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The Regularity and Irregularity of Travel: an Analysis of the Consistency of Travel Times Associated with Subsistence, Maintenance and Discretionary Activities

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Summary

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Keywords: Travel Time Stability, Time Allocation, Discretionary Activities, Switching Model

JEL Classification: R4, R41

This document presents results drawn from the Multinational Time Use Study (MTUS), but the interpretation of this data and other views expressed in this text are those of the author. This text does not necessarily represent the views of the MTUS team or any agency which has contributed data to the MTUS archive. The author bears full responsibility for all errors and omissions in the interpretation of the MTUS data.

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July 2016

Abstract

Regular and irregular travel patterns coincide with different underlying purposes of travel and days of the week. Within this paper, it is shown that the balance between subsistence (i.e. work) and discretionary (i.e. leisure) activities is related to differences in travel patterns and explains consistency across years. Using eight years of time use diary entries this paper finds that travel time related to subsistence activities tends to be regular and stable. In contrast, travel time associated with discretionary activities tends to be more unpredictable and varies greatly between discretionary and non-discretionary days. These findings have consequences for the travel time budget literature as consistency of average travel time is found to be driven by work days, which are frequent and have stable travel times. This is offset by discretionary days as they tend to have longer travel times with greater variability but are fewer in number.

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Section 1 – Introduction

Regular and irregular travel patterns occur due to different underlying purposes of travel and these travel patterns differ greatly between a work day and a discretionary day. Time use choice between subsistence, maintenance and discretionary activities has been of interest to transport researchers due to their impact upon travel behaviour (refer to Bhat and Misra (1999); Yamamoto and Kitamura (1999); Bhat (2005); Lee, Washington, and Frank (2009) and Akar, Clifton, and Doherty (2011) for examples). Consistent travel time expenditure across years, nations and people has been discussed in the transport literature since the 1960s (refer to Mokhtarian and Chen (2004) and Ahmed and Stopher (2014) for reviews of this literature). Within this paper these two streams of literature are linked together as subsistence, maintenance and discretionary activities are shown to drive differences in travel patterns while also being related to consistency across years. While trips related to subsistence activities (i.e. work) tend to be planned and remain stable irrespective of whether the day is dominated by discretionary activities, trips related to leisure and household duties are less stable and differ to a great degree based on whether it is a discretionary day or not. This work assumes that the rational locator hypothesis, or alternatively the co-location hypothesis, does occur; but is only relevant for travel related to work on discretionary and non-discretionary days.

Using an endogenous switching model this paper estimates a counterfactual travel time for each individual in the American Time Use Study (ATUS)[1]. The counterfactual travel time is calculated for those with a non-zero travel time between 2005 and 2012 and is based on whether the day is a discretionary day or not. Computing estimates of travel time with a distinction for discretionary days and non-discretionary days allow for the production of an estimate of the proportion of the sample that would have similar travel times no matter the purpose of their day. Reviewing the difference between discretionary and non-discretionary days is important as travel budgets have been contended

[1] This paper utilises the American Time Use Study (ATUS) which has been accessed via the Multinational Time Use Study (MTUS).

to result in a consistent average daily travel time and monetary expenditure – hence the development of the terms ‘travel time budget’ and ‘travel money budget’. It has been noted that time use and travel surveys tend to show that travel expenditures are approximately 1.1hrs per person per day (Schafer & Victor, 2000) or, alternatively, seventy minutes plus or minus 10 (Ahmed & Stopher, 2014). And while most studies have focused on confirming whether average travel time is similar across time periods and/or groups, variations that depend upon socio-demographics, household size, city size, employment status and changes in life events have been found to exist (Ahmed & Stopher, 2014; T. Kim, Choo, Shin, Park, & You, 2016; Kitamura & Susilo, 2005; Moutou, Longden, Stopher, & Liu, 2015; Raux et al., 2011).

Differences in travel patterns have also been attributed to the types of activities engaged in at the destination of travel and different days of the week. With respect to different days of the week, Yamamoto and Kitamura (1999) focused on the importance of the relationship between travel and purpose when reviewing time allocation across in-home and out of home discretionary activities across work and non-work days. Bhat and Misra (1999) also reviewed discretionary activities but in contrast to this study they did so with a focus on weekdays and weekends. Their paper estimated the elasticities of time spent in activities and also focused on whether the activity was in-home/out-of-home and occurred on a weekday/weekend. Holden and Linnerud (2011) reviewed the irregularity of travel for leisure and the issues that this raises for transport policy, as well as the level of road transport emissions. With leisure travel being undertaken by choice and not necessity, Holden and Linnerud (2011) point out that as transport policy and planning have tended to focus on everyday travel and this means that policies aimed at reducing energy use and emissions may have unintended effects on irregular and discretionary leisure travel. An example of these unintended consequences is the reduction of the average trip length that induces additional demand for leisure travel on weekends or holidays. Recently, Stopher, Ahmed, and Liu (2016) reviewed average travel time expenditures and found that there was greater variability on weekends than weekdays and all days of the week. In this study, they noted that “this is a new finding, because weekend days have not been the subject of prior

research on travel time expenditures/budgets" (Stopher et al., 2016). This finding reinforces the importance of a focus on discretionary and non-discretionary days in relation to travel time expenditures.

While consistent average travel times have been repeatedly found in the literature, the reason for this consistency has not been adequately established. Upon utilising a consistent travel time of 1.1 hours, Schafer and Victor (2000) noted that "the cause for the empirically observed constant travel budget is not clear" (Schafer & Victor, 2000). This is still the case as Ahmed and Stopher (2014) reviewed three disparate groups of theories for stable travel time budgets. These theories are based on economic, evolutionary and energy expenditure perspectives. One of the first papers to focus on an economic perspective was Tanner (1981) which proposed a generalised cost made up of the cost of travel and the time spent travelling. However, it should be noted that this generalised cost was found to be constant across cross-sectional data but not over time. In the same year, Goodwin (1981) proposed a generalised cost that was a combination of time, effort and money devoted to travel. This was found to be more stable across short periods of time.

