Generalising LUTI Models to Systems of Cities:

Web-Based Interfaces to Simulation

Michael Batty

m.batty@ucl.ac.uk

@jmichaelbatty

http://www.complexcity.info/
http://www.spatialcomplexity.info/

My Main Themes

- Complexity:

  Models were simple and are now complicated or complex

- Data Has Changed: A New Take on Big Data

  Big Data: data is extensive but also more flawed, trickier

- Models Have Changed: Extensive Places, Many Interactions, Many Users

  Models are bigger, more complex, many more types

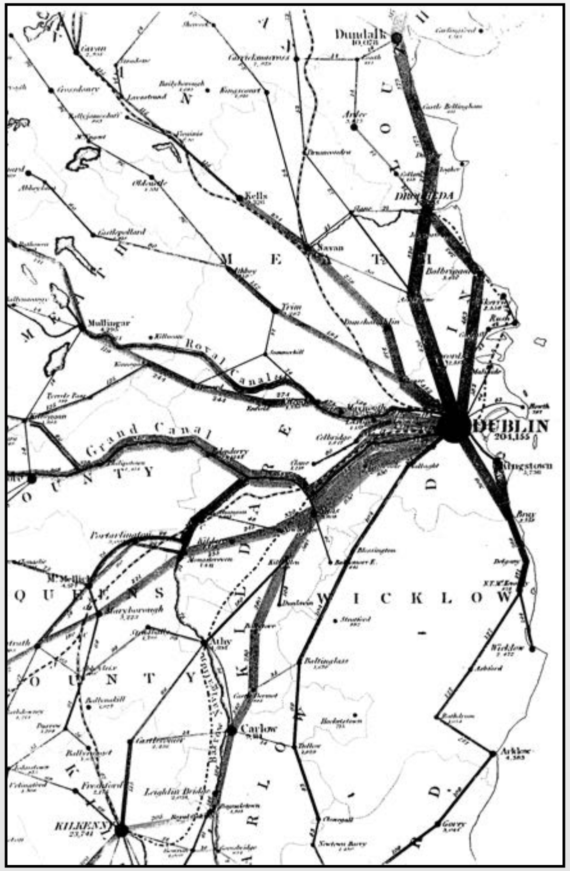
- Here Bigness In Modelling Means Building Our Model For Everywhere and Everyone

  Our model is a LUTI model for England and Wales

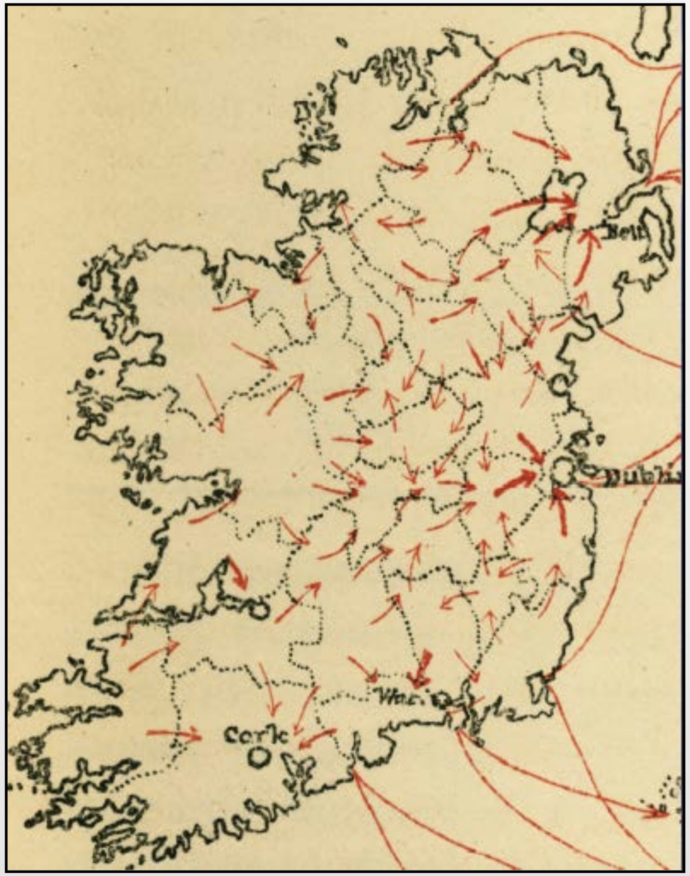
- Let Me Explain What We Are Doing

Let Me Begin with Some Examples of Big Data:

Dublin 1837, Ireland 1888, London 1955



Harness, 1837

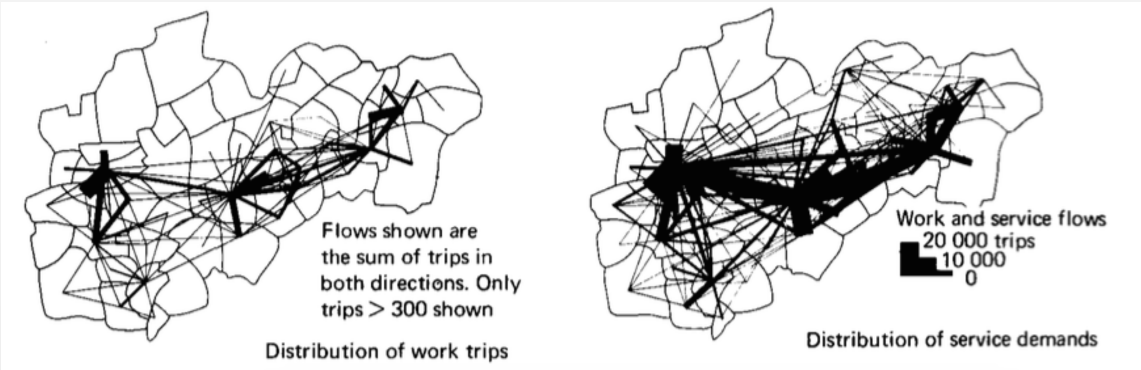


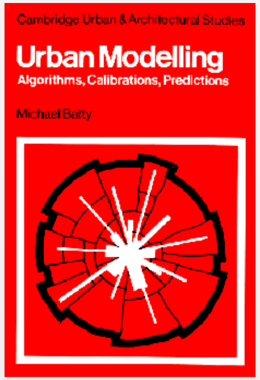
Ravenstein 1888

https://www.youtube.com/watch?v=pcBJfkE5UwU

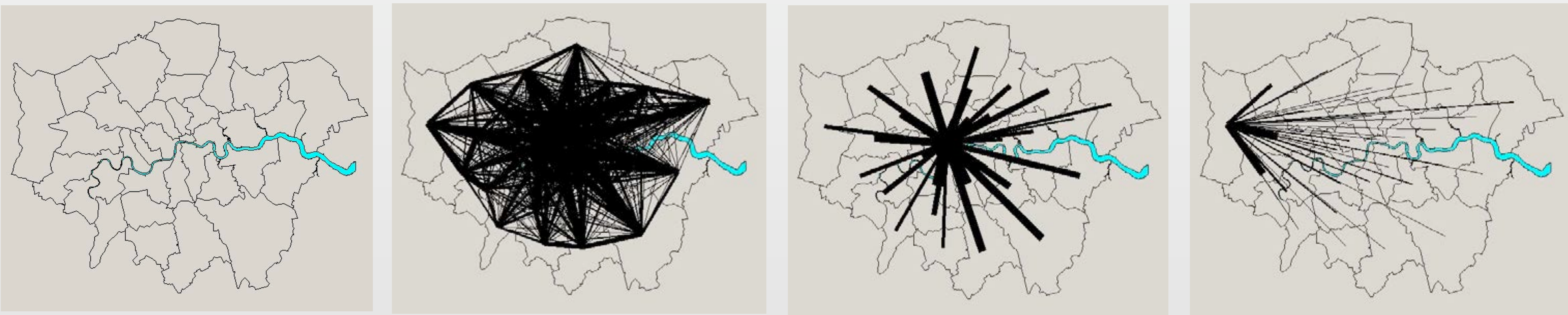
Always Had Big Data: Visualising Flows

An early model circa 1967-8 Central and NE Lancs

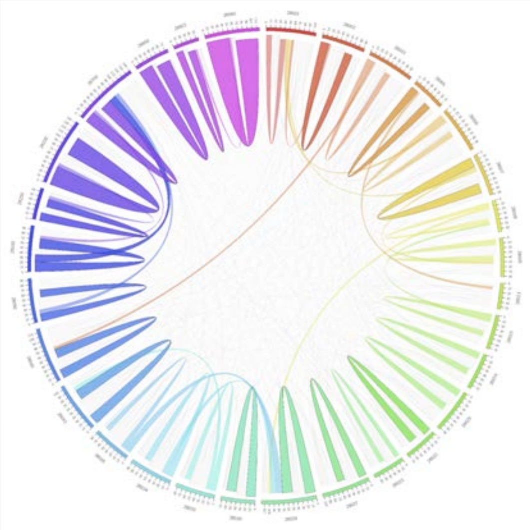


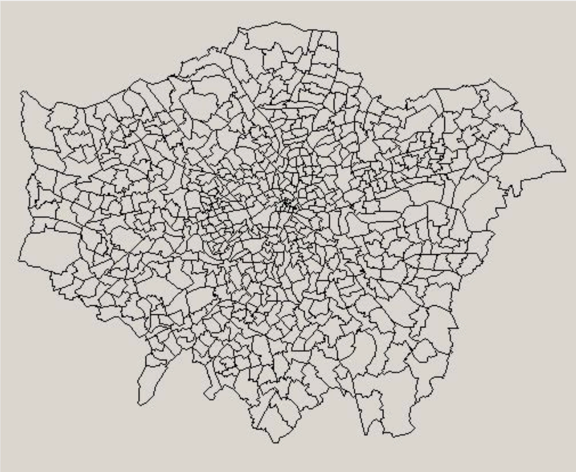


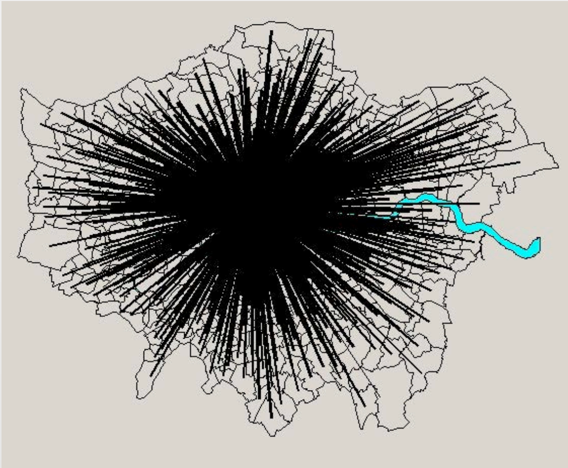
M. Batty (1976)
Urban Modelling
Cambridge UP

