Abstract
This paper combines a spatial microsimulation model with a classic model of travel demand for the valuation of commuting travel times in Ireland. The aim of the research is to investigate the potential variations in the value of commuting travel times relative to disposable income across Irish regions. Preliminary empirical analysis of commuting data in Ireland provides evidence to suggest a non-linear relationship between the values of commuting travel-time and the duration of the commuting trip. Thus, a rationale arises for the simulation of the value of commuting travel time across various travel-time bands for motorised modes of travel to work. The simulation process generates individual-level value estimates for each small-area geographic unit in Ireland. GIS tools are subsequently used to characterise the spatial distribution of the value of commuting travel time relative to individual disposable income across Ireland, establishing if there are regional variations that suggest commuting as something similar to a regional ‘virtual’ poll tax.

INTRODUCTION
Individuals spend a significant amount of their time commuting, which in most cases is considered an unpleasant, but necessary activity. Accordingly, commuters would like to diminish the number of trips, to travel to closer destinations and to reduce travel time for any given trip. This would allow them to reallocate time into other more pleasurable (or more profitable) activities.

Since the 1960s, the subject of the allocation of time has been extensively explored and as such it has become an important element for public policy. Empirically, disaggregated discrete choice models have traditionally been used to compute the value of travel time. These models measure the trade-offs between travel time and the cost faced by commuters, whereby willingness to pay to reduce travel time by one unit is the marginal rate of substitution (MRS) between cost and time for a given utility function. Travel choice models are estimated using a linear combination of cost (and time) characteristics of each alternative mode of transport and a set of socio-economic variables [1].

Empirical analysis of commuting data provides evidence to suggest a non-linear relationship between the values of commuting travel-time and the duration of the commuting trip. Using data from POWSAR, a subset of the Irish Census of Population 2002, Figure 1 depicts the non-linear relationship between travel time and the value of travel across four time bands. Figure 1 shows that the value of time increases with trip duration. This is consistent with previous studies in the UK and with economic theory [2]. Various reasons for this non-
linearity have been suggested in the literature including experiment design/questionnaire [2, 3]. However, regardless of the reasons for this result, there is a rationale for the simulation of the value of commuting travel time across various travel-time bands in this study.

Estimating four travel cost model based on commuting time bands (0-15 minutes, 16-30 minutes, 31-60 minutes and 60 plus minutes), the aim of this paper is to examine if the value of time taken to commute as a percentage of disposable income in Ireland, imposes a ‘virtual’ poll tax on different regions. Current commuting data in Ireland does not include individual income data; thus this paper combines data from a value of travel time (VoT) model and a spatial microsimulation model to achieve this objective.

**Figure 1 Non-Linear Relationship between Travel Time and Value of Travel Time**

**METHODODOLOGY**

**SPATIAL MICROSIMULATION MODEL**

SMILE is the static spatial microsimulation model [4, 5] used here. It uses a combinational optimisation technique, simulated annealing, to match the LII (2000) and SAPS (2002) datasets, matching on age, sex, household size and education level, creating a micro-level synthetic dataset for the whole population of Ireland, which includes health variables. For a full discussion on the algorithm and datasets used to create the statistical match, please see Reference 4. Ballas et al., (2006) [6] also provides an outline of the simulated annealing process and various other methods that may be used to create synthetic data at varying spatial scales. Merging data for POWSAR (2002) to the baseline dataset created by SMILE provides a geo-referenced, attribute rich dataset containing: commuting/travel to work (TTW), income, demographic and socio-economic data. Combining income and commuting data the dataset created by SMILE can be used to examine the spatial relationship between VoT and disposable income in Ireland.

**VALUE OF TRAVEL TIME**

As outlined above, in the traditional travel choice literature, the alternative-specific utility function for travel choice is usually represented through the linear combination of travel cost and travel time characteristics of each of the alternatives considered and a set of socio-economic variables. However, Figure 2 depicts a strong non-linear relationship between travel time and the value of travel time in Ireland. Thus, dividing commuting travel time into four time bands (0-15 minutes, 16-30 minutes, 31-60 minutes and 60 plus minutes) a binary logistic model is estimated for the choice of mode of travel to work in Ireland. In this model, an individual chooses between two modes of travel to work: (1) Motorcycle, Car Driver or Car Passenger and (2) Bus or Train. Mode availability is taken into account in the estimation process and the probabilities are computed accordingly. The attributes of the alternatives and the characteristics of the decision maker included are those typically used for modelling travel mode choice. While (self-reported) travel times for the chosen modes of travel to work...
are available in the data, the travel times for the non-chosen modes are not. The method employed by De Palma and Rochat (2000) [7] is used to estimate the travel times for the non-chosen alternatives in the data set. A comprehensive analysis of the alternative formulations for generating a travel time variable for Ireland was carried out in Commins and Nolan (2010) [8], where De Palma and Rochat's (2000)[7] approach was found to be the most robust method in this regard. Travel cost information is constructed as a basic measure of cost per kilometre using information on 2002 public transport fares and car operating (fuel) costs. In addition to the alternative-specific variables, a number of socio-economic variables are used for the analysis. These include the gender, age and socio-economic group of the decision maker, the nature of residential occupancy, and the industrial categorisation of the decision maker’s employer. A land use explanatory variable is introduced in the model to identify whether the commuter’s usual residence is in a rural or urban area.

Using the travel cost/value parameters across the four travel time bands - 0-15 minutes, 15-30 minutes, 30-60 minutes and 60+ minutes - data is merged into the dataset created by SMILE. Combining the travel cost time parameters from the VoT models with the geo-referenced income data from SMILE one can obtain a spatial distribution of the ‘burden’ or ‘tax’ of commuting on income.