In contrast to these theories, the focus of this paper is on the allocation of time between competing activities and the hypothesis that findings of consistent travel time expenditures are likely to be due to the stability of planned travel related to subsistence activities and financial/time constraints on the discretionary activities and travel that one would ideally wish to engage in. While we may dream of days filled with leisure that are chosen at our discretion, the reality is likely to be a five day working week with time for leisure in between our household commitments. As a result, the focus on discretionary and non-discretionary days is motivated by the labour economics discussion of the decision between allocating time to labour and leisure. It is also consistent with the words of George Bernard Shaw who stated that "labour is doing what we must; leisure is doing what we like; and rest is doing nothing whilst our bodies and minds are recovering from their fatigue" (Shaw, 1928). Hence,

the interest of this paper lies in the division between subsistence, maintenance and discretionary activities and the travel that is related to each activity on discretionary and non-discretionary days. This infers that individuals maximise utility based on a utility function that is a function of leisure time, activities related to household duties, time spent at work and income derived from labour. The importance of labour and residence when considering travel has been raised before and Becker (1965) noted that the marginal value of travel is related to the value for land and the distance from employment, as well as faster modes of travel being used for long distance travel. For recent examples of transport studies focused on the location of work or residence and how this impacts travel refer to the literature surrounding the rational locator hypothesis, or alternatively the co-location hypothesis, and Levinson and Wu (2005); C. Kim (2008); Tilahun and Levinson (2008); Tillema, van Wee, and Ettema (2010) and Ettema (2010). In accordance, within the rational locator hypothesis I expect that people will tend to minimise their travel to work based on where they live and also be willing to travel longer for leisure activities that have a high value of utility associated with them.

The paper is made up of the following sections. Section 2 specifies the endogenous switching model of the time spent travelling on a discretionary and non-discretionary day. Section 3 commences with an overview of the travel trends across years and days of the week using data from the ATUS. The switching model will then be used to estimate travel time related to a range of activities. Differences on a discretionary and a non-discretionary day will then be compared using counterfactual analysis. Section 4 discusses how these results stand in comparison to the travel time budget literature and their implications for future research. The concluding section is used to summarise the findings presented in the paper.

Section 2 – Methodology

To analyse the patterns of travel time and the activities that are associated with this travel, this paper utilises the responses to the American Time Use Study (ATUS) that are captured in the Multinational Time Use Study (MTUS). The focus of this paper is on the period between 2005 and 2012 with each set of annual observations treated as a separate survey. The ATUS collects data on the time an individual allocates to travel, work and searching for work, education, household duties and leisure/personal activities. This allows for an analysis of the total time travelled per day and the amount of time that is associated with travel for work, household duties and leisure/personal activities. For further details on the data used refer to Fisher, Gershuny, and Gauthier (2012) and the MTUS website (www.timeuse.org/mtus.html). Note that section 3 will commence with a review of the patterns of time use across activities. This section presents the methodology used to measure the difference in travel for days that are dictated by discretionary activities and otherwise.

A focus on discretionary days and non-discretionary days is motivated by the trade-off between labour and leisure as a core decision that is expected to influence a person's decision on where to live, where to work, how to travel and how to have fun. All of these factors (and the utility that a person derives from each element) will impact upon time use choice between subsistence, maintenance and discretionary activities, as well as the mode and the time spent travelling. The key hypothesis is that travel related to a subsistence activity is stable as in most cases it is planned using a long time horizon and is jointly determined by the decision of where to live, where to work and the type of commute that the individual is willing to endure. This decision is assumed to include a consideration of the intended travel mode, average travel time and the regularity of travel related to work. In comparison, a discretionary day is more likely to involve a mixture of short-term and long-term decisions on the recreation activities that one will engage in. It is hypothesised that this will lead to greater variance in travel times depending upon the location of the activity and the utility derived from the activity that is the purpose of the travel. Note that whether travel is desired for its own sake is important and that

accurately capturing "travel behavior may require viewing travel literally as a "good" as well as a "bad" (a disutility)" (Mokhtarian & Salomon, 2001). And while this factor is not explicitly modelled in this paper, it is expected to reinforce the need to estimate travel times for discretionary and non-discretionary days separately. A workday commute is likely to be valued differently to a journey on a weekend. As differences in travel time may occur due to traffic/congestion and be dependent upon whether an occupation involves driving or travel, the analysis of the results in section 3 will focus on the entire distribution and the percent of the sample with minor changes in travel.

The specification of the model that I estimate is shown in equations one to three. I_i^* is a latent variable that captures whether the activities of the day in question are driven by subsistence or discretionary activities. An individual *i* is expected to allocate their time based on whether the day is dictated by discretionary activities or otherwise. t_{ji} is the amount of time that individual *i* spends travelling to engage in activity *j*. Consistent with Lee et al. (2009), the activities that are focused upon include subsistence activities (*j=s*), maintenance activities (*j=m*) and discretionary activities (*j=d*). To estimate the model data on work, household duties and leisure/personal activities from the ATUS is used to capture subsistence, maintenance and discretionary activities.