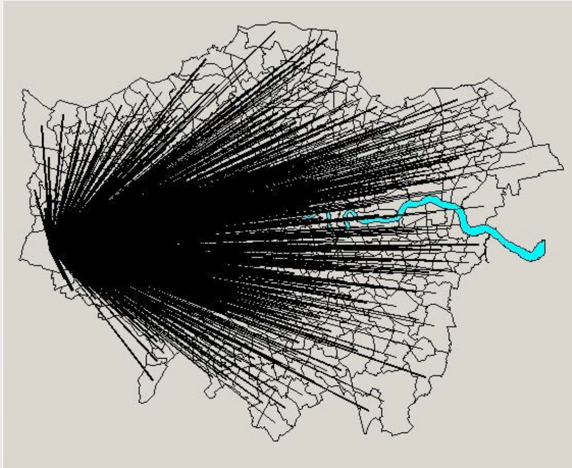


$n^2=33^2=1089$, not so big but hard to visualise

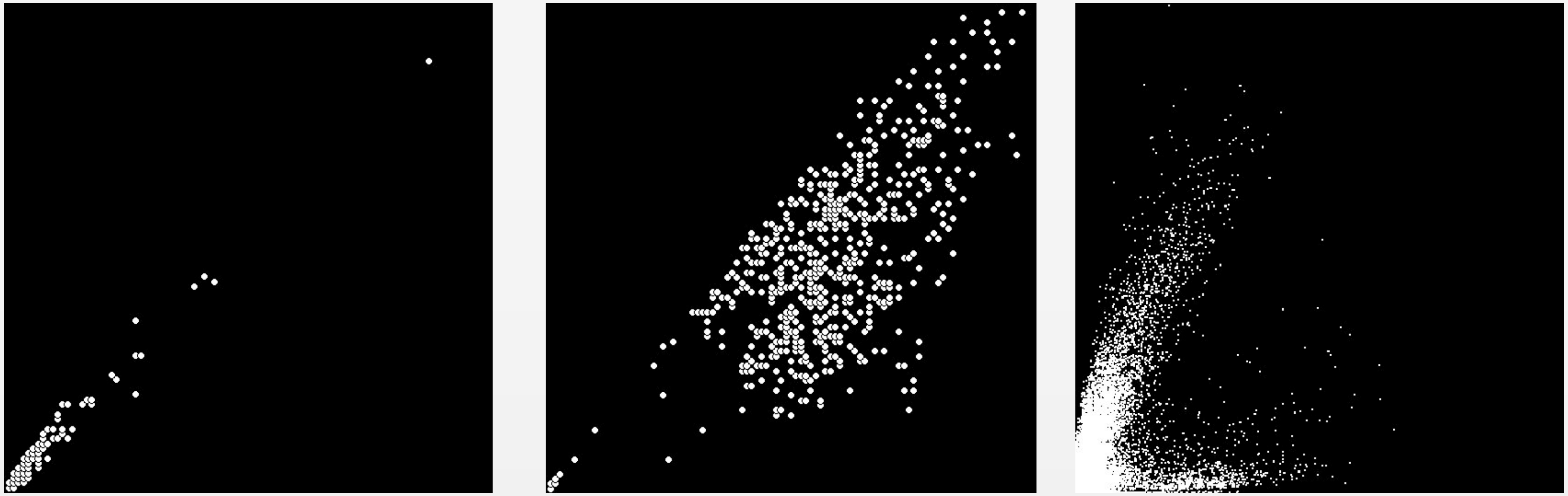








$n^2=633^2=400,689$, bigger but impossible to visualise

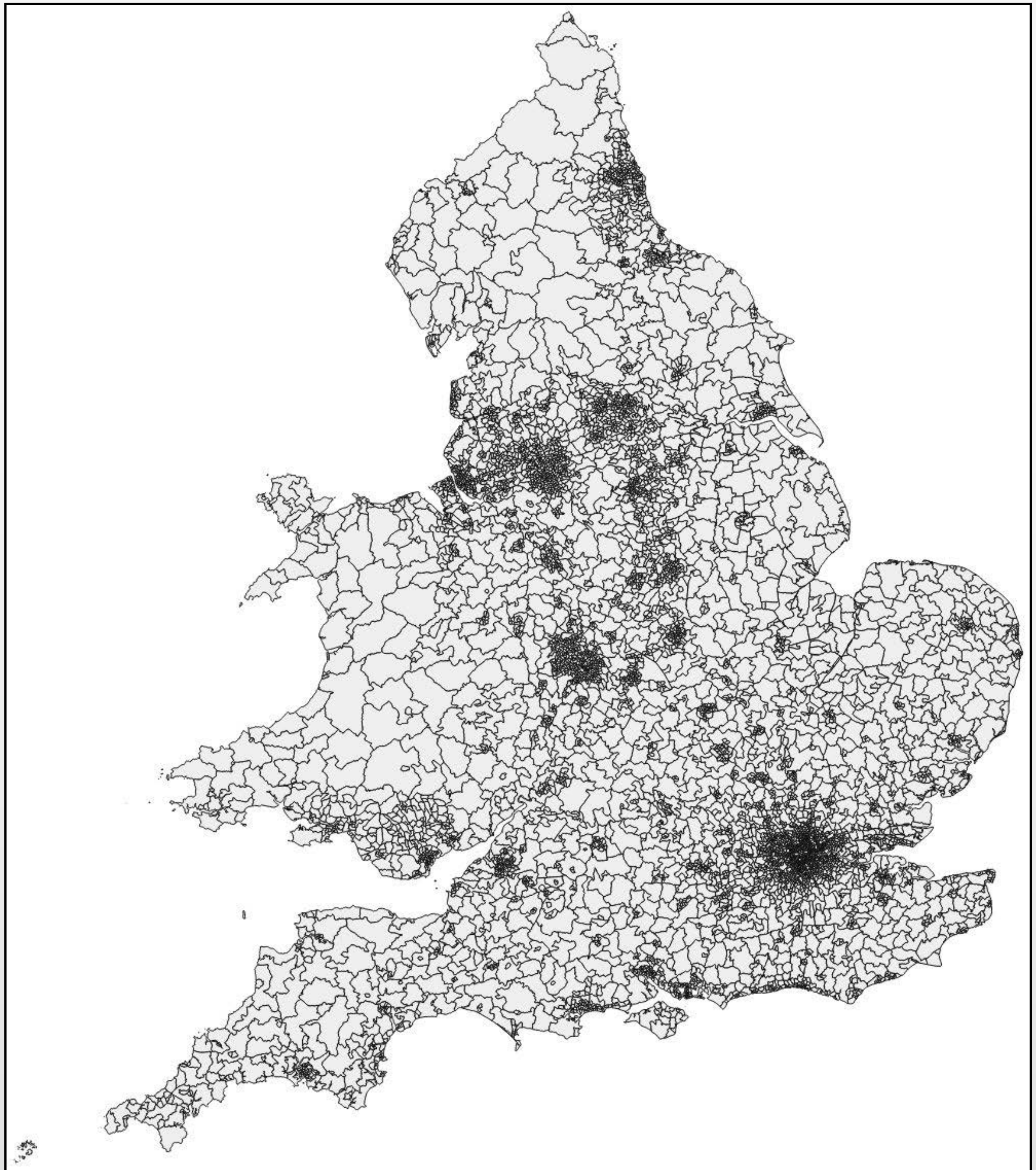


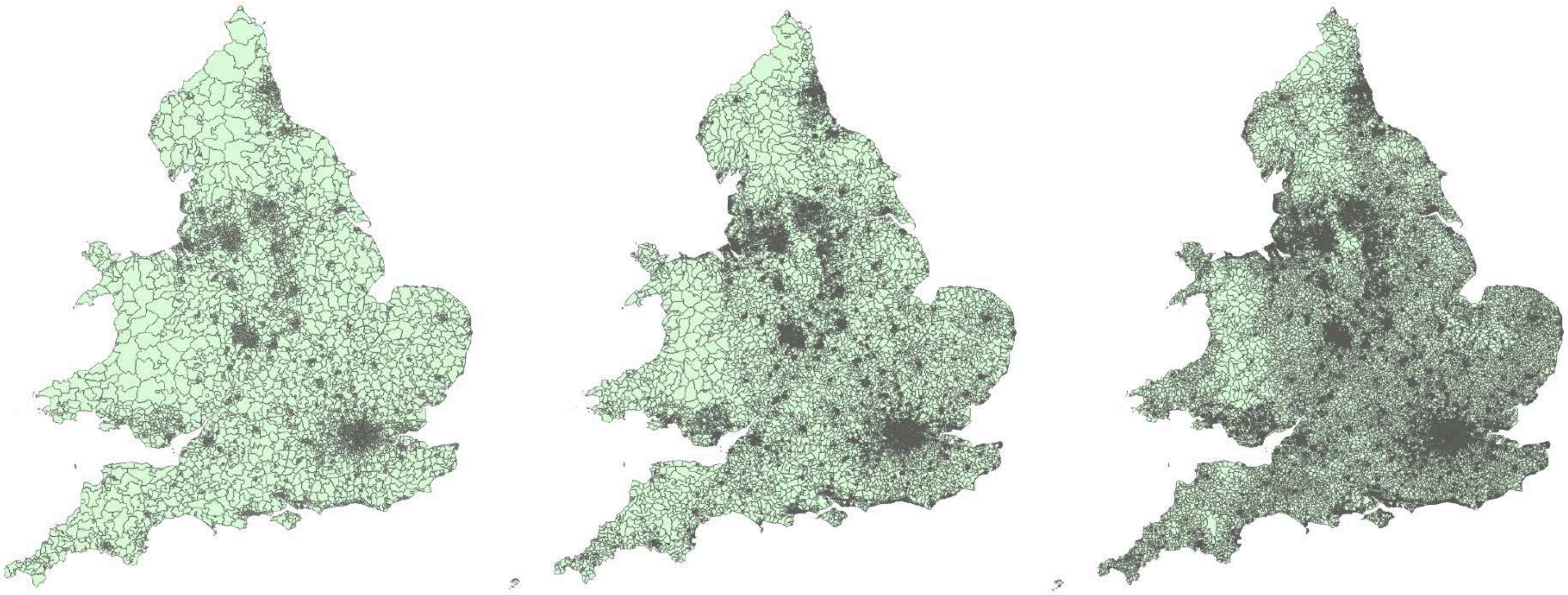
Even our statistics breaks down when we get large numbers like over several thousand as you can see on the left and above right for 400K data points where the pattern is highly convoluted. This is from a gravity model.

Big Data Leads to Big(ger) Models

Now what happens when we really do scale up to the level of MSOAs of which there are 7201 in the UK – do we partition the spatial system and argue we don't need to scale up to $n^2=7201^2=51,854,401$?

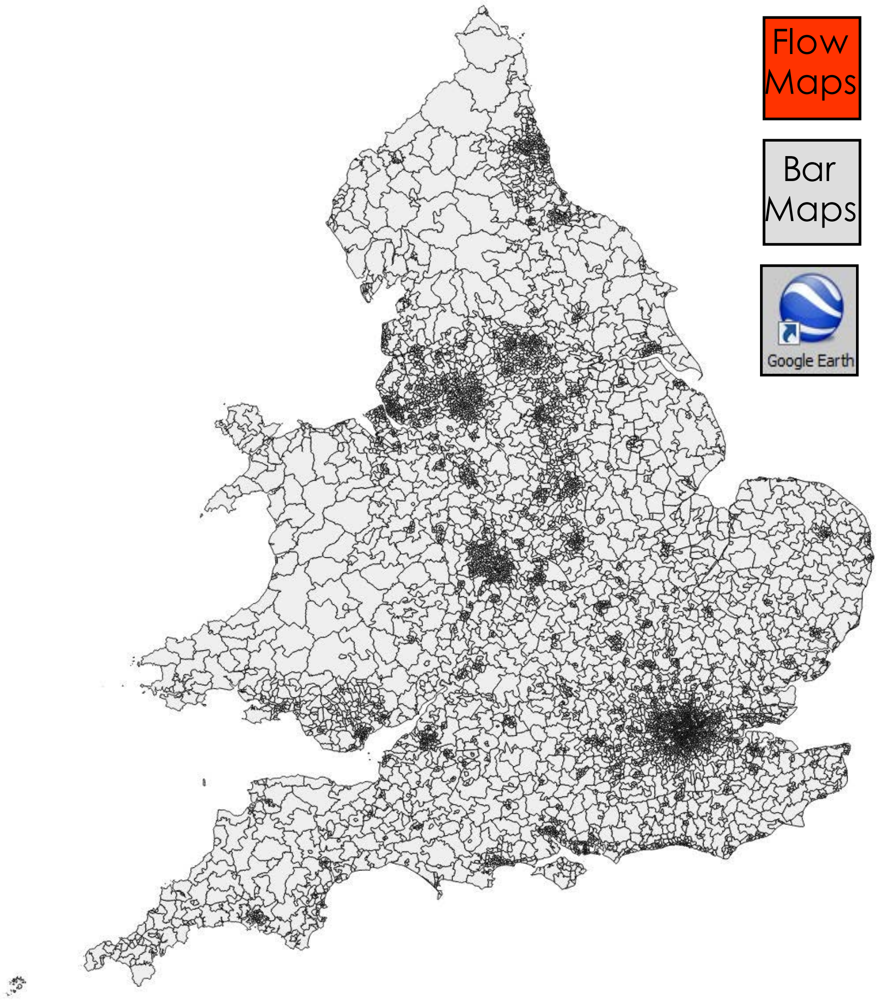
Circa 52 million points is an issue but our models run in a matter of seconds but that is a lot of data to store – ok it is sparse but sparsity isn't structured so we can't easily partition and in any case we want to compute any possible flow e.g. between, say central London and say Newcastle. Here is the problem scaled up and this is what we are grappling with at present.

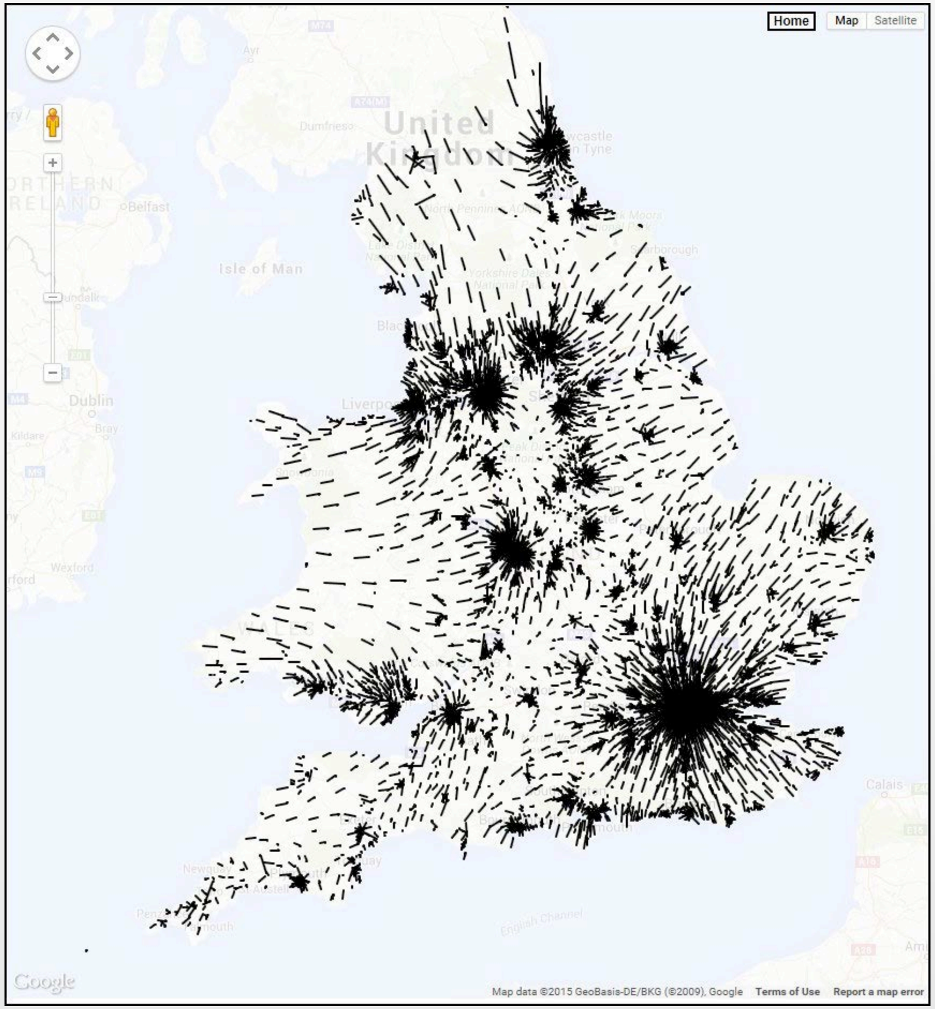




(a) MSOA (A=7201) (b) LSOA (A=34753) (c) OA (A=181408)

ONS Geographies for MSOA, LSOA and OA levels.





$$[x_i, y_i] = [[x_i, y_i], \left[\left[x_i + \frac{\sum_j T_{ij}\,[x_i - x_j]}{n}\right], \left[y_i + \frac{\sum_j T_{ij}\,[y_i - yy_j]}{n}\right]\right]]$$

An Idea of the Model:

Essentially a couple of nested spatial interaction-discrete choice-like models – one for residential, the other for the retail sector, cross sectional static

$$T_{ij}^{k} = O_i \frac{D_j^{obs} \exp(-\beta^k d_{ij}^k)}{\sum_k \sum_j D_j^{obs} \exp(-\beta^k d_{ij}^k)} \qquad k=1,\ k=2,\ k=3 \quad road, rail, bus$$

$$P_j = \sum_k \sum_i T_{ij}^k$$

$$S_{j\ell}^{k} = P_j \frac{W_\ell^{obs} \exp(-\lambda^k d_{j\ell}^k)}{\sum_k \sum_\ell W_\ell^{obs} \exp(-\lambda^k d_{j\ell}^k)}$$

$$O_\ell = \sum_k \sum_j S_{j\ell}^k$$

The Web and the Desktop: Users are also Data

We are building this aggregate LUTI model of the UK – well E&W at present – we will add Scotland before long – which is of the nature we have been implying –

Without going into details, the model takes a few seconds to run – it will take a lot longer when finished as we will add sectors and of course the number of big data we have to hold in RAM might be very large – currently we need to hold 3 x 2 such 52 million sized matrices – we may need to go up to multiples of this and that will involve a lot of packing and moving in and out of core, I think

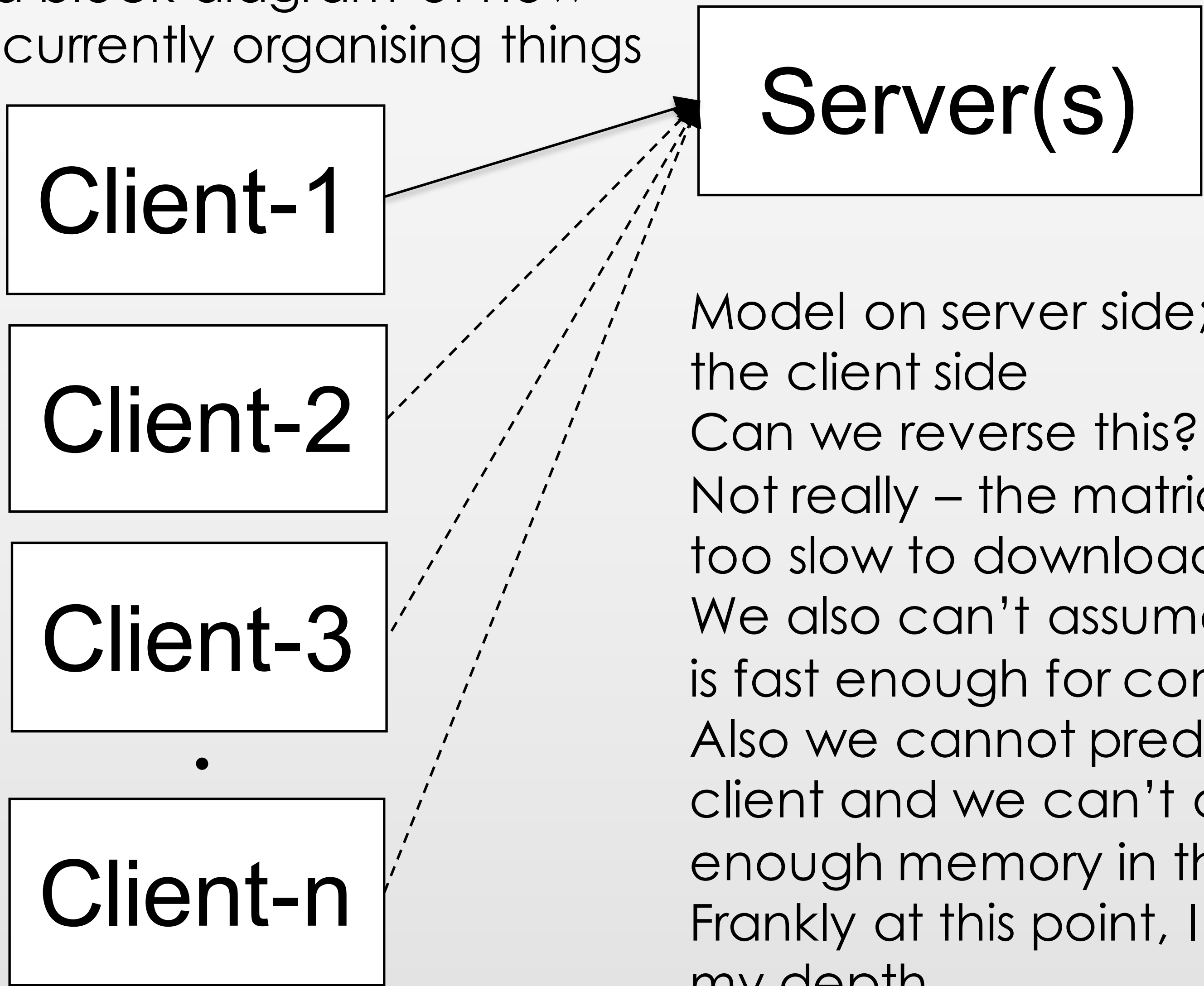
But the real issue is users – if our model is this large, and we have many users, then our data problem is exploded by the users –

Our big data is our original and predicted data from the model, times the number of users. Why are users data ? Well because they are using data differently – they are making their own predictions and thus scaling up the data.

