Chapter 12

The Role of Migration Costs in Residential Sorting

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Abstract Economists generally employ two ‘revealed preference’ approaches to measure households’ preferences for non-market amenities—the hedonic and equilibrium sorting models. The conventional hedonic model assumes free mobility across space. Violation of this assumption can bias the estimates of household willingness to pay for local amenities. Mobility constraints are more easily handled by the sorting framework. In this chapter, we examine the role of migration costs in household residential sorting and apply these two models to estimate the willingness to pay for clean air in the USA and China. Our results demonstrate that ignoring mobility costs in spatial sorting will underestimate the implicit value of non-market amenities in both countries. Such a downward bias is larger in developing countries, such as China, where migration costs are higher.

Keywords Migration costs · Discrete choice models · Residential sorting · Willingness to pay · Hedonic valuation · Equilibrium sorting models

12.1 Introduction

In the economics literature, an established way of putting a monetary value on things that affect the quality of life but are not traded in a conventional market, and so have no observable market price, is to infer the implicit value consumers place on things from the choices they make. Consider, for example, housing choices and decisions with respect to residential location. The nature of the housing market means that

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living in an area with a high level of amenities will come at a premium price. This implies trade-offs. Homebuyers and renters alike will both need to sacrifice other forms of consumption in order to afford them. Where we choose to live potentially reveals a lot about our preferences and the trade-offs we are willing to make between housing costs and various features of the local social and physical landscape. This includes our preference for ethnic and social homogeneity (Sethi and Somanathan 2004), a potentially important driver of segregation (Chap. 2). Economists refer to approaches that rely on these trade-offs to value local features as “revealed preference” techniques. These techniques attempt to estimate the value people place on particular goods or services from the actual decisions they make rather than simply asking them—an approach that falls under the category of “stated preference” techniques. The problems with stated preference techniques are that people may have an incentive to overstate or understate how much they value various goods and services (Loomis 2011). It is often not practical or cost-effective to obtain up-to-date large sample survey evidence.

Over the past 40 years, hundreds (perhaps even thousands) of economics papers and reports have used the ‘hedonic framework’ (Rosen 1974) revealed a preference approach to value local non-marketed amenities from education to crime to air quality. The attraction of the technique is that it uses observed behaviour in housing and labour markets to recover the economic value of non-marketed amenities. Under the standard assumption that households choose the residential locations that maximise their utility, marginal rates of substitution between local amenities and other goods will equal the price ratio. As a result, the marginal willingness to pay (MWTP) for those amenities can be measured by their implicit prices, as reflected in how housing prices and wages vary with amenity values.

In the conventional hedonic framework, households are assumed to have full information, be fully mobile, and make location choices within a discrimination-free environment. These three assumptions are maintained throughout the literature with very few exceptions. Under these assumptions, equilibrium is achieved when every household occupies its utility-maximising location and nobody wants to move, given housing prices, housing characteristics, wages, tax rates, and amenity levels. In this chapter, we discuss the implications of these three conventional assumptions for non-market valuation, move beyond the assumption of free mobility, and focus on the role of migration costs in residential location sorting and hedonic valuation.

If people can move freely among locations when they buy homes and choose jobs, wages and rents must adjust to reflect the implicit prices of local amenities; hence, MWTP for amenities can be inferred from variation in housing prices and income across space. In reality, however, migration is costly; moving to a new city entails both out-of-pocket costs and the psychological costs of leaving behind one’s family and cultural roots. Moreover, migration costs are substantially higher in a developing country context, where there are frequently institutional migration costs, such as the *hukou* system in China (see Chap. 1 Sect. 1.1, and Sect. 12.5.1 below).

How will migration costs affect estimates of MWTP for non-market amenities? Consider an improvement in air quality in a particular city. In response to the changing demands of the citizenry to live there, we would expect housing prices to rise and

wages to fall until a new equilibrium is reached. If migration is costless, these changes will fully reflect the population's value for cleaner air. But if migration is costly, the benefits people get from moving to the city and enjoying its improved air quality must now compensate them for the higher rents and lower income and the cost of moving. MWTP estimates that ignore these moving costs will be biased.

Equilibrium sorting models provide an alternative revealed preference approach for non-market valuation that can easily incorporate mobility costs. Households' locations were 'sorted' according to income, housing prices, migration costs and their preferences for non-market amenities such as local public services, social characteristics and environmental quality. The location choice decisions of households reflect their tradeoff between income, housing costs, and moving disutility (i.e. the inconvenience of moving house, which incurs a psychological cost that is added to the financial cost of moving) as well as local amenities. Consequently, estimates derived from these decisions can be used to evaluate willingness to pay for local amenities. Recently, Bayer et al. (2009) proposed a solution to control for (i.e., consider) the physical and psychological moving costs associated with migration distance in the equilibrium sorting framework. Freeman et al. (2019) enriched the description of mobility constraints by further accounting for differential institutional migration costs across space in the developing country context.

This chapter discusses the role of migration costs in non-market valuation and estimates willingness-to-pay for air quality improvements in the world's largest developed and developing countries—the USA and China. In the USA context, the MWTP estimated using the hedonic model is positive but increases substantially in magnitude when accounting for moving costs in the residential sorting framework. Even though we typically think that internal migration costs are relatively small in countries such as the USA, overlooking mobility costs in spatial sorting can lead us to understate the implicit value of clean air.

Migration costs are very high in China due to the mobility restrictions imposed by the *hukou* system. The *hukou* acts as an internal passport, without which internal migrants are not entitled to the same rights and benefits as local people. A conventional hedonic model which assumes free mobility recovers a *negative* estimate of the value of cleaner air in China. Given the adverse effects of severe air pollution on health and productivity in developing countries such as China, these estimates are unreasonable. Consistent with intuition, the MWTP for air quality has an expected positive sign when we use an equilibrium sorting model and take migration costs into account.

Our results reveal salient differences between the conclusions of the conventional hedonic framework and those of the residential sorting framework incorporating migration costs. In the United States, although the MWTP estimated by the hedonic model is significantly understated, it still has a positive sign that is consistent with prior expectations. But in China, overlooking mobility costs can yield a 'perverse' negative sign of the MWTP for clean air. This is because the bias problem is more severe in developing countries such as China where migration costs are substantially higher than that in a developed country context.

12.2 Frictions in Spatial Sorting

In the canonical work on hedonic valuation, households are assumed to have complete information, be freely mobile, and make location choices within a discrimination-free environment. In the real world, however, households might only have incomplete information about the characteristics of locations in their choice set, be restricted by physical and institutional mobility costs when moving to other places, and suffer from discrimination (outright or statistical) when making location choices. These frictions in spatial sorting can bias the estimates of the implicit value of non-market amenities.

12.2.1 *Incomplete Information*

Online resources have made the housing search process easier than ever. Yet households still face uncertainty about the amenities, public services, and job opportunities available when moving to a new location. When peoples' beliefs are not consistent with true values, they might choose a location that does not maximise their utility, which in turn results in welfare losses (Leggett 2002). Researchers lack detailed information about the extent of people's knowledge when they move into new areas. As a result, this aspect of the location decision is generally ignored in the economic models described in this chapter.

