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More residents, more jobs? 2015 update
The relationship between population, employment and accessibility in London

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Executive summary

The aim of this paper is to provide an update of an analysis originally produced by Volterra Consulting for GLA Economics in 2005 (which itself used 2000 data), of the relationship between employment density, population density and levels of transport accessibility in London.

The main findings of this report are:

- Areas within London with a **low level of transport accessibility** show a **strong and significant relationship between employment and population density**. Taking all areas within 45 minutes reach by public transport and with a "catchment population" below 700k, the median ratio of employment to population density is 0.25, slightly higher than the previous results (using 2000 data), which showed a median ratio of 0.23.

- By contrast, for areas with a **high level of transport accessibility, the relationship between population density and employment density is not significant** (once differences in accessibility levels are taken into account). This means that an increase in the resident population does not increase the chances of a rise in local employment in the area. These are areas in which accessibility is the strongest driver of employment density, and population density is usually lower than in other areas.

- Results suggest that **an increase in the resident population of 1,000 will on average have the potential to give rise to a further 171 jobs in the locality**. However, compared to the 2005 analysis this effect is smaller; in 2000 the relationship was 230:1,000 (+ 25.7 per cent larger than that given by the 2013 data).

The paper concludes by noting that, in areas of low transport accessibility, land turned over for housing will have employment growth associated with it in the locality.

Introduction

Previous work established strong links between employment density, population density, and levels of public transport accessibility in London. In 2005, GLA Economics published a piece of research prepared by Volterra that broke down these relationships to better understand the interactions between them. This analysis was based on 2000 data[1].

This report aims to update the original analysis produced by Volterra, in order to provide a 2013 snapshot of the relationship between population and employment in London; as well as to examine the role transport accessibility plays in this relationship.

The analysis presented in this report has been produced using the latest available data sources, with respect to four dimensions: i) *population*, ii) e*mployment*; iii) s*ocio-economic characteristics*, and iv) g*eography*. It also provides additional information as compared to the 2005 report, whenever possible, in order to better explain and disentangle the link between population and employment. A comparison with the results obtained by Volterra in 2005 (using 2000 data) is presented, when available[2].

The first section discusses the rationale behind this analysis, and the importance of the relationship between employment and population for London's economy, as well as for Londoners. It is then followed by a section which briefly explains the data sources used to construct a comprehensive database for London as well as outlining the methodology and the rationale behind it.

The third section is concerned with describing the relationship between employment and population in London in 2013, followed by a section analysing the role that transport accessibility might play on shaping that relationship.

[1] GLA Economics (2005). "More residents, more jobs? The relationship between population, employment and accessibility in London". Volterra Consulting.
[2] The econometric analysis has been produced using IBM SPSS Statistics Version 19.

The rationale

As noted in the previous report, it often makes sense to think about demographic and employment trends separately. Population increase is affected by birth and death rates and by migration patterns, all of which are only indirectly the result of economic pressures. Jobs, however, are the result of business investment, public spending and economic opportunities which do not appear to have much to do with population trends.

However, some important dynamics are missing from this brief summary. It is obvious that where there are more residents there will be more employment opportunities, to cover greater demand for health centres to gyms to schools to estate agents etc.; so more economic activity is associated with areas with more people. Moreover, local residents setting up in business may prefer to establish their business near their home, even if their customers are in a different part of the country (or abroad).

Identifying the job-population association is a complicated task. A prescriptive approach (e.g. how many estate agents a residential development will require) should be avoided. Furthermore, the approach needs to capture investments by residents that are not for local consumption.

This paper builds on the methodology originally adopted by Volterra back in 2005 – with minor adjustments, in looking at these issues and in identifying the job creation potential that is associated with different levels of residential density across London.

Impact assessment studies for residential and commercial developments can often be used to estimate changes to employment and population levels in the local area. This will typically be based on the ratio of employment to population in the surrounding region, a method that works well for discrete and well defined, smaller urban areas than for London.

Therefore, due to the size and nature of London, levels of both public transport and highway accessibility influence the location of employment and population. Most London workers expect to commute to work; principally by either car or public transport[3]. Therefore, this paper explores how accessibility and the location of population influence employment location, and how these three variables interact.

[3] According to GLA Intelligence, based on an analysis of the Census 2011, people living in London tend to have shorter distances to commute than those living in England and Wales, and are more likely than others to travel to work by using public transport, and less likely than others to travel by either driving or being a passenger in a car or van. More detailed analysis and figures are reported in the following reports:
GLA Intelligence (2014). "2011 Census Snapshot: Method of Travel to work in London", CIS 2014-06 Census Information Scheme.
GLA Intelligence (2014). "2011 Census Snapshot: Distance Travelled to work in London", CIS 2014-07 Census Information Scheme.

Data sources and methodology

This analysis is built around three dimensions, namely population, employment and geography. For each of those, three different data sources were used to construct the variables feeding into the different models presented later on in this report.

- *Population* – GLA population projections and Mid-year estimates 2014 round, published in April 2015[4]. These are housing-linked projections incorporating data from the 2013 Strategic Housing Land Availability Assessment (SHLAA), short-term migration trends, and using the Capped Household Size projections model. With regard to population accessibility by public transport, Transport for London (TfL) data is used. In particular, the total time spent on a journey, weighted to account for traveller preferences is calculated by constructing a "generalised time matrix" looking at the "catchment" within 75 minutes of travel (equivalent to 45 minutes "real time")[5].

- *Employment* – Office for National Statistics (ONS) Business Register and Employment Survey (BRES), 2013 provisional data[6]; the latest employment (i.e. employees and working proprietors) data was used.

- *Socio-economic characteristics* – A few characteristics are included in this dimension:

  – Department for Communities and Local Government (DCLG) Indices of Deprivation 2010, as measure of "multiple deprivation" at the small area level[7];
  – ONS 2013 Mid-year estimates for Mean age of the population living in the area[8];
  – ONS Census 2011 for Employment rates of working age population (16-64 year olds) living in an area.

- *Geography* – ONS 2011 wards definition for the London region (649 wards)[9], and Area size (in kilometres) from DCLG.

With regard to the model developed and the methodology adopted in this paper, detailed information is provided in two other reports produced by Volterra and published by GLA Economics in 2005[10] and 2008[11], regarding, in particular, the clustering techniques. Therefore,

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[4] For more details, please see here.
[5] The distinction between 75/45 minutes generalised time is purely a technical matter for computing travel times. 45 minutes is usually applied to real time outputs; however, 75 minutes is conventionally used as the equivalent value when constructing a "generalised time matrix".
[6] For more details, please see here.
[7] DCLG produces the "English Indices of Deprivation", based on a model of multiple deprivation developed around "the idea of distinct domains of deprivation which can be recognised and measured separately. These domains are experienced by individuals living in an area. People may be counted in one or more of the domains, depending on the number of types of deprivation that they experience." (DCLG, 2011). For more details about the methodology and the latest estimates, please refer to: DCLG (2011). "The English Indices of Deprivation 2010", Neighbourhoods Statistical Release.
[8] For more details, please see here.
[9] For a full list of wards, according to the Census 2011 wards definition, see: https://geoportal.statistics.gov.uk/Docs/Boundaries/Census_merged_wards_(E+W)_2011_Boundaries_(Full_Extent).zip [14th August 2015].
[10] See footnote 1.
[11] GLA Economics (2008). "Comparing locations: Grouping wards in London, the South East and East of England", Volterra Consulting, GLA Economics Working Paper 28.

throughout this report, only variations to the main model and methodology adopted in those two reports will be highlighted.

However, it is useful to briefly summarise the main tools of analysis used in the different sections of this report:

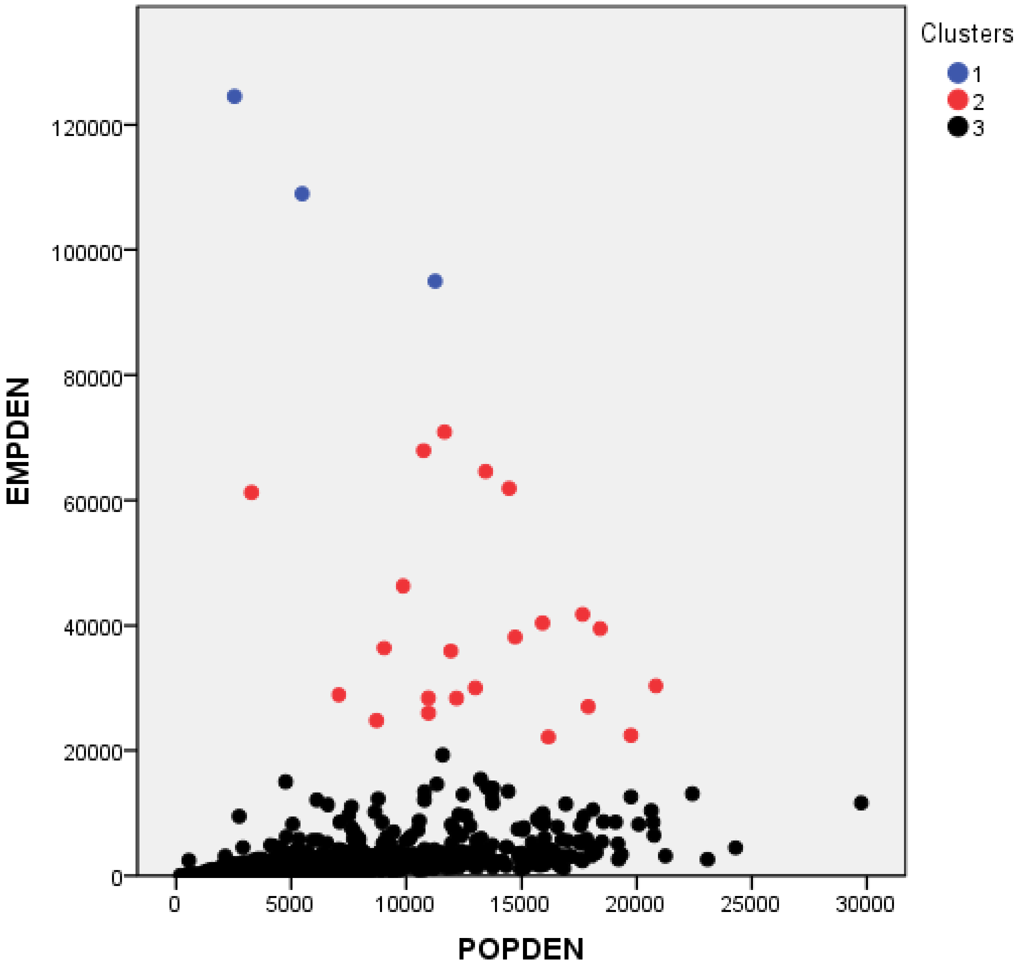
- *Fuzzy clustering* – wards in London are selected and then grouped together by applying a clustering technique called "fuzzy clustering". The method adopted is known as "k-mean clustering method", which allows researchers to "endogenously" group the wards together, based on similarities and dissimilarities around a few characteristics (i.e. the "socio-economic characteristics" described above), and according to pre-set parameters (imposed by the researcher such as the maximum number of clusters – or group, allowed);

- *Econometric analysis* – the relationship between the density of the population and the density of employment in London is also analysed by producing an estimate of the coefficient which relates the two together. In other words, simple econometric techniques (also known as "inference analyses") allows the researcher to understand, for instance, how many jobs are created in a certain area when 1,000 additional people move into that same area. In this framework, an estimate for the role played by accessibility will also be computed.

Employment and population

Figure 1[12] plots the relationship between employment and population density for London at ward level. It can be seen that the majority of wards have relatively low employment densities, below 20,000 people per square kilometre, but a small selection of wards have significantly higher values.

Figure 1: Population density against employment density, by ward in London



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)
Blue circles = Cluster 1 wards (City of London, Holborn and Covent Garden and West End wards)
Red circles = Cluster 2 wards (Wards around the fringe of Cluster 1 wards)
Black circles = Cluster 3 wards (all other wards in London)

Source: GLA Economics

In Figure 1, three different groups emerge, and are highlighted with different colours. The blue circles at the top left of the graph (Cluster 1) constitute the City of London, Holborn and Covent Garden, and West End wards. The red circles (Cluster 2 wards) represent the wards

[12] Based on 2011 Census wards definition (649 wards in total). However, the City of London wards are represented as a single geography, and treated so throughout this analysis. Employment data comes from the ONS BRES 2013 provisional data. Population data comes from the GLA SHLAA population projections and ONS Mid-year estimates, 2014 round.

around the fringe of Cluster 1 wards which share similar characteristics. Finally, the black circles represent all other wards in London. These wards were identified and grouped together by means of "fuzzy clustering" techniques, as detailed in previous work[13].

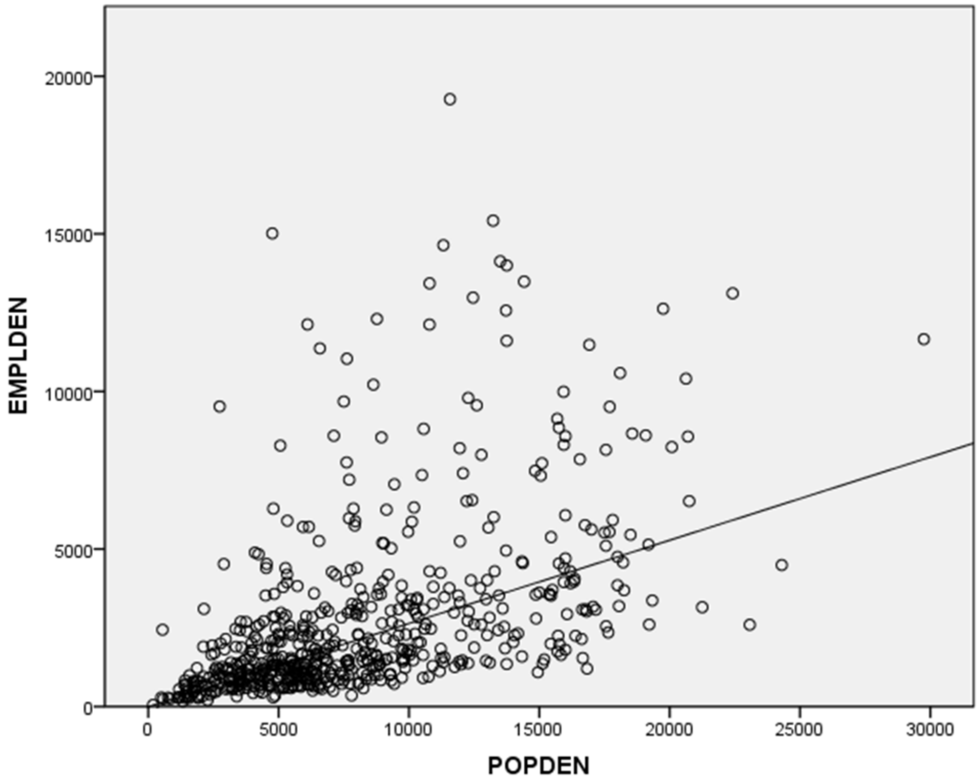
As mentioned in the previous section of this report, fuzzy clustering allows for the identification of wards that share similar social and economic characteristics. In this analysis, a series of socio-economic characteristics are used to endogenously generate the wards clusters, namely employment rates of the working age population in the area, mean of the age of the population in the area, and the DCLG Indices of deprivation.

This exercise generated the three different clusters shown in Figure 1, with Cluster 1 composed of those wards with the most extreme values for (high) employment density, (low) population density and (small) physical area, followed by Cluster 2. Therefore, Clusters 1 and 2 wards are to be considered "outliers" (i.e. very high employment density and relatively low population density), and, as such, they could skew the results of the analysis. Indeed, Volterra's fuzzy clustering analysis[14] revealed that Clusters 1 and 2 exhibit properties that are completely unique, not just in London, but throughout Great Britain. In these wards there exists a minimal relationship between employment and population density. Employment has risen in these areas to such an extent that housing has effectively been pushed out over time. As the trend for these 49 wards[15] completely opposes the trend for the other 600 in London, they are excluded from the analysis.

Figure 2 re-plots the same graph in Figure 1 with the "central London" employment clusters (i.e. Clusters 1 and 2) removed. A much more clearly defined, positive relationship between the two variables can now be seen. Overlaid on the plot is the fitted line from a linear regression of employment density on population density.

[13] See footnote 9.
[14] See footnote 10.
[15] Please note that throughout this analysis, City of London is considered as a single ward, whereas in reality it is composed of 25 different wards. This decision was made based on the small area size covered by the borough.

Figure 2: Population density against employment density, by ward in London – Cluster 3



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)
Plotted line represents linear fitted trend.

Source: GLA Economics

As there is no evidence for inclusion of an intercept term in the linear regression, the gradient coefficient that emerges is 0.305. The direct implication of this result therefore would be that for each additional person living in a ward there are approximately 0.30 jobs. Conversely, for each job in a ward there would be approximately 3.28 people living in that ward. Details of the regression analysis mentioned here are reported in the Appendix. One might argue this is a conservative estimate, thinking about the number of commuters into areas such as the Central Activities Zone (CAZ) area[16]. In fact this could be explained by issues around causality of the relationship between employment and population densities.