We could have one model for each user but we don't know who the users are? We thus want them to access this on the web.... Let me see if I can demo it from here – in fact I am hoping you have some web links ……if you haven't then you can do it on your phone and then it really does look dreadful –

The Web and the Desktop: Users are also Data

Here is a block diagram of how we are currently organising things



Model on server side; Maps on the client side
Can we reverse this?
Not really – the matrices are too slow to download to client?
We also can't assume the client is fast enough for computation.
Also we cannot predict the client and we can't assume enough memory in the client
Frankly at this point, I am out of my depth

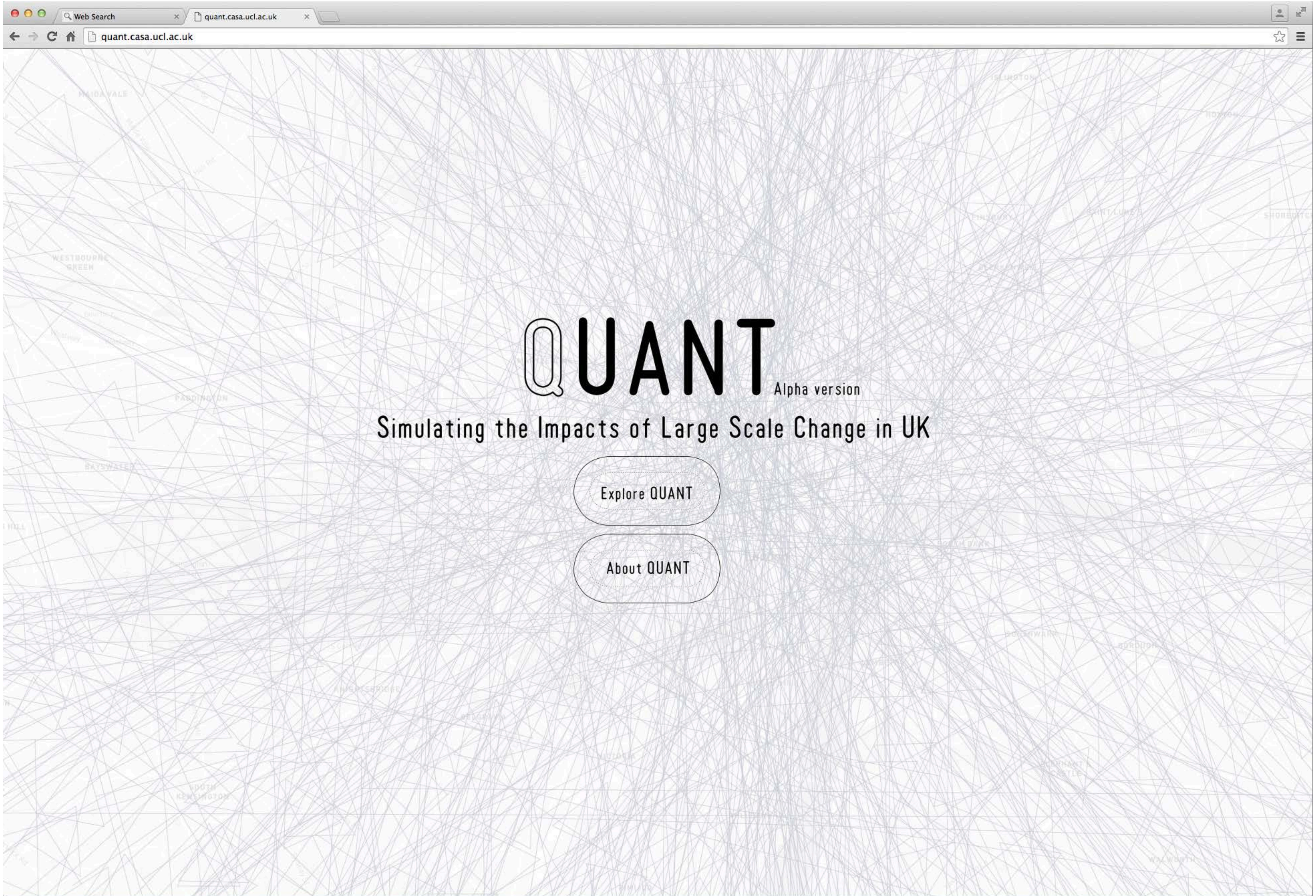
So Let Me Give You A Demo Of What We Are Doing

The web link is

http://quant.casa.ucl.ac.uk/

For those who want to try it out

There is always ***a caveat emptor*** with demo models like this. We are building it as a demo for the FCC and it not supposed to be a flashy app or anything – it is something that local authority planners and consultants might use as a resource along with many other complementary decision support tools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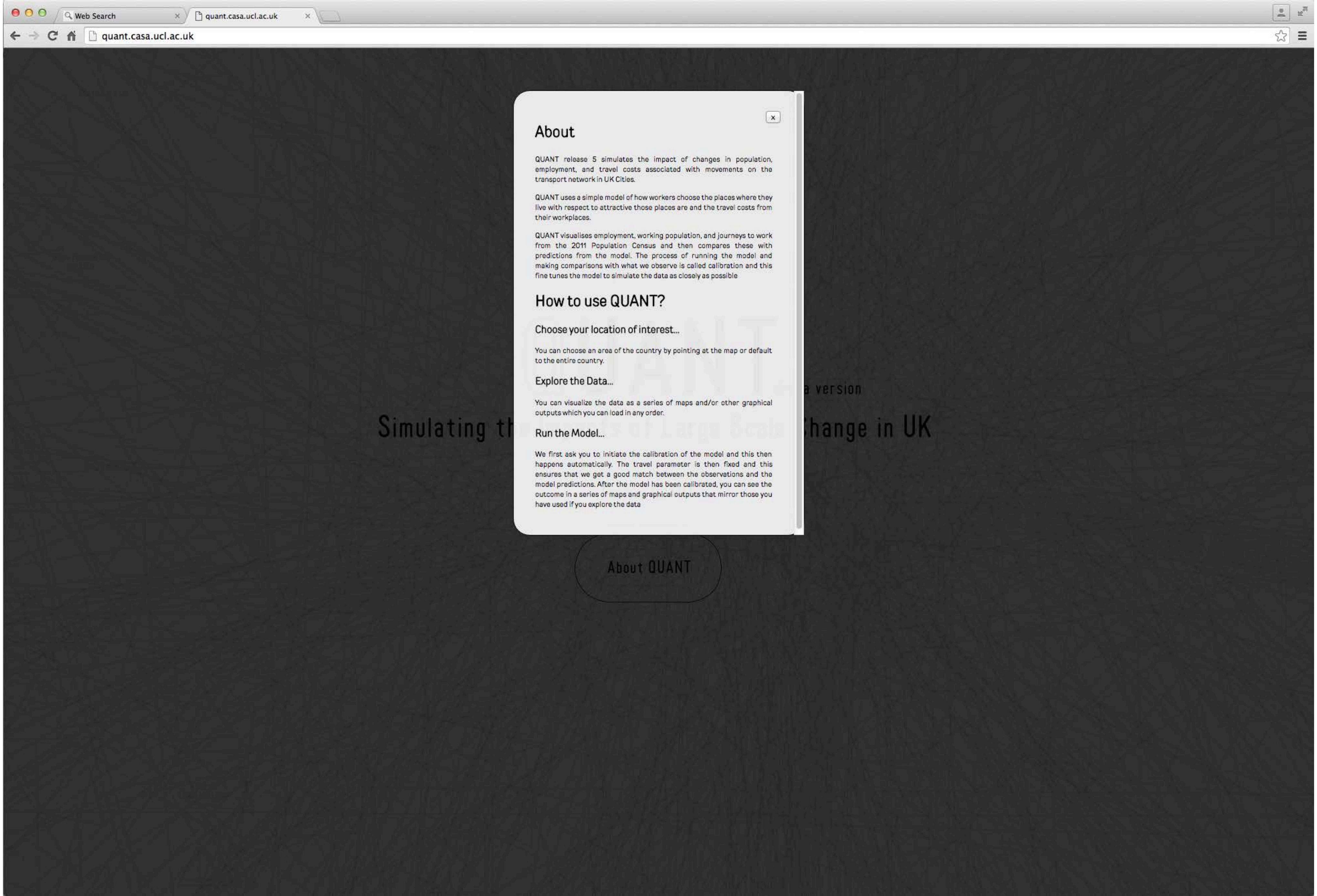
quant.casa.ucl.ac.uk
QUANT
Alpha version
Simulating the Impacts of Large Scale Change in UK
Explore QUANT
About QUANT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quant.casa.ucl.ac.uk
quant.casa.ucl.ac.uk
About
QUANT release 5 simulates the impact of changes in population, employment, and travel costs associated with movements on the transport network in UK Cities.
QUANT uses a simple model of how workers choose the places where they live with respect to attractive those places are and the travel costs from their workplaces.
QUANT visualises employment, working population, and journeys to work from the 2011 Population Census and then compares these with predictions from the model. The process of running the model and making comparisons with what we observe is called calibration and this fine tunes the model to simulate the data as closely as possible
How to use QUANT?
Choose your location of interest...
You can choose an area of the country by pointing at the map or default to the entire country.
Explore the Data...
You can visualize the data as a series of maps and/or other graphical outputs which you can load in any order.
Run the Model...
We first ask you to initiate the calibration of the model and this then happens automatically. The travel parameter is then fixed and this ensures that we get a good match between the observations and the model predictions. After the model has been calibrated, you can see the outcome in a series of maps and graphical outputs that mirror those you have used if you explore the data
a version
Simulating th
hange in UK
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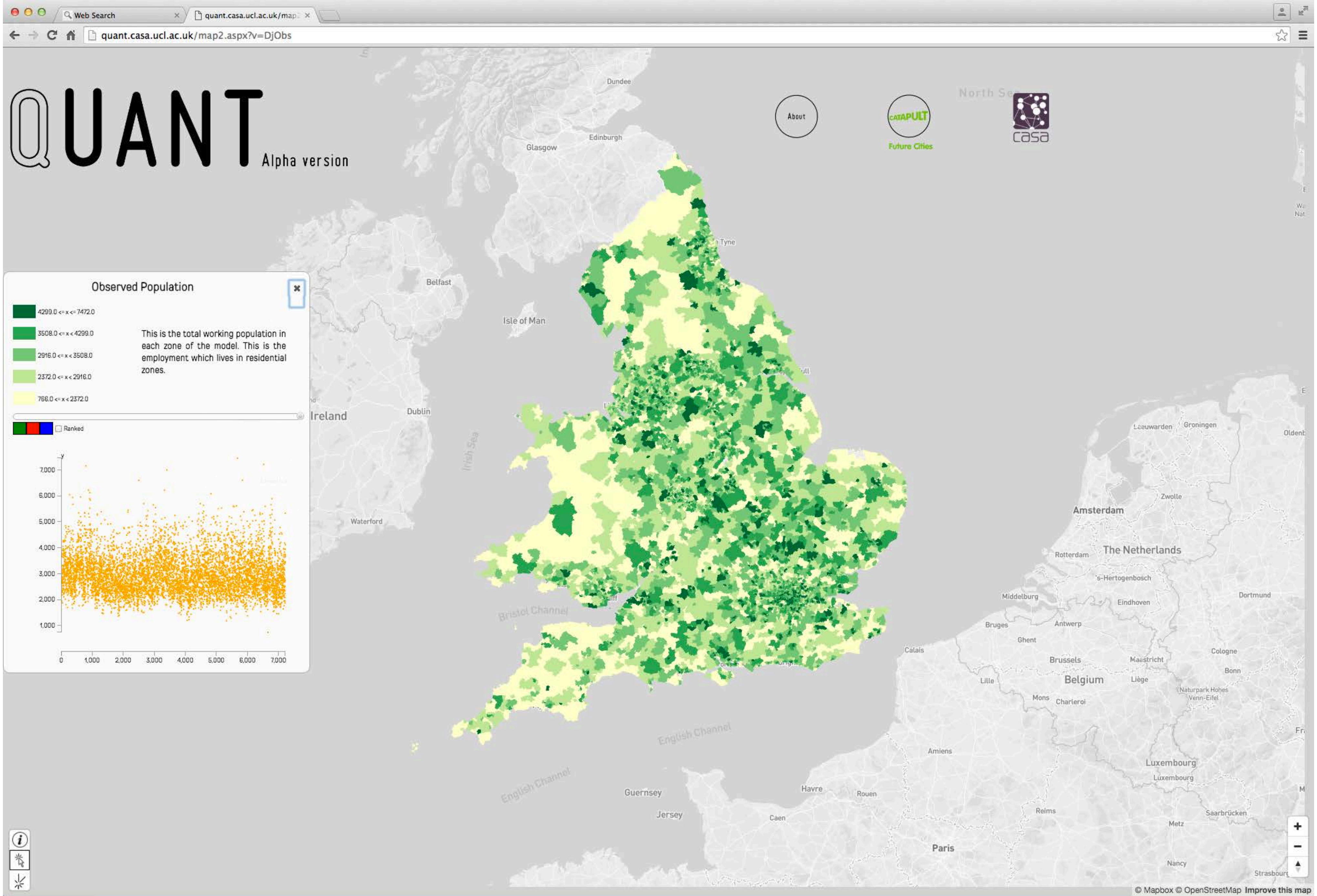
Employment
Population
Work Flows
United Kingdom



