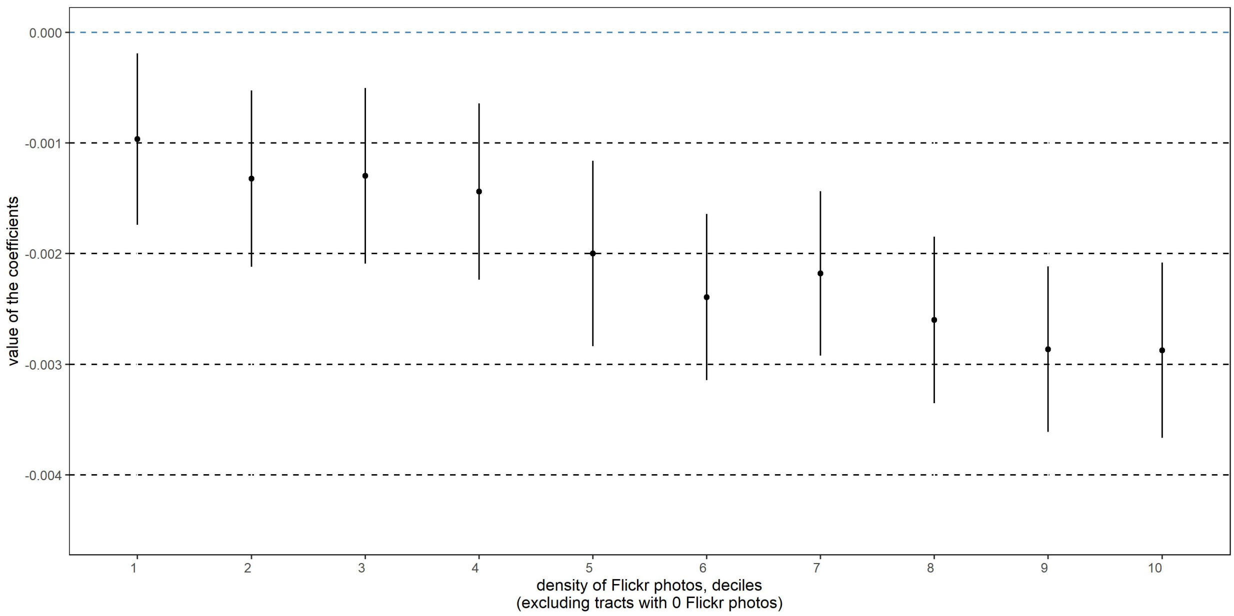
(d) Density of Flickr photos

Figure 2.3: The spatial distribution of economic activity in the historical centre

The next figures further investigate the relationship between tourism intensity, as measured by Flickr photos, and economic activity within the historical center of Venice. Figure 2.4 figure plots the coefficients of a regression of residential density on dummies for different deciles of the Flickr photo distribution. Deciles are computed for the (roughly) 1000 tracts with a positive number of photos, while the 126 tracts with zero photos are used as the omitted category. Thus, each bin includes roughly 100 locations. Figure 2.4a reports the results of the unconditional regression. It shows a clear negative relationship between tourism intensity, as measured by the density of Flickr photos, and the density of residents. In figure 2.4b, I additionally for the presence of a canal, the presence of a green area, the share of buildings built before 1920, the distance to the train station and the distance to the Rialto bridg. Although these controls do absorb part of the variation (as the pattern becomes slighly flatter), the negative relationship remains stable. Figures 2.5 repeats the same exercise with employment density as dependent variable. Figure Figures 2.5 displays a mild positive relationship, which gets more pronounced at the top of the Flickr photos distribution, and is not affected by the inclusion of the controls. Finally, figure 2.6 looks at the correlation between tourism intensity and the *composition* of employment within each tract. The relationship appears to be positive, as the average employment share in retail services rises from about 7 per cent (omitted intercept) in tract with zero Flickr photos, to almost 30 per cent in tracts in the top decile.



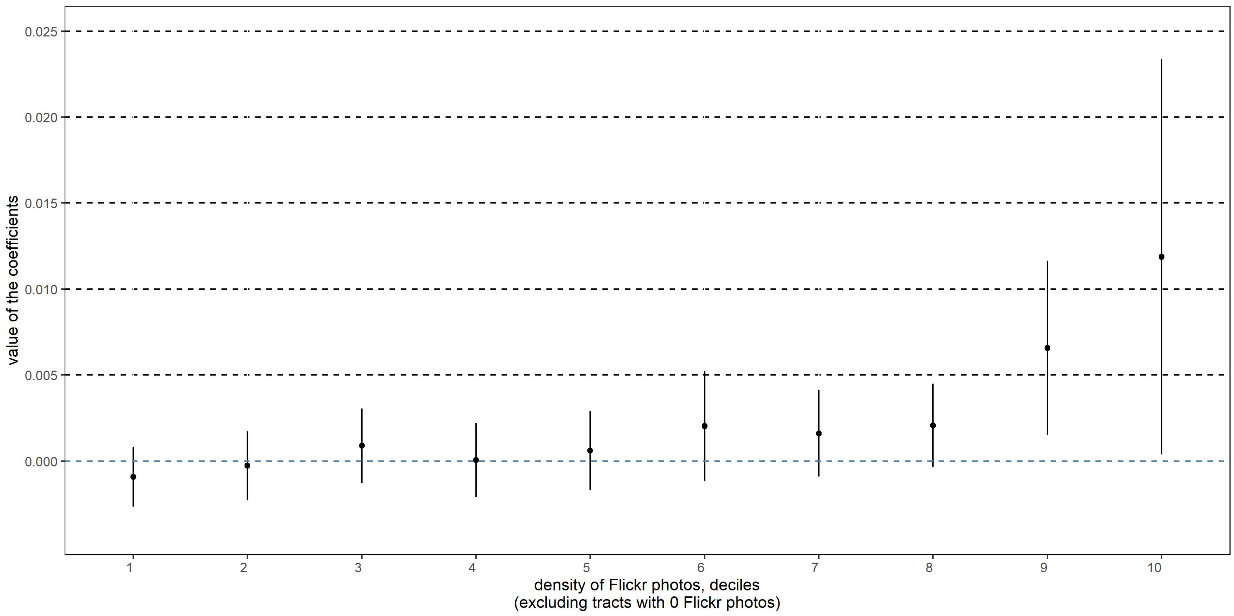
(a) Unconditional



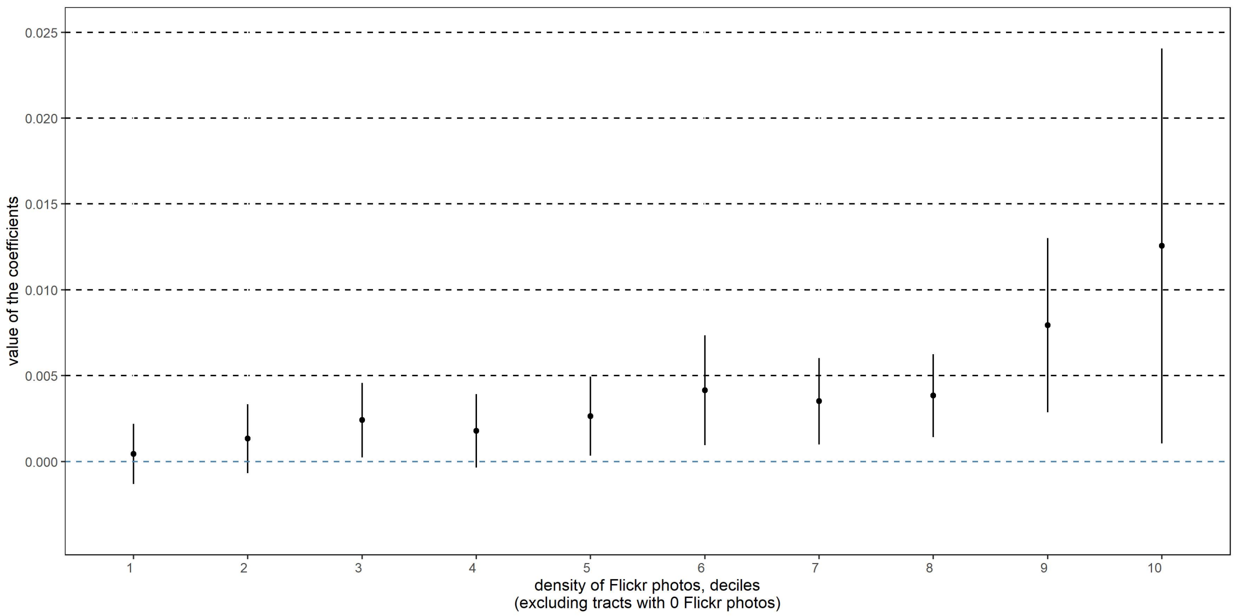
(b) Conditional

Figure 2.4: Density of employed residents and Flickr photos

The figure reports the values of the coefficients of a regression of density of employed residents on dummies for the deciles of the Flickr photos distribution. The omitted category are tracts with zero photos. The vertical segments represent 95 percent confidence interval (computed with heteroskedasticity-robust standard errors). Panel (a) reports the coefficients of an unconditional regression. Panel (b) reports the coefficients of a regression that additionally controls for a canal dummy, a green area dummy, the distance to the train station, the distance of the Rialto bridge, and the share of buildings built before 1920.



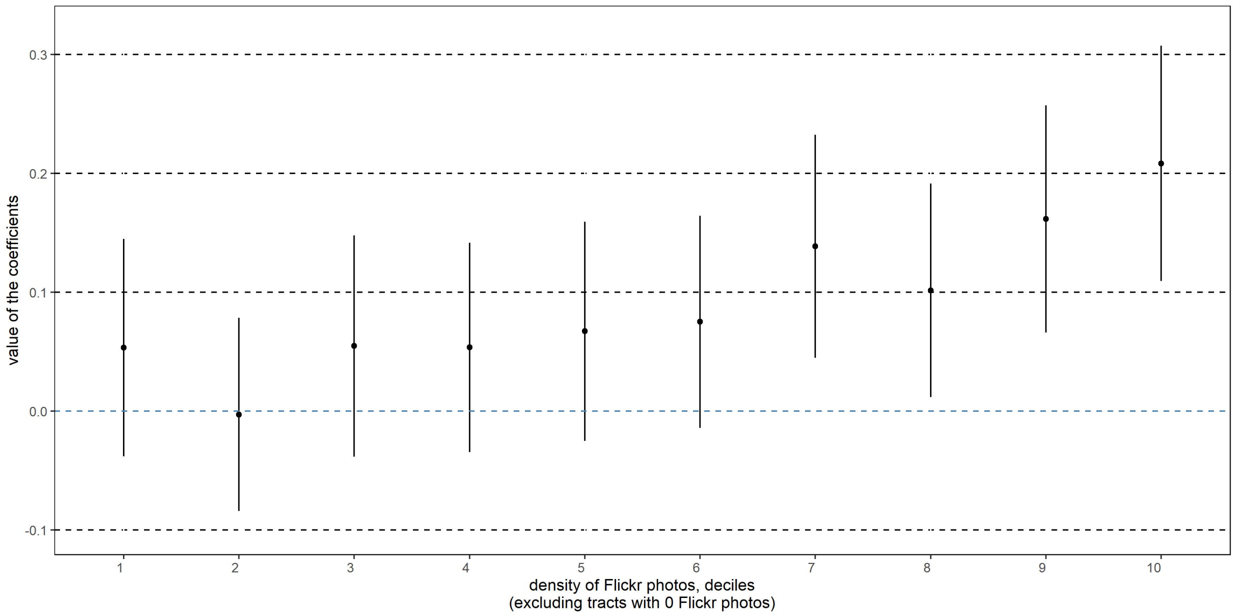
(a) Unconditional



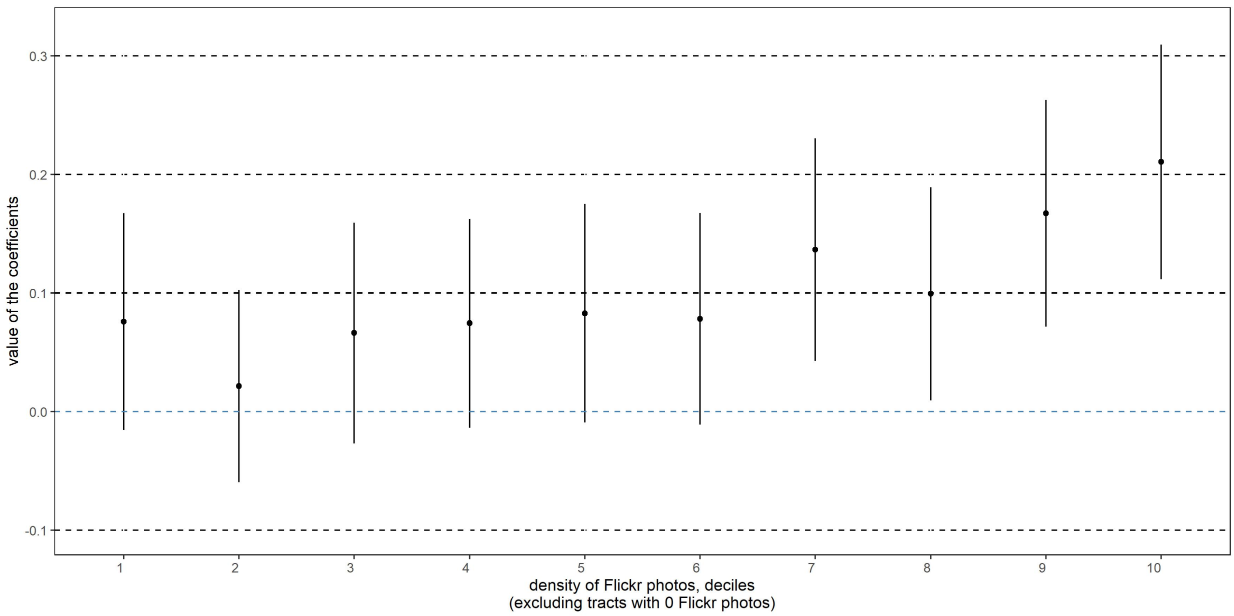
(b) Conditional

Figure 2.5: Density of employment and Flickr photos

The figure reports the values of the coefficients of a regression of employment density on dummies for the deciles of the Flickr photos distribution. The vertical segments represent 95 percent confidence interval (computed with heteroskedasticity-robust standard errors).Panel (a) reports the coefficients of an unconditional regression. Panel (b) reports the coefficients of a regression that additionally controls for a canal dummy, a green area dummy, the distance to the train station, the distance of the Rialto bridge, and the share of buildings built before 1920.



(a) Unconditional



(b) Conditional

Figure 2.6: Density of employment and Flickr photos

The figure reports the values of the coefficients of a regression of the employment share in retail services on dummies for the deciles of the Flickr photos distribution. The vertical segments represent 95 percent confidence interval (computed with heteroskedasticity-robust standard errors).Panel (a) reports the coefficients of an unconditional regression. Panel (b) reports the coefficients of a regression that additionally controls for a canal dummy, a green area dummy, the distance to the train station, the distance of the Rialto bridge, and the share of buildings built before 1920.

2.4 A quantitative urban model of tourism

This section presents a spatial model of urban structure that encompasses two types of agents, residents and tourists, and two sectors of production, retail services and a tradable intermediate input, as well as commuting costs among locations. Amenities, as well as sectoral productivities, differ across locations, and residents and tourists appreciate different types of amenities. In the model, tourists are commuters: they are allowed to lodge in one location, and commute to another location to visit the local attractions and consume a locally-produced non-tradable goods. Therefore, tourists trade off lower land prices with higher commuting costs to the tourist attractions. Tourist demand raises labor demand in the services sector in locations that are rich with tourist attractions, thus shifting employment from the traded sector to the non-traded sector. At the same time, higher consumption prices drive residents out of these locations.

1 Geography and endowments

The economy consists of a set of locations $\mathcal{S}$, whose elements are denoted by $s_i \in \S$ for $i = 1, ...n$. In the following, I refer to locations as tracts, although the empirical applications will include all the Municipalities in the Veneto Region. Agents are of two types: residents and tourists. The total number of residents is n_R, while the total number of tourists is n_T. In a spatial equilibrium with free mobility, n_R and n_T are pinned down by the condition that the expected utility of moving to Venice is equal to a fixed outside option, which is allowed to differ between residents and tourists.

In each tract, the supply of floorspace is fixed to H_i, with $\sum_{i=1}^{S} H_i = H$. Land can be used both for residential and for commercial purposes. Tracts also differ along other dimensions: unpriced local amenities for residents, $A_{R,i}$, and for tourists $A_{T,i}$; local productivities in the retail services and in the intermediate sector, $a_{s,i}$ and $a_{k,i}$; and, finally, their geographic location, as described by the commuting cost matrix D.

Each resident is endowed with one unit of labour that is supplied inelastically to the labour market; as a result, the labour force is equal to the number of residents, n_R. Furthermore, residents are entitled to a share ϕ of total rents generated in the economy[4]; following Rossi-Hansberg *et al.*, rents are distributed in equal shares to the resident population. In contrast, the remaining fraction, $1 - \phi$, accrues to absentee landlords. This assumption, while admittedly restrictive, allows me to abstract from individual wealth effects, while at the same time retaining a role for rental income in shaping the welfare effect of tourism.

In sum, nominal income for a resident who works in tract $s_j \in \mathcal{S}$ is: $I_{R,j} = w_j + \phi \frac{q' H}{n_R}$, where w_j is the wage paid in tract s_j and $\mathbf{q}$ is the vector of land prices. In contrast, tourists' income is exogenous and equal to I_T for all tourists.

[4]This assumption could be relaxed. For instance, one could assume that rents are redistributed at the municipality level. In this case, however, the income of residents becomes a function of their place of residence, rather than their place of work only. This complicates the solution of the model.

2 Resident's problem

Residents consume retail services and land services. Furthermore, besides their consumption choice, residents pick one commuting arrangement (s_i, s_j), where s_i denotes their location of residence and s_j denotes their location of employment. The utility function includes four components: *i.* a component that depends on the quantities consumed (c, h), and takes the Cobb-Douglas form; *ii.* a shifter that depends on the quality of the commuting arrangement (A^R_{ij}); *iii.* a commuting cost that depends positively on travel distance (d_{ij}) and, *iv.* finally, an idiosyncratic utility shock (z), defined over all possible commuting pairs, that is assumed to follow a Frechet distribution. All these components enter the utility function in a multiplicative fashion.