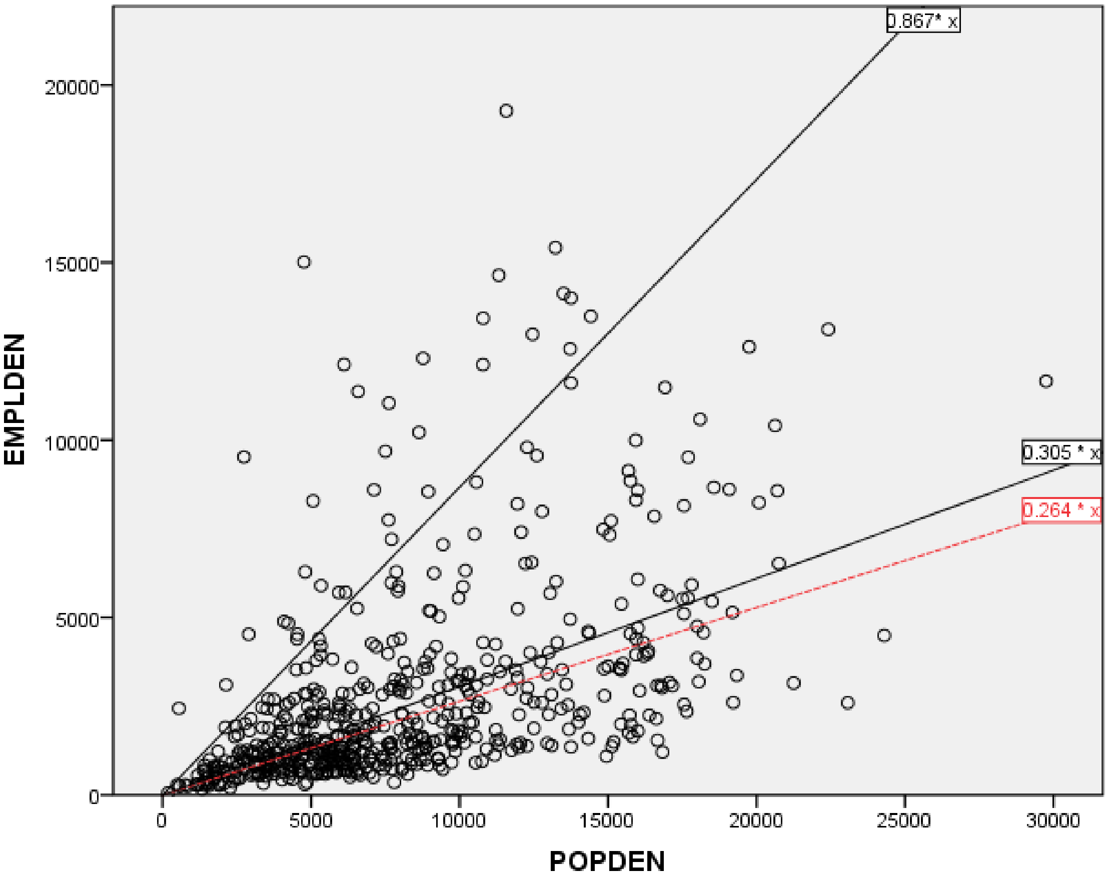
The relationship between population and employment is a two-way relationship. It is not possible to assume causality in either direction. If the relationship was stable, it would be possible to swap the variables around and find the gradient coefficient of regressing population density on employment density to be also around 0.30. However, on doing so a coefficient of 0.867 is actually discovered (see Appendix for details of results).

This issue is graphically shown in Figure 3. Again, employment density is plotted against population density by ward. This time, the dotted trend line (in red) represents the simple linear fit of employment density regressed on population density. The steeper solid line (with gradient

[16] For more details about this, please see GLA Economics (2015). “Work and life in the Central Activities Zone, the northern part of the Isle of Dogs and their fringes”, GLA Economics Working Paper 68.

0.867) shows the fit from swapping the variables around. To further complicate the problem, the shallower solid line (with gradient 0.305) shows the fit from a robust linear regression of employment density on population density.

Figure 3: Population density against employment density, by ward in London – Cluster 3, focus on causality



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)
Dotted red line = simple linear regression of employment density on population density
Steeper line = simple linear regression of population density on employment density
Shallower line = robust linear regression of employment density on population density (M-estimation)

Source: GLA Economics

With such a wide margin of variation in the coefficient estimates (0.264 to 0.867), there is little confidence in using any of these relationships directly to predict either of the variables on the basis of the other[17]. Under-specification of the model is likely to explain this (i.e. some other important independent variables affecting employment density have been omitted, therefore biasing the results).

Clearly there are other factors that affect both employment and population location. As with the previous report, therefore, transport accessibility is considered as a possible third variable to be included in the analysis.

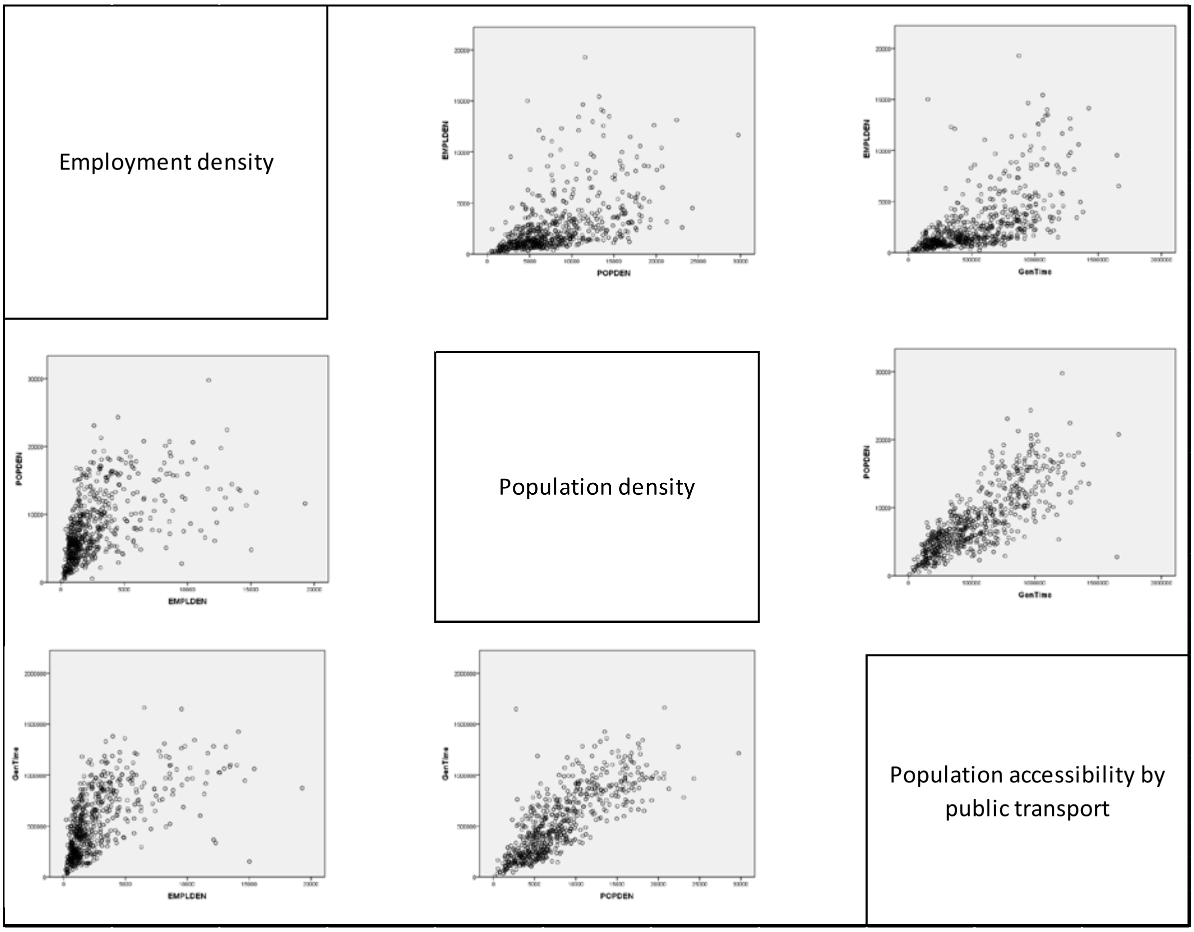
[17] This is also demonstrated if the plots of the residuals against the fitted values for any of these three regressions is examined, a standard statistical test of validity. All exhibit strong degrees of heteroscedasticity, both in the mean and in the variance.

The interaction of accessibility

As mentioned earlier in this analysis, the measure of accessibility is supplied by TfL, and proxies population catchments by public transport within 45 "generalised minutes"[18]. This particular series was used – instead of series that details employment catchments and travel by highway – as this has the highest correlation with the variables of interest[19]. This is not surprising as the majority of commutes in London are made by public transport[20].

Figure 4 presents a Pairs plot of the three variables (i.e. employment density, population density, and transport accessibility) against each other. The *x* and *y* axis labels of each individual sub-graph are given by the corresponding labels in that sub-graph row and column. For instance, the sub-graph in the top centre position plots employment density against population density, as seen in Figure 3.

Figure 4: Pairs of plots of employment density, population density and population accessibility by public transport, by ward in London – Cluster 3



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)

Source: GLA Economics

[18] "Generalised time" is the total time spent on a journey, weighted to account for traveller preferences.
[19] This relationship was previously tested by Volterra in the research published in 2005 (see footnote 1).
[20] See footnote 3.

The strong mutual correlation of the three variables is immediately apparent. The question therefore is how to disentangle the relationship between any two while accounting for the third.

Accessibility is, arguably, the most independent of the variables, with public transport schemes theoretically being able to be introduced without direct causation from employment to population levels. As with the previous report, accessibility, therefore, is taken to be an explanatory variable.

Conventionally, employment or population density could be regressed on the other two variables to find the predominantly influential variable. However, there is an added complication here of strong non-linearities in the individual relationships. For example, as accessibility increases, employment density appears to rise at an increasing rate. Strong multiple linear regression results will simply highlight the pair of variables with the most linear relationship. Again, the results of these inference exercises are reported in the Appendix.