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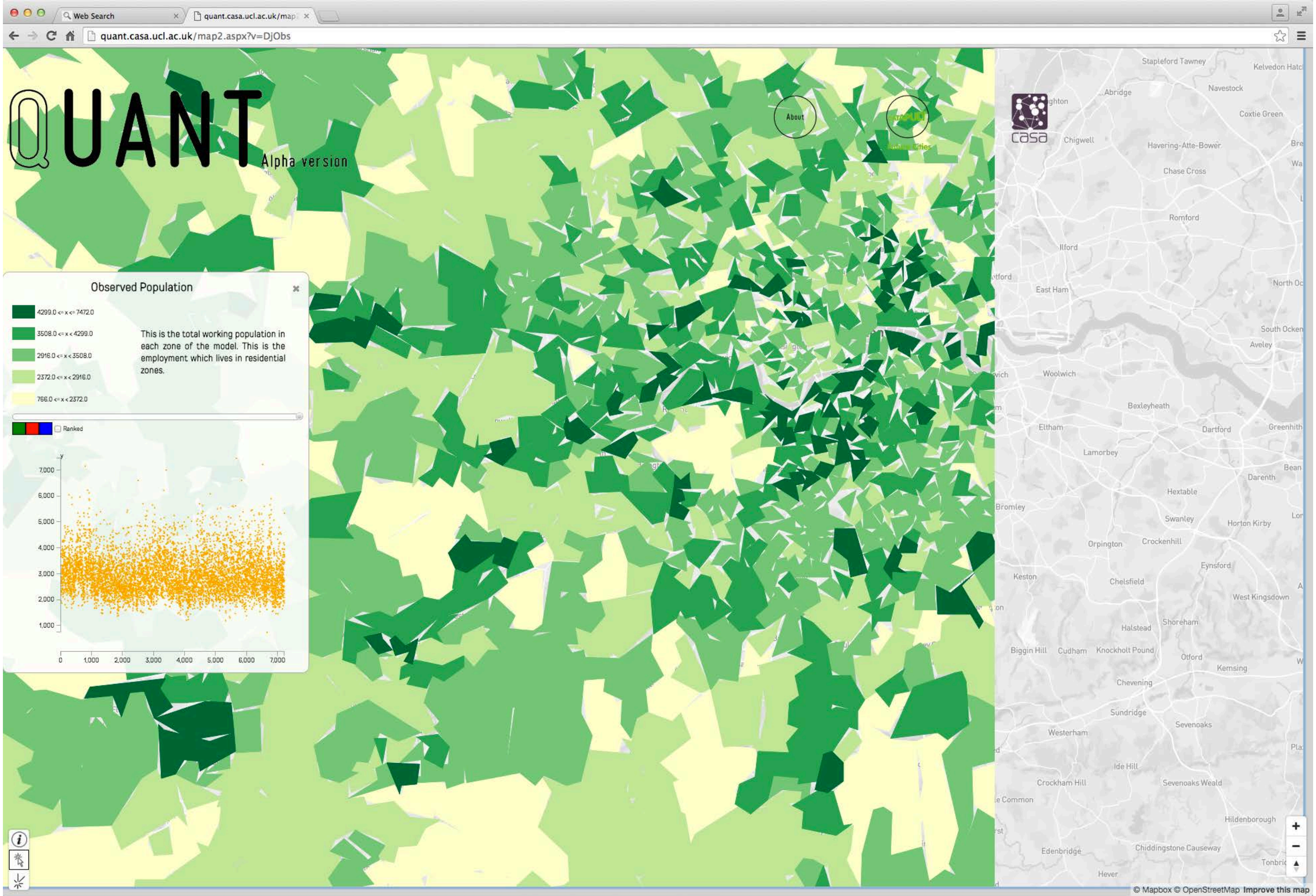
Web Search
quant.casa.ucl.ac.uk/map2
quant.casa.ucl.ac.uk/map2.aspx?v=DjObs
QUANT
Alpha version
About
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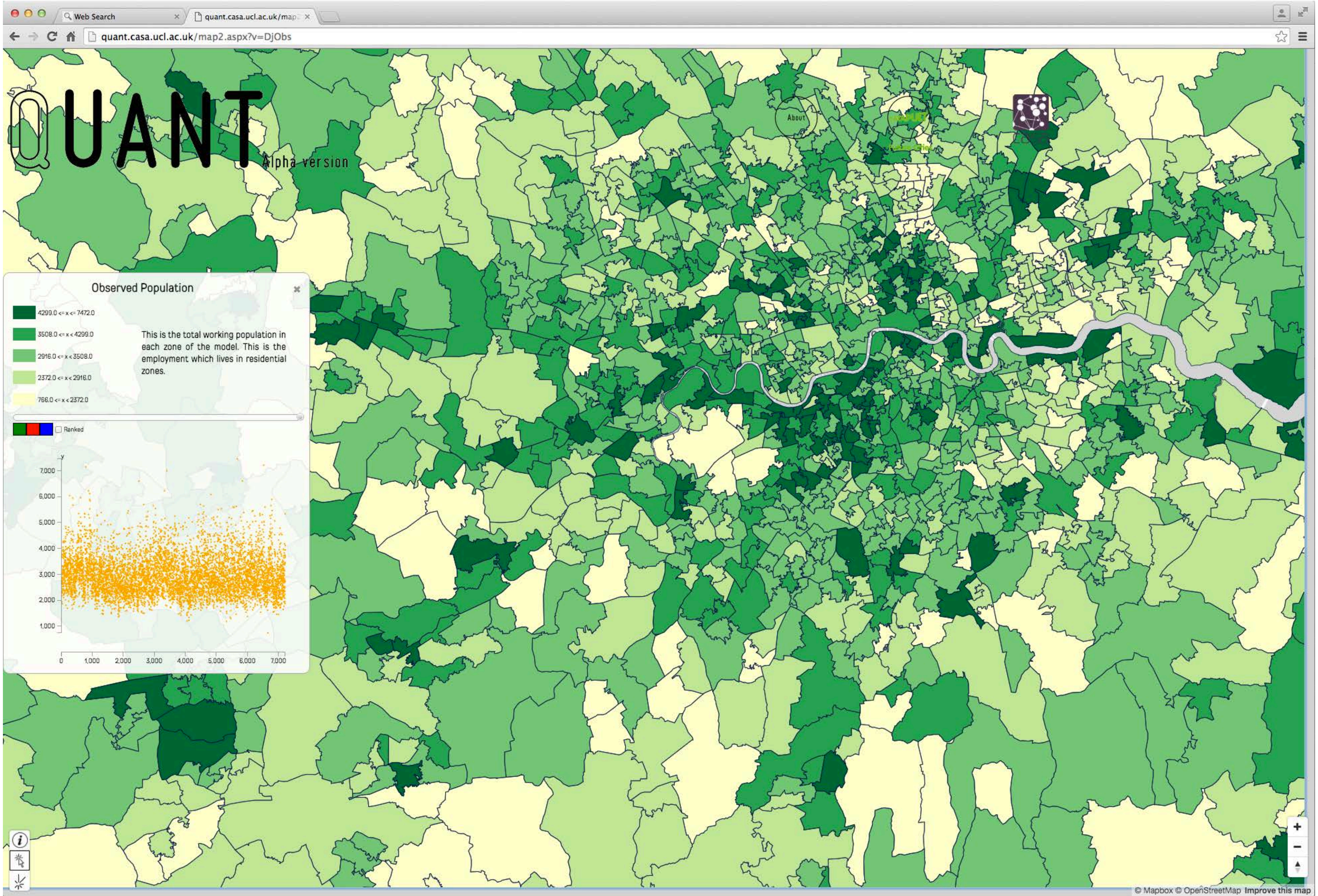
Observed Population
4299.0 <= x <= 7472.0
3508.0 <= x < 4299.0
2916.0 <= x < 3508.0
2372.0 <= x < 2916.0
766.0 <= x < 2372.0
This is the total working population in each zone of the model. This is the employment which lives in residential zones.
Ranked
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Stapleford Tawney
Abridge
Navestock
Coxtie Green
Chigwell
Havering-Atte-Bower
Chase Cross
Romford
Ilford
East Ham
Woolwich
Bexleyheath
Eltham
Dartford
Lamorbey
Darenth
Hextable
Bromley
Swanley
Horton Kirby
Orpington
Crockenhill
Eynsford
Keston
Chelsfield
West Kingsdown
Halstead
Shoreham
Biggin Hill
Cudham
Knockholt Pound
Otford
Kemsing
Chevening
Sundridge
Sevenoaks
Westerham
Ide Hill
Crockham Hill
Sevenoaks Weald
Hildenborough
Edenbridge
Chiddingstone Causeway
Hever
South Ockendon
Aveley
Greenhithe
© Mapbox © OpenStreetMap Improve this map


Web Search
quant.casa.ucl.ac.uk/map2.aspx?v=DjObs
QUANT
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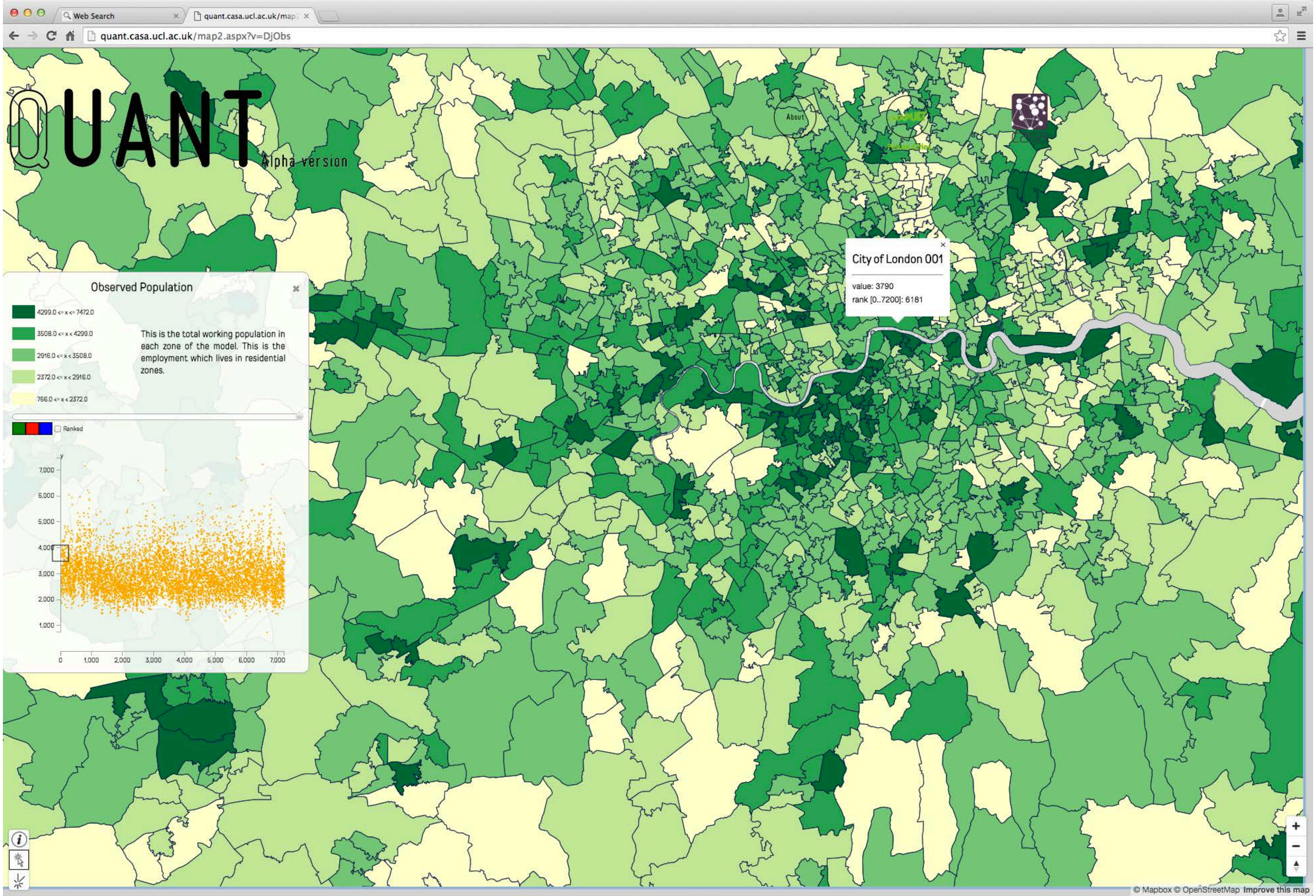
2,000
1,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
© Mapbox © OpenStreetMap Improve this map



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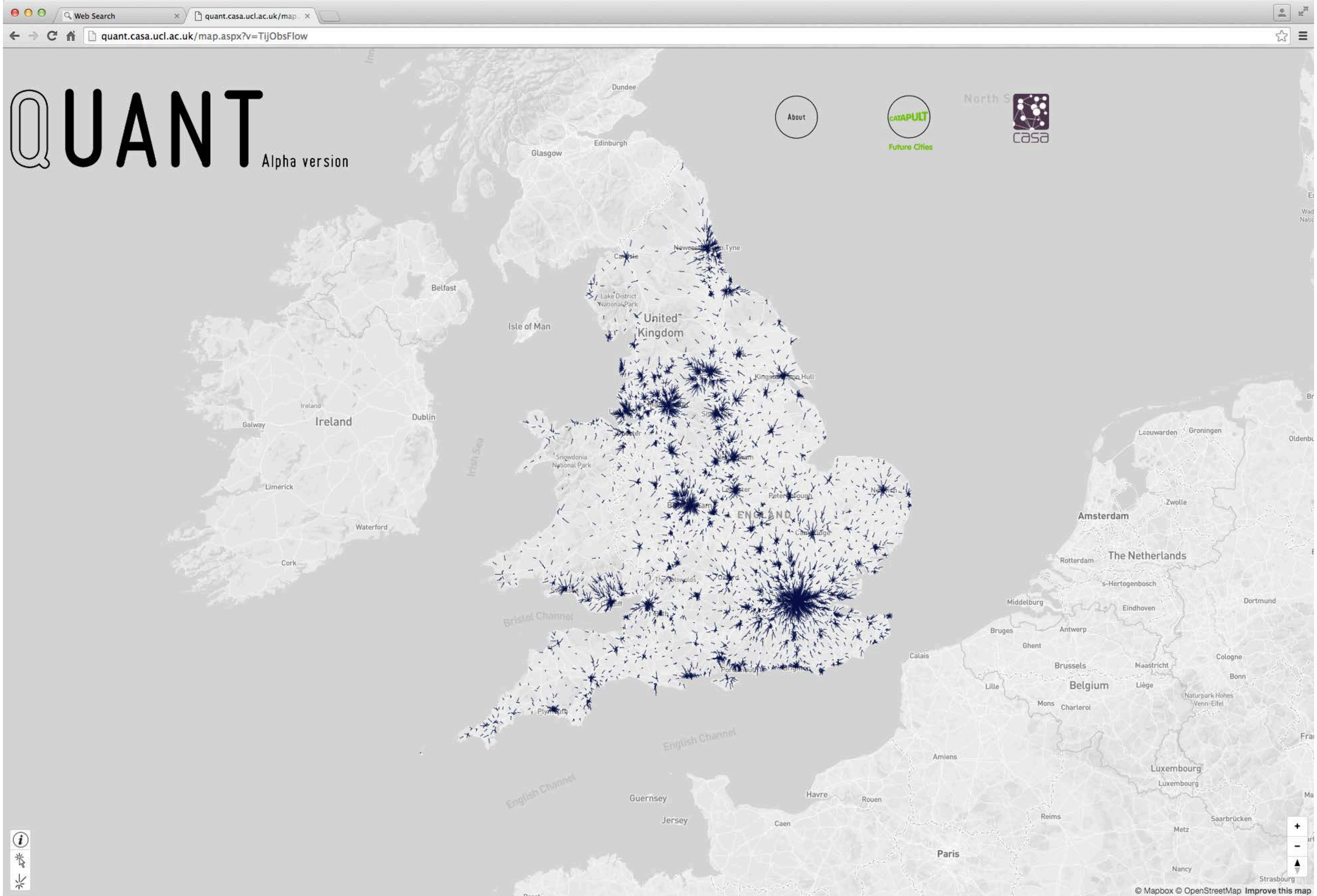