$$I_i^* = \delta\left(t_{di}/\sum_j t_{ji} \geq 0.5\right) + Z_i\gamma + u_i \quad (1)$$

$$t_{1ti} = X_i\beta_1 + \varepsilon_{1i} \quad (2)$$

$$t_{0ti} = X_i\beta_0 + \varepsilon_{0i} \quad (3)$$

Days with a large amount of discretionary activities are expected to coincide with weekends, holidays and days without work. As I specify a discretionary day as those where more than 50% of the day is spent in discretionary activities, i.e. $t_{di}/\sum_j t_{ji} \geq 0.5$, the determination of the two states depends upon the number of hours spent in discretionary activities and this is shown in equation one. Rather than focusing on weekends, discretionary days are captured without consideration of the day of the week to allow for people who work on weekends. Equation one shows that an individual is engaged in a discretionary day when $h_{di}/\sum_j t_{ji} \geq 0.5$ and this infers that if it is not a discretionary day they are

engaged in a mixed-activity day, a subsistence day ($h_{si}/\sum_j t_{ji} \geq 0.5$) or a maintenance day ($h_{mi}/\sum_j t_{ji} \geq 0.5$). Z_i is a vector of characteristics that are associated with the incidence of discretionary days and this includes the days of the week (as weekends are important), as well as the amount of time spent watching television as I expect that this will be a variable that captures days with limited travel and a large amount of discretionary time. When I estimate the model using the observed dichotomous variable δ becomes part of the error term and accounts for how well the dichotomous variable captures the latent variable. It follows that the observed dichotomous realisation of I_i^* is a dummy variable where $I_i = 1$ if $I_i^* > 0$; otherwise $I_i = 0$.

Equations two and three determine the level of travel time in period *n* for the two types of days captured in equation one. X_i is a vector of characteristics that are expected to influence the time spent travelling during a discretionary day ($I_i = 1$) and a non-discretionary day ($I_i = 0$). β_1, β_0 and γ are vectors of parameters that I will estimate and u_i, δ, ε_1 and ε_0 are the disturbance terms. As I expect that the error terms of the three equations will be dependent and that endogeneity is present, it should be noted that the estimation of the three equations occurs simultaneously as the 'movestay' command in STATA used the full information maximum likelihood method. Note that clustered standard errors have been applied to account for individuals in the same household. For further detail on this estimation procedure refer to Lokshin and Sajaia (2004). Note that the endogenous switching model will be estimated for total travel time and travel related to all three activities, *j*, for each year between 2005 and 2012. This leads to 32 sets of regression results as the three equations are solved simultaneously.

$$\gamma_{ti} = abs(\hat{t}_{1ti} - \hat{t}_{0ti}) \quad (4)$$

Estimating the model using two states means that the calculation of a counterfactual estimate is possible and a key variable of interest is the difference in each respondent's travel on a discretionary

and non-discretionary day, γ_{ti}. The calculation of this variable is shown in equation four with $\hat{t}$ denoting the estimated travel time for each individual, *i*, in both states (i.e. $I = 1$ and $I = 0$). This variable allows for a review of the consistency of travel time between a discretionary and a non-discretionary day for each activity, *j*, across the entire distribution. Counterfactual analysis has been primarily used in studies related to labour supply, the distribution of wages and the gender wage gap. For examples of this literature refer to DiNardo, Fortin, and Lemieux (1996); Fortin and Lemieux (1997); Antonczyk, Fitzenberger, and Sommerfeld (2010) and Chernozhukov, Fernández-Val, and Melly (2013).

Section 3 – Results

This section commences with an analysis of the activity and travel patterns that persist across years and days of the week within the United States. Section 3.2 contains the results of the endogenous switching model of travel on discretionary and non-discretionary days. Before estimating a set of regression models in section 3.2, I will review the data on activity and travel patterns across years and days within section 3.1. This preliminary section will reinforce the motivation for this paper's focus on differences in travel during discretionary and non-discretionary days.

3.1 – Activity and travel patterns across years and days of the week

Before reviewing the results of the endogenous switching model estimation, this section will focus on the data for the period between 2005 and 2012. Figure 1 is a box plot of the minutes spent in five different activities with the box indicating the 75^{th} percentile (upper hinge), the median and the 25^{th} percentile values (lower hinge) for each year. There is notable consistency in the inter-quantile range (as reflected in the boxes plotted) and across all of the years the median values are similar. Figure 2 focuses on the observations for 2012 and shows that there is notable heterogeneity across days of the week. While travelling is more stable than time spent at work and searching for work or leisure/personal activities, Table 1 shows that there are some differences in travel time on workdays and weekends. From an average and median of 81 and 60 minutes on Monday, the average and median travel time increases to 95 and 75 minutes on Friday and 95 and 65 minutes on Saturday. It should be noted that the figures and tables in section 3.1 do not include zero observations. Differences between weekdays and weekends are hard to disentangle using these statistics alone as they do not account for those who work on the weekend. Nevertheless, lower time spent working and higher amounts of time devoted to leisure/personal activities are as expected for days on a weekend. Based on the 90^{th} percentile, the mean and the median, Friday has higher travel times than any other day of the week and it is expected that this is due to people leaving work early to start their weekend on

Friday afternoon. This coincides with lower amounts of time at work on Friday than on Monday to Thursday with the average and median working time increasing from 452 and 480 minutes on Fridays to 475 and 495 minutes on Mondays.