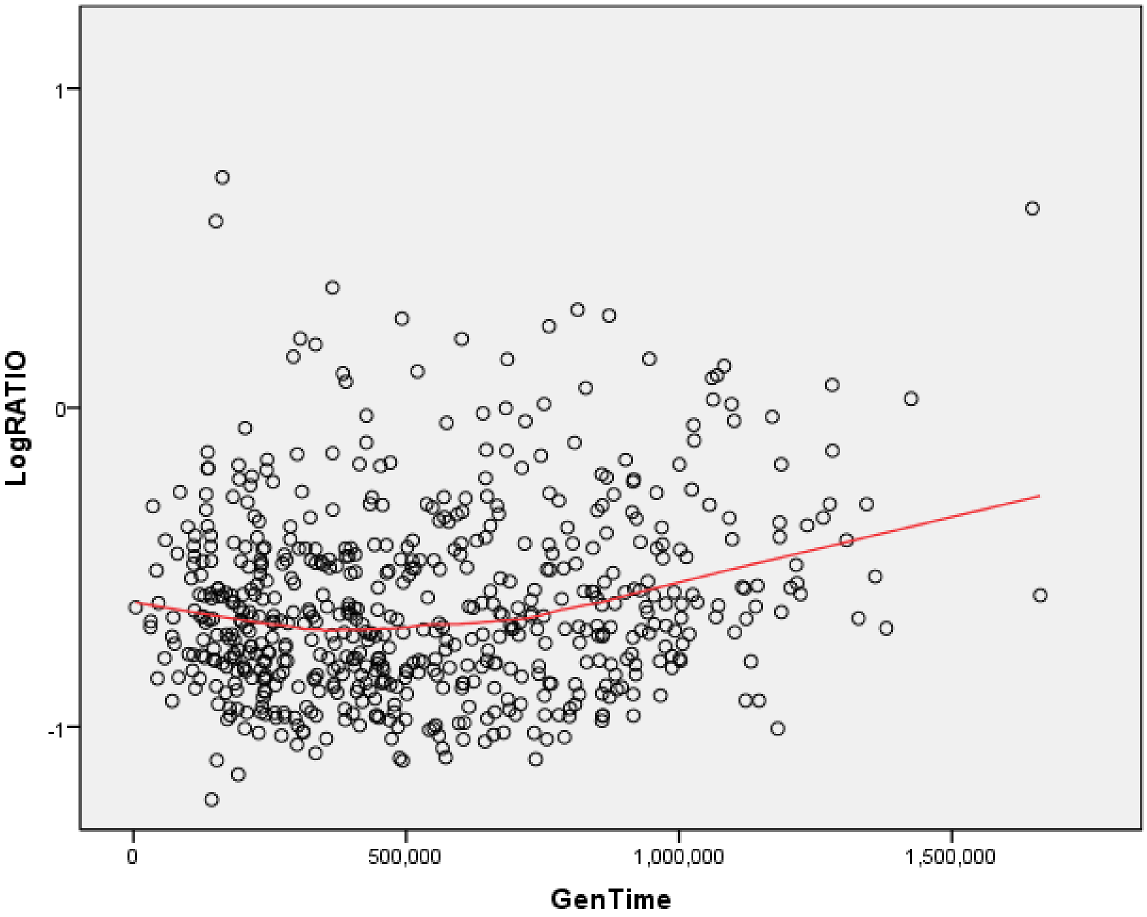
If corrections are made for non-linearities between any two pairs by transforming one of the variables, there is an added complication of distorting relationships with the third variable. It is thus difficult to provide a useful interpretation to the results from a multiple regression.

The approach chosen, therefore, is to reduce the three variables back down to two. This is done by looking at the relationship between accessibility and the ratio of employment density to population density[21]. On average, this derived ratio represents the gradient (i.e. the slope) of the plotted red line in Figure 3.

Figure 5 plots public transport accessibility against the logarithm of the ratio. The ratio's values are logged in order that a few of the very high absolute values do not dominate the chart (i.e. skew the results). To highlight the non-linear relationship between these two variables, a locally fitted regression curve is overlaid on Figure 5. This graph shows that for lower levels of accessibility, the ratio of employment to population density remains relatively constant, although still with a relatively high variance. However, as accessibility increases, the ratio also increases.

[21] More formally: $Accessibility = \alpha + \beta \log \frac{employment\ density}{population\ density}$.

Figure 5: The logged ratio of employment density over population density plotted against population accessibility, by ward in London – Cluster 3

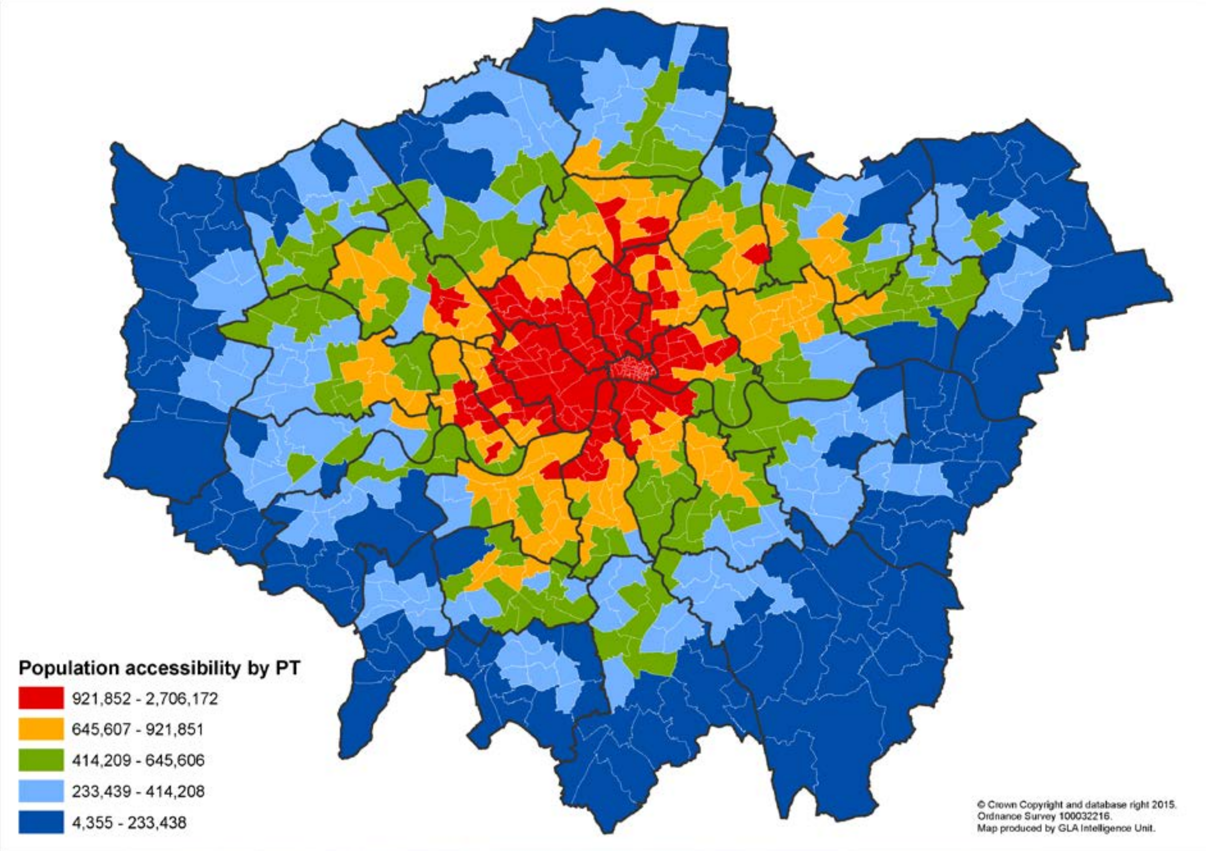


LogRATIO = $log \frac{employment\ density}{population\ density}$
GenTime = Population accessibility by public transport
Red trend line = non-linear local regression curve, span=2/3

Source: GLA Economics

Examining a map of public transport accessibility (Figure 6) reveals that lower values of transport accessibility tend to be in outer London. In these areas, a significant proportion of employment will be serving the local population. The relationship between employment density and population density therefore is relatively stable.

Figure 6: Population accessibility by public transport within 45 generalised minutes, by ward in London



Source: GLA Intelligence Unit

However, as accessibility increases, this relationship breaks down, and employment density begins to rise with respect to population density. Areas with the highest accessibility are in the centre of London. In these areas the proportion of employment that is serving the local population is lower. People are willing to commute to these places from further away in order to reach more specialised and higher paid employment.

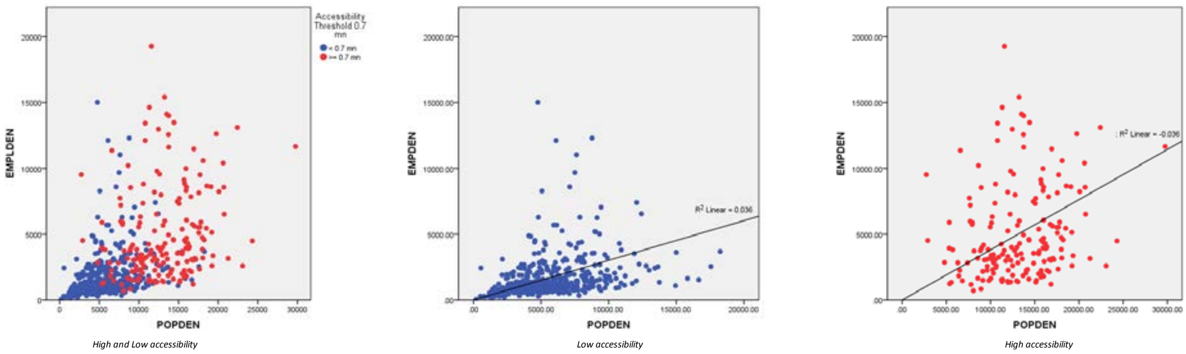
In Figure 7, the points of Figure 2 are re-plotted but now split by levels of accessibility. An accessibility threshold of 0.7 million people was chosen as this appears to be approximately the break point of the relationship in Figure 5. Figure 7 also reports two additional charts highlighting the relationship between employment density and population density for wards characterised by relatively low values of transport accessibility and by relatively high values of transport accessibility respectively. Details about the rationale behind the choice of the accessibility threshold are reported in the Appendix (Figure A1 and Figure A2)[22].