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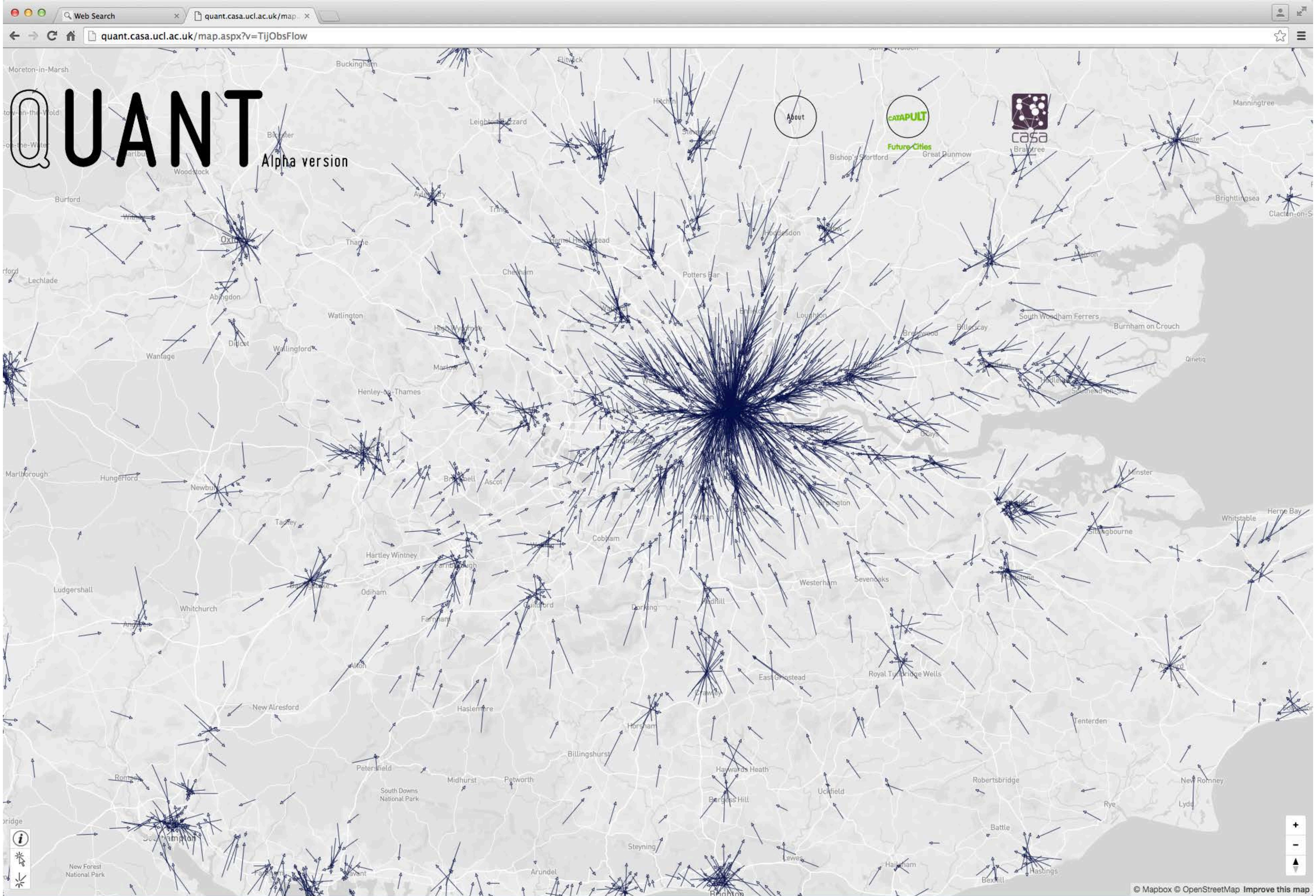
quant.casa.ucl.ac.uk/map.aspx?v=TijObsFlow
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CATAPULT
Future Cities
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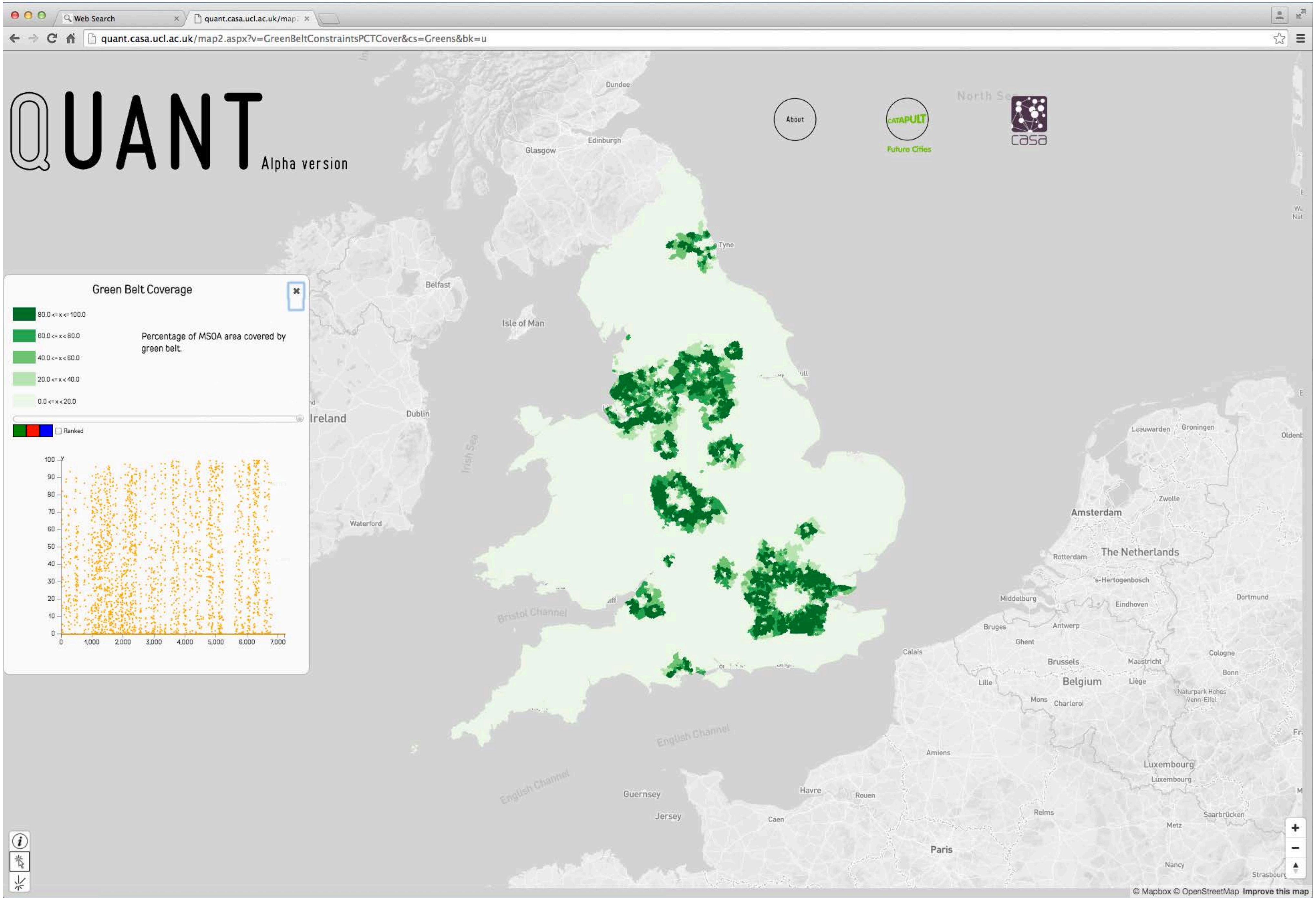

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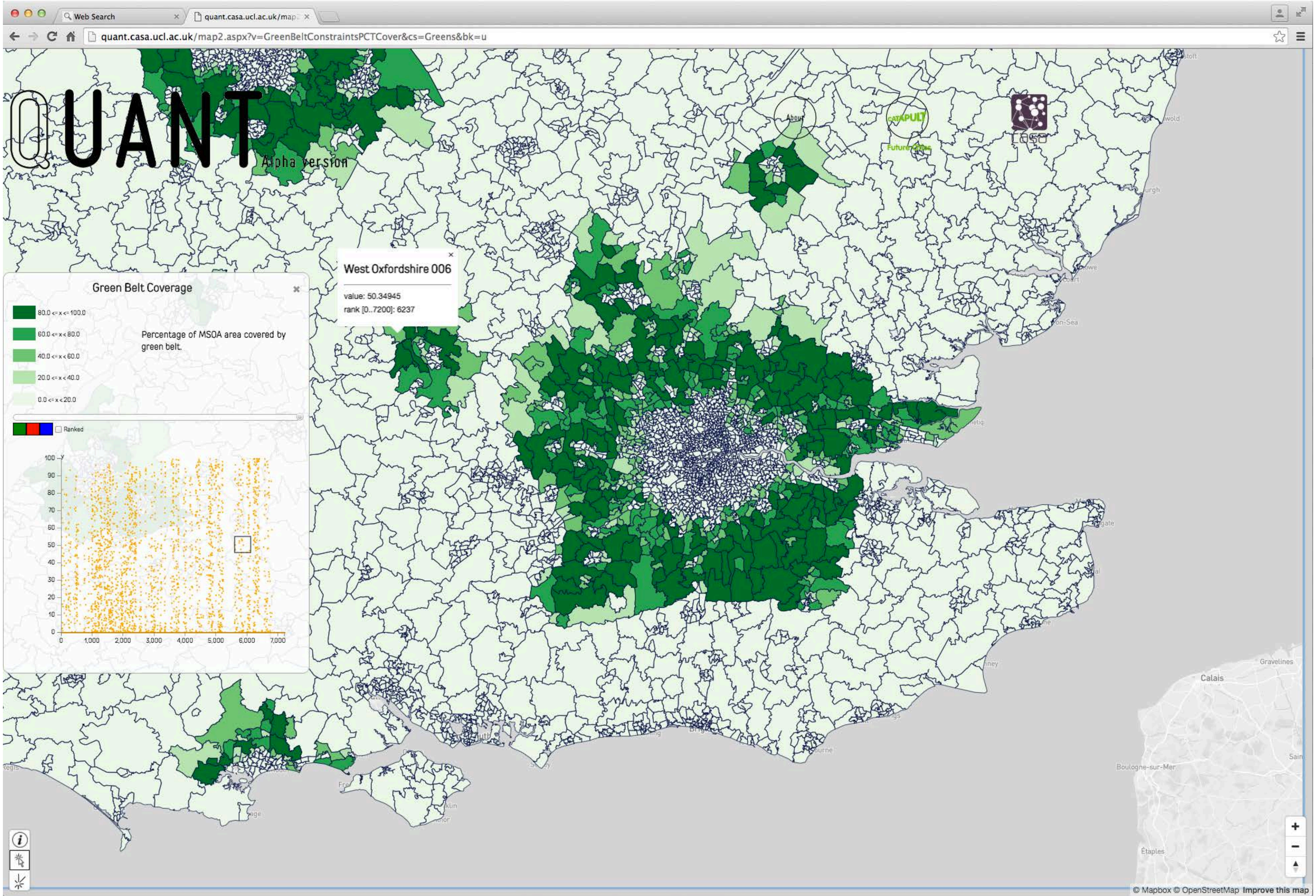
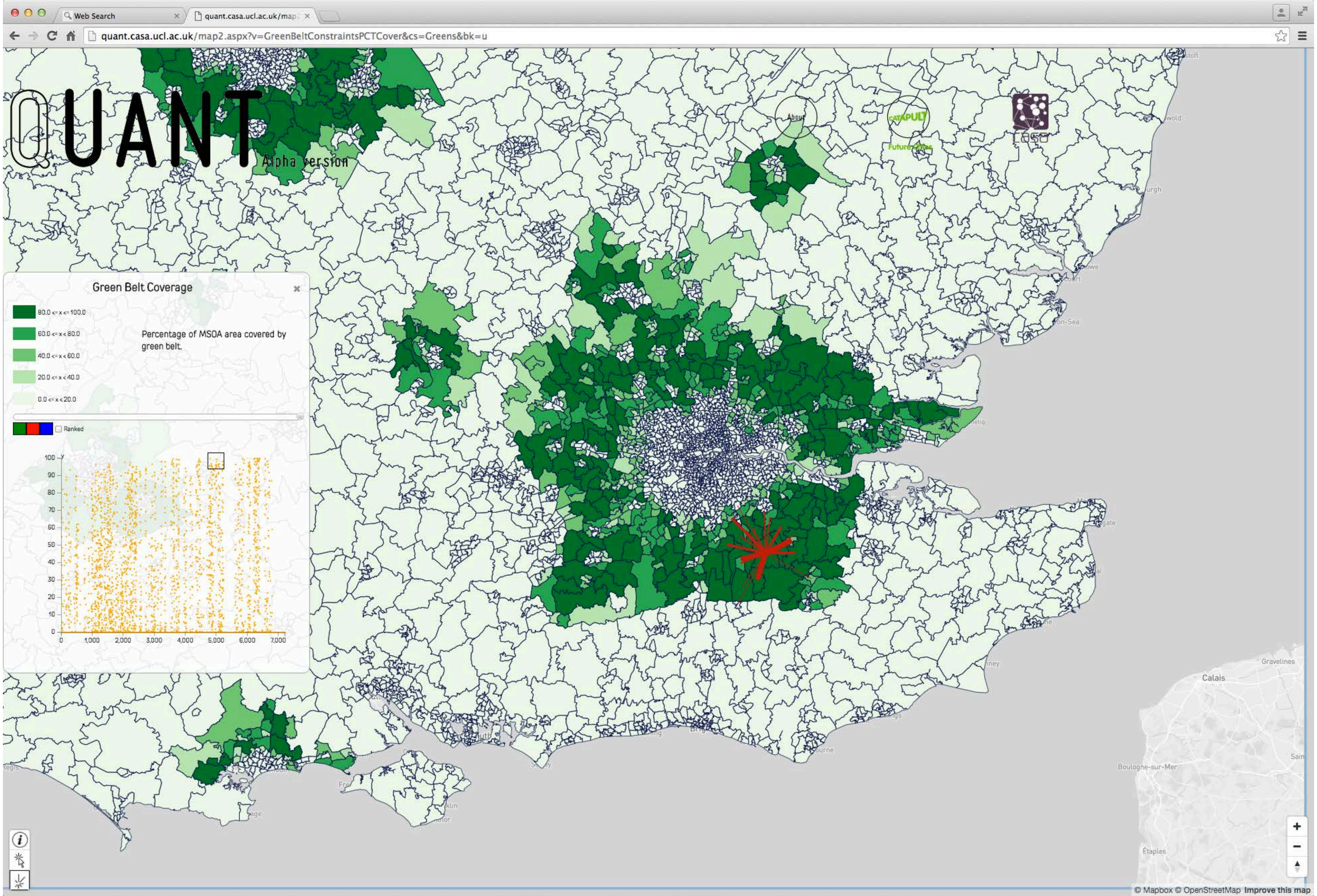


quant.casa.ucl.ac.uk/map2.aspx?v=GreenBeltConstraintsPCTCover&cs=Greens&bk=u
QUANT
Alpha version
West Oxfordshire 006
value: 50.34945
rank [0..7200]: 6237
Green Belt Coverage
80.0 <= x <= 100.0
60.0 <= x < 80.0
40.0 <= x < 60.0
20.0 <= x < 40.0
0.0 <= x < 20.0
Percentage of MSOA area covered by green belt.
Ranked
Calais
Boulogne-sur-Mer
© Mapbox © OpenStreetMap Improve this map