As in standard in urban models, I assume that residents purchase consumption goods and are exposed to amenities in their tract of residence. That implies that $A^R_{i,j} = A^R_i$, and that the budget constraint takes the form:

$$p_i c + q_i h \leq I^R_j,$$

where p_i is the price of retails services in tract i and q_i is the price of land services in tract s_i. Thus, a resident who lives in s_i and works in s_j solves the problem:

$$\max_{\{c,h,s_i,s_j\}_{i=1}^n} U^R_{i,j} = \frac{A^R_{i,j}}{d_{ij}} \left(\frac{c}{\gamma_R}\right)^{\gamma_R} \left(\frac{h}{1-\gamma_R}\right)^{1-\gamma_R} z_{ij}, \quad 0 < \gamma_R < 1, \tag{2.1}$$

$$\text{subject to} \quad p_i c_{ij} + q_i h_{ij} \leq I^R_j, \tag{2.2}$$

where we have adopted the notational shortcut $x_{i,j} \equiv x(s_i, s_j)$.

The solution proceeds in two steps. First, the agent solves (2.1) with respect to c and h, taking the commuting arrangement as fixed. This yields the consumption demands:

$$c^R(s_i, s_j) = \gamma^R \frac{I^R_j}{p_i}, \tag{2.3}$$

$$h^R(s_i, s_j) = (1-\gamma^R) \frac{I^R_j}{q_i}, \tag{2.4}$$

and the indirect utility function:

$$V^R_{ij} = \frac{A^R_i}{d_{ij}} \frac{I^R_j}{(p_i)^{\gamma_R}(q_i)^{1-\gamma_R}} z_{ij}.$$

As a second step, agents solve:

$$\max_{\{s_i,s_j\}_{i=1}^n} V^R_{i,j}. \tag{2.5}$$

Given the properties of the Frechet distribution, (2.5) implies that residents pick commuting arrangment (s_i, s_j) with probability:

$$\pi^R_{ij} = \frac{\left[\frac{A^R_i}{d_{ij}} \frac{I^R_j}{(p_i)^{\gamma_R}(q_i)^{1-\gamma_R}}\right]^{\varepsilon}}{\sum_{r=1}^S \sum_{s=1}^S \left[\frac{A^R_r}{d_{rs}} \frac{I^R_s}{(p_r)^{\gamma}(q_r)^{1-\gamma}}\right]^{\varepsilon}}, \tag{2.6}$$

where ε is the Frechet dispersion parameter. If the law of large numbers holds, this is also the share of residents who pick commuting arrangement (s_i, s_j).

3 A simple model of tourist behaviour

The goal of this section is to obtain an expression for tourist consumption expenditure for retail services and for land services in each tract. This forces us to specify how tourists "use" the city in the context of the model, meaning where they consume, and how much. We start with the simple possible model of tourist behaviour, assuming that tourists, alike residents, consume retail and land services and pick a commuting arrangement. Tourists differ from residents in three respects:

i. they enjoy amenities in the location they *visit*, rather than in the location where they reside;

ii. they do not participate in the labor market, and their income is set exogenously to I_T;

iii. they also consume retail services in the tract that they visit.

These assumption mean that $A^T_{i,j} = A^T_j$ and that the tourist's budget constraint can be written as: $p_j c + q_i h \leq I_T$. As a result, tourist expenditure function can be written as:

$$E^{T,c} = \gamma_T \pi^T_{\cdot,i} I_T n_T, \tag{2.7}$$

$$E^{T,h} = (1-\gamma_T)\pi^T_{i,\cdot} I_T n_T, \tag{2.8}$$

where $\pi^T_{i,\cdot}$ and $\pi^T_{\cdot,i}$ are the marginals of:

$$\pi^T_{ij} = \frac{\left[\frac{A^T_j}{d_{ij}(p_j)^{\gamma_T}(q_i)^{1-\gamma_T}}\right]^{\varepsilon}}{\sum_{r=1}^{n}\sum_{s=1}^{n}\left[\frac{A^T_s}{d_{rs}(p_s)^{\gamma_T}(q_r)^{1-\gamma_T}}\right]^{\varepsilon}}. \tag{2.9}$$

These equation makes clear that tourists have an incentive to commute for leisure purposes. In fact, commuting allows them to visit the locations with the nicest tourist attractions, while at the same time saving on accommodation costs. In so doing, tourists face two trade-offs. First, locations with low land values will tend to be the most remote ones, such that commuting costs tend to be higher. Second, the locations with the best attractions, which attract a large number of tourists, are also going to be the most expensive ones in terms of retail prices.

4 Production

There are two sectors of production in the economy: a non-tradable sector (services) and an intermediate sector. Both sectors make use of a Cobb-Douglas production function, under conditions of perfect competition and constant returns to scale. Since the intermediate input is freely traded, its price must be equal across locations and can be normalized to one.

The services sector, combines labour (L^s), land (H^s) and a tradable good (K^s). Output (Y^s)in location s_i is:

$$Y^s_i = a^s_i (L^s_i)^{\alpha_s}(H^s_i)^{\beta_s}(K^s_i)^{1-\alpha_s-\beta_s}$$

where a_s is the local TFP, that may vary across locations. Profit maximization delivers the usual price equal marginal cost condition:

$$p_i^s = \frac{w_i^{\alpha_s} q_i^{\beta_s}}{\kappa_s a_{s,i}}, \quad i = 1, ..., n \tag{2.10}$$

The intermediate input is produced using labour (L^k) and land (H^k). Output (Y^k) in location s_i is

$$Y_i^k = a_i^k (L_i^k)^{\alpha_k} (H_i^k)^{1-\alpha_k}.$$

Let w_i^k denote the wage rate such that firms in the intermediate sector break even in location s_i; then, the first order conditions gives:

$$w_i^k = \kappa_k (a_i^k)^{\frac{1}{\alpha_k}} q_i^{-\frac{1-\alpha}{\alpha}}, \tag{2.11}$$

where $\kappa_k = \alpha_k^{\alpha_k}(1-\alpha_k)^{1-\alpha_k}$. Given that labour is perfectly mobile across sectors, in equilibrium there will be a unique wage rate within each location. In locations where the intermediate good is produced ($L_i^k > 0$), the wage rate will be given by $w_i = w_i^k$. However, in locations where $L_i^k = 0$, equation (2.11) will not hold, and the wage is determined in the services sector. I return to this issue in section 6.

Finally, before closing this section, note that total land expenditure on part of firms in location s_i can be written as:

$$q_i(H_i^s + H_i^k) = \frac{\beta_s}{\alpha_s} w_i L_i^s + \frac{1-\alpha_k}{a\alpha_k} w_i L_i^k, \tag{2.12}$$

that is, as a function of the wage and number of workers in each sector.

5 Market clearing

There are four markets in the economy: the land market, the service market, the market for the intermediate good, and the labour market. In equilibrium, all markets clear. This gives us four equilibrium equations.

$$(1-\gamma_R) \sum_{j=1}^{S} \pi_{i,j}^R n_R I_j^R + E_i^{T,h} + q_i(H_i^s + H_i^k) = q_i H_i \tag{2.13}$$

$$\gamma \sum_{j=1}^{S} \pi_{i,j}^R n_R I_j^R + E_i^{T,c} = w_i \pi_i^R n_R + q_i H_i^s + K_i^s \tag{2.14}$$

$$K_i^s = Y_i^k + M_i \tag{2.15}$$

$$L_i^s + L_i^k = \pi_{.,i}^R n_R. \tag{2.16}$$

Note that in equation (2.14), I have substituted the zero profit condition for the retail sector. When all the above conditions hold, the balance of payments is in equilibrium by Walras' Law. In fact, considering (2.13)-(2.16) jointly, we obtain:

$$\sum_{j=1}^{S} \pi_{i,j}^R n_R I_j^R + [\gamma_T \pi_{.,i}^T + (1-\gamma_T)\pi_{i,.}^T] n_T I_T = q_i H_i + w_i \pi_{.,i}^R n_R + M_i \tag{2.17}$$

This equation says that the total expenditure in a location (on the left-hand side) must be equal to the total amount of money that flows out of the location (on the right-hand side), which is given by total land income, total wages, and payments to the imported intermediate input.Summing over all tracts i, we get:

$$n_T I_T = \sum_{i=1}^{n} M_i + (1-\phi) \sum_{i=1}^{n} q_i H_i$$

This equation makes clear that the local economy is exchanging tourism exports with tradeble inputs for the retail services sector.

6 Sectoral specialization

Given that the trade input is homogenous, and that there are constant returns to scale in the services sector, locations may completely specialize in services production. In this case, equation (2.11) doesn't hold, and the wage rate is determined in the services sector. At the same time, complete specialization depends on local demand conditions. In the following I describe how to derive the equilibrium wage and sectoral specialization in each location.

Let w_i^s, $i = 1, ..., .n$, denote the wage rate that makes services sector firms break even at $L_i^k = 0 \iff L_i^s = \pi^s_{\cdot,i} n_R$. By the first-order conditions in the services sector, together with (2.15) and (2.16), we have:

$$w_s^i = \frac{\alpha_s}{1-\alpha_s-\beta_s} \frac{M_i}{\pi^R_{\cdot,i} n_R}. \tag{2.18}$$

Then, in equilibrium, the wage actually paid in a location s_i will be

$$w_i = \max\{w_i^s, w_i^k\}. \tag{2.19}$$

In all locations where $L_i^s > 0$, we can pin down the fraction of the labor force employed in the services sector as follows[5]:

$$\begin{aligned}
w_i L_i^s &= \frac{\alpha_s}{1-\alpha_s-\beta_s} K_i^s \\
&= \frac{\alpha_s}{1-\alpha_s-\beta_s} (Y_i^k + M_i) \\
&= \frac{\alpha_s}{\alpha_k(1-\alpha_s-\beta_s)} w_i L_i^k + \frac{\alpha_s}{(1-\alpha_s-\beta_s)} M_i \\
&= \frac{\alpha_s}{\alpha_s + \alpha_k(1-\alpha_s-\beta_s)} (w_i \pi^R_{\cdot,i} n_R + \alpha_k M_i)
\end{aligned}$$

where the first equality follows from the service sector's first order conditions and the second equality follows from (2.15), the third equation follows from the first order condition in the intermediate sector, and, finally, the fourth equality follows from labor market clearing. (2.16).

Let $\theta_i \equiv L_i^s / (\pi^R_{\cdot,i} n_R)$ denote the fraction of location s_i's workers employed in the retail sector, and let

$$\bar{\theta}_i = \frac{\alpha_s}{\alpha_s + \alpha_k(1-\alpha_s-\beta_s)} \left(1 + \alpha_k \frac{M_i}{w_i \pi_i^R n_R}\right).$$

[5]In equilibrium, retail services will be produced in all tracts where either $\pi^R_{i,\cdot} > 0$ or $\pi^T_{i,\cdot} > 0$. Since commuting shares are the outcome of Frechet-distributed shocks with full support, the case $\pi^R_{i,\cdot} = 0$ and $\pi^T_{i,\cdot} = 0$ can only occur when $A_i^R =$ and $A_i^T = 0$. In these locations, retail services are not produced. Similarly, the intermediate sector is not produced in locations where its productivity, a_i^k, is equal to zero.

Then

$$\theta_i = \begin{cases} 0, & \bar{\theta}_i < 0 \\ \bar{\theta}_i, & 0 \leq \bar{\theta}_i \leq 1 \\ 1, & \bar{\theta}_i > 1 \end{cases} \tag{2.20}$$

This equation reveals some of the mechanisms of the model. Given an increase in the number of tourists to Venice, everything else constant, labor demand in the services sector increases, and this effect will be stronger in locations with high tourist amenities - see equation (2.9). Until $\theta_i < 1$, $i = 1, ..., n$, the shift in labor demand will be absorbed by moving employment from the traded sector to the services sector. When $\theta = 1$, further increases in labor demand translate into wage increases.

7 Welfare

Taking the expectation over the distribution of idiosyncratic shocks, the average welfare of residents in Venice is:

$$\mathbb{E}[u^R] = \Gamma\left(\frac{\varepsilon - 1}{\varepsilon}\right)\left[\sum_{r=1}^{S}\sum_{s=1}^{S}\left(\frac{A_r^R}{d_{rs}}\frac{I_s^R}{(p_r)^\gamma (q_r)^{1-\gamma}}\right)^\varepsilon\right]^{\frac{1}{\varepsilon}}$$

where $\Gamma(\cdot)$ is the Gamma function.

Similarly, the average welfare of tourists in Venice:

$$\mathbb{E}[u^T] = \Gamma\left(\frac{\varepsilon - 1}{\varepsilon}\right)\left[\sum_{r=1}^{S}\sum_{s=1}^{S}\left(\frac{A_s^T}{d_{rs}(p_s)^\gamma (q_r)^{1-\gamma}}\right)^\varepsilon\right] I^T$$

In an equilibrium where agents, both residents and tourists, are free to move between Venice and alternative locations at no cost, average welfare for each type of agent must be equal to an exogenously given level of utility $\bar{U}^R$ for residents and $\bar{U}^T$ for tourists.

8 Equilibrium

Definition 5. *A general equilibrium is a vector of land prices* $\{q_i\}_{i=1}^n$*, retail prices* $\{p_i\}_{i=1}^n$*, and wages* $\{w_i\}_{i=1}^n$*, a consumption allocation* $\{c_{i,j}^R, h_{i,j}^R, E_i^{T,c}, E_i^{T,h}\}_{i=1}^n$*, a pair of commuting matrices for residents and tourists* $\{\pi_{i,j}^R, \pi_{i,j}^T\}_{i,j=1}^n$*, and a vector of specialization ratios* $\{\theta_i\}_{i=1}^n$ *such that:*

i. (2.3) *hold for residents and* (2.7) *hold for tourists*

ii. the commuting matrices are given by (2.6) *for residents and by* (2.9) *for tourists;*

iii. the first-order condition hold in the services sector (2.10) *as well as in the intermediate sector* (2.11).

iv. wages are given by (2.19) *and the fraction of workers in a location employed in the services sector is given by* (2.16).

2.5 Calibration

In this section, I combine the available data with the structure of the model to infer the unobserved location fundamentals as well as some key parameters of the model. The logic of the exercise is clear: first, given factor supplies, the market equilibrium equations allow to compute the vector of land prices, wages, and non-tradable prices such that land, labour, and non-tradable markets clear. Second, given prices, the equations that describe the optimal behaviour of consumers and firms allow us to recover the unobserved fundamentals.

In particular, in the next sections, I show that given information on the parameters $\{\gamma_R, \gamma_T, \alpha_s, \beta_s, \alpha_k\}$, on the matrix of bilateral distances $\{dist_{i,j}\}$ on the matrix of commuting flows $\{\pi^R_{i,j}\}$, on tourist income I_T, and, finally, on $\{\pi^T_{i,.}, \pi^T_{.,i}, H_i\}$, it is possible compute the unique vectors of residential amenities $\{A^R_i\}$, tourist amenities $\{A^T_i\}$, and tradable sector productivities $\{a^k_i\}$ that are consistent with the observed equilibrium. Figure 2.11 shows the outcome of this exercise: it diplays maps of location fundamentals for the historical center of Venice.

1 Calibrated parameters

I calibrate some standard parameters using either survey information or previous results in the literature. The share of non-tradables expenditure for residents, γ_R is obtained from the Survey of Household Expenditure, conducted on a yearly basis by the National Statistical Institute (*Istat*, 2011). The survey reports a share of expenditure on housing services of 0.298 for the Veneto region, therefore I set $\gamma_R = 0.7$. The corresponding parameter for tourists, γ_T is obtained from the International Tourism Survey (Bank of Italy, 2016). In the earliest available year, 2014, the survey tells us that international tourists directed to North-Eastern Italy spent 42 per cent of their budge on accommodation services. Accordingly, I set $\gamma_T = 0.58$.

The *Visitor Survey* (2012), a joint project between the Department of Economics of the *Ca' Foscari* university and the Municipality of Venice, contains information on the daily expenditure of Venetian tourists. At the end of 2012, 2606 tourists were interviewed in the main touristic hotspots of historical Venice, and asked information on the detail of their trip as well as their holiday budget allocation. The average expenditure for overnight stayers is 169 euros, while the average expenditure for day-trippers. Finally, I set $\alpha_s = 0.6$, $\beta_s = 0.2$, and $\alpha_k = 0.75$.

In addition to these calibrated parameters, the quantification strategy requires information on the share of tourists who visit each tract $\{\pi^T_{.,i}\}$, on the share of tourists who lodge in each tract $\{\pi^T_{i,.}\}$, and on the supply of housing stock $\{H\}$. I approximate $\{\pi^T_{.,i}\}$ with the share of Flickr photos taken in each tract, over the total number of photos taken in the study area. As a proxy for $\{\pi^T_{i,.}\}$, I use the share of beds in each tract over the total number of beds.

2 Gravity equation

The commuting gravity equation is:

$$\log \pi^R_{ij} = c + \delta_i + \delta_j + \kappa\varepsilon \log dist(i,j) \tag{2.21}$$

It yields an estimate of the combined parameter ($\kappa\varepsilon$). The computation of the bilateral travel distances along the transport network is a time-consuming process, and at the moment, the algorithm I set up is still too slow. Therefore, for the time being, I set $\kappa\varepsilon$ equal to 0.1, which is the value estimated in Ahlfeldt *et al.* (2015) using the same methodology.

3 Incomes and wages

Labor market equilibrium requires:

$$\pi^R_{\cdot,j} = \sum_i \frac{(I^R_j)^\varepsilon / e^{\varepsilon\kappa dist(i,j)}}{\sum_s (I^R_s)^\varepsilon / e^{\varepsilon\kappa dist(i,s)}} \pi^R_{i,\cdot}. \tag{2.22}$$

Given data on $\pi^R_{\cdot,j}$, $\pi^R_{i,\cdot}$, and $dist(i,j)$, together with the parameter $\varepsilon\kappa$, this is a non-linear system of S equations in the S-dimensional adjusted income vector $\hat{I^R} = \{(I^R_j)^\varepsilon\}_j$. I feed into this equation the share of employed residents living in each tract (from the Population Census) as a measure of $\pi^R_{i,\cdot}$ and the share of employees in each tract (from the Industry and Services census) as a measure of $\pi^R_{\cdot,j}$.