Figure 7 plots population density against employment density by ward; the wards are divided into the two groups according to their level of accessibility with respect to the chosen threshold:

[22] Please note that an error in Volterra's original paper led to set an accessibility threshold of 1.7 million. This mistake was also recognised by Michael Batty (UCL) who reviewed the paper in 2007. See, in particular, para 2, p. 5. However, it is clear this was just a reporting mistake, and that Volterra's original threshold was actually based on those wards with very high employment density and relatively low population density (i.e. the wards belonging to cluster 1 and cluster 2 in this analysis). To confirm this, TfL's "Travel in London" report 6 was also consulted. TfL reports the number of jobs available by mass public transport within 45 minutes travel time, and are consistent with the estimates reported here.

wards with high values of transport accessibility (greater than or equal to 0.7 million people) in red; and wards with low values of transport accessibility (less than 0.7 million people) in blue.

Figure 7: Population density against employment density, by ward in London – Cluster 3, low and high accessibility levels



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)
Accessibility threshold = 0.7 million people
Plotted lines represent linear fitted trend

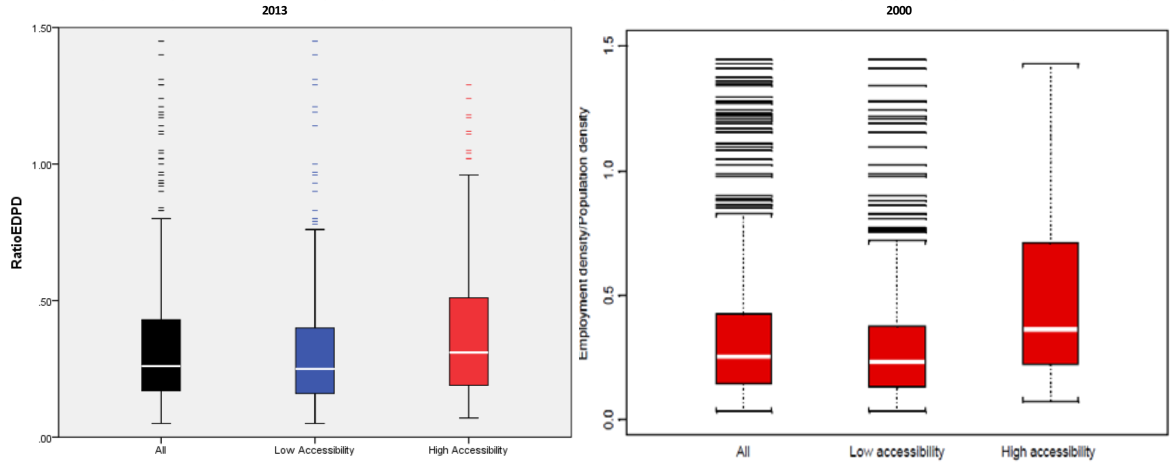
Source: GLA Economics

If all three variables were moving in unison, Figure 7 would show a division in the points similar to a concentric circle around the intersection of the axis. Instead, it shows that nearly all the areas of high employment density are areas with high accessibility (mostly in Inner London). This is true even for those areas with lower population density. In fact, areas within London with low levels of accessibility (mostly in Outer London) show a strong and significant relationship between employment and population density; and they tend to cluster around the bottom left of the chart in Figure 7.

Returning to the problem of estimating the average ratio of employment density to population density, the difference can be seen by looking at boxplots of the ratio, split by the 0.7 million threshold in transport accessibility.

The ratio results here are given in the un-logged format, and these are compared with the results obtained by Volterra in 2005.

Figure 8: Boxplots of ratio of employment density to population density, split by transport accessibility (0.7 million threshold), and truncated at ratio of 1.5 – Cluster 2, London, 2000 and 2013



RatioEDPD = Ratio of Employment density (people per square kilometre) over Population density (people per square kilometre)

Accessibility threshold = 0.7 million people; "All" = transport accessibility data for all wards in cluster 3; "Low accessibility" = values for wards with population accessibility by public transport < 0.7 million people; "High accessibility" = values for wards with population accessibility by public transport >= 0.7 million people.

*Note: boxes represent the inter-quartile range (IQR) of the selected data, with the white central line representing the median value. The "whiskers" extend to the first point outside range of 1.5*IQR from median. Beyond the whisker range, outlying values are indicated individually.*

Source: GLA Economics (left-hand chart) and Volterra (right-hand chart)

In Figure 8, the chart on the left reports the results for 2013, whereas the chart on the right is taken from the 2005 paper, and reports the results for 2000.

The mean ratio with all the data is equal to 0.36 (very close to the coefficient estimate of the regression of employment density on population density), but, due to the skewed nature of the data, the median is equal to 0.26. These estimates compare with 0.38 and 0.25 respectively for the 2000 results.

When the whole dataset is split into two groups according to values of population accessibility by public transport, this distribution shifts.

The chart shows that areas within London with low levels of accessibility show a strong and significant relationship between employment and population density, as already suggested earlier in this document. Taking all areas with a public transport 45 minutes catchment area below 0.7 million people, the median ratio of employment to population density is of 0.25, slightly higher than previous results for 2000, which showed a median ratio of 0.23.

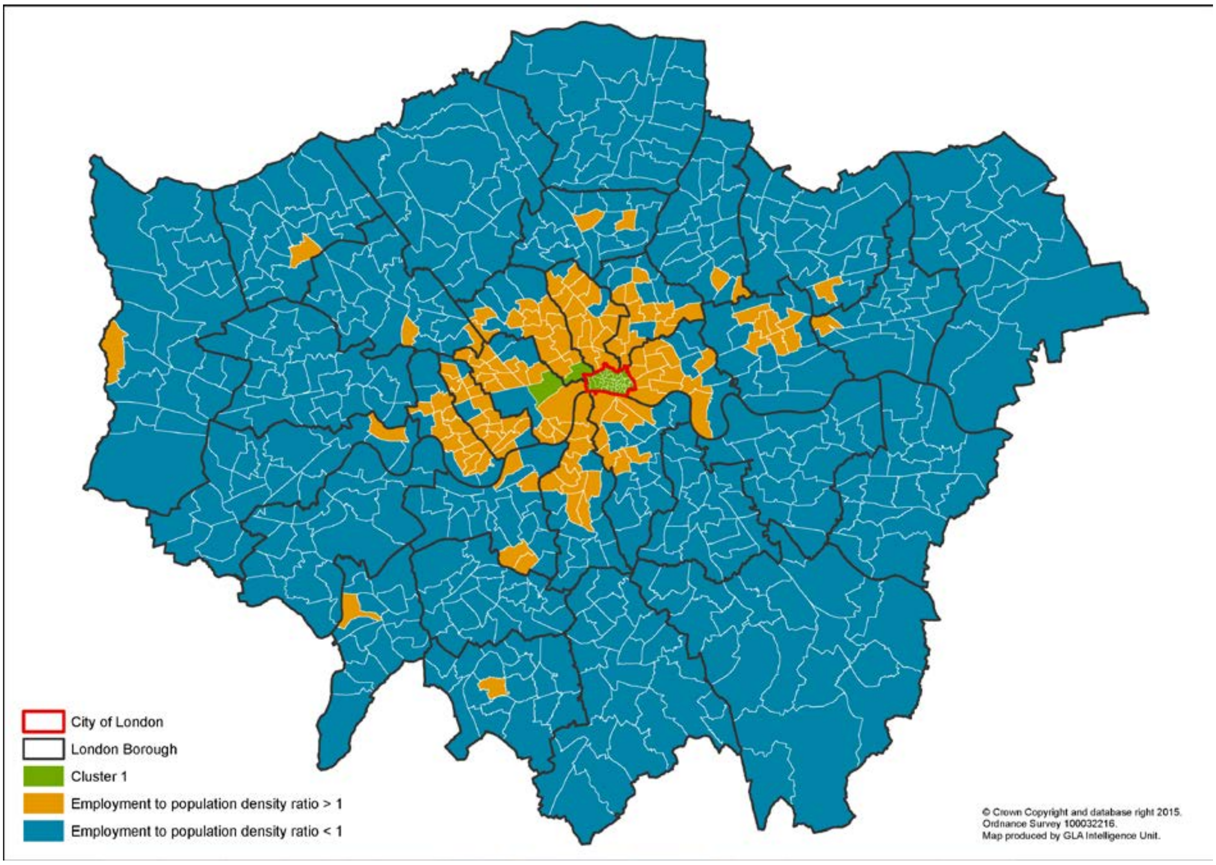
With regard to areas of relatively high accessibility, these present a mean ratio of 0.42 (*versus* 0.59 in 2000), and a median ratio of 0.31 (*versus* 0.36 in 2000). As opposed to areas with relatively low accessibility, in areas with high levels of accessibility the relationship between population density and employment density, once differences in accessibility levels are taken into account, is not significant. This suggests that an increase in the resident population does not increase the chance of a rise in local employment in the area. These are in fact areas in which we expect accessibility to be the strongest driver of employment density (e.g. more specialised and higher paid jobs are offered; therefore, people are willing to travel to reach these areas), and population density is usually lower than in other areas. The results of an inference exercise (reported in the Appendix) confirm these trends.