RESULTS

Using data from SMILE, average commuting time can be mapped for Ireland. From Figure 2, one can see that commuting time is highest in Dublin and the Dublin hinterland. However, given that the POWCAR dataset is spatially represented at the ED level, the value of using a spatial microsimulation model is limited. It is through the combination of the travel time and disposable income at the micro-level that SMILE becomes a useful tool for examining commuting patterns in Ireland. The next section presents compares the spatial pattern of commuting and disposable income in Ireland at the ED level.

As outlined above this paper presents the VoT across four travel time bands (0-15 minutes, 16-30 minutes, 30-60 minutes and over sixty minutes). Using the data created by SMILE, the following analysis examines the relationship between the average VoT and disposable income at the ED level. Figure 3(a) presents the average VoT for commuters in the 0-15 minutes travel band. From Figure 3(a), one can see that commuters living in four urban centres in Ireland – Galway, Limerick, Cork and Waterford – have the highest VoT. Figure 3(b) presents the VoT as a percentage of disposable income at the ED level in Ireland. From Figure 3(b) one can see that for commuters the first time band (0-15 minutes) commuting/VoT does not have a disproportionate impact on commuters across space.

Figure 4(a) presents the average VoT for commuters in the 16-30 minutes travel band. From Figure 4(a), one can see that commuters living in four urban centres in Ireland – Galway, Limerick, Cork and Waterford – and the hinterland of each of these cities have the highest VoT. Figure 4(b) presents the VoT as a percentage of disposable income at the ED level in Ireland. Similar to Figure 3, from Figure 4(b) one can see that for commuters the first time band (16-30 minutes) commuting/VoT does not have a disproportionate impact on commuters across space.

Figure 5(a) presents the average VoT for commuters in the 31-60 minutes travel band. From Figure 5(a), one can see that again commuters living in four urban centres in Ireland – Galway, Limerick, Cork and Waterford – and their hinterland have the highest VoT. However, from Figure 5(a) one can also note that commuters in the North East region have higher than average VoT. Figure 5(b) presents the VoT for time band three as a percentage of disposable income at the ED level in Ireland. From Figure 5(b) one can see that unlike Figures 3 and 4, a spatial pattern of the impact of the VoT becomes evident. Commuting in the 31-60 minute time band in the North West and the West of the country has a higher impact on disposable income compared to the rest of the country.
Figure 2 Average Commuting Time (mins) by ED

Figure 3(a) Average VoT for commuters in the 0-15 minutes travel band

Figure 3(b) VoT as a percentage of disposable income at the ED level in Ireland for commuters in the 0-15 minutes travel band
Figure 4(a) Average VoT for commuters in the 16-30 minutes travel band
Figure 4(b) VoT as a percentage of disposable income at the ED level in Ireland for commuters in the 16-30 minutes travel band

Figure 5(a) Average VoT for commuters in the 16-30 minutes travel band
Figure 5(b) VoT as a percentage of disposable income at the ED level in Ireland for commuters in the 16-30 minutes travel band
Figure 6(a) presents the average VoT for commuters in the 60 plus minutes travel band. From Figure 6(a), one can see that commuters living in the East of the country – specifically in the greater Dublin area have the highest VoT. Figure 6(b) presents the VoT for time band four as a percentage of disposable income at the ED level in Ireland. From Figure 6(b) one can see that although commuters in the greater Dublin area have the highest VoT for time band 4, the impact of travel time on their disposable income is low compared to the North West of the country. This would seem to indicate that although individuals commuting in the greater Dublin area have a higher than average VoT in time band 4 than the rest of Ireland, their level of disposable income is higher and acts as a compensatory measure in terms of monetary value.

To examine these results further Table 1 provides an analysis of average income across the four income bands and degree of urbanicity – rural, town and city. For each time band, one can see that city residents have higher levels of income. Thus, explaining why the disposable income of residents in urban areas, particularly the GDA although displaying higher levels of VoT, is not as negatively impacted. Thus, it is the spatial pattern of disposable income in Ireland and VoT that places a ‘virtual poll tax’ on commuters in Ireland, rather than travel time alone.
Table 1 Average income across the four income bands and degree of urbanicity

<table>
<thead>
<tr>
<th>Time Band</th>
<th>Rural</th>
<th>Town</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-15 minutes</td>
<td>€20,818</td>
<td>€22,442</td>
<td>€23,478</td>
</tr>
<tr>
<td>16-30 minutes</td>
<td>€20,452</td>
<td>€22,977</td>
<td>€24,021</td>
</tr>
<tr>
<td>30-60 minutes</td>
<td>€20,878</td>
<td>€24,025</td>
<td>€24,426</td>
</tr>
<tr>
<td>60+ minutes</td>
<td>€21,797</td>
<td>€24,359</td>
<td>€24,197</td>
</tr>
</tbody>
</table>

DISCUSSION
This paper combines a spatial Microsimulation model and a travel cost model to examine the relationship between disposable income and the value of travel time at the small area level in Ireland. This paper found that commuting time is higher in urban areas than rural area and that the VoT is also higher – particularly along the east coast in the Greater Dublin Area. However, combining commuting data within a spatial Microsimulation model, this paper also found that disposable income is also higher in urban areas. Thus, in the highest commuting time band, although urban residents commute longer distances, higher wages lessens the ‘burden’ of commuting. In contrast, commuters in the North West and West of Ireland, although they commute short distances, lower wages in these regions means that the spatial burden of travel cost is higher in these areas. It is only through combining a spatial Microsimulation model and a VoT model that such an analysis is feasible.

REFERENCES