In order to back out actual income from the solution of (2.22), a value for ε is required. I rely on the idea in Ahlfeldt *et al.* (2015) and calibrate ε in order to match the spatial variation of income in the Veneto region. In particular, we have:

$$Var(\log \hat{I^R}_j) = \varepsilon^2 Var(\log I^R_j)$$

To obtain an empirical counterpart of I^R_j, I use income data provided by the Italian Revenue Agency (*Agenzia delle entrate*) for tax year 2012. The data reports total taxable income at the Municipal level for several income categories, plus total taxes paid by taxpayers. Therefore the identification of ε comes from variation across the 577 locations that correspond to Municipalities in the Veneto Region, other than Venice (including one observation for Venice, either the mean or the median adjusted income, doesn't influence the results). As shown in figure 2.7, the number of employeed workers at the Municipality level in the Tax Agency data closely matches the number of employed workers in the Census data (the black line represents the 45 degree line). This gives us confidence that the Tax Agency file provides indeed an accurate income measure for our sample. I define I^R_j to be the sum of pre-tax mean employment income and mean real estate income in each location[6].I obtain a value of 9.5 for ε. As a comparison, Ahlfeldt *et al.* (2015). obtain an estimate of 6.7.

[6]It is not clear whether one should use pre-tax or after-tax income as a proxy for I^R_j; in this context, using after-tax income has the clear disadvantage that the data only report total taxes, including taxes paid on other income categories (e.g. capital gains). On the other hand, one could imagine that taxes are redistributed to residents in the form of lump-sum payments. For these reasons, I prefer to focus on pre-tax income.

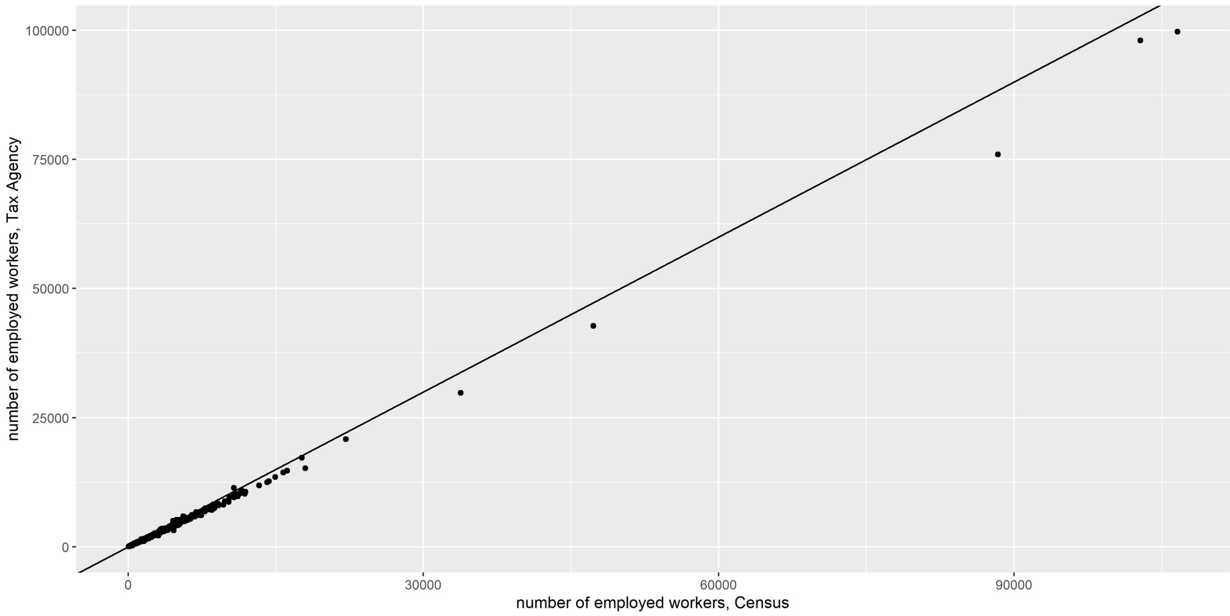


Figure 2.7: Number of employed workers in the Census data and in the Tax Agency data

With this value of ε in hand, we can back out the total income earned by workers at each location. As a final step, I derive wages as:

$$w_j = I_j^R - \phi \frac{qH}{n_R}, \tag{2.23}$$

where, again, the average real estate taxable income in the Revenue Agency data is used as a measure of $\phi qH/n_R$. Note that this procedure doesn't require knowledge of ϕ to get at wages[7].

4 Floorspace prices

The price of floorspace is computed from equation (2.13) . First, I use the commuting matrix, along with the vector $\{I_j^R\}$ computed in section 3, to derive the average income of residents in each residential location i. Conditional on the parameter γ^R, this delivers the floorspace expenditure of residents in each tract i. Second, I use the data on the number of beds to proxy for the share of tourists who lodge in a tract i. Conditional on the a parameter γ^T, and on tourist's income I_T, this delivers floorspace expenditure of tourists in tract i. Third, in order to compute the expenditure on floorspace for commercial purposes by firms in both sectors, I use equation (2.12), along with the wages from (2.23). Finally, I use information on the amount of developed area by main use in each location, combine with information of the number of floors in residential buildings from the Census files to construct a measure of the total supply of floorspace in each tract. More details are reported in the appendix B

At this point, I can assess the performance of the model by comparing the model-implied floorspace prices with the floorspace prices available in the OMI *Osservatorio del Mercato immobiliare* data (see section 2.2

[7]How to calibrate the parameter ϕ, i.e. the share of rents accruing to the resident population, is an open question. One option is to calibrate it so that $\phi \sum_i q_i H_i$ in the model matches the real estate income observed in the Tax Agency data. However, such a calibration, which delivers a value of 4%, misses the implicit rents paid by home-owners in reality.

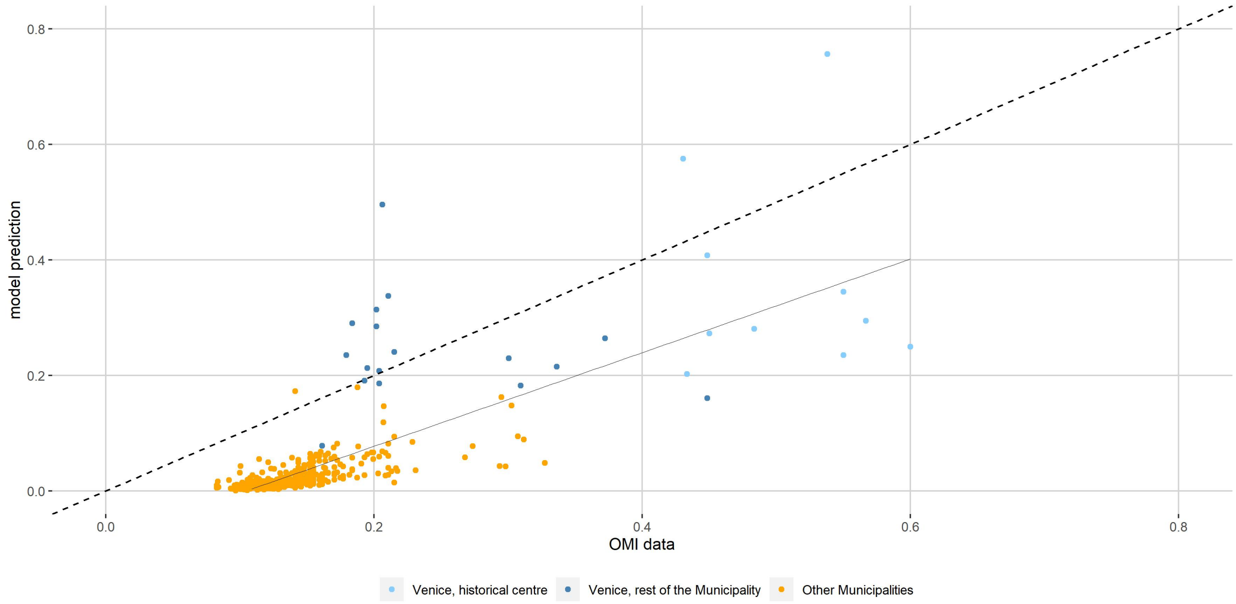


Figure 2.8: Validating land prices

The x axis reports the value of the floorspace price for each model location in the OMI (*Osservatorio del Mercato immobiliare*) data. The y axis reports the floorspace price implied by the model. The solid black line is the OLS regression line. The dashed black line is the 45-degree line

for details). The OMI zone have an intermediate size as compared to Municipalities and Census tracts, which are the two types of spatial units in my data. For the Municipality of Venice, I then match each Census tract to the OMI zone that contains its centroid, and compute the model-implied average as the average floorspace price over all tracts within an OMI zone.

Figure 2.8 reports the outcome of the validation exercise. The first key message that emerges from the figure is that the model does a good job at capturing the variation in the data. The regression coefficient is 0.8 with a t-statistic of 28. Recall that floorspace prices are computed as the ratio of total floorspace expenditure over floorspace supply, and that I relied heavily on the structure of the model and on empirical proxies to construct both measures. Such a performance gives us confidence that the model captures the important economic forces, and that the empirical proxies are meaningful. The second message of figure 2.8 is that the model doesn't explain as well the variation within the Municipality of Venice; in fact, the model overestimates the floorspace in OMI zones outside the historical center (in dark blue in the figure).

5 Tradable sector productivity

In those Census tracts where the tradable sector is active, the productivity parameter a_k can be computed, given information on land prices and wages, and on the paramter α_K, from equation (2.11). In contrast, the productivity of tradable production is not identified for those Census tracts where the sector is absent . However, in these tracts, equation (2.11) provides an upper bound to a_k, as the productivity level that would allow the tradable firms to poach a worker from the non-tradable sector.

To minimize the amount of missing values, I exploit a spatial interpolation strategy. I compute a_k for tracts fully specialized in the non-tradable sector by spatial interpolation. If the predicted a_k exceeds the upper bound, I set a_k equal to its upper bound. The details of this procedure are reported in the Appendix B.

6 Residential amenities

Given information on wages, land prices, and commuting distances, residential amenities (including non-tradable TFP) are identified up to a constant from equation (2.6).

In order to compute the price of the non-tradable good, we use (2.10) together with the value of land prices we have computed in the previous step.

7 Tourist amenities

The approach to compute tourist amenities is similar to the one we used to compute wages. Once we condition on the tract of origin, the share of tourists who commute to a given destination depends on a term that summarizes its attractiveness and on bilateral distance. As far as residents are concerned, the attractiveness of an employment location coincides with the wage it offers. For tourists, the attractiveness of a destination is a function of its tourist amenities (A_T) plus, given the previous assumptions, of the price of non-tradable goods produced there. We can write:

$$\pi^T_{\cdot,j} = \sum_i \pi^T_{ij|i}\pi^T_{i,j}, \quad \text{where}$$

$$\pi^T_{ij|i} = \frac{\left(\frac{A^T_j}{(p^S_j)^\gamma}\right)^\varepsilon d_{ij}^{-\varepsilon}}{\sum_s \left(\frac{A^T_s}{(p^S_s)^\gamma}\right)^\varepsilon d_{is}^{-\varepsilon}}$$

Given information on $\pi^T_{\cdot,j}$ and $\pi^T_{i,\cdot}$, this is a system of S equations in S unknowns, whose solutions delivers the vector of tourist attractiveness indicators $\left\{\left(A^T_j/(p^S_j)^\gamma\right)^\varepsilon\right\}$ for each Census tract. Conditional on the value of parameters ε and γ, and given the vector of non-tradable prices obtained from equation (2.10), one can deduce the value of tourist amenities in each tract from its tourist attractiveness.

Figure 2.9 plots residential amenities on the x-axis against tourist amenities on the y-axis. Both measures are normalized to have value 1 in *Piazza San Marco*, and plotted on a log scale. The blue line represents the regression line, while the black line represents the 45 degree line. Two main messages emerge from this figure: first, residential amenities and tourist amenities are positively correlated; second, there is still a substantial amount of dispersion around the regression line (in blue).

2.6 Policy analysis

In this section, I sketch some ideas (and some issues) related to how to use the quantified model to perform some interesting policy counterfactuals.

1. no tourism scenario: solving the model with $n_T = 0$;

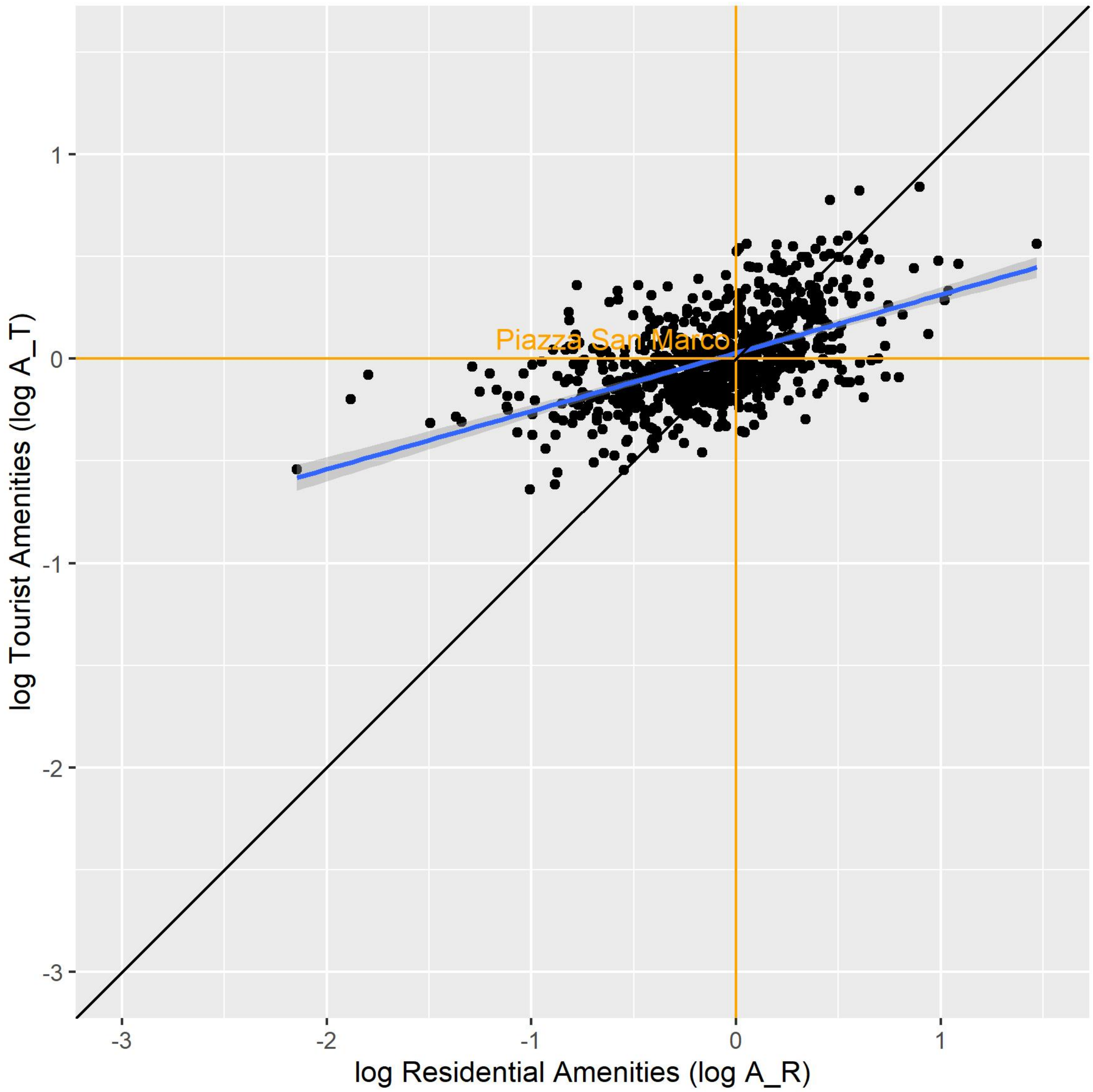


Figure 2.9: Residential and Tourist amenities

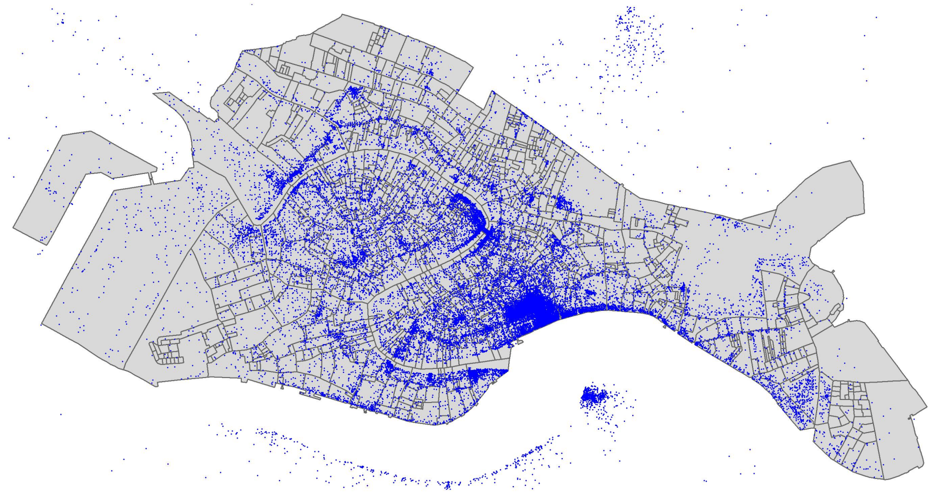
2. tourism diffusion policies:
   (a) making the distribution of tourism amenities (A_T) more uniform in the historical center of Venice (or within the Municipality);
   (b) forcing tourists to lodge outside the historical center;
3. tax policies:
   (a) an entrance tax to all tourists who visit the historical center of Venice, independently of where they lodge. Thus, all tourists who visit a tract i in the historical center of Venice would receive income $I_i^T = I^T - t^e$. The revenue from such policy is $\pi^T_{\cdot,i} n_T t^e$;
   (b) an overnight tax, charged on all tourists who reside in the historical center. Thus, all tourists who consume floorspace in tract i in the historical center of Venice would receive income $I_i^T = I^T - t^o$. The revenue from such policy is $\pi^T_{i,\cdot} n_T t^o$;

   The revenues from these taxes would redistributed be lump-sum to residents.