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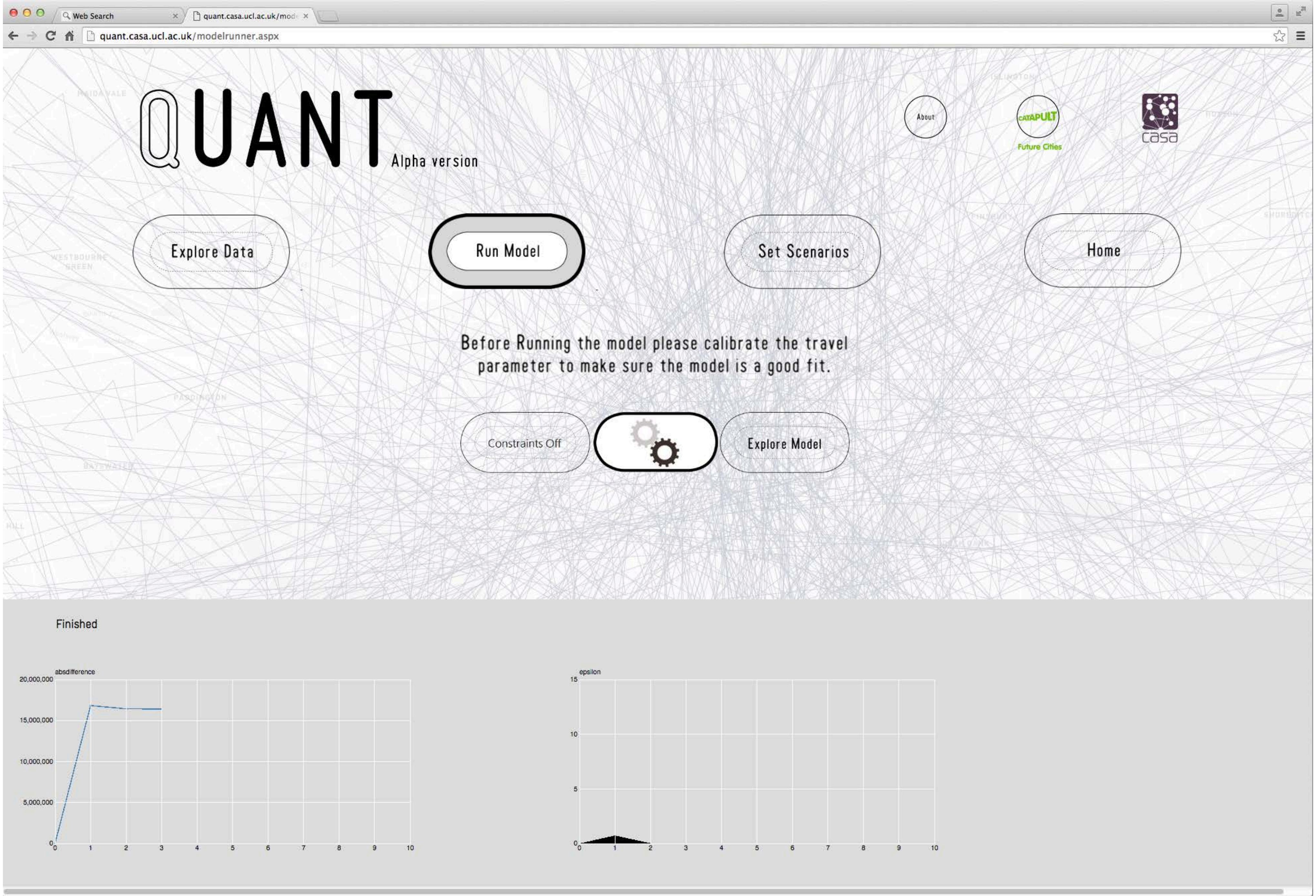
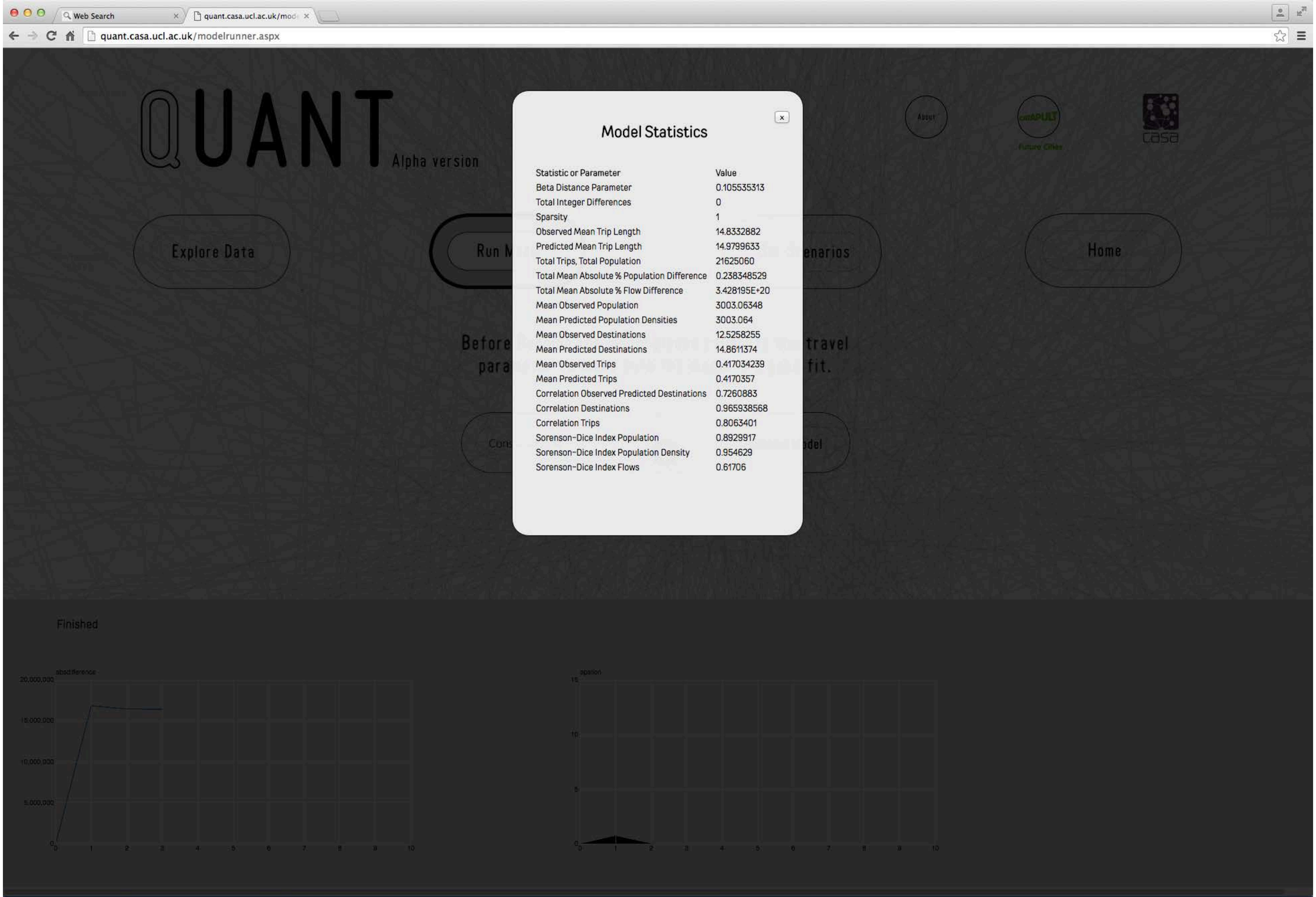
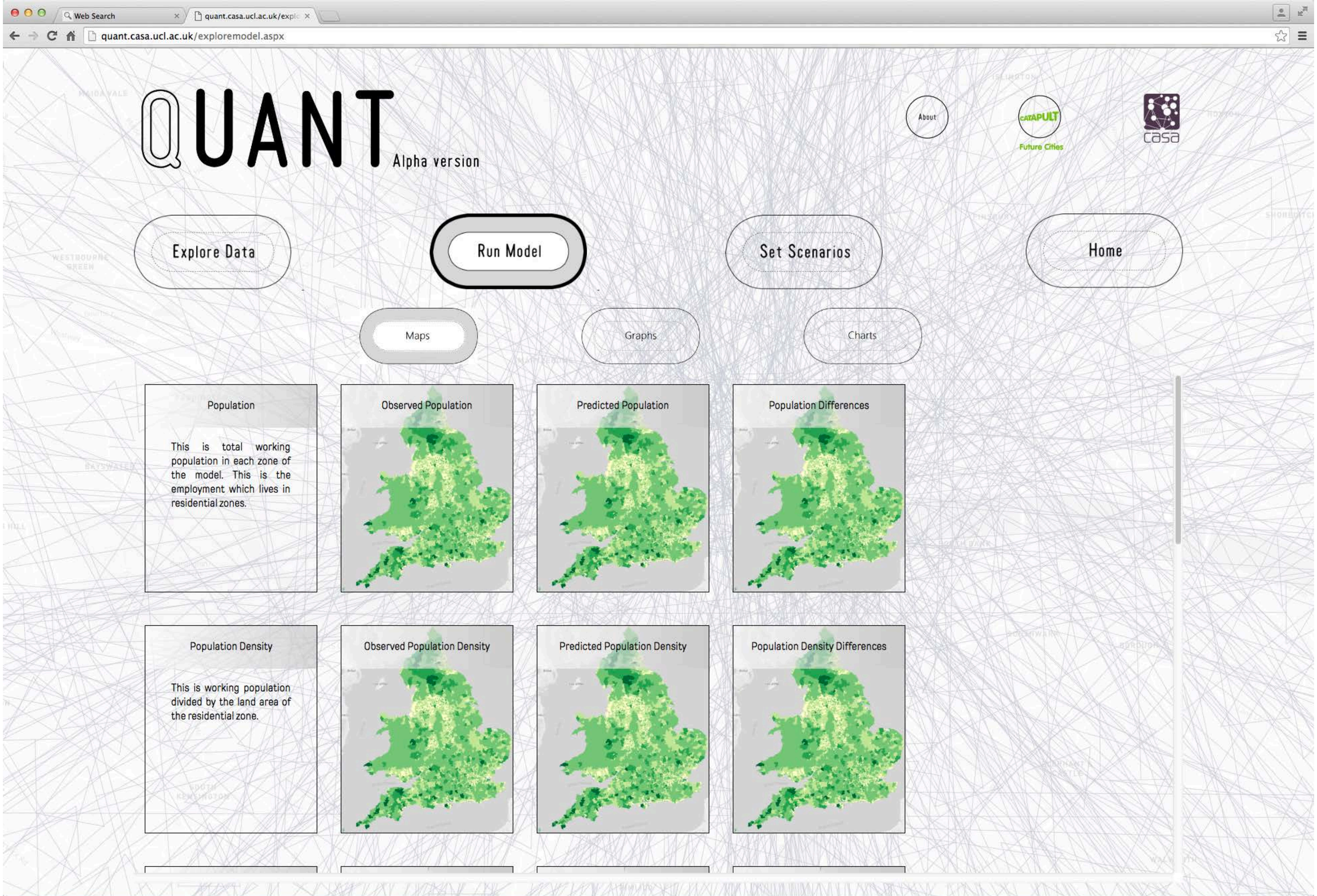

quant.casa.ucl.ac.uk/modelrunner.aspx
QUANT
Alpha version
About
Future Cities
casa
Explore Data
Run Model
Set Scenarios
Home
Before Running the model please calibrate the travel parameter to make sure the model is a good fit.
Constraints Off
Explore Model
Finished
absdifference
20,000,000
15,000,000
10,000,000
5,000,000
0
epsilon
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10



Statistic or Parameter	Value
Beta Distance Parameter	0.105535313
Total Integer Differences	0
Sparsity	1
Observed Mean Trip Length	14.8332882
Predicted Mean Trip Length	14.9799633
Total Trips, Total Population	21625060
Total Mean Absolute % Population Difference	0.238348529
Total Mean Absolute % Flow Difference	3.428195E+20
Mean Observed Population	3003.06348
Mean Predicted Population Densities	3003.064
Mean Observed Destinations	12.5258255
Mean Predicted Destinations	14.8611374
Mean Observed Trips	0.417034239
Mean Predicted Trips	0.4170357
Correlation Observed Predicted Destinations	0.7260883
Correlation Destinations	0.965938568
Correlation Trips	0.8063401
Sorenson-Dice Index Population	0.8929917
Sorenson-Dice Index Population Density	0.954629
Sorenson-Dice Index Flows	0.61706



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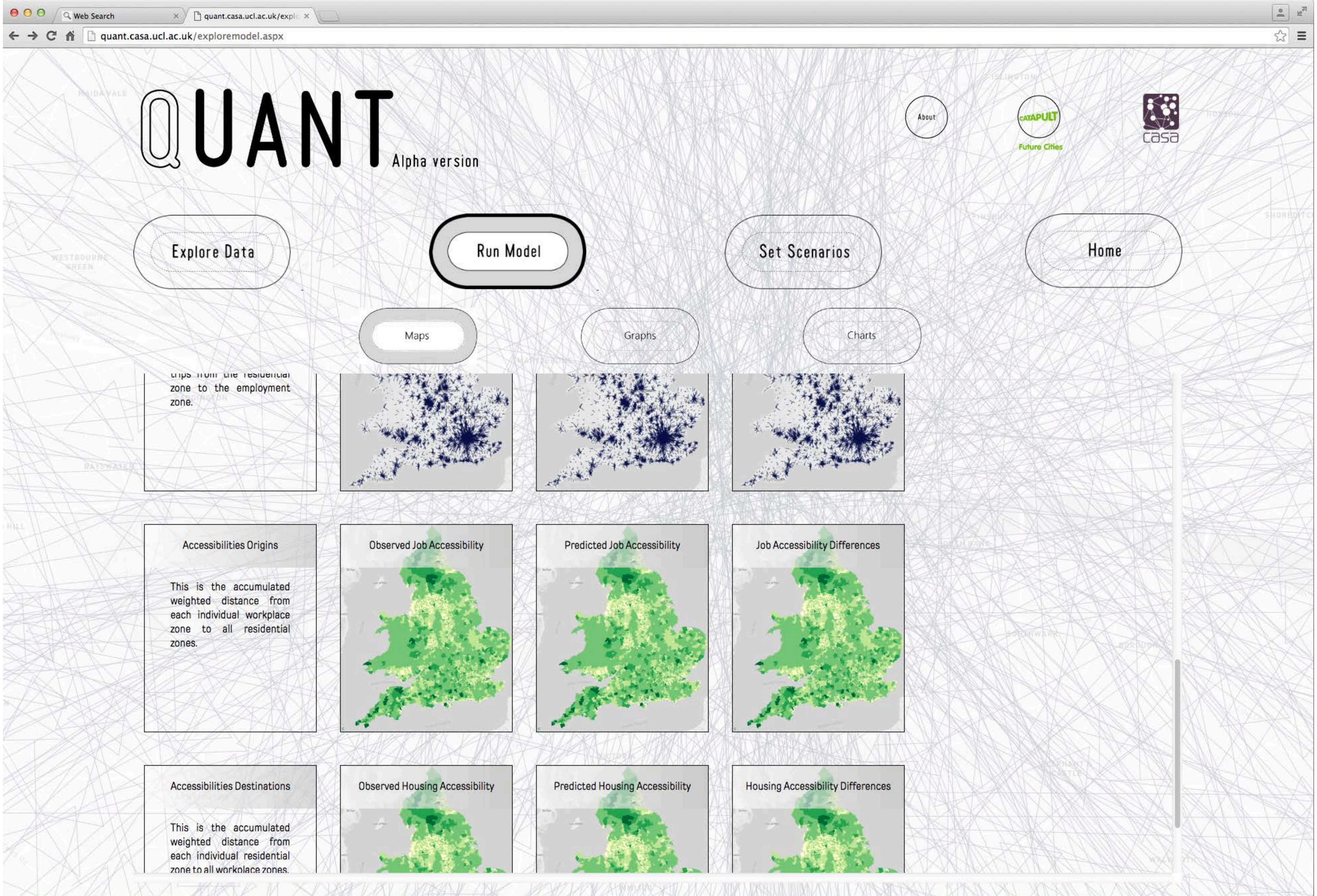
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quant.casa.ucl.ac.uk/exploremodel.aspx
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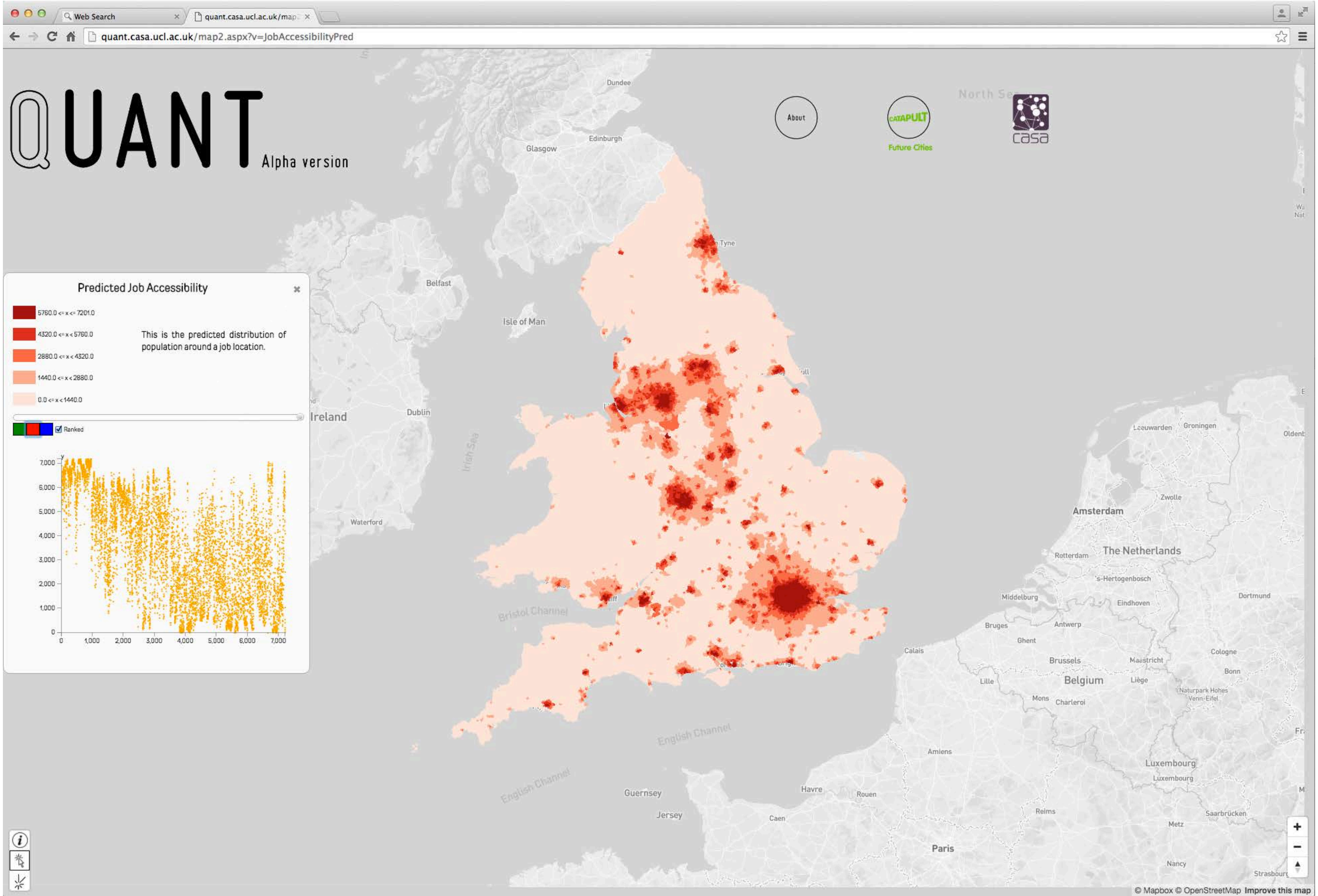
Maps
Graphs
Charts
zone to the employment zone.
Accessibilities Origins
This is the accumulated weighted distance from each individual workplace zone to all residential zones.
Observed Job Accessibility
Predicted Job Accessibility
Job Accessibility Differences
Accessibilities Destinations
This is the accumulated weighted distance from each individual residential zone to all workplace zones.
Observed Housing Accessibility
Predicted Housing Accessibility
Housing Accessibility Differences