Figure 3 focuses on the time spent travelling for each activity between 2005 and 2012. Again, there is consistency across years in the median and the inter-quantile range (as shown by the boxes plotted). The corresponding averages are shown in Table 2 and the average values for total travel tend to oscillate around 88 minutes, which is higher than 70 minutes plus 10 but it should be noted that this would decrease if zero travel times were not coded as missing observations[2]. Travel for work oscillates around 44 minutes, while travel related to household duties and personal/leisure activities are around 60 and 52 minutes, respectively. So while there is consistency across years, notable differences in travel times occur based on the activity they are related to. This indicates that a review of differences in travel during a discretionary and non-discretionary days is warranted and accordingly, Figure 4 and Table 3 focus on the data from 2012 and the time spent travelling for each activity for each day of the week. The values for total travel match those from before (in Figure 2 and Table 1). The importance of Figure 4 and Table 3 is the comparison of travel times across the activities they are associated with for each day of the week. Higher travel times on weekends are driven by travel for leisure/personal activities. This is reflected in an increase in the average travel time associated with leisure/personal activities of more than 20 minutes and almost 18 minutes when comparing Saturday and Sunday to Thursday. Travel related to household duties also increases, but does so by a lower amount. As these values have zeros coded as missing, the travel times reviewed in this section are for cases where a journey commences. In the next section, the regression estimates do have zeros included so the estimates aggregate to match total travel times.

[2] Note that observations with zero travel times have been coded as missing in section 3.1 so the statistics do not capture irrelevant observations for the relevant travel purpose. For example, those who are unemployed or retired are unlikely to have non-zero travel times for travel related to work and should not be counted when producing statistics on average travel times for this type of travel. As the regression analysis will include variables capturing cases of unemployment and retirement in section 3.2 zeros are included in the analysis.