12.2.2 *Discrimination*

In housing markets, discrimination takes the form of significant constraints on individual choices—that is, the options that might have been chosen are unavailable for one reason or another. These constraints may take the form of outright restrictions on a housing purchase. There may also be indirect constraints that make it difficult to obtain a loan or other institutional constraints that might be hard to detect. An estate agent may even neglect to show a house to a potential purchaser based on their perception of their ability to pay, a form of 'statistical' discrimination based on prejudice or assumptions about buyers' preferences. Applied research on residential locations seldom has information on the set of choices available to a potential mover, making it difficult to prove that discrimination has occurred. However, experimental evidence collected in audit studies conducted by the US Department of Housing and Urban Development has shown that minority groups are systematically provided with recommendations for houses in neighbourhoods with higher poverty rates, lower levels of education and skills, and higher levels of pollution compared to their white counterparts (Christensen and Timmins 2018). If discrimination is at play, then we cannot expect all housing units to be freely chosen. A failure to account

for this can present problems of interpretation across the various models we describe later in this chapter.

12.2.3 *Moving Costs*

‘Moving costs’ will vary according to location. Within a city, they may involve the cost of renting a truck and spending a day of hard labour to load and unload it or the costs of hiring someone to do that back-breaking work for you. Buying or selling a house requires mortgage applications, inspections, and a closing process with lots of paperwork. Moving to a new city can add psychological costs such as losing social networks and familiarity with one’s surroundings. In many developing countries, there can be additional institutional forms of moving costs inherent in the migration policy. For example, in India, state-level entitlement schemes discriminate against migrants from other states and inhibit inter-state mobility (Kone et al. 2018). In China, the *hukou* system limits or even prohibits internal migrants’ access to many government-provided benefits (Tombe and Zhu 2019).

In the following sections, we will relax the conventional assumption of free mobility, discuss the role that migration costs play in shaping spatial sorting and incorporate their effects in non-market valuation.

12.3 How Economists Model Residential Choice

Where we choose to live potentially reveals a lot about our preferences and the trade-offs we are willing to make between various features of the social and physical landscape. These may include things such as beautiful views, the avoidance of pollution, and practical considerations such as employment prospects. For many years, economic researchers have used data about residential location decisions to calculate the value of attributes such as these for use in policy-making. For the most part, this work has focused on the USA and Europe, where information on housing markets and migration decisions were readily available (Kuminoff et al. 2013). More recently, these models have been applied to low and middle-income countries, such as China and Brazil. This is valuable from a policy perspective as these are countries where the value of urban amenities (and disamenities) may be particularly relevant for policy-making. Air pollution, for example, is often far worse in lower-income countries.

‘Equilibrium sorting’ models combine data on housing market fluctuations with information on household behaviour to estimate the parameters and factors behind individual decision-making. Importantly, these parameters summarise how consumers differ from each other as the range and variety of preferences play an important part in the sorting process. For ‘large’ policies, these models can be used to predict new outcomes in the ‘equilibrium’ or balance of determining factors. This

may involve changes in equilibrium prices and quantities. It may also involve changes in how local public services, such as education and crime prevention, operate. These models can monitor how these local public services affect decision-making and, in turn, predict how they will be affected by future policies on the supply of or demand for housing. Because they can simulate new distributions of households across neighbourhoods, these models can also be used to determine welfare measures for policies that have yet to be implemented. In this way, such models contrast with simpler empirical methods that compare ‘before’ and ‘after’ with actual policies, thereby limiting analysis to those policies already implemented.

We begin by providing a review of the methods used by economists to model residential location decisions and discuss how those models are used to value local amenities. We then describe a particular case in which these methods have been used to value air quality in the USA and introduce the important role of migration costs in that context. We typically think of internal migration costs as being relatively small in countries such as the USA. Equally, external migration costs are also thought to be relatively small between the European Union member states. Nevertheless, once they are included in a model to assess location choice, we see that the values for local characteristics gleaned from individual decisions can change dramatically.

With this as a backdrop, we then move on to consider the role of migration costs in China. An internal system of migration restrictions known as the *hukou* applies across China. Individuals are assigned a *hukou* based on their birth location, and that *hukou* provides them access to the local housing market, labour market, and public services such as education. Obtaining a *hukou* in another location, especially in attractive destinations such as Shanghai and Beijing, can be particularly difficult. The *hukou*, therefore, creates a very real barrier to migration, raising the possibility that simple models of migration behaviour, which ignore migration ‘frictions’, could yield biased conclusions. After a brief discussion of the details of the *hukou* system, we show how estimates of the value placed on clean air in China can differ not just in magnitude but in perceptions, depending upon whether one takes into account the restrictions imposed by the *hukou* or not. We conclude with observations on other important considerations when applying simple models of migration in China.

12.3.1 The ‘Rosen-Roback’ Framework

There is a long history in the economics of using residential location decisions to measure the value that individuals place on local public services and amenities. Tiebout (1956) wrote that individuals ‘vote with their feet,’ revealing their preferences for local taxes and the public goods that those taxes provide by the trade-offs they make in the housing market. Households ‘sort’ across locations according to their wealth, their particular housing preferences, local public services, social characteristics, employment opportunities, and the implications for commuting. Equilibrium models of ‘sorting’ based on Tiebout begin with a simple premise: the amount and character of housing and public goods vary across an urban area. Each household

selects its preferred bundle of public and private services given its income the relative prices involved.

The idea of ‘voting with one’s feet’ next appeared in the ‘hedonic framework’ (Rosen 1974).¹ The simplest hedonic models consider a world in which individuals choose from a set of houses, trading off higher prices for nicer amenities. In an ‘equilibrium’, where everyone is happy and no longer has an incentive to move, the resulting relationship between house prices and amenities in the market reveals the households’ preferences for amenities relative to price. For example, when considering two otherwise identical houses apart from location, if one is in a marginally better location for schools, then the difference in their equilibrium prices will reveal a willingness to pay for school quality. Many economic papers and reports² have used this method to value local public services, from education to crime to air quality.

A more complicated model that may be more relevant for studying choices over large geographic spaces (e.g., across metropolitan areas rather than across neighbourhoods in a city) considers households’ choices over residential location, recognising that this can affect both where one lives and one’s employment opportunities. This model was suggested in work by Rosen (1979) and then formalised by Roback (1982). The ‘Rosen-Roback’ framework begins with a utility maximisation problem.

Readers unfamiliar with the equations and formulae used in models of this kind may wish to skip to Sect. 4.3.3 at this point. Those familiar with modelling may find the following detailed description useful for understanding how the modelling works.

12.3.2 *Technical Discussion*

Households, indexed by $i = 1, 2, \dots, N$, choose among cities indexed by $j = 1, 2, \dots, J$ that have attributes denoted by a vector X_j —this might include air quality, public safety, school quality, and climate variables. In order to choose a city, households may consider labour market opportunities to determine the level of income (I_{ij}) that they can earn. Because income varies according to varying factors and characteristics, we can write it as a function of X_j , $I_{ij}(X_j)$.

Households can take that income and spend it on housing services, H_i , and other consumption, C_i . These are broad catch-all categories differentiated primarily because the price of a unit of housing services, P_j , can differ by location, whereas the price of a unit of general consumption is the same everywhere and is normalised to one for convenience. For this discussion, a unit of housing services could be thought

¹ The implied relationship between property values, housing characteristics, and local public goods can be described by a hedonic price function. While the hedonic price function had appeared in several earlier papers, Rosen (1974) developed the microeconomic foundations of the method, arguing that the hedonic price function can be interpreted as describing an equilibrium relationship as a continuous array of differentiated varieties of a product at a single point in time.

² At the time of writing, a search on Google Scholar for the term ‘property value hedonics’ yielded 22,800 hits. For summaries of the hedonic literature, see Champ et al. (2003) and Palmquist (2005).

of as a square foot of living space.³ Because the price of a unit of housing services can differ by location, we can also write it as a function of X_j , $P_j(X_j)$.