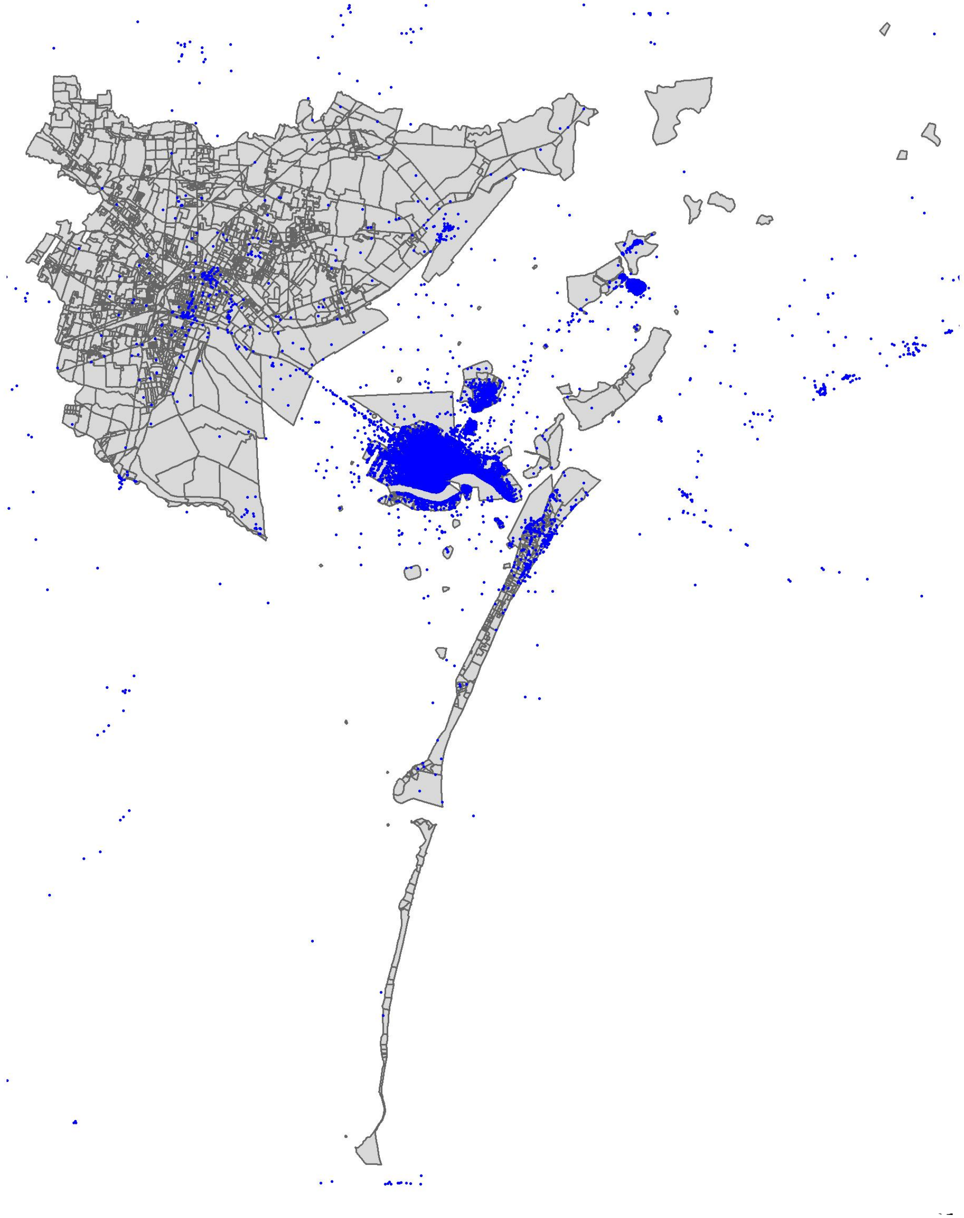
At the moment, the solution of the model relies on a convergence procedure (see section C for the details) that finds a solution provided that the value of ε is 5-6 or lower. The procedure nests two loops, on wages and on floorspace prices. Floorspace prices converge smoothly within a wide parameter range. However, equation (2.18), which gives the value of wages in locations fully-specialized in services, displays an oscillatory pattern when the labor supply elasticity (governed by ε) is too high. In this case, tiny difference in wages induce large sways in labor supplies; but when $\pi^R_{\cdot,j}$ goes to zero in one tract, the denominator of (2.18) also goes to zero, so that the wage explodes in the next iteration.

2.7 Conclusions

Despite its importance in the current debat on cities, the impact of tourism on urban structure has not been studied within a quantitative economic framework. In this paper, I presented a quantitative model of urban tourism, and I quantified the model using a rich dataset on economic activity within the Municipality of Venice, as well as across other municipalities in the broader region of Veneto. The structure of the model allows to back out the value of residential amenities, tourist amenities, as well as manufacturing productivity in each location.



(a) Historical city



(b) Municipality

Figure 2.10: Geotagged Flickr photos

(a) Productivity of the tradable sector

(b) Residential amenities

(c) Tourist amenities

Figure 2.11: Location fundamentals

Appendices

A Data

Flickr

The script queries photos for the whole Province of Venice and taken from year 2008 to year 2014, month by month. The scraping delivers 422329 photos taken in the geographic area of interest by 22440 distinct users. First, I trim photographers who are in the top 1% of the distribution of the number of photos taken and in the length of stay distribution; after this step, I end up with 294831 photos. Second, I keep only photos taken by photographers who take photos over a period shorter than 21 days. After this step, the dataset includes 185531 photos. Third, I keep only photos taken on land, discarding the photos taken on waterways. Fourth, in the main analysis I only use 168769 photos taken between 2008 and 2014, 144415 of which were taken within the Municipality of Venice[8].

Transport network

The transport network merges three shapefiles: the road network for the Municipality of Venice, a manually-constructed shapefile for the main ferry lines, and the road network for the *Regione Veneto*. The following paragraphs describe how each shapefile was cleaned (or constructed), and the procedure adopted to combine them.

I start from the 25762 features of the shapefile of all roads provided by the Venice municipality. First, I use the *v.net.component* function (GRASS) to split the network into its (weakly) connected components. The main component of the network (20972 features) connects most of the mainland and the historical centre. I keep this component plus the components for some of the lagoon islands (*Lido, Giudecca, Murano*) that are reached by the major ferry lines.

There are two main types of ferry lines in the historical centre: one group of lines travels along the *Canal Grande* and connect the *Santa Lucia* train station to *Piazza San Marco*; a second group of lines circles around the historical center, with detours to reach the islands of *Murano* and *Giudecca*. In order to allow for water transport (the main means of public transport in the Venice lagoon), I manually geocoded the stops for the main ferry lines, and then computed the ferry route by connecting these point features into a line. I also geocoded some additional points to avoid the most blatant cases of the ferry route crossing over land, although this might still occur in minor cases. Finally, I connected each ferry stop to closest feature in the Venice road shapefile, and I attribute a travel speed of 4 kilomters per hour (walking speed) to these newly created connections.

The shapefile for the Veneto road network contains XXX features. This shapefile doesn't provide direct information on the speed limit, but it does contain the main coding used to assign speed limits in Italy. I

[8]The Flickr website was launched in 2004. From 2004 to 2011, in my dataset the number of photos uploaded on Flickr increases steadily. However, the correlation in the number of photos taken at the tract level remains remarkably high over this period

attribute the speed limit to each road segment using this classification.

Then, I first apply the *snap* tool from the *v.clean* function, which connects line vertices that are less than a given threshold, set to 2 meters. This operation corrects minor mistakes in the network. Second, I split the networks in its (weakly) connected components, and keep only the main connected component.

I compute the intersection points between the Veneto roads and the boundary of the Venice municipality. There are 57 such "access points". Then, I connect the access points to the nearest feature in the Venice road network (which, in almost all cases, is the continuation of the road on the other side of the border). I attribute a travel speed of 50 kilometers per hour to these newly created connections.

At this point, the Venice road network has been extended to reach the ferry stops as well as the intersection ponits between the Veneto road network and the boundary of the Municipality. There are two remaining steps: first, I append all ferry lines and all Veneto roads to the Venice roads shapefile; second, I connect the centroids of each spatial unit to the network. This completes the construction of the transport network.

B Variables

Total supply of floorspace

In order to build a tract-level measure of the total supply of floorspace, I combine the Census data and the shapefile for the universe of buildings, which reports the building's main use.

From the Census shapefile, I obtain the number of residential buildings with 1 floor, 2 floors, 3 floors, 4 or more floors. I then compute the average number of floors per building in each tract, assuming buildings in the top-censored category have 5 floors. While it would be desirable to know the number of floors for all buildings, the Census files do not report this information.

I assume the number of floors in buildings used for industrial activities is equal to one. Thus, their floorspace is assumed to be equal to the area they cover. For all other buildings, their supply of floor space is computed as: $developedarea \times averagenumberoffloors$ in each tract i. Therefore, total supply of workspace in tract i is computed as:

$$H_i = developedarea_i \times averagenumberoffloors_i + industrialarea_i \tag{2.24}$$

The share of residential buildings with a given number of floors is missing in 394 tracts where no residential buildings are recorded. However, in the buildings shapefile, we observe a positive amount of developed, *non-industrial* land in 176 of these tracts. For the moment, I assume average number of floors in these tracts is equal to 3, which is equal to the sample median and mean (3.13).

Interpolation of manufacturing productivity

We observe positive manufacturing employment in 661 tracts. In these tracts, I can compute the value of the local productivity straight from equation (2.11), except in 13 tracts where the land price is missing. For all the other tracts, equation (2.11) implies an upper bound $\bar{a}_k$ to the productivity of the manufacturing sector.

I compute an interpolated value for a_k, denoted by $\hat{a}_k$, using a simple nearest neighbor method. This method imputes $\hat{a}_k$ equal to the average of the K nearest neighbors. I set $K = 5$, and I construct the set of nearest neighbors for each tract using the straight line distance.

In all tracts where a_k is unobserved because L_k is equal to zero, I compare the interpolated value with the upper bound and I set a_k equal to the minimum of the two: $a_k i = \min(\bar{a}_{ki}, \hat{a}_{ki})$.

In 13 tracts where the land price is missing, I set a_k equal to the imputed value, $a_k = \hat{a}_k$.

C Numerical procedure

The model is solved in terms of wages and floorspace prices, nesting two convergence loops. In the inner loop, I iterate on the vector of floorspace prices, taking the vector of wages as given. In outer loop, I iterate on wages, until convergence. The details of the convergence procedure are:

1. start with an initial guess for wages and floorspace prices w_0, q_0;
2. compute the price of services goods from equation (2.10), and residents' incomes;
3. compute the commuting matrices for residents and tourists using equations (2.6) and (2.6)
4. compute the expenditure on floorspace for commercial purposes from (2.12);
5. compute a new vector of floorspace prices from the market clearing condition (2.13);
6. if the floorspace price is in a neighborhood of the initial guess q_0, move on to the next step, otherwise update the guess and go back to step 2;
7. compute intermediate good imports using equation (2.17);
8. compute the wage bid in each sector using equations (2.11) and (2.18), and use equation (2.19) to derive a new vector of wages;
9. if the new wage is in a neighborhood of the initial guess w_0, stop, otherwise update the guess and go back to step 2;

Chapter 3

Market areas in general equilibrium

3.1 Introduction

We consider the problem of a continuous distribution of sellers (farmers) who have to decide where to ship their goods among a finite set of markets (cities). Both cities and farmers are arranged on a subset of the Euclidean plane. Space matters, in that carrying goods from the countryside to the city entails the payment of a shipping cost that increases with distance; in contrast, goods produced in cities (manufactures) are freely traded across markets. We study the equilibrium partition of space into mutually-exclusive market areas, such that all farmers within a market area carry their goods to the same city. We find that, under CES preferences, this equilibrium partition exists and is unique, independently of the underlying geography.

The theory of market areas has a long history in economics. In 1924, Frank Fetter formally stated the *economic law of market areas*[1] in a note on the *Quarterly Journal of Economics*:

> *The boundary line between the territories tributary to two geographically competing markets for like goods is a hyperbolic curve. At each point on this line the difference between freights from the two markets is just equal to the difference between the market prices, whereas on either side of this line the freight difference and the price difference are unequal. The relation of prices in the two markets determines the location of the boundary line: the lower the relative price the larger the tributary area. (Fetter, 1924)*

A number of subsequent papers in the fields of economics and geography have derived the economic law of market areas in more general settings: Hyson and Hyson (1950) introduced city-specific freight rates (see also (Parr, 1995)); Boots (1980) also considers an arbitrary number of cities; Hanjoul et al. (1989) extends the transport cost function to depend non-linearly on Euclidean distance. All these papers maintain two assumptions: first, there is a stylized geography, such that all non-market locations are homogenous and distance is equal to the Euclidean metric; second, and more importantly, prices are taken to be fixed. In other words, the price posted on an urban market is unrelated to the supply of farmers who decide to trade

[1] For a discussion of the history of this idea before Fetter's article, see (Hebert, 1972) and (Shieh, 1985)

there.

We generalize the theory of market areas along three dimensions. First, we consider a general geography where locations are allowed to differ in terms of productivity, and where the distance between two points is not necessarily the Euclidean metric. Second, we include a second sector of production that is active in cities and produces a freely tradable good (manufacturing); by specifying the source of income for urban dwellers, this extension allows us to close the model in general equilibrium. Third, prices are pinned down endogenously by market equilibrium conditions. Crucially, then, market prices and market areas will be jointly determined.

The economic setting we describe in this paper is reminiscent of the one studied in new economic geography papers such as Fujita and Krugman (1995), with the important difference that the distribution of population is given. Our question is whether there exists a way to split the economic space into market areas, such that all markets clear. Furthermore, we ask this question in a two-dimensional setting with a heterogeneous geography and an arbitrary number of locations. In so doing, we connect our paper to the recent literature on quantitative economic geography – see Redding and Rossi-Hansberg (2017) for a review, whose aim is to give empirical content to trade and economic geography models. Two papers are particularly worth discussing. First, Nagy (2018a) builds a quantitative economic geography models where prices and market areas are jointly determined in equilibrium in a world of heterogenous locations. His model also features trade costs for trade across cities and population mobility[2] . Second, a recent paper by Rossi-Hansberg et al. (2020) derives the optimal plant location decision for a firm, given a continuous distribution of consumers in space. Our approach in this paper is to study the formation of market areas in a framework that is simple enough to characterize its equilibrium properties, but which at the same time retains enough heterogeneity to be suitable for applied work.

The next section describes the model and section 3.3 presents our existence and uniqueness results.

3.2 Model

1 Set up

Let X be an open bounded subset of the Euclidean plane $\mathbb{R}^2$ with Lipschitz boundary ∂X, and $S \subset X$ be a finite set of n points. We refer to $x \in X$ as rural locations, and to $s \in S$ as cities. For each city $s \in S$ we are given a continuous function

$$d_s : \mathbb{R}^2 \to \mathbb{R}_+, \qquad \mathbb{R}_+ = \{x \in \mathbb{R} \ : x \geq 0\},$$

that assigns to a point $x \in \mathbb{R}^2$ a non-negative value $d_s(x)$ representing the "distance" from the rural location x to the city s.

Agents, either farmers or urban workers, consume two goods: an agricultural good (e.g., wheat) that is produced in the countryside, and a manufacturing good (e.g., clothing) that is produced in cities. In the

[2]Nagy (2018b)'s model also features technology diffusion and endogenous growth, such that the incentive to innovate for the urban sector is related to the size of the surrounding market area

rest of the paper, we index goods with lower-case letters (a for agricultural output and m for manufacturing output), and agents with upper-case letters (A for farmers and M for urban workers).

Farmers ship their produce to one urban market, where they also purchase manufacturing goods. For simplicity, we assume that consumption takes place in cities.

Agricultural output per capita is given by a function $y^a : X \to \mathbb{R}_+$, assumed to be continuous and bounded from above and below:

$$0 < y^a_{min} \leq y^a(x) \leq y^a_{max}, \quad \forall x \in X. \tag{3.1}$$

Manufacturing output in city $s_i \in S$ is denoted by y^m_i, with $y^m_i > 0$ for $i = 1, ..., n$.

In this exercise, we take the distribution of population over space and between sectors as given. Thus we are given a function: $L^A : X \to \mathbb{R}_+$ that is assumed to be continuous, while the urban population in city $s_i \in S$ is denoted by L^m_i, for $i = 1, ..., n$.

Finally, farm goods are costly to transport. Each time a farmer ships his goods from a rural location $x \in X$ to a city $s \in S$, a share $\Delta(x, s)$ melts in transit - that is, shipping costs take the iceberg form. We also assume that shipping costs are an exponential function of distance:

$$\Delta(x, s) = \exp(\delta d_s(x)), \quad \delta > 0.$$

In contrast, manufacturing goods are traded between cities at no cost.

2 Consumption problem

All agents in the economy order consumption baskets according to a utility function: $u : \mathbb{R}^2_{++} \to \mathbb{R}$, where we denoted $\mathbb{R}^2_{++} = \mathbb{R}_+ \times \mathbb{R}_+$. We assume the utility function takes the CES form:

$$U(c^M, c^A) = ((c^m)^\alpha + (c^a)^\alpha)^{\frac{1}{\alpha}}, \quad \alpha < 1$$

, where $1/(1-\alpha)$ is the elasticity of substitution between manufacturing and agricultural goods.

While rural and urban workers have the same preferences, they differ in terms of their income. Income for a farmer in location x, who ships his produce to city s_i, is: $\omega(x, s_i) \equiv p_i y^a(x)/\Delta(x, s_i)$, where $p_i (= p_{s_i})$ is the price of the agricultural good in city s_i, and q is the price of the manufacturing good. Since the manufacturing good is freely traded, by standard non-arbitrage arguments it must command the same price on all markets. Income for a urban worker in city s_i is equal to $\omega_i \equiv q y^M_i$, where q is the price of manufacturing goods.

Let us now turn to the consumption problem. An agent whose income is $\omega > 0$, and who faces consumption prices $q, p > 0$, solves the following constrained concave maximization problem:

$$\max_{c^m, c^a} u(c^m, c^a) \quad \text{such that} \quad qc^m + pc^a \leq \omega, \quad c^m, c^a \geq 0, \tag{3.2}$$

which yields the unique demand functions

$$c^m(q, p, \omega) = \frac{p^{\frac{1}{1-\alpha}}}{q^{\frac{\alpha}{1-\alpha}} + p^{\frac{\alpha}{1-\alpha}}}\omega, \quad c^a(q, p, \omega) = \frac{q^{\frac{1}{1-\alpha}}}{q^{\frac{\alpha}{1-\alpha}} + p^{\frac{\alpha}{1-\alpha}}}\omega.$$

Furthermore, the indirect utility function associated to problem (3.2) is:

$$V(q,p,\omega) = v(q,p)\omega, \quad \text{with} \quad v(q,p) = (q^{\frac{\alpha}{1-\alpha}} + p^{\frac{\alpha}{1-\alpha}})^{\frac{\alpha-1}{\alpha}} \tag{3.3}$$

Before we turn to describe the farmer's trading choice, we present in the following lemma some properties of the indirect utility function, which will turn out to be useful when proving the existance and the uniqueness of the equilibrium.