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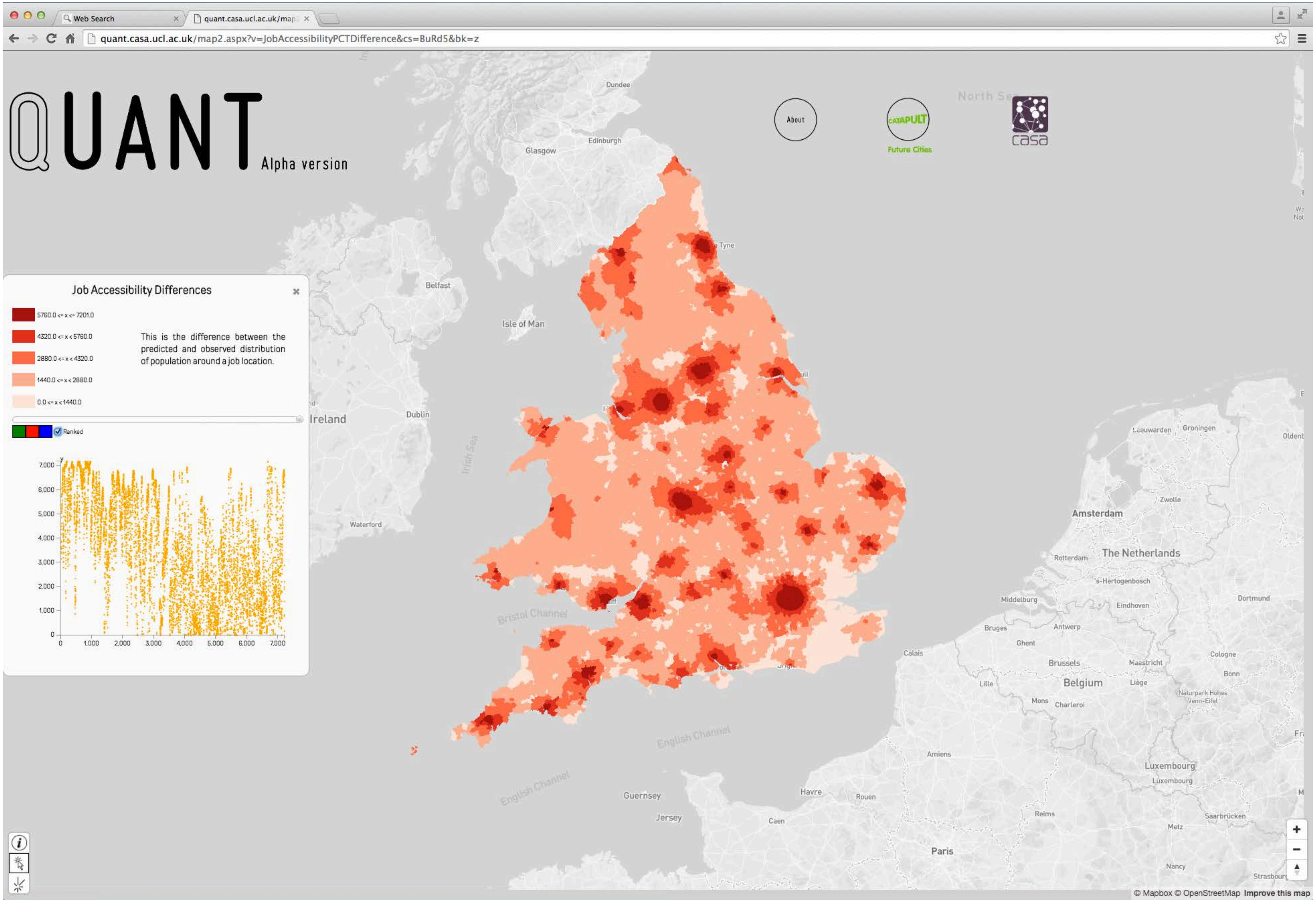

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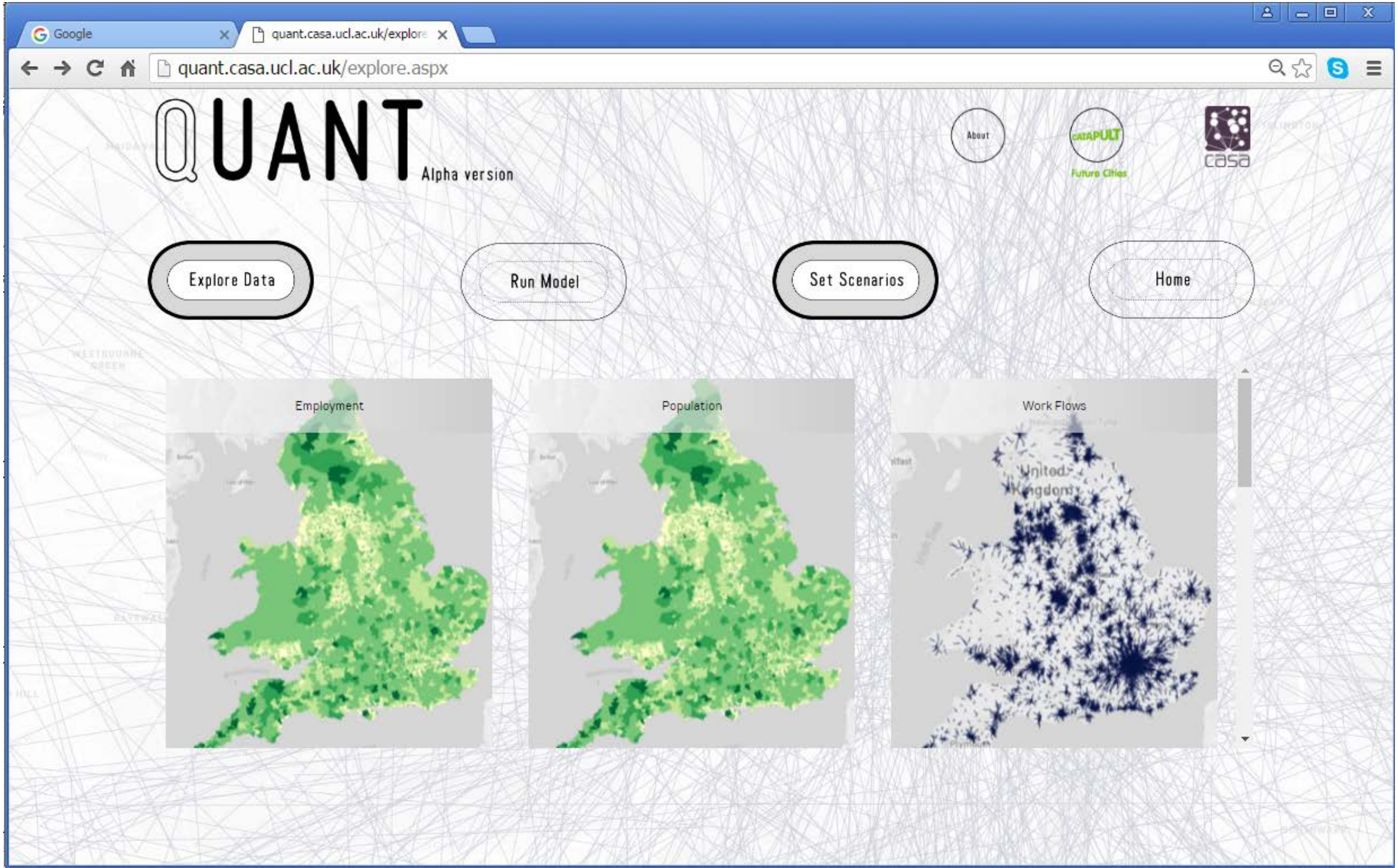
Google
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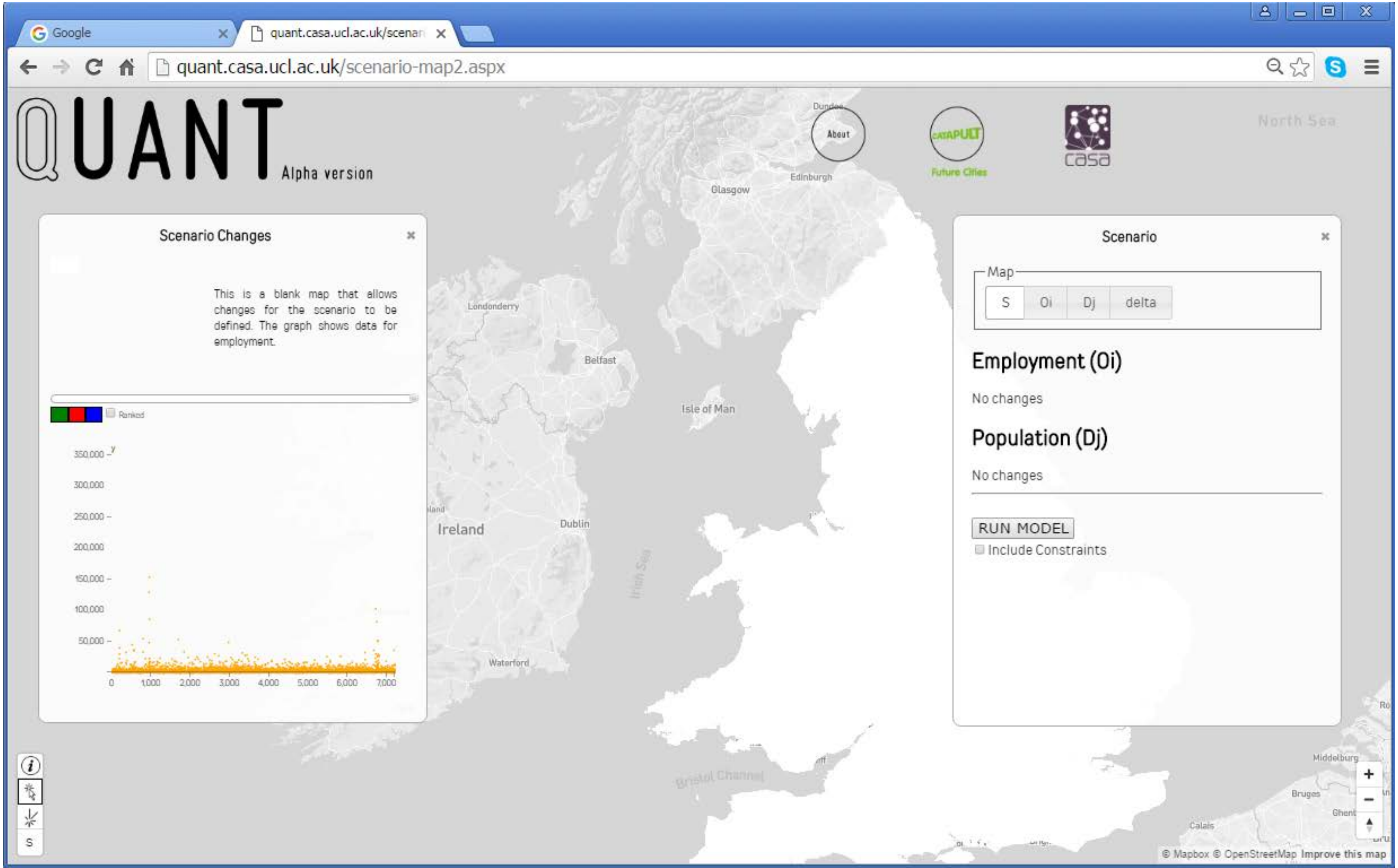
United Kingdom


Google
quant.casa.ucl.ac.uk/scenario-map2.aspx
QUANT
Alpha version
About
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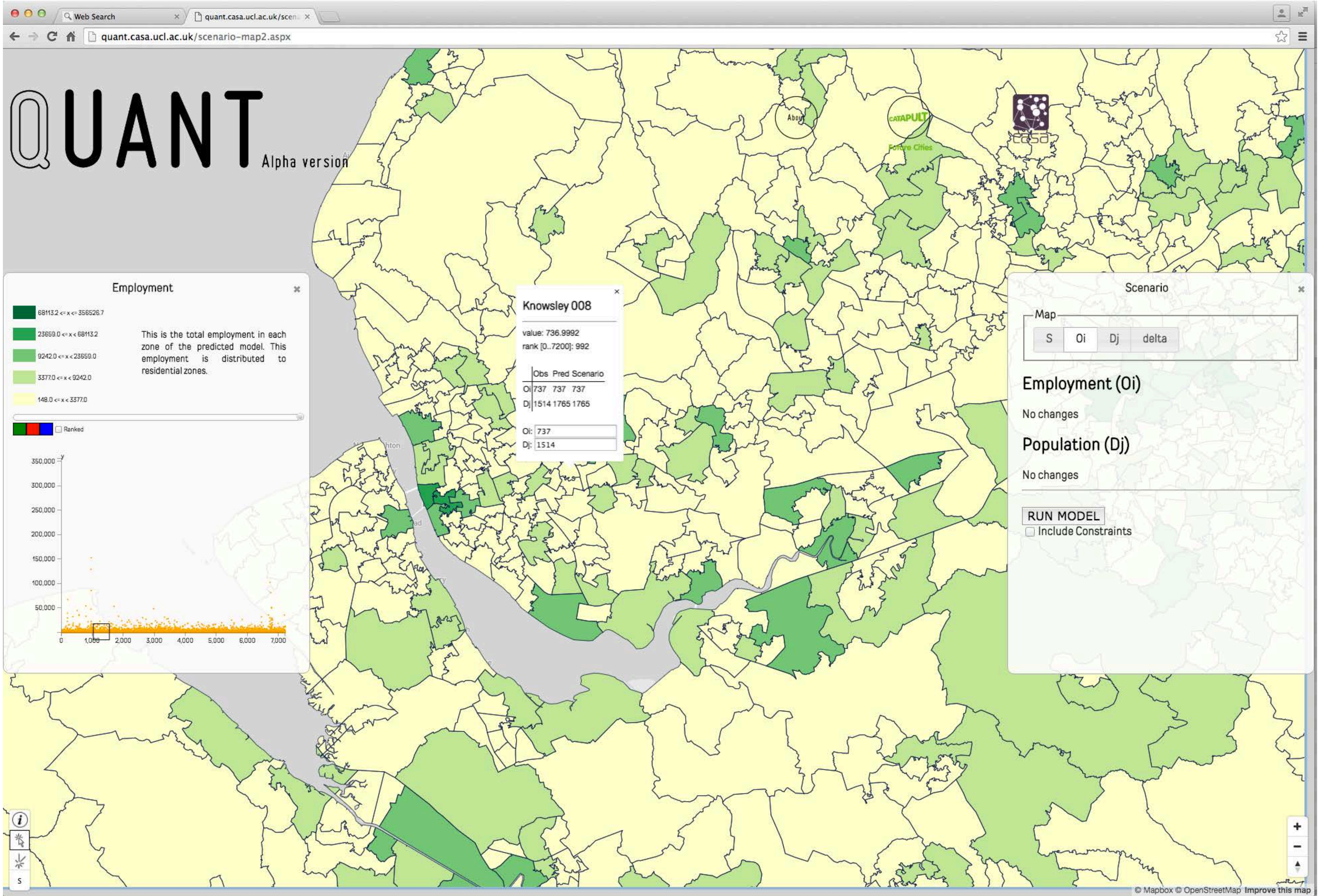
casa
North Sea
Dundee
Edinburgh
Glasgow
Scenario Changes
This is a blank map that allows changes for the scenario to be defined. The graph shows data for employment.
Ranked
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Londonderry
Belfast
Isle of Man
Ireland
Dublin
Irish Sea
Waterford
Bristol Channel
Scenario
Map
S
Oi
Dj
delta
Employment (Oi)
No changes
Population (Dj)
No changes
RUN MODEL
Include Constraints
Middelburg
Bruges
Ghent
Calais
© Mapbox © OpenStreetMap Improve this map