Despite a strong relationship between employment and population density in low accessibility areas, there is still a large margin of variation within the group when looking at the ratio between employment to population density. As reported above, the median value of the ratio was 0.25 in 2013, but the first quartile was equal to 0.16 of the distribution, and the third quartile to 0.40 of the distribution. Compared to the 2000 data, this variation appears to be more stretched towards the top of the distribution. However, this is mainly because we are dealing with very small geographical areas, and a certain degree of randomness in the data needs to be allowed for.

However, there is enough evidence to suggest that in areas of low transport accessibility land turned over for housing could be associated with employment growth in the local economy. Taking the coefficient of employment density regressed alone on population density in areas of low accessibility, it can be deduced that an increase to the resident population of 1,000 will on average have the potential to give rise to a further 171 jobs in the locality (See regression 5 in the Appendix) . Compared to the pre-recession period, however, the effect is smaller. According to the 2005 paper, the relationship in 2000 was of 230:1,000 (+25.7 per cent higher compared to 2013 results). Nonetheless, the difference needs to be interpreted with caution, given the (small) size of the geographical areas.

In Figure 1, the areas with the highest ratio of employment density to population density were in the very centre of London. Excluding these wards, Figure 7 showed that those areas with the highest accessibility also had a high ratio of employment to population density. Mapping accessibility reveals that the most accessible areas are in the centre of London. A natural conclusion therefore would be that all those areas with a high ratio of employment to population density are in the centre of London. Predominantly this is the case, but, interestingly, there are areas in Outer London with a high ratio.

Figure 9: Areas of London with employment to population density ratio > 1, all wards

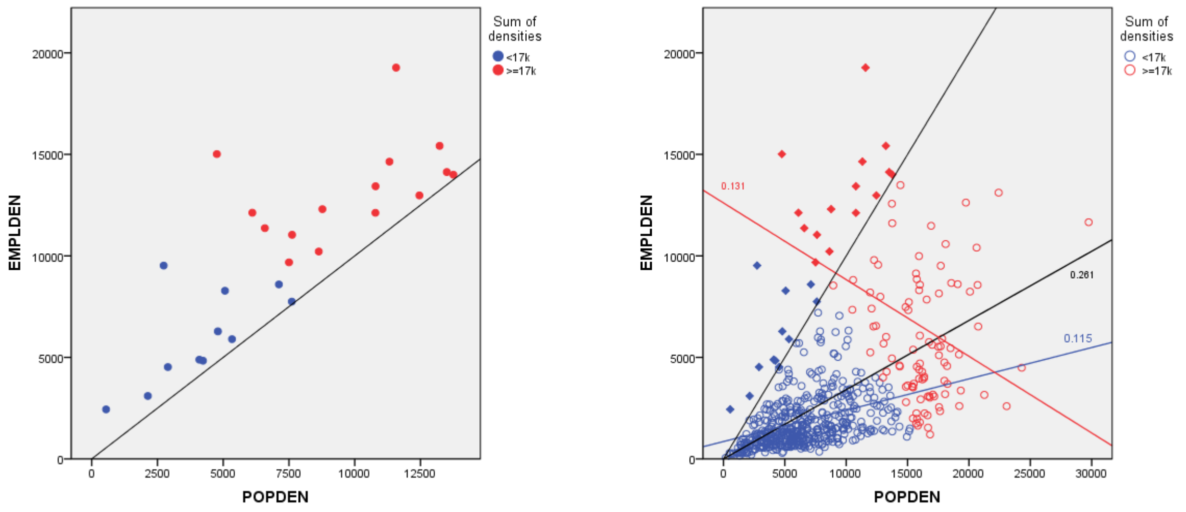


Source: GLA Intelligence Unit

To illustrate this phenomenon, Figure 9 highlights all those wards in London with a ratio of employment to population density of greater than one. This is not a specific break point, but does represent the point at which there are more jobs per hectare than residents within each ward, and as shown by Figure 8 wards with a ratio above one represent the top end of London's distribution.

Figure 10 provides an alternative visual representation of this split, by dividing the wards according to whether the ratio of employment density over population density is greater or less than 1, as well as whether the sum of the two densities (i.e. employment density and population density) is greater or equal to 17,000 or less than 17,000.

Figure 10: Segregation of London wards, Cluster 3



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)
Steep fitted line = gradient equals to 1 – the dots above this trend line represents the wards with employment to population density ratio >1
Red dots = (employment density + population density) > =17,000
Blue dots = (employment density + population density) < 17,000

Source: GLA Economics

The red wards have a high ratio of employment to population and have high absolute population and employment. These wards are indeed very central, and indeed these wards have high values of transport accessibility. The blue wards have a high ratio, but low absolute values, and are dispersed across Outer London. These high employment areas are relatively easy to identify. In the far West, for example, is Heathrow airport. In the South are the retail centres of Kingston, Wimbledon, Sutton, Croydon and Bromley. Despite having lower transport accessibility, these Outer London areas maintain high relative levels of employment. It is hypothesised that these jobs are sustained to a greater extent by the local resident populations, and might show higher values of road accessibility, rather than public transport accessibility.

Conclusion and further research

Previous work has established strong links in London between employment density, population density and levels of transport accessibility. In this report the analysis originally produced by Volterra for GLA Economics in 2005 (using 2000 data) was updated with the most recent available data, in order to better understand the interactions between the three dimensions above.

Areas within London with low levels of accessibility exhibit a strong relationship between employment and population density. These predominantly Outer London areas have a higher proportion of employment that serves the local population. Taking all areas with a public transport 45-minute population catchment area that is below 0.7 million results in a median ratio of employment to population density of 0.25 (compared to 0.23 in 2000).

For areas of high public transport accessibility, above 0.7 million people, the relationship between population density and employment density breaks down. Here instead, accessibility itself becomes a stronger determinant of employment density. In these areas of high accessibility, a lower proportion of employment exists to serve the local population. In its place, more specialised and higher paid employment is found, access for which is predominantly gained by public transport.

Despite finding a significant relationship for areas of London with low public transport accessibility, there is still a large margin of variation around the employment to population density ratio. The median value of the ratio is equal to 0.26, but the 33 and 66 per cent quantiles of the distribution are equal to 0.16 and 0.40 respectively (0.16 and 0.31 in 2000).

These results suggest one of two things. Either there are unknown variables that are unaccounted for in this analysis, or at this low level of geographic disaggregation there is an inherent degree of randomness in the data. The reality is probably a combination of the two.

Care must be taken to not draw conclusions for geographic areas that are too small. Attempting to estimate the impact of population or employment change at the ward level would not provide realistic results. At borough or equivalent level, however, average ratios could be used, provided that the accessibility was suitably low across geography.

Nonetheless, there is reasonable evidence to suggest that land turned over for housing in areas of low transport accessibility could be associated with employment growth in the local economy. Taking the coefficient of employment density regressed alone on population density in areas of low accessibility, it can be deduced that an increase to the resident population of 1,000 will on average have the potential to give rise to a further 171 jobs in the locality. This effect is smaller than that found in the previous analysis; according to the 2005 analysis by Volterra, the relationship in 2000 was of 230:1,000 (+25.7 per cent as compared to 2013 results).

Appendix

Regression summaries

1. Simple linear regression of employment density on population density

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	POPDENa	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.514	.264	.263	2443.415

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1282480046.145	1	1282480046.145	214.811	.000
	Residual	3570225246.548	598	5970276.332		
	Total	4852705292.693	599			

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	290.540	195.381		1.487	.138
	POPDEN	.305	.021	.514	14.656	.000

Source: GLA Economics

2. Simple linear regression of population density on employment density

Descriptive Statistics

	Mean	Std. Deviation	N
POPDEN	8073.64	4797.883	600
EMPLDEN	2752.79	2846.286	600

Correlations

		POPDEN	EMPLDEN
Pearson Correlation	POPDEN	1.000	.514
	EMPLDEN	.514	1.000
Sig. (1-tailed)	POPDEN	.	.000
	EMPLDEN	.000	.
N	POPDEN	600	600
	EMPLDEN	600	600

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	EMPLDENa	.	Enter

Model Summaryb

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.514	.264	.263	4118.777

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3644120986.435	1	3644120986.435	214.811	.000
	Residual	10144666801.133	598	16964325.754		
	Total	13788787787.569	599			

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	5688.151	234.019		24.306	.000		
	EMPLDEN	.867	.059	.514	14.656	.000	1.000	1.000

Source: GLA Economics

3. Simple linear regression of employment density on population density, accessibility and accessibility squared for wards with public transport accessibility less than 0.7 million people

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	GenTime, POPDEN, AccSQ	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.354	.126	.119	1620.21274