Lemma 1. *The indirect utility function V has the following properties:*

i. $\lim_{p_i \to +\infty} V\left(q, p_i, \omega(x, s_i)\right) \to +\infty$*;*

ii. $\lim_{p_i \to 0} V\left(q, p_i, \omega_i\right) \to +\infty$

iii.

$$\frac{\partial V(p_i, q, \omega(x, s_i))}{\partial \omega(x, s_i)} = \frac{\partial V(p_i, q, \omega_i)}{\partial \omega_i} = v(p_i, q), \quad i = 1 \ldots n.$$

iv. $v(q,p) > 0$

The first and the second properties tell us that indirect utilities of at least some agents explode at the extreme values of the price domain. These properties must be considered in conjuction with the fact that $V(q,p,\omega) \geq 0$ for all $q, p > 0$. The third bullet point is a well-known consequence of the fact that CES preferences are homogenous of degree one in consumption levels, and it implies that marginal utility of wealth is the same for all agents, irrespective of their location. The fourth property is saying that the marginal utility of wealth is strictly positive, the reason being that with CES preferences consumers choose to consume a stricly positive quantity of all goods.

3 Farmer's trading choice

In our model, farmers choose the urban market where to sell their produce, as well as purchase consumption goods. Therefore, they solve

$$\max_{s_i \in S} V(x, s_i)$$

Then, we can rewrite the trading problem as:

$$\min_{i \in S} d_i(x) - \frac{1}{\delta} \log v(p_i, q), \tag{3.4}$$

where we have used (3.3) and taken logs.

Let $\Omega_i(\lambda) \subset X$ denote the set of farmers who choose to ship their goods to city s_i, i.e., the city i's market area, where λ denotes the full vector of weights. Then, the total supply of farm goods to city i is given by

$$\int_{\Omega_i(\lambda)} \frac{Y^a(x)}{\Delta(x, s_i)} dx.$$

4 Market equilibrium

We define the excess demand function for farm goods in city s_i as:

$$Z_i(p) = \int_{\Omega_i} c^a\left(q, p_i, \omega(x, s_i)\right) L^A(x)dx + c^a(q, p_i, \omega_i)L_i^M - \int_{\Omega_i} \frac{Y^a(x)}{\Delta(x, s_i)}dx, \quad \text{for } i = 1, \ldots, n. \tag{3.5}$$

where p denotes the full vector of prices in the economy: $p = (p_1, ..., p_n, q) \in \mathbb{R}^{n+1}_{++}$, and

$$\mathbb{R}_{++} = \{x \in \mathbb{R} \colon x > 0\}.$$

To close the model in general equilibrium, we need the market clearing condition for manufacturing goods. Since the good is freely traded, market clearing holds at the aggregate level. The excess demand for manufacturing goods in the economy is:

$$Z_{n+1}(p) = \sum_{i=1}^{n} \left[\int_{\Omega_i} c^m\left(q, p_i, \omega(x, s_i)\right) L^A(x)dx + c^m(q, p_i, \omega_i)L_i^M\right] - \sum_{i=1}^{n} Y_i^m \tag{3.6}$$

where $Y_i^M = Y_{s_i}^M$.

Definition 6. *An equilibrium price vector in this economy is a price vector p^* such that $Z_i(p^*) = 0$ for $i = 1, ..., n+1$, where c^a, c^m and $\{\Omega_i\}_{i\in Y}$ jointly solve the consumer's problem* (3.2) *the farmer's trading problem* (3.4)*.*

3.3 Equilibrium characterization

This sections characterizes the equilibrium properties of the model described in section 3.2. We show that there exists an equilibrium price vector, and, furthermore, that the equilibrium price vector is unique. Remarkably, these results hold independently of the underlying geography, and independently of the elasticity of shipping costs with respect to distance.

Our line of attack proceeds in two steps: we first show that a price vector p is an equilibrium if and only if p is an extremum point of a certain cost function. Then, we show that this cost function does indeed attain a maximum. One advantage of this approach is that existence and uniqueness of the equilibrium can be proven within the same analytical framework.

We define the cost function $\mathcal{F} \colon \mathbb{R}^{n+1}_{++} \to \mathbb{R}$ as

$$\mathcal{F}(p) = -\sum_{i=1}^{n} V(p_i, q, \omega_i)L_i^M - \int_X V(x, p)L^A(x)dx, \tag{3.7}$$

where

$$\begin{aligned} V(x, p) &= \sup_{s_i \in S} V\left(p_i, q, \omega(x, s_i)\right) \\ &= \sup_{s_i \in S} v(q, p_i)\frac{y^a(x)}{\Delta(x, s_i)} \end{aligned}$$

is the indirect utility function of a farmer in $x \in X$, maximized over trading locations.

The basis of our approach is the following proposition:

Proposition 7. *Under the assumptions of section 3.2, $p \in \mathbb{R}^{n+1}_{++}$ is an equilibrium if and only if $\nabla \mathcal{F}(p) = 0$.*

Proof. See appendix A. □

This proposition implies that, in order to study the properties of the equilibrium, we can study the properties of cost function $\mathcal{F}$.

1 Existence

Given proposition (7), we need to show that the cost function (3.7) does indeed attain a maximum. The next theorem provides this proof.

Theorem 8. *Let the assumptions of Section 1 hold and assume that $\{d_s(\cdot)\}_{s \in S}$ is and admissible system. Then there exists a price vector $p^* \in \mathbb{R}^{n+1}_{++}$ such that $Z(p^*) = 0$.*

Proof. See appendix A. □

2 Uniqueness

Theorem 9. *Under the assumptions of Theorem 8, there exists a unique (normalized) equilibrium price vector.*

Proof. See appendix A. □

3.4 Conclusions

We consider the problem of a continuous distribution of sellers (farmers) that optimally choose a trading location where to ship their goods. We generalize previous statements of the theory of market areas along three dimensions: first, we consider a general geography where locations are allowed to differ in terms of productivity, and where the distance between two points is not necessarily the Euclidean metric. Second, we include a second sector of production that is active in cities and produces a freely tradable good (manufacturing); by specifying the source of income for urban dwellers, this extension allows us to close the model in general equilibrium. Third, prices are pinned down endogenously by market equilibrium conditions. Crucially, then, market prices and market areas will be jointly determined. Taken together, these features make the theory of market areas suitable for applied work.

Appendices

A Proofs

Proof of Proposition 7

Proof. By the definition of equilibrium we need to show that $\nabla\mathcal{F}(p)=0$ is equivalent to $Z(p)=0$. Since $\mathcal{F}$ is zero homogeneous we have that $p\cdot\nabla\mathcal{F}(p)=0$ for every $p\in\mathbb{R}^{n+1}_{++}$, so in particular $\frac{\partial\mathcal{F}}{\partial q}$ is determined by $\frac{\partial\mathcal{F}}{\partial p_i}$, $i=1,\dots,n$ and we can deduce its formula afterwards.

In order to calculate $\nabla\mathcal{F}$ let

$$\mathcal{F}_1(p)=-\sum_{i=1}^n V(p_i,q,qy_i^M)L_i^M,\quad \mathcal{F}_2(p)=-\int_X V(x,p)L^A(x)dx,$$

so that $\nabla\mathcal{F}=\nabla\mathcal{F}_1+\nabla\mathcal{F}_2$.

Since $\mathcal{F}_1$ is differentiable in $\mathbb{R}^{n+1}_{++}$, we obtain:

$$\begin{aligned}\frac{\partial\mathcal{F}_1}{\partial p_i}(p)&=-\frac{\partial V(p_i,q,\omega_i)}{\partial p_i}L_i^M\\&=c^a(p_i,q,\omega_i)L_i^M\frac{\partial V(p_i,q,\omega_i)}{\partial\omega_i},\end{aligned}$$

where we have applied Roy's identity in the second step.

For $\mathcal{F}_2$ the situation is more subtle. In order to differentiate under the integral sign we need to verify some properties of the integrand.

Consider the change of variable $p\mapsto\bar p$, where $\bar p_i=p_i^{\frac{\alpha}{\alpha-1}}\Big/\left(q^{\frac{\alpha}{\alpha-1}}+p_i^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha-1}{\alpha}}$, $\bar q=1$, and define $\bar V(x,\bar p)=V(x,p)$, that is

$$\bar V(x,\bar p)=\sup_{i=1,\dots,n}\left\{\frac{\bar p_i}{\Delta(x,s_i)}\right\}. \tag{3.8}$$

First, for each $\bar p\in\mathbb{R}^{n+1}_{++}$, the map $x\mapsto\bar V(x,\bar p)L^A(x)$ is measurable on X, since it is continuous and bounded. Then we have to show that the map $\bar p\mapsto\bar V(x,\bar p)L^A(x)$ is differentiable for almost every $x\in X$. This is true since the bisectors have measure 0, which are the only points where the function is not differentiable. So we find that

$$\frac{\partial\bar V(x,\cdot)L^A(x)}{\partial\bar p_i}(\bar p)=\chi_{\Omega_i}(x)\frac{\mathrm{d}V(q,p_i,\omega(x,s_i))}{\mathrm{d}p_i}L^A(x),$$

almost everywhere in $x\in X$, where $\chi_{\Omega_i}(x)$ is the characteristic function of the Voronoi region Ω_i. Finally we can bound this derivative by a measurable function independent of $\bar p$ as follows:

$$|\chi_{\Omega_i}(x)\frac{y^a(x)L^A(x)}{\Delta(x,s_i)}|\le y^a(x)L^A(x),$$

for all $p\in\mathbb{R}^{n+1}_{++}$.

Then, letting $\bar{\mathcal{F}}_2(\bar p)=\mathcal{F}_2(p)$, we can apply (Klenke, 2013, Theorem 6.28) that gives

$$\frac{\partial\bar{\mathcal{F}}_2}{\partial\bar p_i}(\bar p)=-\int_{\Omega_i}\frac{Y(x)}{\Delta(x,s_i)}dx,\quad \bar p\in\mathbb{R}^{n+1}_{++}.$$

By the chain rule formula we obtain:

$$\frac{\partial\mathcal{F}_2}{\partial p_i}(p)=-\int_{\Omega_i}\frac{\mathrm{d}V(q,p_i,\omega(x,s_i))}{\mathrm{d}p_i}\mathrm{d}x,\quad \bar p\in\mathbb{R}^{n+1}_{++}.$$

By Roy's identity, we finally obtain:

$$\frac{\partial \mathcal{F}_2}{\partial p_i}(p) = \int_{\Omega_i} \left[c^a\left(p_i, q, \omega(x, s_i)\right) - \frac{y^A(x)}{\Delta(x, s_i)} \right] L^A(x) \frac{\partial V\left(p_i, q, \omega(x, s_i)\right)}{\partial \omega(x, s_i)} dx, \quad p \in \mathbb{R}^{n+1}_{++}.$$

Using Lemma 1, we can write:

$$\frac{\partial \mathcal{F}}{\partial p_i}(p) = \left(c^a(q, p_i, \omega_i) L_i^M + \int_{\Omega_i} c^a\left(p_i, q, \omega(x, s_i)\right) L^A(x) dx - \int_{\Omega_i} \frac{y^A(x) L^A(x)}{\Delta(x, s_i)} dx \right) v(q, p_i), \quad p \in \mathbb{R}^{n+1}_{++}$$

Given that the the marginal utility of wealth $v(q, p_i)$ is strictly positive (see Lemma 1), it is easy to see that $\frac{\partial \mathcal{F}}{\partial p_i}(p) = 0$ is equivalent to $Z_i(p) = 0$. This proves the equivalence of the statement, since $p \cdot Z(p) = 0$ gives $Z_{n+1} = 0$ and $p \cdot \nabla \mathcal{F}(p) = 0$ gives $\frac{\partial \mathcal{F}}{\partial q}(p) = 0$. □

Proof of Theorem 8

Proof. Let $m = \mathcal{F}(1, \ldots, 1)$ and consider the superlevel set

$$C_m = \{p \in \mathbb{R}^n_{++} : \mathcal{F}(p) \geq m\}.$$

By definition $C_m \neq \emptyset$ and it is closed since F is continuous. We claim that there is $\lambda > 1$ such that $C_m \subseteq \{p \in \mathbb{R}^n_{++} : \frac{1}{\lambda} \leq p_i \leq \lambda\}$. Indeed, if we consider a sequence $\{p^k\}_{k \in \mathbb{N}}$ with $p^k \to p$ where $p_i = 0$ for at least one $i \in \{1, \ldots, n\}$, then it is easy to check that $\mathcal{F}(p^k) \to -\infty$. The same happens for a converging sequence $\{p^k\}_{k \in \mathbb{N}}$ with $p_i^k \to +\infty$ for at least one $i \in \{1, \ldots, n\}$.

C_m is then a compact non-empty superlevel set of a continuous function. By Weierstrass theorem, F attains a maximum $\bar{p}^*$ in C_m.

□

Proof of Theorem 9

Proof. By Proposition 7 we saw that equilibrium points are extrema of the cost function $\mathcal{F}$. It is then enough to show that $\mathcal{F}$ has a unique global maximum for $q = 1$. First note that $\sup_{p \in \mathbb{R}^n_{++}} \mathcal{F}(p) < +\infty$ since $\mathcal{F}(p) \leq 0$ for every $p \in \mathbb{R}^n_{++}$, where now $p = (p_1, \ldots, p_n)$ with an abuse of notation.

Consider the change of variable $p \mapsto \bar{p}$, where $\bar{p}_i = p_i^{\frac{\alpha}{\alpha-1}} / \left(q^{\frac{\alpha}{\alpha-1}} + p_i^{\frac{\alpha}{\alpha-1}} \right)^{\frac{\alpha-1}{\alpha}}$, $\bar{q} = 1$ and define $\bar{\mathcal{F}}(\bar{p}) = \mathcal{F}(p)$, that is

$$\bar{\mathcal{F}}(\bar{p}) = -\sum_{i=1}^{n} \left(1 - \bar{p}_i^{\frac{\alpha}{1-\alpha}}\right)^{\frac{\alpha-1}{\alpha}} y_i^m L_i^M - \int_X Y(x) \bar{V}(x, \bar{p}) \mathrm{d}x,$$

where $\bar{V}(x, \bar{p})$ was already defined in (3.8). If we show that $\bar{\mathcal{F}}$ is strictly concave in $\mathbb{R}^n_{++}$ and it attains a global maximum, then the same will be true for $\mathcal{F}$ since the change of variable $p \mapsto \bar{p}$ is a smooth diffeomorphism of $\mathbb{R}^n_{++}$.

Let

$$\bar{\mathcal{F}}_1(\bar{p}) = \sum_{i=1}^{n} \left(1 - \bar{p}_i^{\frac{\alpha}{1-\alpha}}\right)^{\frac{\alpha-1}{\alpha}} y_i^m L_i^M, \quad \bar{\mathcal{F}}_2(\bar{p}) = \int_X Y(x) \bar{V}(x, \bar{p}) dx,$$

so that $\bar{\mathcal{F}} = -\bar{\mathcal{F}}_1 - \bar{\mathcal{F}}_2$. It is easy to check that $\bar{\mathcal{F}}_1(\bar{p})$ is strictly convex in $\mathbb{R}^n_{++}$ since its Hessian is just a diagonal matrix with strictly positive entries. The function $\bar{V}(x, p)$ is convex in p, since it is the sup of linear functions. The convexity carries directly to $\bar{\mathcal{F}}_2(\bar{p})$ which is just obtained by integration on another variable. Since the sum of a strictly convex function and a convex function is strictly convex, we have just showed that $\bar{\mathcal{F}}$ is strictly concave in $\mathbb{R}^n_{++}$, and therefore it attains a unique global maximum $\bar{p}^*$ in C_m

Finally define p^* with $p^*_i = \bar{p}_i / \left(1 - (\bar{p}^*_i)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{\alpha}{\alpha-1}}$. Then p^* is the unique point in $\mathbb{R}^n_{++}$ such that $\nabla \mathcal{F}(p^*) = 0$.

since $\partial \mathcal{F}/\partial p_i(p) = \alpha p_i^{\alpha-1} \partial \bar{\mathcal{F}}/\partial \bar{p}_i(\bar{p})$, and so the unique equilibrium price vector. $\square$

Chapter 4

The rise of (urban) Europe: a Quantitative-Spatial analysis

"The study of industrialisation in any given European country will remain incomplete unless it incorporates a European dimension."

—Pollard (1973)

"When studying population history on a European scale, national or regional differences do not render useless a highly aggregated approach because similar forces were acting over a broad geographic area and the units in the system were influencing each other."

— Jones (1981)

4.1 Introduction

How Europe developed from a poor and isolated society in the early Middle Ages to the centre of the Industrial Revolution in the XIXth century is a long-lasting open question in the social sciences. This is not surprising: understanding the rise of Europe means understanding the drivers of long-term development and ultimately the roots of sustained modern growth. In this paper, we focus on the role of trade and market integration in fostering urban growth, manufacturing productivity and long-term development. In particualar, market access-based explanations have received some attention in the literature. While these studies did produce a number of valuable insights, most of them focused on single historical episodes or on limited geographical settings. Furthemore, as we discuss below, most studies have relied either on informal narratives or on reduced form regressions.

This paper studies the rise of Europe from a novel perspective. We develop a quantitative economic geography model that incorporates some key features of the pre-Industrial economic context, and that is suited to answer questions on the role of trade for long-term development. In the model, there is a finite set of cities that produce the manufacturing goods, and a continuous set of rural locations devoted to agriculture. Locations are allowed to differ in terms of productivity and geographic location, as described by the matrix of bilateral distances. Cities are trading places: agricultural goods are shipped from the countryside to one city, that is optimally chosen by each farmer. From the urban market, manufactured and agricultural goods are traded with other cities. Farmers also have an autarky option: they may decide not to engage in trade exchanges and receive an exogenous level of "subsistence" utility. Finally, manufacturing productivity evolves over time through a pre-specified process, that combines persistance and dynamic scale effects.