The last modelling component that we require is a mathematical representation of household preferences for location attributes (X_j), housing (H_i) and other consumption (C_i). Economists refer to that as a utility function, and it is denoted here by $U(C_i, H_i, X_j)$. One can spend many hours studying the properties of utility functions in a microeconomics class, but the key feature is that utility, or happiness, increases with the consumption of things such as better schools (e.g. C_i , H_i , and elements of X_j .) and decreases with the prevalence of detrimental factors such as air pollution (e.g. elements of X_j).

Following the standard practice, we model the household's behaviour by assuming that it chooses location j and C_i and H_i levels with a mathematical optimisation. Equation (12.1) expresses this as a maximisation problem: each consumer i chooses a location j that maximises overall satisfaction represented by the utility function $U_{i,j}$ which, as noted above, is assumed to be determined other consumption, housing, and location attributes: $U_{i,j} = U_{i,j}(C_i, H_i, X_j)$. However, in choosing the location that maximises overall satisfaction, households are constrained by their income $I_{i,j}$. So the consumer maximises $U_{i,j}$ subject to their income which is assumed to be spent either on housing H or other consumption C ,

$$\max_{C_i, H_i, X_j} U_{i,j}(C_i, H_i, X_j) \text{ s.t. } C_i + P_j(X_j)H_i = I_{i,j}(X_j) \quad (12.1)$$

where,

$\max$ maximise

s.t subject to a constraint

C_i individual i 's consumption of the numeraire composite commodity⁴

H_i individual i 's consumption of housing services

X_j amenity vector in location j

P_j price of housing services in location j

$I_{i,j}$ income that individual i would earn in location j

This optimisation problem can be re-written in the form of a constrained objective function known as a Lagrangian.⁵ This combines the utility objective with the budget

³ In practice, a more complicated index of housing services is typically used where, for example, 10 square feet of low-quality housing stock might provide similar housing services as 5 square feet of high-quality housing stock.

⁴ A numeraire composite good is an abstraction that represents all but one of the goods in the relevant budget, which acts as a benchmark in comparing the value of other products or services.

⁵ The Lagrangian function is a mathematical expression that combines the function being optimised with functions describing the constraint or constraints into a single equation. Solving the Lagrangian function allows you to optimize the variable you choose, subject to the constraints you cannot change.

constraint in a single expression, where δ_i represents the ‘shadow value’ of the budget constraint:

$$\max_{C_i, H_i, X_j} \mathcal{L} = U_{i,j}(C_i, H_i, X_j) + \delta_i(I_{i,j}(X_j) - C_i - P_j(X_j)H_i) \quad (12.2)$$

Taking the partial derivatives of the Lagrangian with respect to X_j , C_i and H_i , and setting them equal to zero optimises the objective function. Thus, the constrained optimisation problem yields the following first-order conditions:

$$\frac{\partial U_{i,j}}{\partial X_j} + \delta_i \left(\frac{\partial I_{i,j}}{\partial X_j} - H_i \frac{\partial P_j(X_j)}{\partial X_j} \right) = 0 \quad (12.3)$$

$$\frac{\partial U_{i,j}}{\partial C_i} - \delta_i = 0 \quad (12.4)$$

$$\frac{\partial U_{i,j}}{\partial H_i} - \delta_i P_j(X_j) = 0 \quad (12.5)$$

Economists regularly talk about ‘marginal willingness to pay’ for a local attribute X_j as the amount of other consumption (C_i) that a household would be willing to give up in exchange for a small increase in X_j , holding the household’s utility fixed. This is a concept based in trade-offs.

It is useful because it avoids direct comparisons of levels of happiness measured in ‘utils’ (i.e., units of utility, which can differ in ways that we cannot observe), opting instead to measure welfare in terms of other units of consumption. This idea depends on how much ‘other consumption’ the individual is willing to give up in order to obtain greater access to amenities such as clean air. The concept is a staple of work in public economics, underlies countless regulatory studies, and determines how government funds are allocated.

To consider how first-order conditions might be used to measure willingness to pay for X_j , we calculate the change in consumption (C_i) given a change in X_j while holding utility at a fixed point. Mathematically, this is found by taking the total derivative of the utility function with respect to X_j and C_i while holding utility fixed at $\bar{U}$ and then rearranging the expression:

$$\bar{U} = U_{i,j}(C_i, H_i, X_j) \quad (12.6)$$

$$d\bar{U} = 0 = \frac{\partial U_{i,j}}{\partial C_i} dC_i + \frac{\partial U_{i,j}}{\partial X_j} dX_j \quad (12.7)$$

$$\left. \frac{dC_i}{dX_j} \right|_{d\bar{U}} = - \frac{\partial U_{i,j} / \partial X_j}{\partial U_{i,j} / \partial C_i} \quad (12.8)$$

Equation (12.6) represents the fixed utility jointly determined by consumption, housing services and amenity X_j . Taking the derivative of Eq. (12.6) with respect to consumption C_i and amenity X_j yields Eq. (12.7), which represents the tradeoff between consumption and amenity. Rearranging Eq. (12.7) yields Eq. (12.8). $\frac{dC_i}{dX_j}$ represents the amount of consumption that household i would sacrifice for a one-unit improvement in amenity X_j while holding utility fixed at $\bar{U}$, which we define as the marginal willingness to pay (MWTP) for X_j . Equation (12.8) indicates the MWTP for X_j is the opposite of the ratio between the marginal utility of the amenity and the marginal utility of consumption C_i .

Using the first-order conditions from the constrained optimisation problem, we can develop an equation to measure the marginal willingness to pay for X_j :

$$MWTP_X = \frac{\partial U_{i,j}/\partial X_j}{\partial U_{i,j}/\partial C_i} = H_i \frac{\partial P_j}{\partial X_j} - \frac{\partial I_{i,j}}{\partial X_j} \quad (12.9)$$

Noting that H_i may not be readily observable, we can modify this expression to make it easier to work with. In particular, multiply each term by $\frac{1}{I_{i,j}}$ and multiply and divide the first term by P_j . The resulting equation is:

$$\frac{MWTP_X}{I_{i,j}} = H_i \frac{\partial P_j}{\partial X_j} \frac{P_j}{P_j} \frac{1}{I_{i,j}} - \frac{\partial I_{i,j}}{\partial X_j} \frac{1}{I_{i,j}} \quad (12.10)$$

It describes the marginal willingness to pay for X_j as a share of income. By rearranging terms, this can be re-written as a function of the income share of housing expenditures ($s_{i,j}$) and the derivatives of the log of price and income:

$$\frac{MWTP_X}{I_{i,j}} = \underbrace{\frac{P_j H_i}{I_{i,j}}}_{s_{i,j}} \frac{\partial \ln P_j}{\partial X_j} - \frac{\partial \ln I_{i,j}}{\partial X_j} \quad (12.11)$$

where $\frac{\partial \ln P_j}{\partial X_j} = \frac{\partial P_j}{\partial X_j} \frac{1}{P_j}$ and $\frac{\partial \ln I_{i,j}}{\partial X_j} = \frac{\partial I_{i,j}}{\partial X_j} \frac{1}{I_{i,j}}$. Equation (12.11) indicates that the fraction of the marginal willingness to pay for X_j in household income is equal to the income share of housing expenditure multiplied by the derivative of log housing price with respect to X_j minus the derivative of log income with respect to X_j . In particular, the Rosen-Roback framework suggests recovering $\frac{\partial \ln P_j}{\partial X_j}$ and $\frac{\partial \ln I_{i,j}}{\partial X_j}$ by linear regression:

$$\ln P_j = X'_j \beta + \varepsilon_j \quad (12.12)$$

$$\ln I_{i,j} = X'_j \theta + Z'_i \gamma + u_j \quad (12.13)$$

where X_j is a vector of local amenities and Z_i is a vector of individual attributes there might be an effect on earnings based on characteristics such as education, age, and gender.