Figure 1 – Minutes spent in each activity – 2005 to 2012 – By year

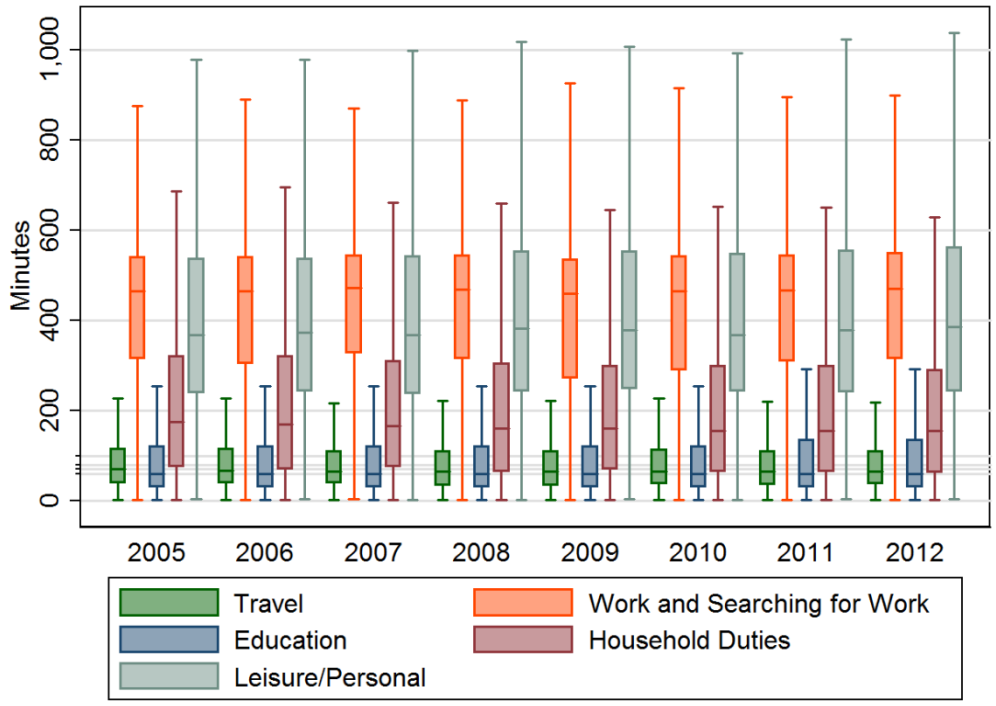


Figure 2 – Minutes spent in each activity – 2012 – By day

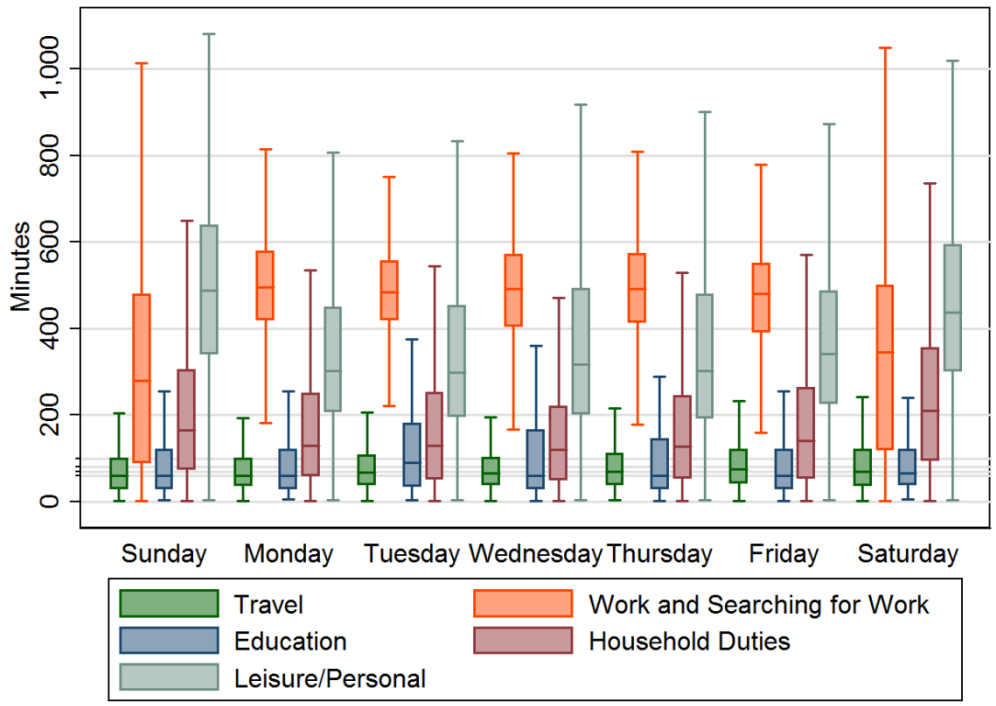


Table 1 – Statistics of the minutes spent in each activity – 2012 – By day

Day of the week	Statistic	Travel	Work and Searching for Work	Education	Household Duties	Leisure/Personal
Sunday	**Mean**	**84.96**	**303.30**	**101.66**	**203.14**	**489.56**
	Median	60.00	270.00	60.00	165.00	488.00
	10^{th} percentile	18.00	30.00	20.00	30.00	213.00
	90^{th} percentile	180.00	624.00	240.00	425.00	768.00
	Inter-quantile range	70.00	385.00	90.00	225.00	295.00
Monday	**Mean**	**81.19**	**475.11**	**106.71**	**178.61**	**343.79**
	Median	60.00	495.00	60.00	130.00	304.00
	10^{th} percentile	20.00	210.00	15.00	20.00	138.00
	90^{th} percentile	150.00	655.00	255.00	430.00	623.00
	Inter-quantile range	64.00	160.00	90.00	193.50	240.00
Tuesday	**Mean**	**84.24**	**474.69**	**151.62**	**176.12**	**345.03**
	Median	66.00	485.00	90.00	132.00	298.00
	10^{th} percentile	20.00	240.00	17.00	20.00	123.00
	90^{th} percentile	154.00	660.00	370.00	405.00	653.00
	Inter-quantile range	67.00	135.00	147.00	198.00	258.00
Wednesday	**Mean**	**83.27**	**474.50**	**120.02**	**166.66**	**363.15**
	Median	65.00	492.50	60.00	122.00	321.00
	10^{th} percentile	20.00	245.00	15.00	20.00	123.00
	90^{th} percentile	160.00	675.00	325.00	415.00	674.00
	Inter-quantile range	64.00	165.00	130.00	169.00	285.00
Thursday	**Mean**	**88.13**	**478.48**	**120.08**	**178.24**	**347.08**
	Median	70.00	491.00	60.00	129.00	303.00
	10^{th} percentile	25.00	240.00	15.00	20.00	117.00
	90^{th} percentile	159.00	675.00	340.00	418.50	661.00
	Inter-quantile range	70.00	157.00	115.00	190.00	284.50
Friday	**Mean**	**95.44**	**452.06**	**99.97**	**176.88**	**377.23**
	Median	75.00	480.00	60.00	140.00	343.00
	10^{th} percentile	23.00	180.00	15.00	20.00	148.00
	90^{th} percentile	183.00	635.00	235.00	395.00	663.00
	Inter-quantile range	77.00	160.00	90.00	205.50	256.50
Saturday	**Mean**	**94.77**	**339.39**	**109.29**	**241.03**	**450.30**
	Median	65.00	345.00	65.00	210.00	433.00
	10^{th} percentile	20.00	30.00	20.00	30.00	188.00
	90^{th} percentile	195.00	630.00	240.00	492.00	723.00
	Inter-quantile range	84.00	380.00	80.00	260.00	291.00

Figure 3 – Minutes spent travelling for each activity – 2005 to 2012 – By year

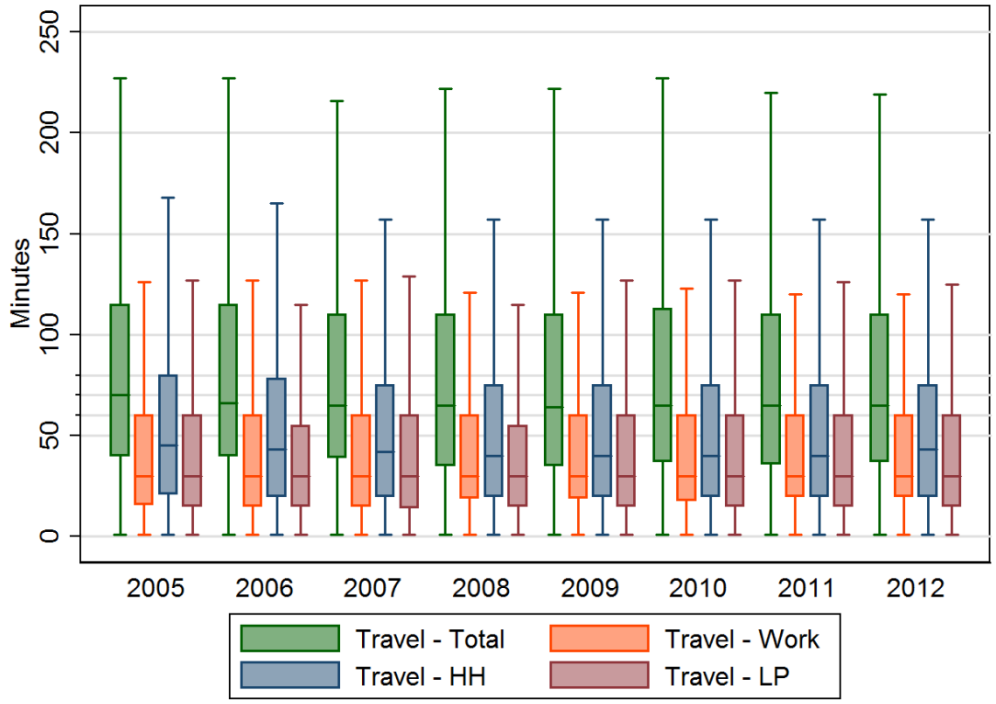


Table 2 – Average minutes spent travelling for each activity – By year

Year	Travel - Total	Travel - Work	Travel - HH	Travel - LP
2005	91.29	44.30	61.73	51.67
2006	88.84	43.11	60.28	49.80
2007	87.83	41.44	59.36	53.04
2008	87.11	43.51	59.58	49.69
2009	86.77	44.59	58.27	51.51
2010	89.06	44.14	59.22	54.76
2011	88.03	44.27	60.21	53.16
2012	88.21	45.09	60.72	52.61