Our empirical analysis exploits existing data on urban population for all European cities that passed the 5000 population threshold at least once before 1850. We select the largest cities in 1600 with the requirement that they account for 75% of the total urban population. Thus, our final sample includes 369 major European cities. Importantly, except for a few cases, these cities appear in the sample from the first century (year 1100). We complement this data with data on agricultural productivity and with geographical information on navigable rivers and ruggedness.

Although the model is described in continuous space, our empirical analysis is carried out at the grid cell level. We split Europe in over 5000 cells of 0.25 degree. Using the geographical information to impute transit costs, we use the Fast Marching Method to compute travel distance between each pair of cells in the sample.

Having data on agricultural productivity, we back out the unobserved vector of city-level manufacturing productivities such that the model matches the data exactly in the first period, and we calibrate the model parameters using central values in the literature.

Then, we use the model to run three quantitative experiments, focusing on the role of trade costs in different sectors. In the first exercise, as a baseline, we fix the value of trade costs and let the model run for eigth centuries, such that each century correspond to one iteration.

The second and third exercise are motivated by leading historical narratives on the evolution of trade frictions in the pre-Industrial era. In particular, there is plenty of historical evidence that market intergation started deepening very early in our study period. However, the Commercial Revolution Lopez (1976) of years 1100-1300 mainly involved manufactured goods, especially cloth and spices. Accordingly, we run an exercise where the trade costs for manufacturing goods decreases continously from the the beginning to the period to the end, whereas the trade cost for agricultural goods stay fixed.

Finally, we run a third exercise where, in addition to reducing the trade costs for manufactured goods, we also reduced the trade costs for agricultural goods from the XVIth century onwards.

Our results point toward a novel explanation for the patterns of European pre-Industrial development, and in particular as concerns the role of trade costs. In fact, while previous analysese have focused on the role of manufacturing trade, we show that such an explanation is at odds with the large increase in dispersion in the city size distribution that we observe in the data. In contrast, market integration in the *agricultural* sector, combined with an early reduction in trade costs for manufacturing, has the potential to explain the rise of urban giants and the North-South shift in a unified way.

Our paper contributes to the literature on long-term macroeconomics (Galor, 2005; Galor and Weil, 2000; Cervellati and Sunde, 2005), and in particular to the stream of papers that acknowledges the importance of trade as a determinant of long-term development. (see e.g. Michalopoulos and Papaioannou, 2018, for a recent review).

Secondly, our paper is related to the literature on quantitative economic models - see Redding and Rossi-Hansberg (2017) for a review, and especially to the papers who take a dynamic perspective (Desmet and Rossi-Hansberg (2014); Desmet et al. (2018); Nagy (2018a); Allen and Donaldson (2018); Eckert and Peters (2018)). In particular, Nagy (2018a) develops a dynamic model of city formation and applies it to the U.S. urbanization in the XIXth century. In his model, agricultural goods are produced in rural locations and traded to cities, while manufacturing goods are traded across cities. We extend Nagy's model to allow for trade in agricultural goods *across* cities[1], although, importantly, we take the city network as fixed. Our paper is also related to Fajgelbaum and Redding (2018) [2], who investigate the link between falling trade frictions and structural change in Argentina from 1869 to 1914.

Finally, our paper is related to several studies on European economic history that have studied urbanization (de Vries, 1984) and trade (Findlay and O'Rourke, 2007) from an historical perspective. Historians, as well as economists, have also devoted much effort in explaining the little divergence, i.e. the shift of the centre of economic activity towards the North of Europe prior to the Industrial Revolution. While many arguments have been put forward, ranging from institutional (e.g. North and Weingast, 1989; De Long and Shleifer, 1993), demographic (van Zanden, 2009; Jedwab et al., 2019), and cultural (Jacob, 1997; Mokyr, 2002) factors to the importance of the Atlantic trade (e.g. Allen, 2003; Acemoglu et al., 2005), these studies typically rely on historical narratives or reduced-form regressions.

4.2 Urban growth in pre-Industrial Europe

In this section we present the data and we show some stylised facts about urban growth in pre-Industrial Europe, namely from year 1000 to year 1800.

1 Data

Our main dataset comes from Bairoch et al. (1988), which reports urban population century by century. The dataset includes all European cities westwards of the Ural mountains that ever passed a population treshhold of 5.000 inhabitants. We supplement the data with the recent corrections by Bosker et al. (2013). Furthermore, we take into account the "Malanima critique" and remove from the sample the agro-towns in

[1] In their Appendix 5, Allen and Arkolakis (2014) add a second traded sector to their baseline one-sector model, and characterize the properties of the equilibrium under the assumption of no spillovers in productivity or amenities.

[2] See also (Coşar and Fajgelbaum, 2016).

Sicily (Malanima, 1998). These are cities that appear two be large in the data, but that historically hosted predominantly a rural population.

We make also make use of the caloric suitability index by Galor and Özak (2016), which we use as a measure of agricultural productivity. The index is reported on a 5 arcminute by 5 arcminute level and based on the widely used suitability index byRamankutty et al. (2002). Figure 4.2 shows the Ramankutty index for our area of analysis. Finally, we use data on navigable rivers and elevation from the Natural Earth database.

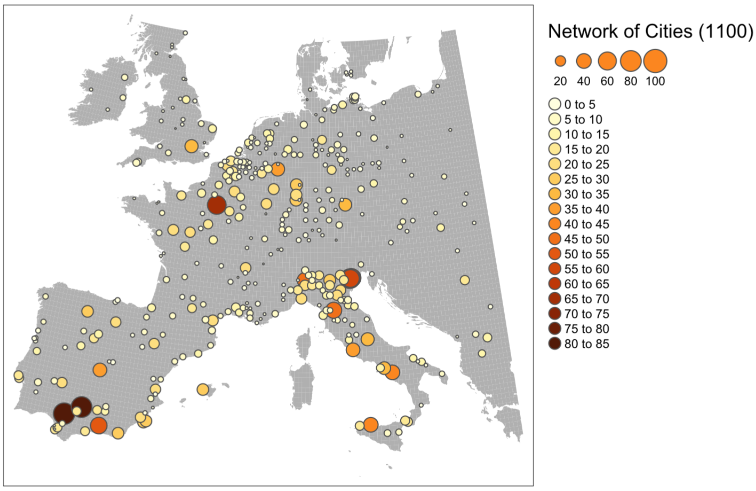


Figure 4.1: Our baseline balanced sample with roughly 400 cities in Europe

2 Stylised facts

We show some key patterns of urban growth in pre-Industrial Europe, which motivate our theory and our quantitative analysis.

First, the left panel of figure 4.3 shows the steady increase of urban population in pre-Industrial Europe: total urban population for our sample of cities increased from roughly 2.5 million in year 1000 to 12.5 millions in 1800. The increase becomes particularly pronounced from year 1500 onwards.

However, this growth pattern was far from even in space. As the right panel of the figure 4.3, the share of urban population in Northern-Europe increased steadily over our study period[3]. While in year 1000, 40% of the European urban population was concentrated in South, this figure increases by 15 percentage points in the next eight centuries. Notably, the pattern is visible from the very first century, and it keeps a linear pace for most of the period, only accelerating after the 1600 century. This is at odds with explanations of the North-South shift that focus on the Atalantic trade (see, for istance, Acemoglu et al. (2005)).

A second feature of the data is the remarkable increase in inequality in city sizes across European cities.

[3]While the intercept of the fitted line clearly depends on where we place the parallel to define the North vis a vis the South, the stylised pattern is insenstitive to this choice

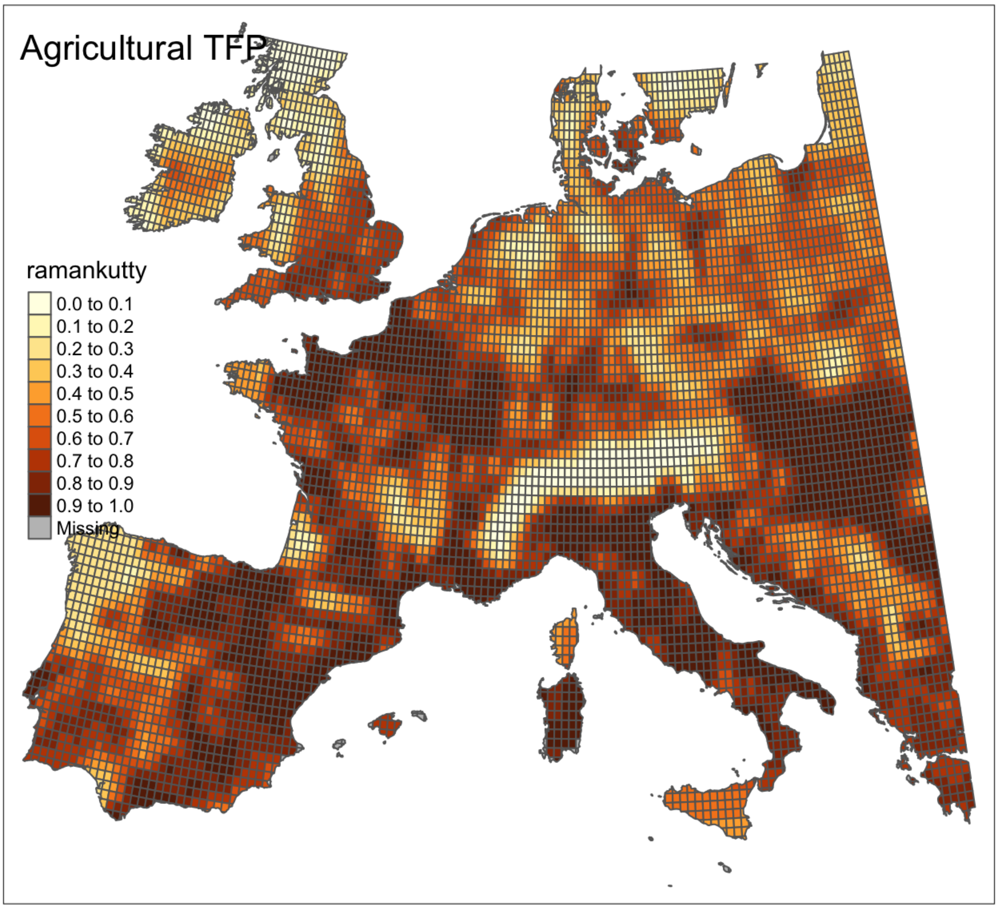


Figure 4.2: Agricultural productivity in each gridcell.

The left panel of figure 4.4 shows this by plotting the Gini index of the city size distribution computed century by century for our sample of cities.

Finally, the right panel of figure 4.4 shows a striking fact that has so far received little attention, but which is crucial to understand the North-South shift and the evolution of the city size distribution in a unified framework: the increase in city size inequality took place predominantly in the North. Interestingly, the value of the Gini index in the North is roughly *half* than the value in the South at the start of the period. However, whereas in the South the index increases by roughly 10 percentage points over the study period, in the North the index increases three-fold, by nearly 40 percentage points. Again, the pattern is visible from the onset of the study period.

4.3 Model

We now present a spatial theory of European industrial development. There is a finite set of urban locations where the manufacturing sector operates, and a continuous set of agricultural locations engaged in agriculture. Besides their production site, the two sectors differ in terms of their economies of scale and of the size of trade frictions. Farmers can decide to ship their goods to an optimally chosen urban market, or to remain in autarky and receive a substistence level of utility which is fixed exogenously. Trade takes

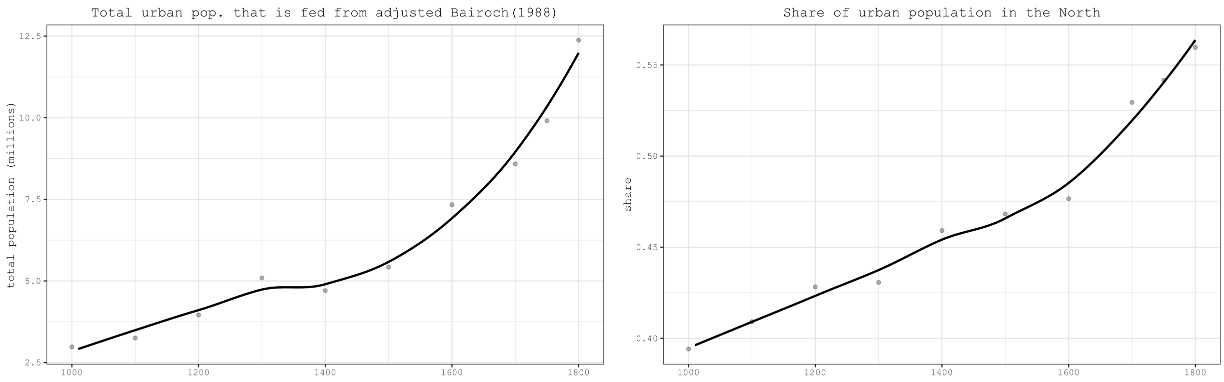


Figure 4.3: The left-panel plots the total urban population in Europe century by century. The right-panel plots the share of urban population in the North of Europe (defined here as the upper half of our study area)

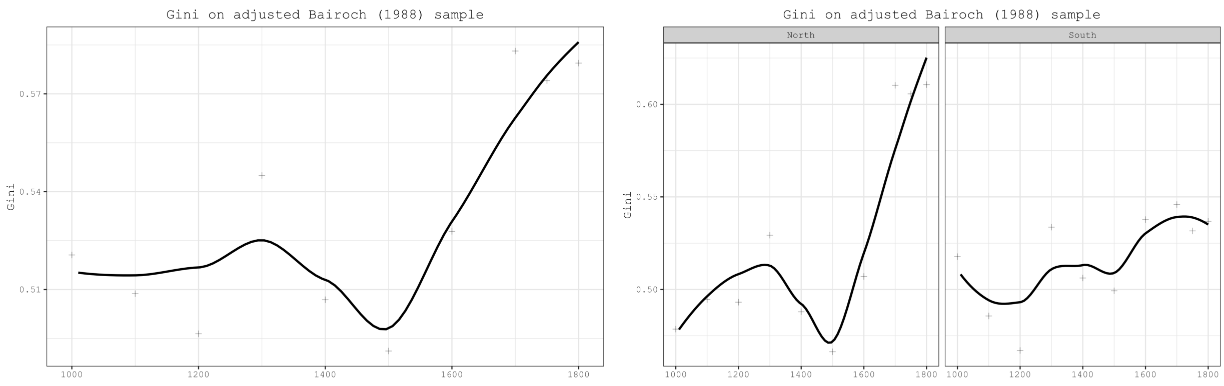


Figure 4.4: The left panel plots the Gini index of the city size distribution for our sample of 369 cities, century by century; the right panel shows the same plot for cities in Northern Europe and Southern Europe separetely.

place in cities, where Armington-type varieties of both goods are exchanged with other cities. Technological process takes place in the manufacturing sector, through a pre-specified process that combines persistence and dynamic scale effects.

1 Geography and endowments

The economy consists of a discrete set of cells $\mathcal{X}$, which we label rural cells. In a subset $\mathcal{Y} \subset \mathcal{X}$, there is a city. Elements of $\mathcal{X}$ are denoted by r or s, whereas the elements of $\mathcal{Y}$ are denoted by i or j. We take the set of cities, as well as their location, as given in each period. Time is discrete and indexed by t, where $t = 1000, 1100, ..., 1800$. In the following, except when required to avoid confusion, we suppress the current time subscript t, and retain only the previous period subscript $t-1$.

There are two sectors in the economy. Cities produce a manufacturing (or urban) good, whereas rural locations produce an agricultural (or rural) good. We index sectors by $k = M, A$.

As in Nagy (2019), cities are trading places. That is, goods can only be exchanged in cities. Farmers commute to cities to sell agricultural goods and purchase manufacturing goods. We denote the set of rural cells trading with city i by Ω_i; we refer to Ω_i as the rural hinterland around city i.

Rural cells differ in terms of agricultural productivity, in the amount of land available for agriculture, and in geographic position. All these fundamentals are taken to be time-invariant.[4] Urban cells further differ in terms of manufacturing productivity, which in turn is allowed to evolve over time.

Agents are *ex-ante* identical. All of them are endowed with one unit of labor that is supplied inelastically to the market. In equilibrium, they are employed in the urban sector (workers) or in the rural sector (farmers). Farmers own an equal share of land at their rural location r. Thus, urban income equals the urban wage rate, whereas rural income equals farm revenues per capita.

Labor is freely mobile across sectors and across locations.[5] The total urban population in the economy, denoted by $\bar{L}_t^M$, is exogenously given at each time $t = 1000, 1100, ..., 1800$.

2 Production

The farm good is produced using labor l^A and land h under conditions of constant returns to scale. Farm output in r is given by:

$$y_{r,t}^A = \phi_r^A (l_{r,t}^A)^\beta (h_r)^{1-\beta}, \quad 0 < \beta < 1 \tag{4.1}$$

where ϕ_r^A is agricultural productivity, $l_{r,t}^A$ is the rural population in $r \in \mathcal{X}$, h_r is land area, and β is the the Cobb-Douglas parameter. Land use in agriculture is the source of the congestion in the economy, given that land is available in fixed supply.

[4] In the empirical application, cells differ in land area because of the earth curvature and because the coastline cuts through some of them.

[5] While migration frictions were certainly important in pre-Industrial Europe, novel historical evidence suggest such as Lucassen and Lucassen (2009) or Schäfer (2013) suggest that the degree of mobility in pre-Industrial Europe was similar to if not higher than the one observed today.

Manufacturing output in city s at time t given by:

$$Y_{i,t}^M = \phi_{i,t}^M L_{i,t}^M, \tag{4.2}$$

where $L_{i,t}^M$ is the labor force employed in manufacturing and $\phi_{i,t}^M$ is manufacturing TFP.

As common in the economic geography literature, we assume that there are external economies of scale in manufacturing. More specifically, manufacturing TFP takes the form:

$$\phi_i^M = \tilde{\phi}_{i,t-1}^M (L_i^M)^{\gamma_1} \tag{4.3}$$

where $\tilde{\phi}_{i,t-1}^M$ is a time-varying component that is taken for given at time t, and γ_1 is a parameter capturing the strength of agglomeration spillovers in the economy. In subsection 3, we explain how we model the term $\tilde{\phi}_i^M$, which is the source of technological progress in our model.