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	156444833.324	3	52148277.775	19.865	.000
	Residual	1089412069.024	415	2625089.323		
	Total	1245856902.348	418			

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	417.223	341.746		1.221	.223
	POPDEN	.067	.036	.113	1.838	.067
	AccSQ	.000	.000	-.014	-.068	.946
	GenTime	.003	.002	.283	1.287	.199

Source: GLA Economics

4. Simple linear regression of employment density on population density, accessibility and accessibility squared for wards with public transport accessibility equal or greater than 0.7 million people

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	GenTime, POPDEN, AccSQ	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.429	.184	.170	3215.75475

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	412438046.112	3	137479348.704	13.294	.000
	Residual	1830370918.860	177	10341078.638		
	Total	2242808964.972	180			

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-8953.986	5321.788		-1.683	.094
	POPDEN	.048	.060	.058	.803	.423
	AccSQ	.000	.000	-.613	-1.144	.254
	GenTime	.020	.011	1.006	1.861	.064

Source: GLA Economics

5. Simple linear regression of employment density on population density for low accessibility areas only

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	POPDENa	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.292	.085	.083	1653.38637

ANOVAb

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	105909640.655	1	105909640.655	38.742	.000
	Residual	1139947261.694	417	2733686.479		
	Total	1245856902.348	418			

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	760.174	180.054		4.222	.000
	POPDEN	.171	.028	.292	6.224	.000

Source: GLA Economics

6. Simple linear regression of employment density on population density for high accessibility areas only

Variables Entered/Removedb

Model	Variables Entered	Variables Removed	Method
1	POPDENa	.	Enter

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.191	.036	.031	3474.67817

ANOVAb

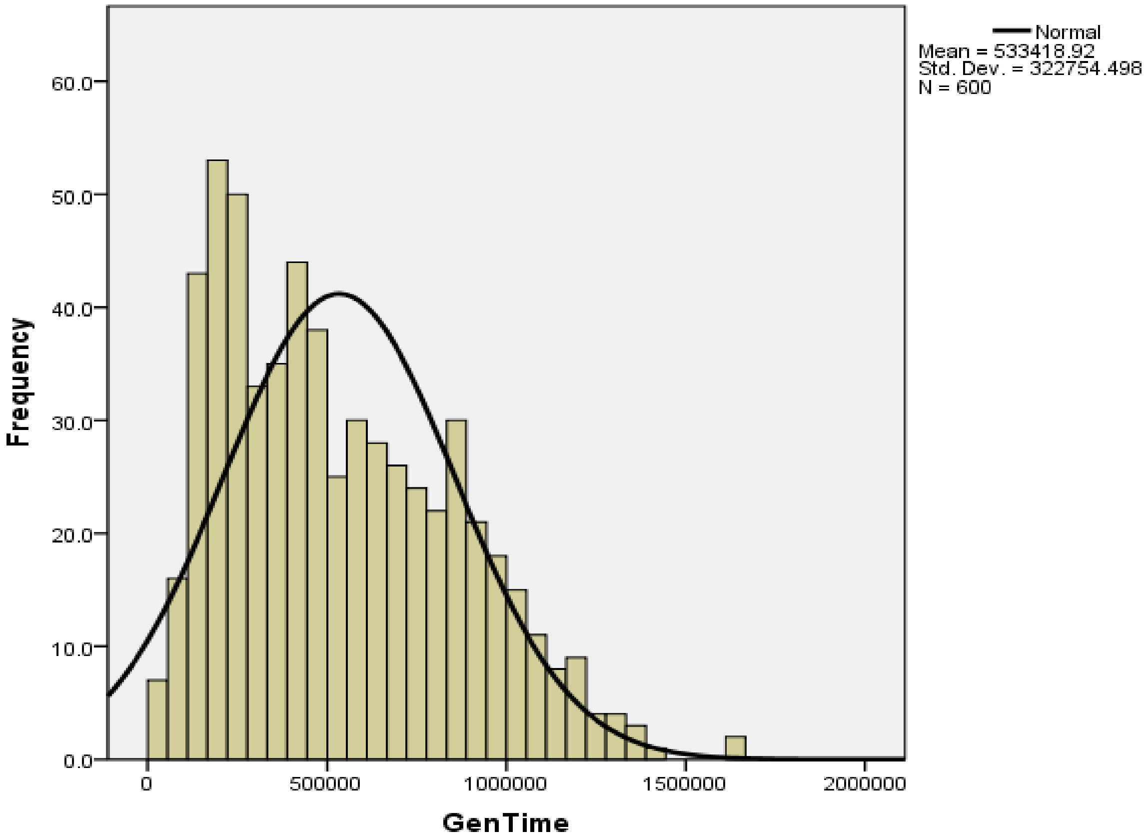
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	81672439.024	1	81672439.024	6.765	.010
	Residual	2161136525.948	179	12073388.413		
	Total	2242808964.972	180			

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2956.020	844.358		3.501	.001
	POPDEN	.158	.061	.191	2.601	.010

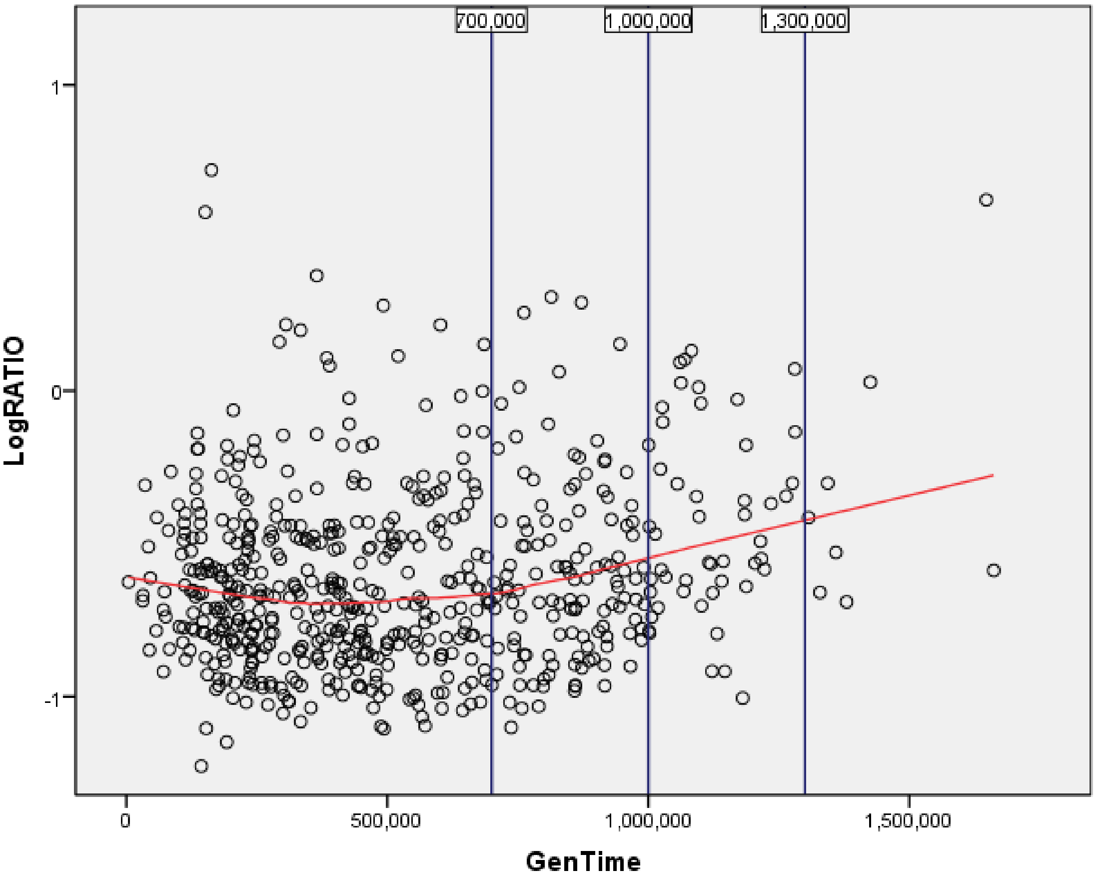
Source: GLA Economics

Figure A1: Distribution of cluster 3 wards in London according to transport accessibility values