12.3.3 Reflecting on the Assumptions Implicit in Modelling Sorting Behaviour

Suppose we pull back from the mathematical derivations in the previous section. We can see that a measure of the value placed on some local attribute—such as air quality—can be found from the sum of two different partial derivatives—such as the way that housing service costs and incomes vary across cities with that local attribute. While the value assigned to that attribute will vary, other local attributes are kept fixed. In other words, desirable attributes will be found where houses cost more and people are paid less to do the same job, all other factors being equal. The model reflects two different margins over which individuals may make trade-offs, but is based on a number of simplifying assumptions.

Economists are sometimes maligned for the assumptions they make when describing human behaviour.⁶ This is certainly the case in their treatment of residential location decisions. An underlying assumption behind the canonical hedonic model is that everyone knows everything about every housing unit available in every city in the nation. Households are also assumed to have accurate and complete information about things such as air quality or average daily rainfall. Until recently, this was an especially dubious assumption in a place such as China, where official government reports did not describe the full extent of air pollution. On the modelling side, everyone is assumed to have the same preferences and to face no costs when deciding to pack up and move. Until very recently (Bayer et al. 2016), all households in such models were treated as though they rented property, whether this was the case or not. As a consequence, capital gains were not taken into account in models that charted housing decisions. Finally, households are assumed to face no discrimination that might directly limit the options available to them, and everyone is assumed to face the same set of prices in the housing market. Recent research has found this to also be an over-simplification (Christensen and Timmins 2018; Christensen et al. 2020).

In the remainder of this chapter, we will maintain these assumptions for the purposes of simplicity, but we will modify one in particular. The traditional economic modelling of decisions around residential location assumes free mobility. This assumption is tenuous, especially in the context of developing countries, and it will bias conclusions in the traditional hedonic model where moving costs are correlated

⁶ The old story goes that a physicist, a chemist, and an economist are stranded on a desert island with no implements and a can of food. The physicist and the chemist each devise an ingenious mechanism for opening the can. The economist merely says, ‘assume we have a can opener...’ (Boulding 1970). ‘Assuming the can opener’ has become shorthand for economists’ tendency to assume away important parts of the discussion.

with the availability of preferred amenities. The greater the cost of moving in relation to the marginal benefits of an improvement in the amenity, the greater the bias will be.

12.3.4 Reconsidering Moving Costs

In the context of our economic model, individuals may have idiosyncratic preferences for locations. These might arise from a preference for one's hometown, or simply a financial or psychological cost associated with moving away from one's current residence, wherever that may be. Either way, this creates an important form of moving cost that makes the individual's starting point relevant to the analysis.

Consider a simple example of what this implies for the Rosen-Roback framework. All households simultaneously choose their location along with consumption of a composite commodity C and housing service H . Each location j is characterised by a quantity X_j of a location-specific amenity. In addition, there is a moving cost M_j associated with settling in city j . We treat M_j as a long-run migration cost (i.e. the cost incurred by adults choosing where to live relative to their birthplace). As such, these costs are primarily psychological and do not appear in the budget constraint. In order to simplify things enough to put them in that framework, suppose that everyone starts from the same original location so that M_j (i.e. migration cost to location j) can be treated as a location attribute just such as the elements of X_j .

$$\max_{C_i, H_i, X_j} U_{i,j}(C_i, H_i, X_j, M_j) \text{ s.t. } C_i + P_j(X_j)H_i = I_{i,j} \quad (12.14)$$

After incorporating migration costs into utility function, and the MWTP for amenity is expressed as Eq. (12.15):

$$MWTP_X = H_i \frac{\partial P_j}{\partial X_j} - \frac{\partial U_{i,j}}{\partial X_j} - \frac{\partial U_{i,j} / \partial M_j}{\partial U_{i,j} / \partial C_i} \cdot \frac{dM_j}{dX_j} \quad (12.15)$$

If mobility had no utility cost (i.e. $\frac{\partial U_{i,j}}{\partial M_j} = 0$) or migration costs did not vary systematically with the amenity being valued (i.e., $\frac{dM_j}{dX_j} = 0$), this would not be a concern. Suppose, however, that $\frac{\partial U_{i,j}}{\partial X_j} < 0$ and $\frac{dM_j}{dX_j} > 0$ (i.e. people do not like to move, and preferable locations are further away from where everyone is starting out). The traditional Rosen-Roback hedonic model would subsequently understate $MWTP_X$ by an amount equal to the final term in the expression above. Important for policy purposes, an understatement of $MWTP_X$ in relative terms would prove dramatic for local attributes where the true willingness to pay is small relative to the size of mobility costs. For example, households may be very likely to move from their starting point to a different city in order to access better schools for their children,

but may be unlikely to make a similar move in order to get cleaner air. The bias from ignoring moving constraints will therefore be greater for the latter.

12.4 The Sorting Model Framework with an Application to the Value of Particulate Matter Reductions in the USA

Migration costs in the USA are surprisingly high, although relatively low in comparison with China. Table 12.1, taken from Bayer et al. (2009), reports the probability that the head of a household under the age of 35 is living in each of the nine US census divisions in the 2000 Census, given that they were born in each of those nine divisions. Notice that the diagonal elements of the matrix, which represent the frequency of ‘stayers’, comes close to 80% in the case of the South Atlantic division and only fall to 58% in the West North Central division.

What do these migration costs imply for non-market valuation using the Rosen-Roback model? We used US Census data from 1990 and 2000 that described the location decisions of households (household heads aged 25–35) to measure the marginal willingness to pay for reductions in air pollution.⁷ Specifically, we used a measure of particulates denoted as PM10—particles measured 10 microns or less in size. These small particles, fine solids, and aerosols—typically 1/7th the diameter of a human hair or smaller—can come from fossil fuel combustion, unpaved roads, construction and demolition, agriculture, mining, and a variety of chemical processes. Particulate matter is known to be one of the most dangerous forms of air pollution, leading to lung cancer, heart attacks and strokes, asthma (particularly in the young and elderly), and even various heritable diseases. A growing body of literature demonstrates the effects of particulate matter pollution on life expectancy (Pope et al. 2009), especially on infant mortality (Arceo et al. 2016; Chay and Greenstone 2003; Knittel et al. 2016), cognitive ability and school performance (Lavy et al. 2014; Suglia et al. 2008), crime (Herrnstadt et al. 2018; Heyes and Saberian 2015), and labour market outcomes (Chang et al. 2019).

Why might migration costs matter for the valuation of particulate matter? Suppose people were more likely to be born in places with currently high levels of pollution (i.e., Northeast, Rust-Belt) and are then reluctant to leave. The wage-hedonic model would interpret their immobility as evidence that air pollution is not very disagreeable. Overcoming this complication requires that we extend the modelling strategy back to the location decision itself, recovering estimates of the disutility of migration as part of the process of estimating MWTP. However, we cannot easily extend the Rosen-Roback model to include migration costs when people have *idiosyncratic* starting points so that the migration cost associated with a particular destination will

⁷ Specifically, we use 1% and 5% micro data samples from the 1990 and 2000 US Censuses (www.ipums.org). Data are collected for 242 MSA's, representing 86% of the metro US population.