Firms take ϕ_i^M at the time of making their choices. Given perfect competition and constant returns to scale, the off-the-shelf price in city s equals the marginal cost:

$$p_s^M = \frac{w_i}{\phi_s^M}. \tag{4.4}$$

Finally, firms make zero profits in equilibrium:

$$p_i^M Y_i^M = w_i L_i^M. \tag{4.5}$$

3 Technological progress

We assume the following dynamic process for the term $\tilde{\phi}_{i,t}^M$:

$$\tilde{\phi}_{i,t}^M = \tilde{\phi}_{i,t-1}^M + \mu \log L_{i,t-1}^M. \tag{4.6}$$

This equation captures two important forces: first, there is some degree of persistance in manufacturing TFP, since current productivity depends on productivity in the previous period; second, cities receive a shock to manufacturing TFP which is increasing in the size of *urban* population in the previous period. This dynamic externality is meant to capture, in reduced form, the fact that larger cities have larger scope for innovation activities.

4 Trade structure

Agricultural goods are shipped from the countryside to the urban market. Then, from cities, both goods can be traded to other cities. We model trade as Armington (1961). Thus each rural hinterland Ω_i produces a unique variety of manufacturing and agricultural goods, and consumers wish to consume all varieties. Note that farm good varieties acquire their identity, to the consumer's eyes, at the trading location, rather than at the production location.

Shipping goods from one location to another is costly. We assume that trade costs take the iceberg form: it takes $D(r,i)$ units of the farm good to ship 1 unit from rural cell $r \in \mathcal{X}$ to city $i \in \mathcal{Y}$. Similarly, it takes $T^M(i,j)$ and $T^A(i,j)$ units of, respectively, manufacturing good and agricultural good, to ship one unit from one city to another.

Given no arbitrage conditions, delivery prices from city j to city i are given by: $p_{ij}^M = T^M(i,j)p_j^M$ and $p_{ij}^A = T^A(i,j)p_j^A$, for manufacturing and agricultural goods respectively.

Finally, we parametrize trade costs to be an exponential function of distance $d(r,s)$, with $r,s \in \mathcal{X}$. Thus, we have:

$$D(r,i) = e^{\delta d(r,s)}, \quad T^M(i,j) = e^{\tau^M d(i,j)}, \text{ and } T^A(r,i) = e^{\tau^A d(i,j)}.$$

5 Consumer's problem

Agents order consumption baskets according to a Cobb-Douglas utility function defined over manufacturing and agricultural composite goods[6] $U(C^M, C^A) = (C^M)^\alpha (C^A)^{1-\alpha}$, where C^M and C^A are CES bundles of the good varieties imported from all cities:

$$C_i^M = \left(\sum_{j \in \mathcal{Y}} (c_{ij}^M)^{\frac{\sigma^M - 1}{\sigma^M}} \right)^{\frac{\sigma^M}{\sigma^M - 1}}, \quad C_i^A = \left(\sum_{j \in \mathcal{Y}} (c_{ij}^A)^{\frac{\sigma^A - 1}{\sigma^A}} \right)^{\frac{\sigma^A}{\sigma^A - 1}},$$

The parameter α is the share of expenditure devoted to manufacturing goods, and, together with β, it determines the strength of congestion forces in the economy, i.e., how much fixed land supply bites on consumer's welfare. The parameters σ^M and σ^A represent the elasticities of substitution between different varieties, which is allowed to differ between sectors.

We follow Nagy (2018) and assume that all agents, including farmers, consume their goods at the trading place. Then, all agents, both farmers and workers, who do business in city i will face the same consumption prices; as a consequence, in a spatial equilibrium where welfare equalizes, they will also have the same nominal income. We first solve the consumer's problem for a representative agent in i, and then we deal with the farmer's trading choices.

An agent who works or trades in city i solves:

$$\max_{\{c_{ij}^M, c_{ij}^A\}_{j \in \mathcal{Y}}} U(C_i^M, C_i^A) \quad \text{subject to} \quad \sum_{j \in \mathcal{Y}} p_{ij}^M c_{ij}^M + \sum_{j \in \mathcal{Y}} p_{ij}^A c_{ij}^A \leq v_i,$$

whre p_{ij}^M and p_{ij}^A are the prices in i of, respectively, the manufacturing and agricultural variety imported from j.

Nominal income v_i is equal to the wage rate, w_i, for urban workers, and to farm revenues per capita, $(p_i^A / D(r,i)) \times (y_r^A / l_r^A)$, for farmers. Let P^M and P^A denote the standard dual price indices for CES

[6]According to the historical evidence, expenditure shares did not change decisively in our study period. First, there was just not a lot of choice when it came to manufacturing. It is mostly cloth, candles, oil, soap (e.g. Allen, 2001; Malanima, 2009). Second, there is plenty of evidence that the substitution effects took place within goods categories and not across. There was usually a desire to find grain substitutes for bread and also to increase the share of meat (Abel, 1981).

demands, given by:

$$P_i^M = \left(\sum_{j \in \mathcal{Y}} (T_{ij}^M)^{1-\sigma^M} (p_j^M)^{1-\sigma^M} \right)^{\frac{1}{1-\sigma^M}}, \tag{4.7}$$

$$P_i^A = \left(\sum_{j \in \mathcal{Y}} (T_{ij}^A)^{1-\sigma^A} (p_j^A)^{1-\sigma^A} \right)^{\frac{1}{1-\sigma^A}} \tag{4.8}$$

Then, the indirect utilities, V_i^M and $V_{r,i}^A$ respectively, can be written as:

$$V_i^M = \frac{w_i}{(P_i^M)^\alpha (P_i^A)^{1-\alpha}},$$
$$V_{r,i}^A = \frac{(p_i^A / D(r,i)) \times (y_r^A / l_r^A)}{(P_i^M)^\alpha (P_i^A)^{1-\alpha}}, \tag{4.9}$$

6 Gravity

Trade flows in both sectors follow a standard gravity equation. After solving for consumer's demands, the value of city i's imports of goods produced in city j can be written as:

$$X_{ij}^M = \alpha (T_{ij}^M)^{1-\sigma^M} (p_j^M)^{1-\sigma^M} (P_i^M)^{\sigma^M - 1} w_i L_i, \tag{4.10}$$

$$X_{ij}^A = (1-\alpha) (T_{ij}^A)^{1-\sigma^A} (p_j^A)^{1-\sigma^A} (P_i^A)^{\sigma^A - 1} w_i L_i. \tag{4.11}$$

In equilibrium, trade flows depends on the centrality of each city in the urban network, on the size of trade costs, and on the productivity in the two sectors.

7 Welfare equalization

First, all farmers in a rural hinterland must receive the same welfare in equilibrium: $V_{r,i}^A = V_{s,i}^A$, for all $r, s \in \Omega_i$ and all $i \in \mathcal{Y}$. Using this condition together with the production function (4.1), we derive an expression for the rural population in each rural hinterland Ω_i, where again we take the spatial tessellation as given:

$$l_r^A = \frac{\left(\phi_r^A / D(r,i)\right)^{\frac{1}{1-\beta}} h_r}{\sum_{s \in \Omega_i} \left[\left(\phi_i^A / D(r,i)\right)^{\frac{1}{1-\beta}} h_i \right]} \sum_{s \in \Omega_i} l_i^A. \tag{4.12}$$

Rural population in r is a fraction of the total rural population in the corresponding rural hinterland; the term $\left(\phi_r^A / D_{r,i}\right)^{\frac{1}{1-\beta}} h_r$ represents the effective agricultural productivity of rural cell r, net of shipping costs. Let us define: $L_i^A = \sum_{s \in \Omega_i} l_i^A$ and

$$\Phi_i^A = \sum_{s \in \Omega_i} \left[\left(\phi_i^A / D(r,i)\right)^{\frac{1}{1-\beta}} h_i \right]. \tag{4.13}$$

Thus, L_i^A is the total rural population in rural Ω_i, and Φ_i^A is the total effective agricultural productivity in the rural hinterland. Note that the only unknown term in Φ_i^A is rural hinterland Ω_i.

Secondly, welfare equalization between farmers and workers within a rural hinterland implies

$$\frac{p_i^A}{D_{r,i}} \frac{y_r^A}{l_r^A} = w_i \quad \text{for all } r \in \Omega_i, \text{ and all } i \in \mathcal{Y}. \tag{4.14}$$

Summing over all cells in Ω_i and isolating p_i^A, we obtain:

$$p_i^A = \frac{L_i^A}{\sum\limits_{s \in \Omega_i} \frac{y_r^A}{D(r,i)}} w_i.$$

Using the production function (4.1) and equation (4.12), we obtain:

$$p_i^A = \left(\frac{L_i^A}{\Phi_i^A} \right)^{1-\beta} w_i. \tag{4.15}$$

Equations (4.4) and (4.15) define the "city-gate" prices of manufacturing and agricultural varities in city i, before trade frictions are incurred.

Finally, welfare equalizes for urban workers living in different cities:

$$V_i^M = V, \quad \text{for all } i \in \mathcal{Y}. \tag{4.16}$$

8 Market clearing

We require all markets to clear. Therefore, total revenues of a sector in each location $i \in Y$ must equal the total value of exports to all other locations. We have:

$$p_i^M Y_i^M = \sum_{j \in \mathcal{Y}} X_{ji}^M$$

in the manufacturing sector, and

$$p_i^A \sum_{r \in \Omega_i} \frac{Y_r^A}{D_{r,i}} = \sum_{j \in \mathcal{Y}} X_{ji}^A$$

in the agricultural sector. Given that manufacturing firms make zero profits - equation (4.5) - and that workers and farmers around a given city earn the same income, equal to the urban wage, we can rewrite the market clearing conditions as:

$$w_i L_i^M = \sum_{j \in \mathcal{Y}} X_{ji}^M, \tag{4.17}$$

$$w_i L_i^A = \sum_{j \in \mathcal{Y}} X_{ji}^A \tag{4.18}$$

9 Rural hinterlands

Up to this point, we have taken rural hinterlands as given. In this section, we show how they are determined in equilibrium.

Farmers have two options: autarky and trade. If they decide to live in autarky, they receive an exogenous level of utility V_0, which we refer to as subsistence utility. If they decide to trade, they must choose they city that maximizes their indirect utility, as given by equation (4.9). Using the fact that welfare equalizes across cities - see (4.16), we can rewrite equation (4.9) as

$$V_{r,i}^A = \frac{p_i^A}{D(r,i) w_i} \frac{y_r^A}{l_r^A} V.$$

The welfare of a farmer in r who decides to ship her goods to city i depends on her distance to the urban market and on the agricultural price she can command there. Big cities, where a large urban population pushes up the demand for farm goods, will tend to have larger rural hinterlands.

The trading choice of a farmer in $r \in \mathcal{X}$ can be described in the following way:

$$\max\left\{\left(\max_{i\in\mathcal{Y}} V^A_{r,i}\right), V_0\right\}. \tag{4.19}$$

Therefore, the rural hinterland of, say, city i, can border to the rural hinterland of another city (along the border, farmers will be indifferent between trading with city i or city j) or to a subsistence region where the level of utility is fixed at V_0 and the density of farmers is undetermined.

10 Equilibrium

Definition 10. *A competitive equilibrium in this economy is a set of price vectors:* $\{P^A, P^M, p^A, p^M, w\}$, *population distribution across regions and sectors* $\{L, L^A, L^M\}$, *and a common welfare level* V, *such that:*

1. *the markets for manufacturing and agricultural goods clear, (4.17) and (4.18);*
2. *the price indexes are given by (4.7) and (4.8);*
3. *welfare equalizes across cities (4.16), and within rural hinterlands (4.14);*
4. *local labor markets clear* $L^A_i + L^M_i = L_i$, *and the aggregate urban population constraint holds:* $\sum_{i\in\mathcal{Y}} L^M_i = \bar{L}^M$;
5. *rural hinterlands are constructed according to* (4.19);

and where, furthermore: bilateral trade expenditures are given by (4.10) and (4.11), factory prices are given by (4.4) and (4.15), and manufacturing TFP is given by (4.3).

After carrying out all the substitutions, we obtain a system of $6 \times |\mathcal{Y}| + 1$ equations in terms of the same number of unknowns: the $|\mathcal{Y}|$-dimensional vectors: w, P^M, P^A, L^M, L^A, L, plus the welfare scalar V.

The market clearing condition for the manufacturing good:

$$w_i^{\sigma^M}(L^M_i)^{1-(\sigma^M-1)\gamma_1} = \alpha\sum_{i\in S}(T^M_{s,i})^{1-\sigma^M}(P^M_i)^{\sigma^M-1}(\hat{\phi}^M_i)^{\sigma^M-1}w_i L_i. \tag{4.20}$$

The expression for the manufacturing price index:

$$(P^M_i)^{1-\sigma^M} = \sum_{i\in S}(T^M_{s,i})^{1-\sigma^M}(\hat{\phi}^M_i)^{\sigma^M-1}w_i^{1-\sigma^M}(L^M_i)^{(\sigma^M-1)\gamma_1} \tag{4.21}$$

The market clearing condition for the farm good:

$$w_i^{\sigma^A}(L^A_i)^{1+(\sigma^A-1)(1-\beta)} = (1-\alpha)\sum_{i\in S}(T^A_{s,i})^{1-\sigma^A}(P^A_i)^{\sigma^A-1}B_i^{(\sigma^A-1)(1-\beta)}w_i L_i. \tag{4.22}$$

The expression for the agricultural price index:

$$(P^A_i)^{1-\sigma^A} = \sum_{i\in S}(T^A_{s,i})^{1-\sigma^A}B_i^{(\sigma^A-1)(1-\beta)}w_i^{1-\sigma^A}(L^A_i)^{-(\sigma^A-1)(1-\beta)} \tag{4.23}$$

Welfare equalization across cities:

$$w_i = V(P_i^M)^{\alpha}(P_i^A)^{1-\alpha}, \quad \forall s \in S \tag{4.24}$$

The local population constraint:

$$L_i = L_i^M + L_i^A, \quad \forall s \in S \tag{4.25}$$

The aggregate population constraint:

$$\sum_{i \in S} L_i = \bar{L} \tag{4.26}$$

Plus, we have the expression in (4.19) to characterize the optimal trading choices of farmers.

In section A we show that the equilibrium of the model has scale-invariance properties. As in Allen, Arkolakis and Li (2016), this suggests solving the model in two steps. First, we find a rescaled solution of the model ignoring the role of the welfare scalar. Then, we can rescale the solution so that urban population in the model sums up to value observed in the Bairoch data. The details of the numerical procedure are given in section B.

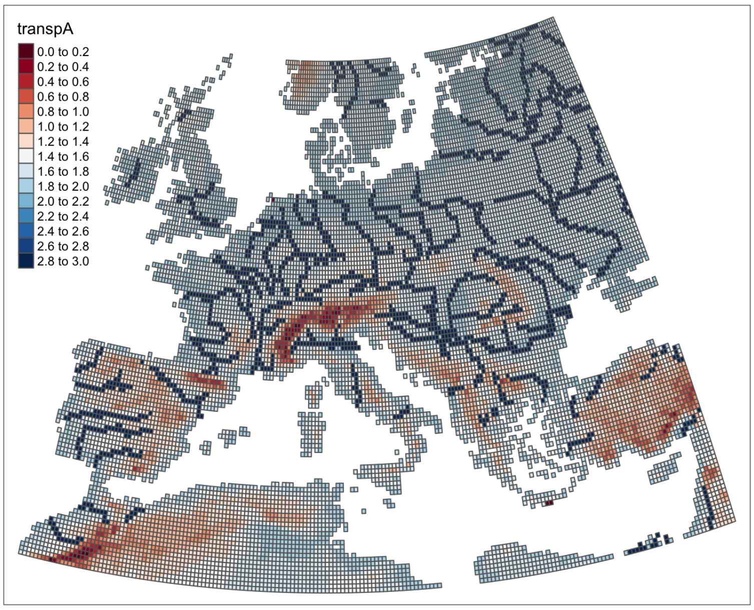


Figure 4.5: Instantaneous (inverse) agricultural tradecosts across Europe for every gridcell that have to be incurred when trading goods. This is then fed into the Fast Marching Method to compute the pairwise effective trade costs between all cells across our study area. Sea gets the value 30 and is thus omitted from the plot to

4.4 Quantitative exercise

In this section, after describing how we give quantiative empirical content to the model, we present three simulation exercises to illustrate the role of trade in costs in shaping the evolution of the European city size distribution for years 1100-1800. While we chose these exercises to match consolidated historical narratives,

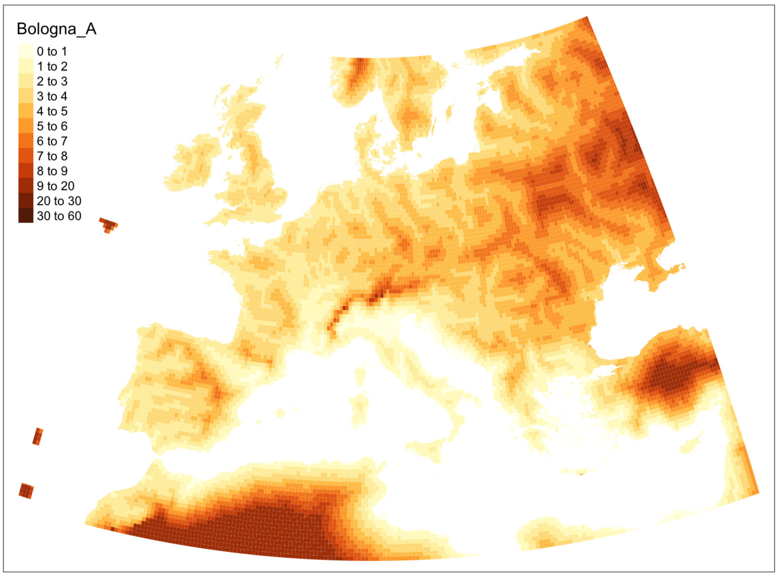


Figure 4.6: For illustrative purposes this plot shows all $|S|$ (i.e. 10208 for our 0.25 degree cell level) iceberg transport costs that one has to incur travelling from Bologna to all the other grids in our sample. One can roughly see the outline of Europe, shaped by the fact that sea transport is a lot more favourable than land transport. The dark-blue epicenter is Northern Italy, and one can spot the shape of the peninunsula and the coastline in the West towards the Iberian peninsula.

they should be taken as an illustration of the model. The values of τ^M, τ^A for each exercise are displayed in figure 4.7.