Figure 4 – Minutes spent travelling for each activity – 2012 – By day

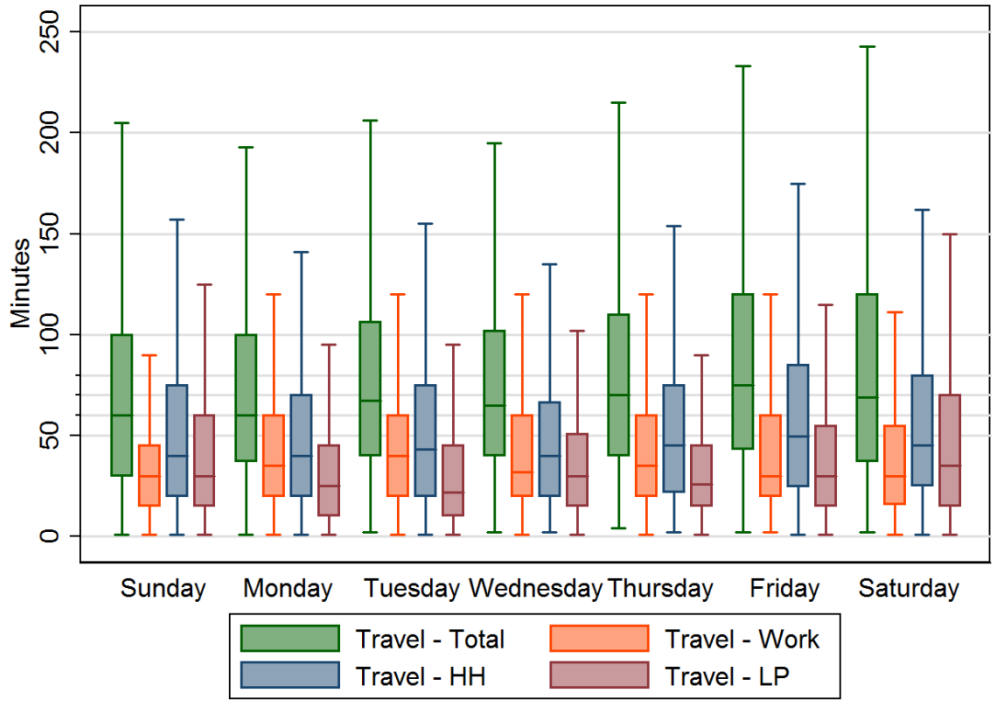


Table 3 – Statistics of minutes spent travelling for each activity – 2012 – By day

Day of the week	Statistic	Travel - Total	Travel - Work	Travel - HH	Travel - LP
Sunday	**Mean**	**84.96**	**36.10**	**61.57**	**57.74**
	Median	60.00	30.00	40.00	30.00
	10^{th} percentile	18.00	6.00	10.00	8.00
	90^{th} percentile	180.00	70.00	120.50	125.00
	Inter-quantile range	70.00	25.00	55.00	45.00
Monday	**Mean**	**81.19**	**46.92**	**54.58**	**43.78**
	Median	60.00	35.00	40.00	25.00
	10^{th} percentile	20.00	10.00	10.00	5.00
	90^{th} percentile	150.00	91.50	115.00	90.00
	Inter-quantile range	64.00	40.00	50.00	35.00
Tuesday	**Mean**	**84.24**	**48.08**	**56.72**	**41.04**
	Median	66.00	40.00	43.00	22.00
	10^{th} percentile	20.00	10.00	10.00	5.00
	90^{th} percentile	154.00	95.00	115.00	99.00
	Inter-quantile range	67.00	40.00	55.00	35.00
Wednesday	**Mean**	**83.27**	**45.38**	**52.76**	**48.25**
	Median	65.00	32.50	40.00	30.00
	10^{th} percentile	20.00	10.00	10.00	6.00
	90^{th} percentile	160.00	90.00	105.00	95.00
	Inter-quantile range	64.00	40.00	47.00	35.00
Thursday	**Mean**	**88.13**	**47.22**	**60.28**	**40.18**
	Median	70.00	35.00	44.00	25.50
	10^{th} percentile	25.00	10.00	10.00	5.00
	90^{th} percentile	159.00	95.00	115.00	90.00
	Inter-quantile range	70.00	40.00	51.00	30.50
Friday	**Mean**	**95.44**	**46.23**	**64.26**	**46.11**
	Median	75.00	30.00	49.00	30.00
	10^{th} percentile	23.00	10.00	10.00	7.00
	90^{th} percentile	183.00	90.00	129.00	105.00
	Inter-quantile range	77.00	40.00	62.00	41.00
Saturday	**Mean**	**94.77**	**41.42**	**64.97**	**61.35**
	Median	65.00	30.00	45.00	35.00
	10^{th} percentile	20.00	10.00	10.00	10.00
	90^{th} percentile	195.00	90.00	130.00	150.00
	Inter-quantile range	84.00	40.00	55.00	55.00

3.2 – Switching model of travel on discretionary and non-discretionary days

To estimate the difference between each person's travel on a discretionary and non-discretionary day this paper employs an endogenous switching model to measure counterfactual estimates. With eight years of time use diary data and four classifications of activities a total of thirty-two regressions are estimated. Based on the Chi-square statistics all thirty-two regressions have a high goodness of fit and are associated with dependence across the three equations. Accordingly, there is strong evidence that accounting for differences in travel on discretionary and non-discretionary days is important and that endogeneity between travel times and the type of day does exist. Rather than presenting the estimation results of all thirty-two regressions, this section will focus on the estimation results for the most recent year, 2012. Regression estimates are presented for each activity and the estimates of γ_{ti} are shown using histograms. Note that the estimates of γ_{ti} for all of the thirty-two regressions are presented in the appendix with Figure 1A containing histograms for all eight years.