Table 12.1 Regional mobility patterns: % birth region by residence region household heads under 35 years of age, 2000 US census data

	New England	Mid-Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
New England	65.02	5.87	2.35	0.94	12.68	0.47	1.88	3.05	7.75
Mid-Atlantic	4.03	63.34	4.55	1.03	18.04	0.22	2.13	2.49	4.18
East North Central	0.59	1.60	73.42	2.83	9.84	2.09	2.78	2.94	3.90
West North Central	0.36	1.77	7.80	57.62	7.27	1.24	5.85	8.51	9.57
South Atlantic	0.99	3.59	4.50	0.84	79.47	2.82	2.67	1.60	3.51
East South Central	1.72	1.29	7.08	0.86	15.45	63.73	4.94	1.29	3.65
West South Central	0.47	1.54	2.13	1.42	6.51	2.49	77.75	3.31	4.38
Mountain	0.89	1.11	3.54	2.43	3.54	1.11	5.09	69.03	13.27
Pacific	0.86	1.61	3.42	1.52	5.13	1.14	2.75	7.69	75.88

differ by individual. The sorting model framework, however, allows us to address this problem directly.

Rather than working from a pair of derivatives that describe the equilibrium of the sorting process, we base sorting models explicitly on the individual's utility maximisation problem. Committing to a particular functional form for utility⁸:

$$\max_{C_i, H_i, X_j} C_i^{\beta_C} H_i^{\beta_H} X_j^{\beta_X} \text{EXP}\{M_{i,j} + \xi_j + \eta_{i,j}\} \text{s.t. } C_i + P_j H_i = I_{i,j} \quad (12.16)$$

where

$M_{i,j}$ long-run (dis)utility of migration associated with moving from individual i 's birth location to destination j (defined below)

ξ_j unobserved attribute of location j .

$\eta_{i,j}$ idiosyncratic utility enjoyed by individual i in location j .

Considering the choice of optimal housing services conditional upon having chosen location j :

$$\max_{\{H_i\}} \ln U_{i,j} = \beta_C \ln(I_{i,j} - P_j H_i) + \beta_H \ln H_i + M_{i,j} + \beta_X \ln X_j + \xi_j + \eta_{i,j} \quad (12.17)$$

First-order conditions with respect to H_i yield the optimal demand for housing services as a function of where individual i chooses to live.

$$-\frac{\beta_C P_j}{I_{i,j} - P_j H_i} + \frac{\beta_H}{H_i} = 0 \quad (12.18)$$

$$H_i^* = \frac{\beta_H}{\beta_H + \beta_C} \frac{I_{i,j}}{P_j} \quad (12.19)$$

Inserting this expression for optimal housing services back into the utility function, we arrive at indirect utility—that is utility with the choice of housing optimised out:

$$\ln V_{i,j} = \beta_I I_{i,j} + M_{i,j} + \theta_j + \eta_{i,j} \quad (12.20)$$

where,

$$\theta_j = B_0 - \beta_H \ln P_j + \beta_X \ln X_j + \xi_j$$

⁸ The functional form refers to the specific mathematical formulation used to describe utility. The Cobb–Douglas utility function, used here, is common in the literature. It says that utility is the product of consumption, housing services, and other amenities each raised to a power that is estimated with data.

$$B_0 = \ln\beta_0 + \beta_C \ln\beta_C + \beta_H \ln\beta_H - (\beta_C + \beta_H) \ln(\beta_C + \beta_H)$$

$$\beta_I = \beta_C + \beta_H$$

Here, θ_j represents city-specific mean utility that is common to the households in city j and captures all the utility-relevant characteristics of the city, and ξ_j captures the unobservable component of θ_j . B_0 is a constant that does not vary with location choice. The household's problem now comes down to choosing the location j that maximises $\ln V_{i,j}$, taking as a given that it will choose the optimal H_i^* once it gets there.

$M_{i,j}$ is written as a function of migration distance, with increasing costs associated with leaving one's birth state, census division, or census region,⁹

$$M_{i,j} = \varphi_1 D_{1,i,j} + \varphi_2 D_{2,i,j} + \varphi_3 D_{3,i,j} \quad (12.21)$$

where,

$D_{1,i,j}$ 1 if moving to location j requires that individual i leaves their birth state (= 0 otherwise).

$D_{2,i,j}$ 1 if moving to location j requires that individual i leaves their census division of birth (= 0 otherwise).

$D_{3,i,j}$ 1 if moving to location j requires that individual i leaves their census region of birth (= 0 otherwise).

This assumes that $\eta_{i,j} \sim$ Type I Extreme Value provides a convenient closed form for the probability that individual i will choose each location j . An econometric procedure is used to recover the vector of parameters that maximise the combined probability of seeing all households choose the locations that they actually did choose. In addition, the model deals with two endogeneity problems—one related to pollution and the other related to housing prices. First, an instrumental variables strategy is used to deal with the fact that pollution is likely to be higher in larger, more economically active cities. People like to live in such cities, and without controlling explicitly for all factors that make a city economically active, the model might mistakenly attribute these desirable features to pollution. We do not go into detail here about how this is addressed, keeping our focus on the role of migration costs. The model also deals with the endogeneity of housing prices—in particular, prices will be higher in cities with desirable amenities that attract people who can move there—that is high demand drives up prices. Without accounting explicitly for all of these amenities, the model is likely to conclude that people prefer high prices. There are strategies to deal with

⁹ US Census divisions are listed in Table 12.1. The US Census regions are Northeast, South, Midwest, and West.

Table 12.2 Utility function parameter estimates (USA)

	Estimate	t-statistic
$\ln(I_{i,j})$	0.673	48.36
$\ln(PM10)$	−0.34	2.27
Migration Cost		
– State	−4.31	−32.69
– Census Division	−1.27	−17.13
– Census Region	−0.878	−18.61
MSA Covariates	Yes	
Regional dummies	Yes	

Table 12.3 Median marginal willingness to pay for a 1 $\mu\text{g}/\text{m}^3$ reduction in PM10

Rosen-Roback hedonic model	Residential sorting model
\$55.20	\$148.70

problems of this kind, but for the purposes of this chapter, we will keep the focus on the role of migration costs.

The results of the sorting model follow below. We begin with the migration cost parameters in Table 12.2. Costs increase with the distance of a move but do so at a diminishing rate. This is sensible if fixed costs are associated with initiating a move, but once the decision to move is made, it is not that much more costly to move cross-country than it is to move outside of one's census division.

We next compare the willingness to pay measures across the two methods in Table 12.3. The Rosen-Roback method ignores migration costs, and the sorting model includes them. The MWTP to avoid a one-unit (i.e., micro-gram per cubic metre) increase in PM10 from the hedonic method is \$55.20, while it rises to \$148.70 when we account for moving costs. Indeed, the naïve model mistakenly interprets the behaviour of many of those who chose not to leave their polluted hometowns as a reduced distaste for pollution. Including mobility costs in a residential sorting model yields estimates of MWTP that are more than three times as large as estimates from a conventional hedonic approach, even in a US application where we would consider mobility costs to be relatively low.