1 Calibration

First, we calibrated the parameters of our model to central values in the literature. The details of the calibration are given in section D. Second, we compute bilateral travel distances for each pair of grid-cells in the sample, following the procedure in Allen and Arkolakis (2014). We assign a transit cost to each grid-cell, and then we use the Fast-Marching Method (FMM) to compute the shortest travel distance between each pair of cells. In order to assign the transit cost to each cell we rely on historical sources Clark and Haswell (1964,?); Masschaele (1993). The matrix of transit cost is shown in figure 4.5, while figure 4.6 shows, for illustrative purposes, the bilateral distance from Bologna to all other grid-cells, as delivered by the FMM. We provide more details in section C. Finally, we compute the vector of unobserved manufacturing productivities so as to match exactly the city size distribution in the first period (year 1100).

Given the parameters of the model, given the values of $\{\phi_r^A\}_{r\in\mathcal{X}}, \{\phi_{i,1100}^M\}_{i\in\mathcal{Y}}$, and given equation (4.6), we can solve the model in each period. We then simulate the model under different time patterns for the value of manufacturing (τ^M) and agricultural (τ^A) trade costs. While we chose these exercises to match consolidated historical narratives, they should be taken as an illustration of the model. The values of τ^M, τ^A for each exercise are displayed in figure 4.7.

2 Exercise 1: constant trade costs

First, as a baseline exercise, we simulate the model in each period keeping τ^M and τ^A fixed. In this exercise, the only source of dynamics is equation (4.6). That is, the city size distribution changes over time only as a result of the underlying evolution of manufacturing productivity.

The results are displayed in figure 4.8. In each panel, the red line represents model 1, while the purple line represents the data. As shown in figure 4.8a, in this scenario, the share of population in Northern Europe remains constant over time, in stark contrast with the data. However, figure 4.8b also shows that the model does a better job at matching the evolution of the Gini index. The reason for this is simple: the dynamic technological externalities reinforce the advantage of large cities over small cities, stretching out the city size distribution, both in the North and in the South - see figure 4.8c. However, there is nothing in this version of the model that should predict the success of the North over the South. The South starts with an advantage, and retains this advantage until the end.

3 Exercise 2: market integration in the manfuacturing sector

Second, we reduce τ^M progressively, starting from the first period. The historical evidence confirms that market integration in the manufacturing sector was deepening very early in our study period, starting from the Commercial Revolution (1100-1300). We then assume that manufacturing trade costs keep decreasing throughout. In this exercise, the city size distribution evolves due to the combined effect of technological progress (equation (4.6)) and market integration in the manufacturing sector.

The blue line in figure 4.8 plots the results. Figure 4.8a shows that the model now predicts an increasing share of urban population in the North, of about 8 percentage points over the whole period, about half of the corresponding increase in the data. However, Figure 4.8b reveals that the model predicts a much flatter pattern for the Gini index in this exercies.

The economic intuition for these results is simple and it can be traced back to Helpman (1998): when manufacturing trade costs decrease, the equilibrium distribution of population gets more dispersed, as consumers spread out to escape congestion forces, since cheap manufacturing varietes become more affordable even in relatively remote locations. This intution gets through even though agents consume a traded goods subject to decreasing returns (agriculture), instead of housing, as in Helpman (1998).

In our context, remote locations at the beginning of the period belong to the less fertile regions in Northern Europe, whereas congestion forces are stronger in the popolous South. This observation clarifies both the shift to the North and the milder increased in inequality in this exercise.

4 Exercise 3: market integration in both sectors

In this exercise, we retain the same evolution of manufacturing trade costs as in exercise 2, but we add a reduction in trade costs for agricultural goods that kicks in later on in the period, namely from year 1400.

In figure 4.8, the green line is associated to exercise 3. The shift of urban population to the North is now slightly more pronounced than in exercise 2, by about 2 percentage points. How about city size inequality? Figure 4.8b shows a striking fact: when τ^A starts to decrease in year 1400, inequality starts increasing. Thus,

The inequality response to a reduction in agricultural trade costs is the *opposite* to the one observed where manufacturing trade costs are reduced. The economic intuition is the flip side of the coin to the results in Helpman (1998), that we discussed in the previous subsection. When trade costs for agricultural goods are low, cities can escape the grips of decreasing returns in land use, and substitute the locally produced agricultural variety with varieties imported from other cities. Increasing returns in manufacturing reinforce this effect, further attracting population to larger, productive cities. Lower τ^A then acts as a force towards agglomeration, albeit one with complex spatial effects.

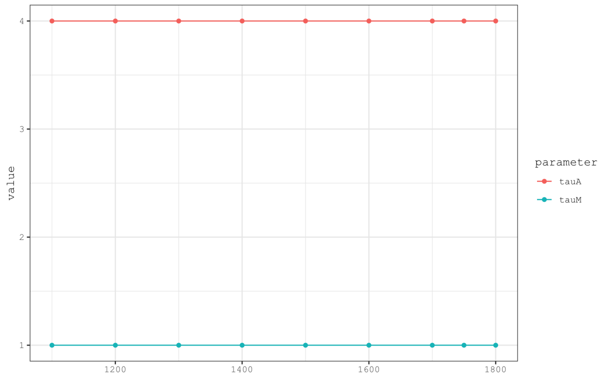
A shown in figure 4.8a, it is Northern Europe that benefits from a reduction in τ^A. One may wonder why this is the case. The reason is two-fold. First, by 1400, when the reduction in τ^A kicks in, Northern cities have already gone some way in closing the gaps with Southern cities, thanks to the previous reduction in τ^M, and have built up manufacturing productivity through the dynamic technological externalities. Second, lower trade costs allow cities to specialize according to their comparative advantage. Since agricultural productivity is higher in Southern Europe, and since Northern Europe starts building up manufacturing productivity in the years of the Commercial revolution, the model predicts a world where, provided that markets are sufficiently integrated, large manufacturing giants emerge in Northern Europe, whereas Southern Europe specializes in agriculture.

5 Summary

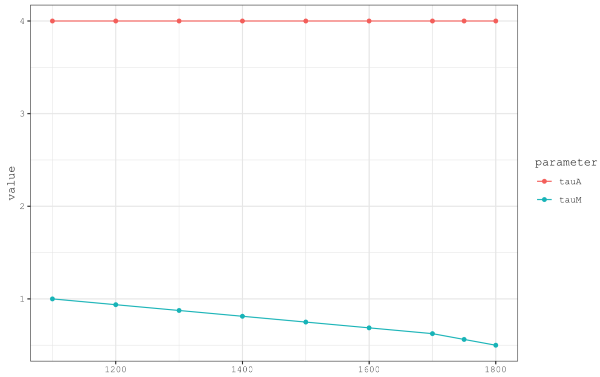
All in all, our simulations results reveal a key insight: when trade costs are reduced in the manufacturing sector, the model cannot make sense of the contemporaneous increase in the Northern share of urban population and increase city size inequality observed in the data. However, a combination of lower τ^M and τ^A can rationalize both patterns.

4.5 Conclusions

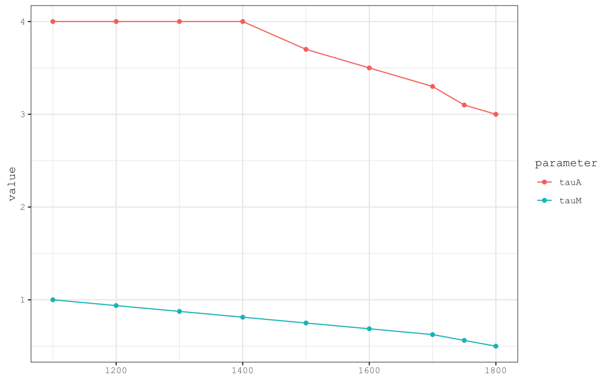
In this paper, we study the rise of Europe, one of the most debated issues in the social sciences. We build a quantitative spatial framework to study the evolution of the European city size distribution in the pre-Industrial era, from year 1100 to year 1800. The model features two sectors of production, agriculture and manufacturing, and trade linkages for both sectors across locations. We explicitly model the relationship between cities and their rural hinterlands. The key insight of the theory concerns the interaction between economies of scale and reductions in trade frictions in different sectors. In particular, reductions in agricultural trade costs act as an agglomeration force, leading to the emergence of urban giants. Some preliminary simulation exercises show that a combination of an initial reduction in trade costs for manufacturing goods, followed by a later decrease in trade costs for agricultural goods, can account for some key features of the



(a) Exercise 1



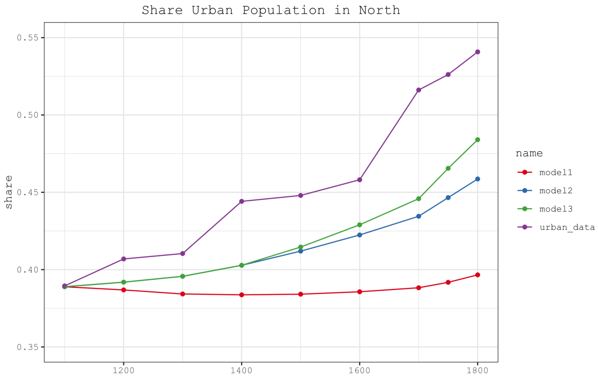
(b) Exercise 2



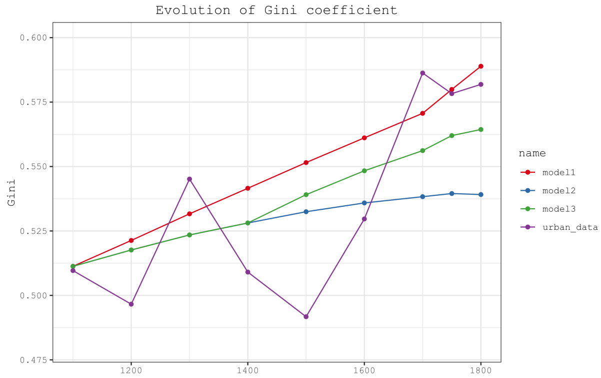
(c) Exercise 3

Figure 4.7: Time evolution of trade costs assumed in the simulations

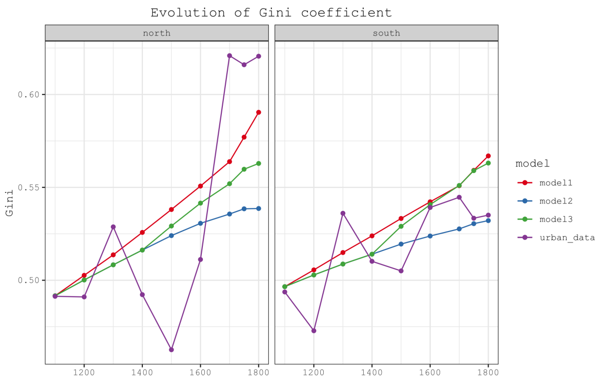
city size distribution in the pre-Industrial era, namely, the gradual shift of urban population to Northern Europe, as well as the increase in city-size inequality. Overall, these results advance a new explanation for European urban development during the centuries that led up to the Industrial Revolution, and offer a new perspective on the role of market integration in fostering this process.



(a) % of urban population in the North



(b) Gini index



(c) Gini index in Northern and Southern Europe

Figure 4.8: Quantitative exercise

Appendices

A Scale invariance

We show that the system of equations (4.20)-(4.26) has scale-invariance properties. That is, the rescaled variables $\tilde{L}_i^M \equiv L_i^M/c$, $\tilde{L}_i^A \equiv L_i^A/c$, and $\tilde{L}_i \equiv L_i/c$, for $c \neq 0$, are the solutions to a system equivalent to (4.20)-(4.26), after a suitable rescaling of the price indexes and the welfare scalar.

To see this, note that (4.20) can be rewritten as:

$$w_i^{\sigma^M}(\tilde{L}_i^M)^{1-(\sigma^M-1)\gamma_1} = \alpha\sum_{i\in S}(\tau_{s,i}^M)^{1-\sigma^M}c^{(\sigma^M-1)\gamma_1}(P_i^M)^{\sigma^M-1}(\hat{\phi}_i^M)^{\sigma^M-1}w_i\tilde{L}_i.$$

Second, define $\tilde{P}_i^M \equiv c^{\gamma_1}P_i^M$, so that

$$\left(\tilde{P}_i^M\right)^{1-\sigma_M} = c^{(1-\sigma^M)\gamma_1}(P_i^M)^{1-\sigma^M} = \sum_{i\in S}(\tau_{s,i}^M)^{1-\sigma^M}(\hat{\phi}_i^M)^{\sigma^M-1}w_i^{1-\sigma^M}(\tilde{L}_i^M)^{(\sigma^M-1)\gamma_1}.$$

It follows that equations (4.20)-(4.21) can be rewritten in terms of the rescaled variables $\tilde{L}_i^M, \tilde{L}s$, and $\tilde{P}_i^M$. Following the same steps, it can be shown that equations (4.22)-(4.23) can be written in terms of $\tilde{L}_i^A, \tilde{L}s$, and $\tilde{P}_i^A$, where $\tilde{P}_i^A \equiv c^{-(1-\beta)}P_i^A$.

Written in terms of the rescaled prices, the welfare equalization condition (4.24) becomes:

$$w_i = \frac{V}{c^{\alpha\gamma_1-(1-\alpha)(1-\beta)}}(\tilde{P}_i^M)^{\alpha}(\tilde{P}_i^A)^{1-\alpha}, \quad \forall s \in S$$

Equations (4.25) and (4.26) trivially hold after the rescaling. Finally, the farmer's problem in (4.19) is also invariant with respect to multiplicative constants.

B Numerical procedure

We adapt the technique developed in Allen, Arkolakis and Li (2016), and proceed in two steps. First, we find a solution to the system fixing $V = 1$. Then, we adjust V so that the constraint on total manufacturing population holds.

In order to carry out step 1, we further elaborate on the system (4.20)-(4.24) to reduce the number of variables we need to solve for in the numerical procedure. First, rearrange (4.24) into: $P_i^M = V^{-\frac{1}{\alpha}}w_i^{\frac{1}{\alpha}}(P_i^A)^{-\frac{1-\alpha}{\alpha}}$ to substitute out P_i^M in (4.20); second, we use (4.21) to substitute out P_i^M in (4.24). We obtain the following system of three equations:

$$w_i^{\sigma^M}(L_i^M)^{1-(\sigma^M-1)\gamma_1} = \alpha\sum_{i\in S}(\tau_{i,s}^M)^{1-\sigma^M}(\tilde{\phi}_i^M)^{\sigma^M-1}(P_i^A)^{(1-\sigma^M)\frac{1-\alpha}{\alpha}}w_i^{1+\frac{\sigma^M-1}{\alpha}}L_i, \tag{4.27}$$

$$w_i^{\sigma^A}(L_i^A)^{1+(\sigma^A-1)(1-\beta)} = (1-\alpha)\sum_{i\in S}(\tau_{s,i}^A)^{1-\sigma^A}(P_i^A)^{\sigma^A-1}B_i^{(\sigma^A-1)(1-\beta)}w_iL_i, \tag{4.28}$$

$$w_i^{\frac{1-\sigma^M}{\alpha}} = \sum_{i\in S}(\tau_{i,s}^M)^{1-\sigma^M}(\tilde{\phi}_i^M)^{\sigma^M-1}(P_i^A)^{(1-\sigma^M)\frac{1-\alpha}{\alpha}}w_i^{1-\sigma^M}(L_i^M)^{(\sigma^M-1)\gamma_1}, \tag{4.29}$$

where P_i^A is given by (4.23).

Our convergence procedure nests two loops: in the inner loop, we find the equilibrium values of L^A, L^M and w such that (4.27),(4.28),(4.29) hold for a given value of the Voronoi weights; in the outer loop, we update the value of the Voronoi weights and iterate until convergence. In detail, the steps of the convergence procedure are:

1. guess the optimal choices of farmers;
2. given these choices, compute total agricultural TFP in each rural hinterland, net of shipping costs, B_i;
3. guess initial values for wages, agricultural labor and manufacturing labor in all cities $s \in S$;
4. given these values, compute the P^A using (4.23);
5. given P^A, and the previous guess, compute the left-hand sides of equations (4.27), (4.28), and (4.29);
6. back out updated values for wages, agricultural labor and manufacturing labor;
7. compute the optimal choices of farmers
8. check the convergence criterion and, if not met, iterate from step 1;

C Computing bilateral distance

Following Allen and Arkolakis (2014) we create an instantaneous cost function $\tau : S \to \mathbb{R}^+$ that assigns values based on first nature geography to each of our observations, i.e. each gridcell. The baseline source for the calibration of transportation costs is Clark and Haswell (1964), which report the effective costs (expressed in grain equivalents) that have to be incurred when transporting one metric tonne for one kilometer (GE per ton km). In the context of subsistence economies these are reported for the three main modes of transportation that we consider: land (by pack animal or carriage), river, and sea. These estimates have been confirmed and refined by Bairoch (1990). For land transport we take into account ruggedness (Riley et al., 1999) and elevation of each gridcell, the higher those values are, the more costly it is to pass this gridcell. Water transport was always cheaper by a substantial amount and cells that have a navigable river in it are cheaper to pass. The fastest mode of transport is via the open sea. For the time being we do not let the transport costs vary over time and thus abstract from technical improvements since they arguably did not affect intra European trade substantially during our study period from 1000 until 1800. Furthermore we abstract from different transport costs for agricultural and manufacturing goods for the time being. 4.5 shows the instantaneous tradecosts that have to be incurred in order to pass the respective gridcell. The baseline ratio of costs of land to river to sea transport was calibrated to be 8:4:1 (Clark and Haswell, 1964; Masschaele, 1993).

For any origin $i \in S$ and destination $j \in S$ pair we apply the FMM algorithm in order to determine the bilateral transport costs between all of our gridcells. The resulting matrix is then of dimension $|S| \times |S|$. 4.6 illustrates the gradient of transport costs for the origin cell which contains the city of Bologna: one can see that open sea transport matters quite a lot and that the Alps to the North are a quite prohibitive barrier. Transporting goods for instance to the interior of Southern Italy or Sicily is costlier than to, say, Barcelona.

Each entry of the bilateral tradecost matrix is then normalised by the effective distance between Bologna and London.

D Calibration

For the time being we assume the main parameters of the model not to vary across time and calibrate them exogenously from the literature:

- Share of consumption expenditure on manufacturing goods
  $\alpha = 0.3$ (Allen, 2001)

- Elasticity of substitution between varieties
  $\sigma^A = \sigma^M = 4$ (calibrated from CES literature)

- Labor share in agricultural production
  $\beta = 0.7$ (Grigg, 1980, 1992)

- Contemporaneous spillovers in manufacturing
  $\gamma_1 = 0.144$ (Allen and Donaldson, 2018, Table 2)

- Dynamic spillovers in manufacturing
  $\mu =??$

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