GenTime = Population accessibility by public transport
Source: GLA Economics

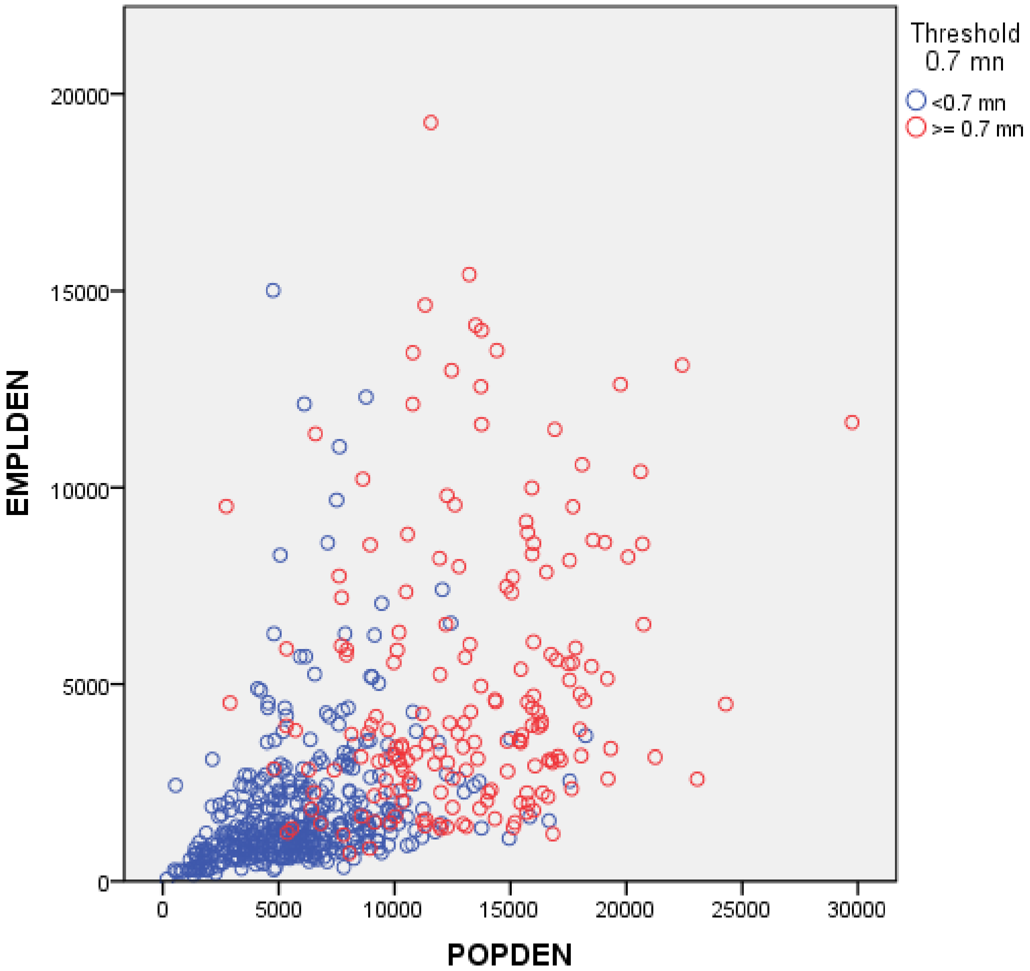
Figure A2: The logged ratio of employment density over population density plotted against population accessibility, by ward in London – Cluster 3, definition of the accessibility threshold at 0.7 million



$LogRATIO = log\,\frac{employment\ density}{population\ density}$
GenTime = Population accessibility by public transport
Red trend line = non-linear local regression curve, span=2/3

Source: GLA Economics

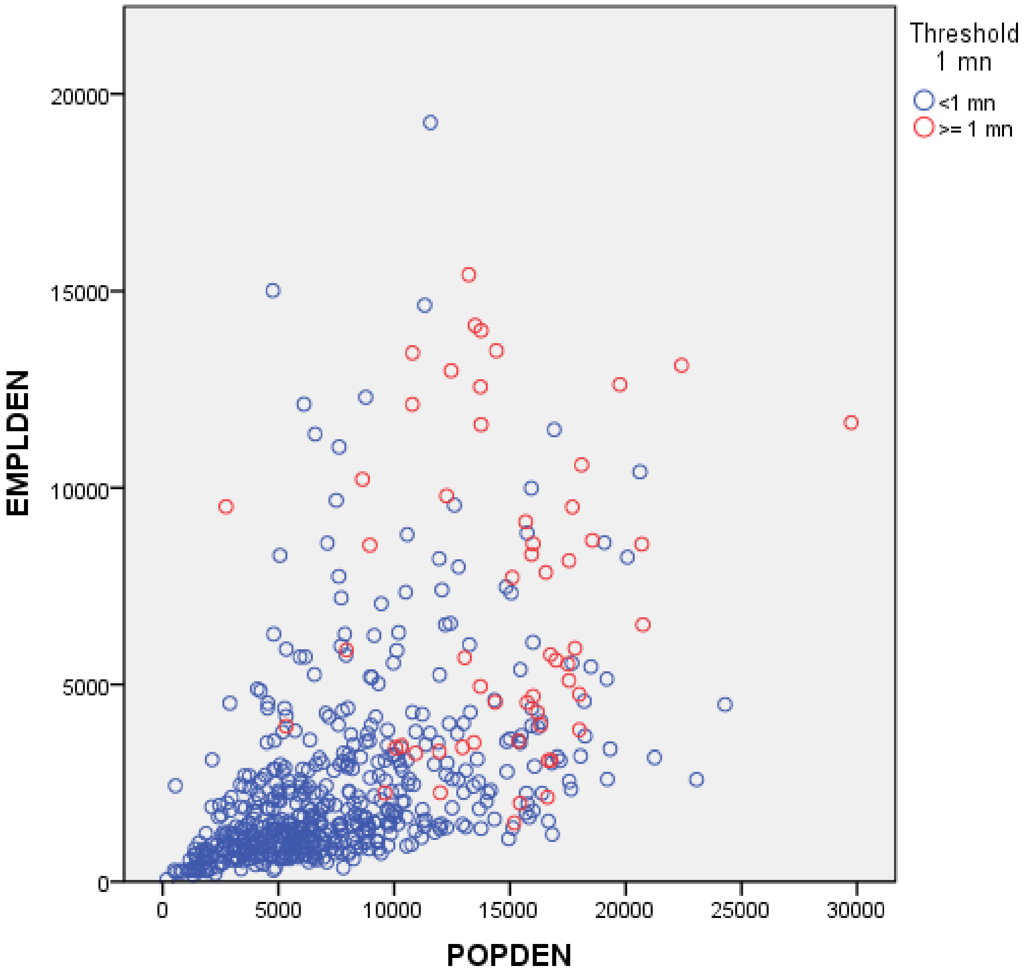
Option 1: Accessibility threshold at 0.7 million people



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)

Source: GLA Economics

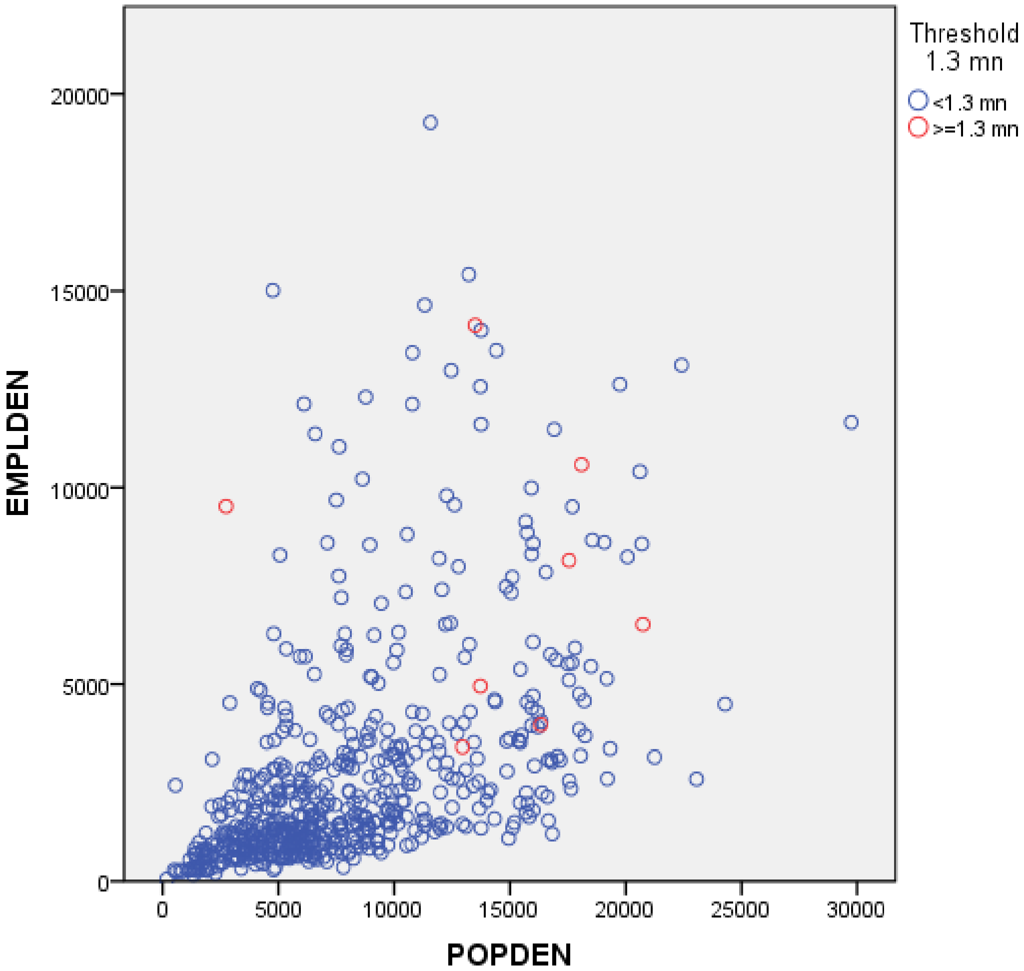
Option 2: Accessibility threshold at 1 million people



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)

Source: GLA Economics

Option 3: Accessibility threshold at 1.3 million people



EMPDEN = Employment density (people per square kilometre)
POPDEN = Population density (people per square kilometre)

Source: GLA Economics

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