12.5 Sorting Under High Mobility Costs: China

12.5.1 Migration Costs in China

High costs of migration in many developing countries are driven by institutional migration restrictions. The *hukou* system in China is a good example of such an institutional restriction. Chan (2009) provides a detailed discussion of China's *hukou*

policy, and we summarise its key features here. In 1958, China's highest legislative body, the National People's Congress, formally instituted a comprehensive and far-reaching system called the *hukou* to control internal migration.¹⁰ The institution required that each person be classified as rural or urban and assigned a locality of *hukou* registration; this would typically be the person's birth location. *Hukou* registration then determines the ability to pursue many activities and eligibility for state-provided goods and services in a specific place. Because of this, all internal migration becomes subject to approvals from local authorities at the destination. Migrants who do not hold a local *hukou* have limited or no access to many government-provided benefits, including public education for children and medical care. The red *hukou* book consequently plays a critical role as an internal passport that gives Chinese people rights to reside and work in a particular location.

Since China's economic reforms in the 1980s, the mobility restrictions imposed by the *hukou* system have been somewhat relaxed. People are now allowed to move to places that are different from their registration localities, but migrants without a local *hukou* are still not entitled to the same rights and benefits as locals. According to the 2019 Urbanisation Plan, China will further relax the *hukou* restrictions on residence in small and medium-sized cities in order to increase labour mobility and encourage urbanisation. In the large cities, which are still the main magnets for migrant workers, the *hukou* policy will continue to impose restrictions.

In China, *hukou* regulation is determined by the local government with the goal of controlling the growth of urban populations. Therefore, the *hukou* restriction is more stringent in large and first-tier cities that face an influx of migrants. However, these cities also offer desirable migrant-specific amenities—such as strong migrant networks, relatively equal economic opportunities and a Mandarin-speaking (rather than local dialect) environment.¹¹ Figures 12.1 and 12.2 illustrate that the share of immigrants and the share of workers using Mandarin as their working language are both higher for higher-tier cities. The overall migration cost associated with a given location will therefore combine the utility loss owing to the *hukou* restriction and utility gain from migrant-specific amenities.

The difficulty of acquiring a local *hukou* varies across cities and is correlated with the population size and city tier. Figure 12.3 illustrates this tendency, revealing a strong positive association between city population and the *hukou* index. The *hukou* index measures the stringency for internal migrants to obtain a local *hukou* across Chinese cities. There are five channels through which internal migrants could apply for local *hukou*: investment, employment, family reunion, a special contribution to local society and other channels specified by local government. Only a very small number of migrants can obtain a local *hukou* through the channel of their special contribution to local society and other channels specified by the local government.

¹⁰ See Chap. 1 Sect. 1.1 and https://www.npc.gov.cn/wxzl/gongbao/2000-12/10/content_5004332.htm for more background information, and Chaps. 4 to 9 for the various impacts of *hukou*.

¹¹ Mandarin is the only official language in China, but local dialects are widely used as oral language and even working language in many small and medium Chinese cities. It is hard for migrants to assimilate in local society and compete with local workers in the labour market in a dialect-speaking environment.

Fig. 12.1 Average share of migrants for cities of different tiers. *Notes* We assign Tianjin and Chongqing to the group of subprovincial city. *Data Source* 2005 One-Percent Population Census of China

Fig. 12.2 Average share of workers using Mandarin as working languages. *Notes* We assign Tianjin and Chongqing to the group of subprovincial city. *Data Source* China Labour Dynamic Survey 2014

Fig. 12.3 City population and *hukou* index. *Data Source* *Hukou* index data are drawn from Wu and Zhang (2010), city population data are drawn from China city statistical yearbook

The *hukou* policy associated with family reunion is implemented by the central government and has no variation across Chinese cities. The spatial stratification of *hukou* regulation is mainly driven by variations in local *hukou* policy associated with investment and employment. The *hukou* regulation based on employment includes the regularity of employment (e.g. years working in a given city, requirements on lowest education attainment) and levels of education and training (e.g. advanced degree, professional qualification, prestigious university graduates). The policy based on investment consists of home purchase and other investments such as founding a company in a given city. Wu and Zhang (2010) construct a *hukou* index for 45 Chinese cities to measure the difficulty of local *hukou* qualification based on the four channels for migrants to get a local *hukou* investment, home purchase, regular employment and talent programme. Zhang et al. (2019) collect data from recent local government documents and employ a similar approach to Wu and Zhang (2010) to further construct *hukou* index for 120 Chinese cities.

Figure 12.4 shows that the *hukou* index is highest for Beijing and Shanghai, followed by sub-provincial cities, and then by provincial capitals in descending order. Therefore, in China today, it is very easy for immigrants to apply for a local *hukou* in small and medium-sized cities, but it is still very hard in large and first-tier cities.

Another prominent feature of the *hukou* system is that it is strongly biased towards higher education and skills (Liang and Lu 2017). Table 12.4 presents the points associated with education attainments and professional qualifications required in the application for local *hukou* in four first-tier Chinese cities. It indicates that migrant workers with a higher degrees or advanced professional qualifications can much more

Fig. 12.4 Average *hukou* index for cities of different hierarchies. *Notes* We assign Tianjin and Chongqing to the group of subprovincial city. *Data Source* Wu and Zhang (2010)

easily get the local *hukou* compared to those with less education or fewer professional skills.

What are the impacts of the *hukou* system on migration in China? In Table 12.5, we calculate the simple share of household heads between the age of 25 and 35 that stay in their *hukou* provinces. This corresponds to the figures in the diagonal elements of the matrix in Table 12.1. The mean value is about 90%—much larger than that in the USA and implies that moving costs will play a larger role in China. In order to determine just what the impacts of those migration costs are, we apply the Chinese data in Freeman et al. (2019) to a model similar to that used above to describe US migration. The raw data on household location sorting in Freeman et al. (2019) are from the One-Percent Population Census of China collected by the National Bureau of Statistics of China.

12.5.2 A Model of Residential Location Choice in China and Implications for WTP Measurements

Following the analysis in Freeman et al. (2019), we first classify Chinese cities into four categories: Beijing and Shanghai, sub-provincial cities along with Tianjin and Chongqing, provincial capitals, and ordinary cities. It is hardest for migrants to obtain

Table 12.4 The comparison of points-based *hukou* policy across Chinese metropolitans

City	Total points required to obtain local <i>hukou</i>	Education	Skills
Beijing	Depends on the population policy	Doctoral degree: 37 points Master degree: 26 points Bachelor degree: 15 points Some college: 10.5 points	
Shanghai	72	Doctoral degree: 27 points Master degrees: 24 points Bachelor degree: 21 points	College English Test Band 6 or 8: 8 points College English Test Band 4: 7 points
Guangzhou	60	College degree & above: 60 points Some college: 40 points High school: 40 points	Junior workers: 10 points Middle-level workers: 30 points High-level workers: 50 points
Shenzhen	100	Junior workers: 10 points Middle-level workers: 30 points High-level workers: 50 points	Junior workers: 20 points Middle-level workers: 40 points High-level workers: 70 points Senior technical worker: 100 points Junior-level professional skill: 70 points middle-level professional skill: 90 points high-level professional skill: 100 points

Data source The official government website of Beijing, Shanghai, Guangzhou and Shenzhen

a local *hukou* in Beijing and Shanghai, followed by sub-provincial cities, provincial capitals and ordinary cities. The pattern is entirely different for migrant-specific amenities—large cities like Beijing and Shanghai offer much better conditions and facilities for migrants than small cities. These include economic opportunities that are more similar to those offered to locals, improved social ties, and a Mandarin-speaking environment. We use the following equation to model the overall migrant costs due to *hukou* regulation and migrant-specific amenities with a series of dummy variables:

$$M_{i,j,s} = \sum_{k=1}^3 \mu_{k,s} D_{k,ij} + \sum_{k=4}^6 \mu_{k,s} D_{1,ij} D_{k,ij} \quad (12.22)$$