3.2.1 – Model estimates

Tables 4 to 7 contain the endogenous switching model estimation results for 2012 and these are broken down by total travel time and travel time related to work, household duties and leisure/pleasure activities. The estimation results are presented with a separate column devoted to equations one, two and three. To evade the dummy variable trap, the constant absorbs a Monday dummy variable and a dummy variable for middle income earners. This needs to be kept in mind when interpreting the coefficient estimates. Based on the variables that are statistically significant in the first column of Table 3, in comparison to Mondays, discretionary days are less likely to occur on a Thursday and more likely to be a Sunday. A positive and significant relationship occurs for those people who have a child and are female. Unsurprisingly, time spent in a leisure/personal activity is significant and discretionary days are also correlated with the amount of time spent watching television. As expected, time spent in other non-leisure activities have negative relationships with the

likelihood that it is a discretionary day. The second column of Table 4 shows that the total number of minutes spent traveling on a discretionary day has a positive and significant relationship with the day being a Thursday, Friday or Saturday. High income earners tend to travel for more minutes than those on middle or low incomes. A negative and significant relationship is found for those who are retired or earn a low income. The third column of Table 4 contains the estimation results for total travel time on a non-discretionary day. Minutes spent traveling on a non-discretionary day has a positive and significant relationship with having a child. A negative and significant relationship with travel on a non-discretionary day is found for those who are female, are part-time workers, are unemployed and are students.

Overall, the model estimates are consistent with expectations as the expected signs are shown for most of the coefficients. Nevertheless, it is important to highlight the differences in the estimates that occur when focusing on travel related to different activities. As shown in Table 5, the total number of minutes spent traveling to work on a discretionary day has a positive and significant relationship with the amount of time devoted to work. Competing uses of time are shown to have a negative and significant relationship with the amount of time spent travelling to work. Being a student has a positive relationship with time spent traveling to work and a negative relationship occurs when an individual is unemployed. Time spent traveling to work on a non-discretionary day is lower on the weekends, as shown by negative coefficients for Saturday and Sunday. A negative and significant relationship for travel time to work on a non-discretionary day is found for those who either live in a rural area, are female, are unemployed, or are retired. High income earners travel more minutes to work on a non-discretionary day than those on earn a middle or low income. Table 6 contains the estimation results for travel related to household duties, which tends to be higher on Thursdays and Fridays irrespective of whether it is a discretionary day or not. High income earners are shown to travel more minutes for household duties than those who earn a middle or low income. Table 7 shows that travel related to leisure/personal activities on discretionary days are higher on Fridays and Saturdays. High income earners are shown to travel for more minutes in relation to leisure/personal

activities on both a discretionary day and non-discretionary day than those who earn a middle or low income. Higher travel related to leisure/personal activities on discretionary days occur on Wednesdays, Fridays, Saturdays and Sundays. With respect to travel related to leisure/personal activities, students and part-time workers tend to travel less on non-discretionary days.

Comparing the estimates across different activities presents some interesting findings. Travel to work has a positive relationship with the amount of time spent in a work activity on a discretionary day, but all of the other cases show that the competition for minutes between activities results in a negative relationship for the minutes in an activity and the time spent travelling. As students travel longer to work on discretionary days and travel less for leisure on non-discretionary days there are signs that location of residence, limited finances and a lack of stable employment may be driving their behaviour as it matches an expectation that students have less choice of where to live and lower/instable incomes from casual work.

3.2.2 – Differences in travel times by activity type

While it is important to confirm that the model estimates make sense, the difference in each respondent's travel on a discretionary and non-discretionary day based on a counterfactual estimate is the key output that this paper uses for assessing whether travel is stable for a given type of travel. Figure 5 shows a set of histograms that capture the differences in travel between a discretionary and a non-discretionary day for all respondents in the sample. As they are based on the estimation results in Tables 4 to 7, these histograms focus on total travel time and travel time related to work, household duties and leisure/pleasure activities. While the y-axis is the same for each quadrant of the figure, it should be noted that the x-axis changes based on the observations of differences in travel time and this is done to show the distribution of the entire sample. All of the columns capture five minute intervals and according the width of each bar is related to the percent of the sample within each five minute

interval. The range of travel times is narrowest in the case of travel related to work and these observations are shown as relatively wide orange columns in the top right quadrant of Figure 5. Table 8 confirms this with an inter-quantile range of 9 minutes for the absolute difference in travel times associated with travel related to work. Travel related to household duties and leisure/personal activities have an inter-quantile range of 15 and 16 minutes, respectively. As the total time travelled is an aggregate of the differences of the sub-categories, the total amount of time spent travelling has the narrowest columns (shown in the top left quadrant of Figure 5) and the widest inter-quantile range of 27 minutes. This pattern is reflected in the width and height of the columns in Figure 5.