quant.casa.ucl.ac.uk/scenario-map2.aspx
QUANT
Alpha version
Employment
68113.2 <= x <= 356526.7
23659.0 <= x < 68113.2
9242.0 <= x < 23659.0
3377.0 <= x < 9242.0
148.0 <= x < 3377.0
This is the total employment in each zone of the predicted model. This employment is distributed to residential zones.
Ranked
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Knowsley 008
value: 736.9992
rank [0..7200]: 992
Obs Pred Scenario
Oi 737 737 737
Dj 1514 1765 1765
Oi: 737
Dj: 1514
Scenario
Map
S
Oi
Dj
delta
Employment (Oi)
No changes
Population (Dj)
No changes
RUN MODEL
Include Constraints
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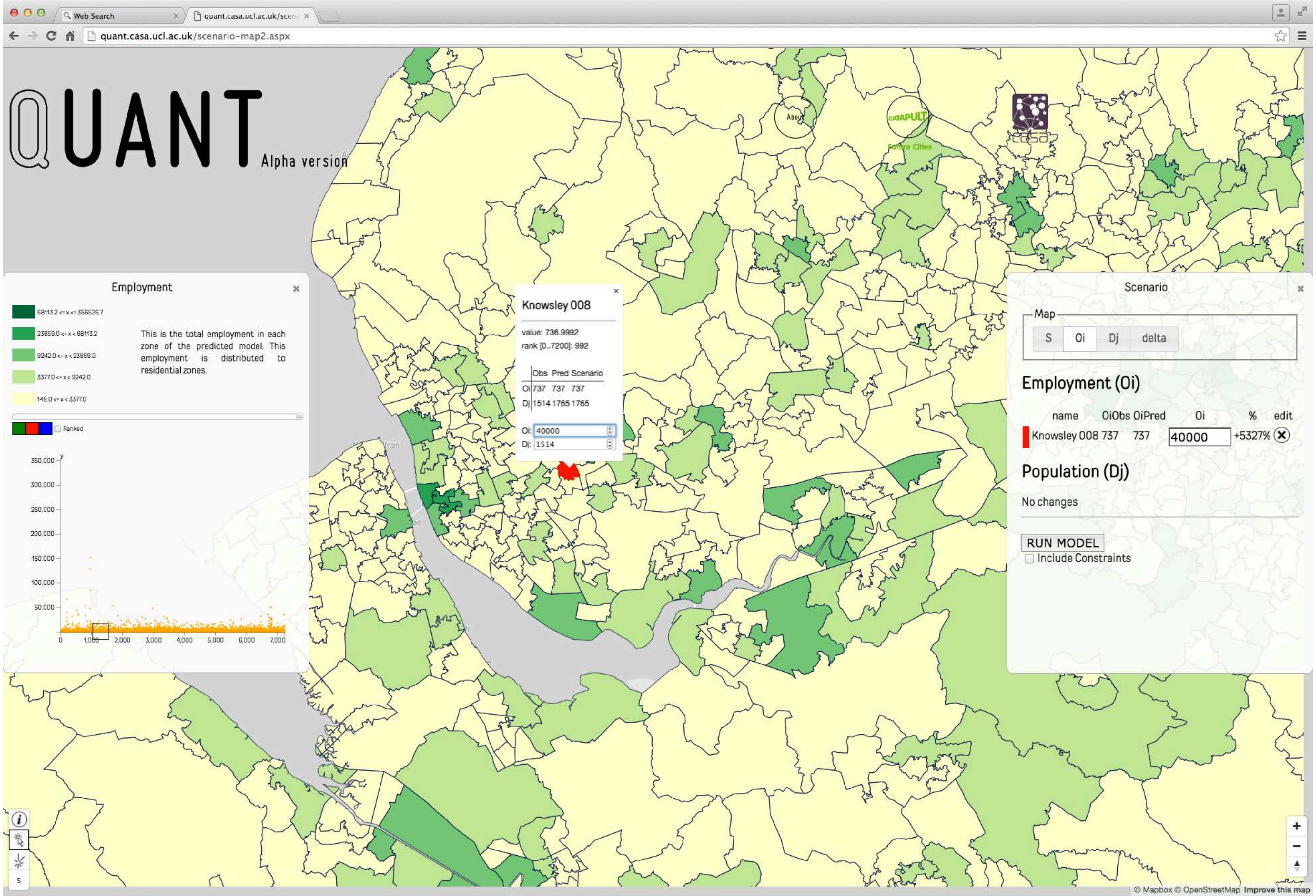

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casa

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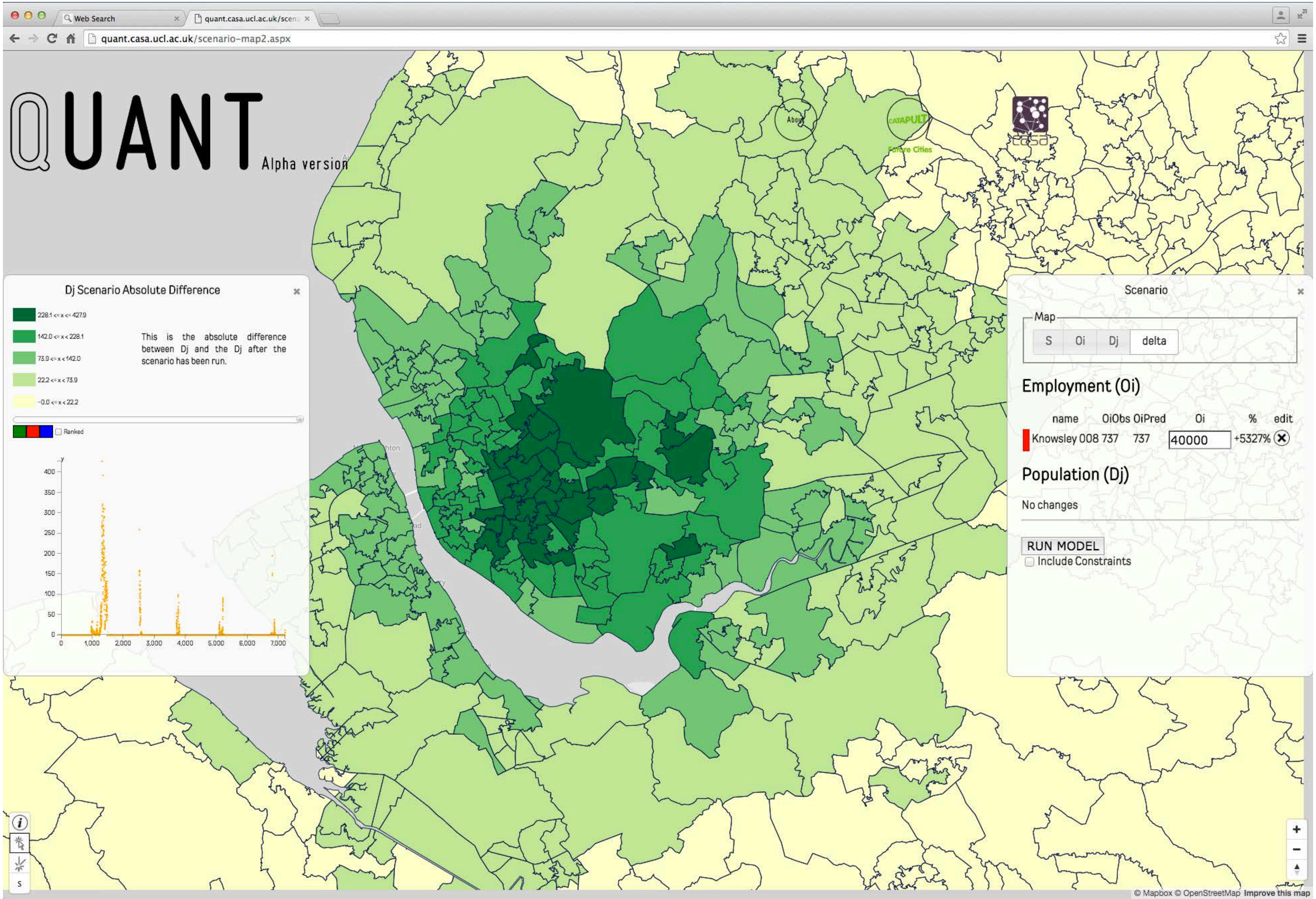

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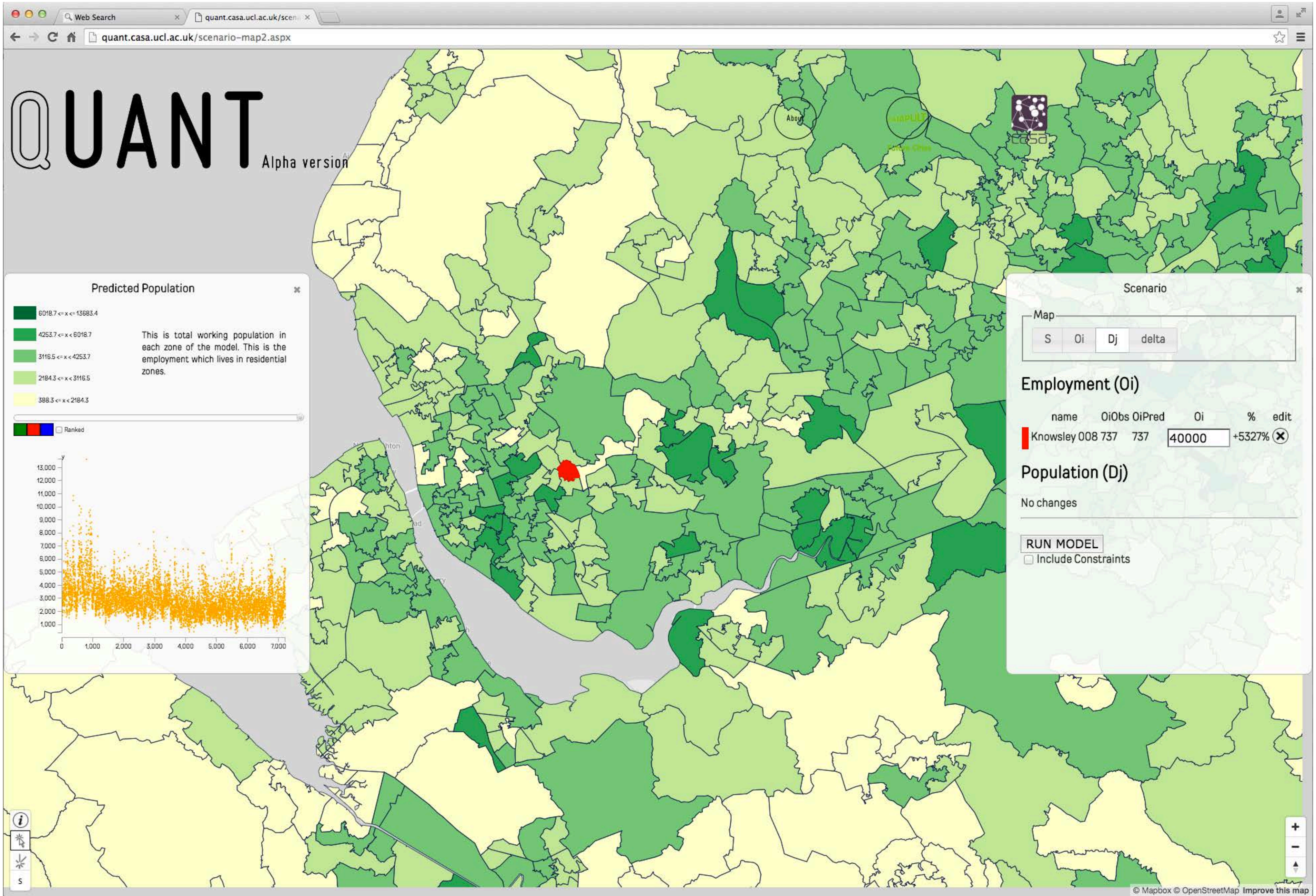
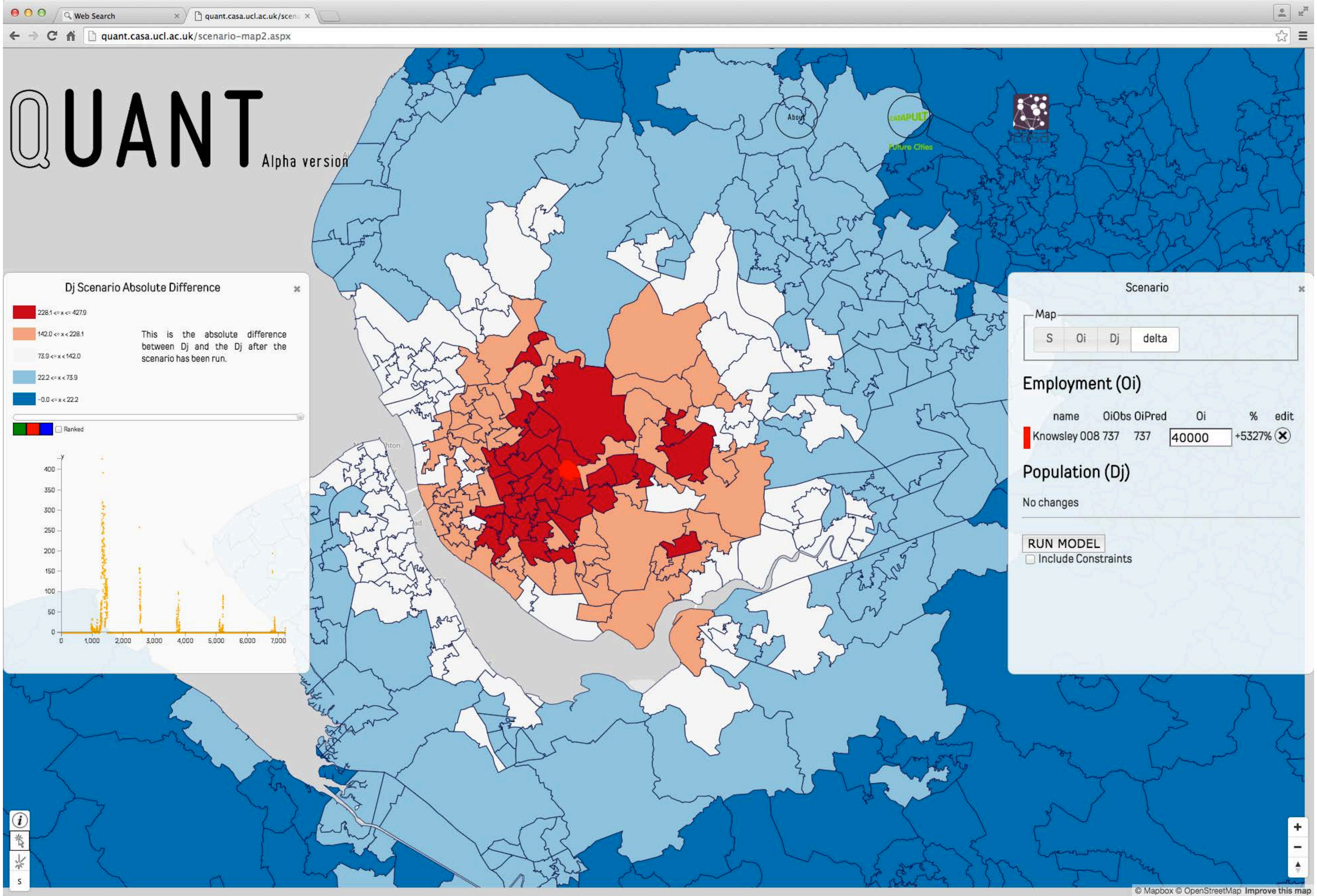

quant.casa.ucl.ac.uk/scenario-map2.aspx
QUANT
Alpha version
Predicted Population
6018.7 <= x <= 13683.4
4253.7 <= x < 6018.7
3116.5 <= x < 4253.7
2184.3 <= x < 3116.5
388.3 <= x < 2184.3
This is total working population in each zone of the model. This is the employment which lives in residential zones.
Ranked
Scenario
Map
S
Oi
Dj
delta
Employment (Oi)
name OiObs OiPred Oi % edit
Knowsley 008 737 737 40000 +5327%
Population (Dj)
No changes
RUN MODEL
Include Constraints
© Mapbox © OpenStreetMap Improve this map



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Conclusions and Next Steps

We need to do many things and the most important is working with decision-makers – people who will use these tools.

Our view is that the process of translating these models into tools is one which is lengthy and involved – more involved than building these models *per se* and we have only just begun to recognise these

The extent to which these models needs to be known by those who use them is still a crucial issue – in fact a more important issue than ever we realised before.

Thanks

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Borkur Sigurbjornsson

http://www.complexcity.info/
http://www.spatialcomplexity.info/
http://blogs.casa.ucl.ac.uk/