Table 12.5 The share of household heads age 25–35 staying within their *hukou* province

Province name	Province code	Share (%)
Beijing	11	97.212
Tianjin	12	99.390
Hebei	13	89.587
Shanxi	14	97.841
Neimenggu	15	94.941
Liaoning	21	95.221
Jilin	22	95.114
Heilongjiang	23	91.179
Shanghai	31	98.802
Jiangsu	32	79.796
Zhejiang	33	85.892
Anhui	34	65.586
Fujian	35	88.005
Jiangsu	36	71.499
Shandong	37	93.301
Heinan	41	76.275
Hubei	42	79.925
Hunan	43	72.785
Guangdong	44	99.089
Guagnxi	45	82.703
Hainan	46	97.638
Chongqing	50	75.272
Sichuan	51	66.255
Guizhou	52	86.092
Yunnan	53	99.083
Shan'xi	61	94.437
Gansu	62	94.897
Qinghai	63	98.612
Ningxia	64	97.869
Xinjiang	65	98.618

Data Source 2005 One-Percent Population Census of China

Notes We only use the household sample whose age lie in Knittel et al. (2016), Palmquist (2005)

$D_{1,ij}$ 1 if location j is outside of worker i 's *hukou* city (= 0 otherwise).

$D_{2,ij}$ 1 if location j is outside of worker i 's *hukou* province (= 0 otherwise).

- $D_{3,ij}$ 1 if location j is outside of worker i 's hukou macro-regions¹² ($= 0$ otherwise).
 $D_{4,ij}$ 1 if location j is Beijing/Shanghai ($= 0$ otherwise).
 $D_{5,ij}$ 1 if location j is a sub-provincial city/Tianjin/Chongqing ($= 0$ otherwise).
 $D_{6,ij}$ 1 if location j is a provincial capital ($= 0$ otherwise).

The first three ‘dummies’—binary variables used to measure categorical factors—measure the disutility with respect to the physical and psychological costs of leaving one’s *hukou* city.¹³ The interactions between the ‘outside of *hukou* city’ dummy and the three city group dummies capture the overall net utility effects of the difficulty of obtaining local *hukou* and migrant-specific amenities, which are measured relative to migration costs in ordinary cities.¹⁴

We first report utility function parameter estimates in Table 12.6. In the first column, we do not account for moving costs, and the estimated coefficient on income in the utility function is negative. High moving costs in China prevent workers from moving to places where they could earn higher wages, so when moving costs are ignored, the model incorrectly interprets their behaviour as expressing a preference for lower wages. Accounting for moving costs is clearly necessary to avoid this. In the second column, we add three dummy variables associated with leaving one’s *hukou* city, *hukou* province, and *hukou* macro-region, respectively, to capture the physical and psychological moving costs, along with the costs of losing the benefits that come with having a local *hukou*. The three dummies are all significantly negative, suggesting that these costs are important. Similar to results from the USA, the mobility costs increase as households leave their *hukou* city, province, and then macro-region, but do so at a decreasing rate. Having accounted for moving costs, the coefficient on income in the second column is now positive, as expected.

The simple specification in column (2) cannot capture the variations in moving costs across the destination cities. We therefore add three interaction¹⁵ terms to capture differences in moving costs across Chinese cities of different tiers. These

¹² There are seven macro-regions in China: East China, North China, Central China, South China, Southwest China, Northwest China and Northeast China.

¹³ In China, most people’s *hukou* city is the same as their birth city. The China Labor-force Dynamics Survey in 2014 provides information on both the *hukou* and birth locations for 14,226 families and 23,594 individuals in 29 provinces of China. Using this data, we find that only 7.08% of people’s *hukou* cities are different from their birth cities. It is natural to guess that this number would be even smaller in 2005. Additionally, it usually takes a long time for migrants to obtain a local *hukou*. Some local governments’ official documents require that migrants must work in the city for more than three years before applying for local *hukou*. Generally, if a migrant has moved from his hometown and obtained a *hukou* in a second city, he will have had to have worked in that city for a long period. Overall, there are significant barriers for households leaving their *hukou* city.

¹⁴ We assume that migration disutility varies across the four city groups. Ordinary cities are considered as the benchmark group in the empirical specification, therefore we do not add the interaction between ‘outside of *hukou* city’ dummy and ‘ordinary city’ dummy.

¹⁵ An interaction occurs when an independent variable has a different effect on the outcome depending on the values of another independent variable. In the present context, the utility effect of moving to different city depends on the tier of destination cities.

Table 12.6 Utility function parameter estimates (China)

	(1)	(2)	(3)
$\ln(I_{i,j})$	−0.184 ^c (0.028)	1.606 ^c (0.064)	1.621 ^c (0.065)
$\ln(PM2.5)$	−0.836 ^c (0.246)	−1.568 ^c (0.452)	−0.983 ^a (0.507)
Out of <i>hukou</i> city dummy ($D_{1,ij}$)		−6.448 ^c (0.030)	−6.846 ^c (0.035)
Out of <i>hukou</i> province dummy ($D_{2,ij}$)		−1.984 ^c (0.042)	−2.102 ^c (0.042)
Out of <i>hukou</i> macro-region dummy ($D_{3,ij}$)		−1.978 ^c (0.037)	−1.991 ^c (0.037)
Out of <i>hukou</i> city dummy ($D_{1,ij}$) × Beijing/Shanghai dummy ($D_{4,ij}$)			4.558 ^c (0.183)
Out of <i>hukou</i> city dummy ($D_{1,ij}$) × Sub-provincial city dummy ($D_{5,ij}$)			2.364 ^c (0.068)
Out of <i>hukou</i> city dummy ($D_{1,ij}$) × provincial capital dummy ($D_{6,ij}$)			1.587 ^c (0.086)
City Characteristics	Yes	Yes	Yes

Notes City characteristics include School, Hospital, GDP. capita, Population, Distance. Seaport, Water. Emission, SO₂.emission, and Dust. emission. Pollutant emissions include, $\ln$ (Water. Emission), $\ln$ (SO₂.emission), and $\ln$ (Dust. emission). Standard errors in parentheses

^a $p < 0.10$
^b $p < 0.05$
^c $p < 0.01$

differences are determined by the *hukou* policies and migrant-specific amenities at the destination cities. The coefficients on the three interaction terms are all positive, so the moving cost is reduced for migrants moving to higher-tier cities. Ignoring these three terms could overestimate moving costs in the larger Chinese cities.¹⁶

The coefficient on the natural log of PM2.5 is significant and negative, but nearly doubles in magnitude when we add in simple controls for migration costs. When we add interaction terms to capture the range in moving costs across a different tier of cities, the effects of particulate matter pollution remains negative and significant—larger than when no controls for moving costs are included, but not as large as when city-level variations are ignored.

Table 12.7 summarises these results and compares them with the results of a Rosen-Roback hedonic model specification, which ignores migration costs. The willingness to pay for a small reduction in particulate pollution estimated with the

¹⁶ These results are in accordance with the geographic distribution of internal migrants in China—the 2005 One-Percent Population Census of China shows that about 31.8% of internal migrants live in the 10 largest cities.

Table 12.7 Estimated MWTP for reduction in PM2.5

	MWTP (\$)
Rosen-Roback model	−3.736
Sorting model without incorporating migration disutility	−162.696
Sorting model incorporating migration distance dummies	34.943
Sorting model with full specification of migration costs	21.697

Rosen-Roback model has a negative value—suggesting that people actually enjoy more pollution. A similar result, seen in the second row, is obtained using our sorting model but ignoring moving costs. This arises from the counter-intuitive result on income.¹⁷ Given the adverse effects of severe air pollution on health and productivity in developing countries such as China, these estimates are unreasonable (Chen et al. 2013; Ebenstein et al. 2017). The remaining rows of Table 12.7 report the MWTP estimated from the residential sorting model incorporating moving costs. Estimates have the expected positive sign. MWTP is larger in the model that ignores city-level variations in moving costs, but it remains significant and positive in both specifications.

12.6 Limitations and Future Directions

Before concluding, we discuss two key limitations of the work presented in this chapter and suggest ways forward for future research.

12.6.1 Dual-Location Choice

In the previous sections, we discussed the *hukou* system in China and its potential effects on estimated MWTP for amenities. In this section, we focus on another dimension of residential sorting that can interact with the *hukou* system. In particular, households are made up of many members and their decisions can affect those members differently. A prominent example of the dual-location choice in China is the case of left-behind children. Figure 12.5 describes the correlation between the *hukou* index and the share of migrants who have left their children behind in their original location. The index measures the degree of difficulty for migrants to obtain the local *hukou* in a given city. The positive correlation between them shows that

¹⁷ Willingness to pay, measured from the sorting model, is the ratio of the coefficients on particulate matter and income. In this specification, the coefficient on income has a counterintuitive negative sign. This translates into the counterintuitive result on the overall willingness to pay.

Fig. 12.5 *Hukou* and left-behind children. *Note* The X-axis denotes the city *hukou* index. The Y-axis denotes the share of migrants having left-behind children. *Data Source* China Migrants Dynamic Survey (CMDS) in 2011

migrants who leave their children behind tend to be those who move to cities with more restrictive *hukou* regulation. Using data from the 2011 China Migrants Dynamic Survey (CMDS), we compare the impact of the *hukou* system and air pollution on the left-behind children in Table 12.8. The first two columns show that the *hukou* index

Table 12.8 *Hukou* index, PM 2.5 and left-behind children

Whether have left- behind children (yes = 1, no = 0)	<i>Hukou</i> index	PM2.5	<i>Hukou</i> index + PM2.5
<i>Hukou</i> index	0.940 ^c		0.916 ^c
	(0.230)		(0.219)
ln (PM2.5)		0.0558	0.0451
		(0.0517)	(0.0470)
Constant	2.121 ^c	1.869 ^c	1.954 ^c
	(0.199)	(0.274)	(0.258)
R-squared	0.102	0.091	0.103
Observations	38,433	38,433	38,433

Notes The household characteristics include *household income*, *household expenditure*, *the age and education attainment of household head*. Standard errors in parentheses cluster at city-level

^a $p < 0.10$

^b $p < 0.05$

^c $p < 0.01$

Data Source China Labor Migrant Survey (CMDS) in 2011

Fig. 12.6 Child age and left-behind children. *Note* The X-axis denotes the age of children and the Y-axis denotes the share of migrants having left-behind children. *Data Source:* China Migrants Dynamic Survey (CMDS) in 2011

significantly affects the left-behind children, but that PM2.5 concentration does not have a significant effect. In column (3), we consider the two factors together, and the results hardly change. The key factor is the availability of public education in the destination cities as children who do not hold a local *hukou* have limited or no access to public education systems in their residential cities. Figure 12.6 shows that the share of migrants that have left-behind children increases sharply when their children are between the ages of 8 to 14—the age in China when children should be enrolled in primary and middle schools.

Figure 12.7 shows a similar positive correlation between the *hukou* index in a destination city and the share of migrant couples who live in different places. Again, as illustrated in Fig. 12.8, we find that the share of migrant couple separation increases sharply when the age of their children is 8 or 14, suggesting one parent is being left behind to care for the child.

12.6.2 Incomplete Information

China provides a unique setting in which to study the impacts of pollution information on residential location sorting. Despite the hazardous level of exposure to pollution, Chinese citizens used to have limited or no access to information about local air quality. In 2000, the ministry of environmental protection of China started to publish air quality data, including an Air Pollution Index (API) and PM10, but only did so for 42 cities. Although fine particles (diameter < 2.5 μm) are more hazardous

Fig. 12.7 *Hukou* and migration couple separation. *Note* The X-axis denotes the city *hukou* index. The Y-axis denotes the share of migrants couples living apart. *Data Source* China Migrants Dynamic Survey (CMDS) in 2011

than larger particles ($2.5 \mu\text{m} < \text{diameter} < 10 \mu\text{m}$) with respect to mortality and cardiovascular and respiratory problems, PM_{2.5} was not included in the calculation of API. The number of cities in which API and PM₁₀ were available increased gradually to 120 in 2012. In 2013, in response to the public demand for the publication of PM_{2.5} data, China launched a nationwide, real-time air quality monitoring and disclosure programme. The Ministry of Environmental Protection started to disclose real-time PM_{2.5} data in most large and median-sized Chinese cities in January 2013. Information on real-time PM_{2.5} has been available in all Chinese cities since January 2015. The disclosure of pollution information has an important impact on households' efforts to mitigate the effects of air pollution. As illustrated in Fig. 12.9, the number of indoor air filtration sales increased sharply in response to the release of information in 2013. Future research could study the implications of information disclosure on the residential sorting decisions of households. Estimates derived from these decisions can be used to quantify the monetised value of pollution information.

12.7 Conclusion

Economists generally employ two revealed preference approaches to evaluate household preferences for non-marketed amenities—the hedonic and equilibrium sorting

Fig. 12.8 Child age and migration couple separation *Note* The X-axis denotes the age of children and the Y-axis denotes the share of migrants couples living apart. *Data Source* China Migrants Dynamic Survey (CMDS) in 2011

Fig. 12.9 The number of air purifier sales for 85 major Chinese cities from 2006 to 2014. *Data Source* Air purifier sales transaction data collected by a marketing firm in China from January 2006 through December 2014 for 85 cities

models. The conventional hedonic model assumes that households can freely move across space. However, when there are significant migration costs, the benefits that households receive from moving to cities with better amenities must compensate them for lower-income and higher housing prices and these costs. As a result, the simple variation in income and housing costs across locations no longer reflects the economic value of differences in non-market amenities. Mobility constraints hinder the use of conventional wage-hedonic techniques to estimate household MWTP for local amenities such as clean air.

In this chapter, we analysed the role of migration costs in household residential sorting and applied both the hedonic model and the equilibrium sorting model *incorporating mobility costs* to estimate household MWTP for air quality improvement in the USA and China. Our findings highlight the potential importance of incorporating mobility constraints into measuring the value of pollution reductions. Ignoring mobility costs in spatial sorting will result in underestimating the economic value of non-market amenities in both the USA and China, and such downward bias is larger in developing countries such as China where migration costs are substantially higher.

As China moves beyond a narrow focus on the pursuit of economic growth towards the more holistic policy target of improving the quality of life of its citizens, there will be new opportunities for revealed preference approaches to contribute to policy decision-making. Many of the environmental concerns that economic development has generated will have major impacts on human wellbeing and need to be factored into economic targets and strategies. For this to happen, their economic value will need to be quantified and decision support tools for economic policy broadened to incorporate them. Revealed preference approaches, particularly equilibrium sorting models, have a potentially important role to play in providing robust estimates of the economic value of lower pollution, green space, leisure facilities, and the aesthetic attributes of where people live and work. This chapter has hopefully demonstrated both the feasibility of estimating equilibrium sorting models in a Chinese context and the need to tailor these methods to the particular features of that context, particularly with respect to migration costs.

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