Within the appendix, Figure 1A presents the histograms for all thirty-two regressions and this captures the full period between 2005 and 2012 with the same four designations of travel time. To assist the assessment of all of these histograms, Table 9 provides a summary of all of the estimation results from the thirty-two regressions conducted. Within this table, the first two columns of each histogram are combined to provide the percent of the sample with an absolute difference in travel time that is less than or equal to ten minutes. This is used as an indicator of the general stability of the travel times observed for the overall sample in any given year. Travel related to work is the type of travel with the most stability across years and this is reflected in Table 9 with the largest amount of the sample deviating their travel by ten minutes or less for a discretionary or non-discretionary day[3]. Over 52%-66% of the sample was estimated to have a change in the amount of travel related to work of 10 minutes or less. This decreases to be between 31%-46% for travel related to household duties and 27%-46% for travel related to leisure/personal activities. This then accumulates to result in total travel time differing for between 17% and 27% of the sample based on whether it is a discretionary or non-discretionary day.

[3] The threshold of ten minutes has been chosen based on the observation made in Ahmed and Stopher (2014) that the literature has found that travel expenditures are approximately seventy minutes plus or minus 10 minutes. It is only intended as a benchmark for the comparison of differences in travel times for total travel and travel related to subsistence, maintenance and discretionary activities.

Table 4 – Switching model estimation results – 2012 – Travel - Total

Variable name	Discretionary dummy	Minutes travelling (Discretionary)	Minutes travelling (Non-discretionary)
	Equation one	Equation two	Equation three
Constant	-5.177***	199.1***	346.0***
	0.305	7.715	14.88
Tuesday dummy variable	0.042	6.841	2.831
	0.154	4.915	3.797
Wednesday dummy variable	-0.0432	6.342	3.354
	0.148	4.737	4.031
Thursday dummy variable	-0.304*	12.81**	10.80***
	0.171	5.04	3.886
Friday dummy variable	-0.216	22.34***	15.69***
	0.138	4.906	3.849
Saturday dummy variable	-0.0636	13.84***	8.971**
	0.118	3.982	4.071
Sunday dummy variable	0.249**	-1.354	-0.988
	0.117	3.859	4.632
Rural Area dummy variable	0.144*	-0.662	-3.701
	0.0852	2.485	3.172
Child dummy variable	0.0730***	-0.0696	2.518**
	0.0281	1.098	1.015
Single Parent dummy variable	0.0036	-0.369	-4.711
	0.108	4.059	3.659
Female dummy variable	0.158**	3.059	-5.431**
	0.0621	-1.966	2.55
Part-time Emp. dummy variable	0.101	-0.486	-10.89***
	0.0765	-3.034	3.161
Unemployed dummy variable	0.0414	-5.989	-17.87**
	0.141	-3.842	7.3
Student dummy variable	-1.073***	0.295	-56.82***
	0.142	4.815	5.958
Retired dummy variable	0.0975	-5.435**	3.666
	0.0946	2.411	8.037
High Income dummy variable	-0.156**	9.651***	12.35***
	0.0689	2.482	2.57
Low Income dummy variable	0.0983	-9.563***	-9.826***
	0.0764	2.264	3.325
Minutes spent working	-0.00828***	-0.134***	-0.314***
	0.000333	0.0128	0.0165
Minutes spent on HH duties	-0.00727***	-0.176***	-0.359***
	0.000345	0.0117	0.0193
Minutes spent on LP activities	0.0168***	-0.161***	-0.301***
	0.000679	0.00873	0.0188
Minutes spent watching TV	0.00299***		
	0.0011		
Wald Chi-sq. - Goodness Fit	506.31***		
Wald Chi-sq. - Independence	255.30***		
Observations	9638		

Note: statistical significance is shown as *** for p<0.01, **for p<0.05 and * for p<0.1.

Table 5 – Switching model estimation results – 2012 – Travel - Work

Variable name	Discretionary dummy	Minutes travelling (Discretionary)	Minutes travelling (Non-discretionary)
	Equation one	Equation two	Equation three
Constant	-3.910***	4.659***	75.02***
	0.353	0.917	5.644
Tuesday dummy variable	0.118	0.674	1.819
	0.189	0.937	2.105
Wednesday dummy variable	-0.000642	-0.0721	0.372
	0.187	0.661	2.21
Thursday dummy variable	-0.251	0.74	1.409
	0.206	0.794	2.039
Friday dummy variable	-0.0292	0.874	0.961
	0.164	0.776	2.088
Saturday dummy variable	0.161	-0.00608	-4.949***
	0.14	0.567	1.797
Sunday dummy variable	0.373***	-0.778	-9.509***
	0.14	0.554	1.905
Rural Area dummy variable	0.125	-0.136	-3.305***
	0.102	0.335	1.282
Child dummy variable	0.104***	0.114	0.411
	0.0326	0.149	0.43
Single Parent dummy variable	-0.0403	0.108	-2.131
	0.132	0.4	1.347
Female dummy variable	0.197***	-0.00561	-6.388***
	0.0755	0.257	1.041
Part-time Emp. dummy variable	0.0647	0.599	0.39
	0.0941	0.513	1.245
Unemployed dummy variable	-0.0161	-1.452***	-7.038***
	0.174	0.333	1.829
Student dummy variable	-1.678***	1.675***	-2.166
	0.185	0.59	2.13
Retired dummy variable	0.116	-0.32	-4.191***
	0.109	0.232	1.188
High Income dummy variable	-0.104	-0.0917	2.453**
	0.0825	0.303	1.106
Low Income dummy variable	-0.0097	0.0463	0.139
	0.093	0.294	1.243
Minutes spent working	-0.0125***	0.0714***	-0.00704
	0.000579	0.00518	0.00554
Minutes spent on HH duties	-0.0109***	-0.00618***	-0.0803***
	0.000568	0.0012	0.00589
Minutes spent on LP activities	0.0183***	-0.00449***	-0.0666***
	0.000955	0.000876	0.00714
Minutes travelling for HH	-0.0103***	-0.00547**	-0.0784***
	0.000724	0.0024	0.00725
Minutes travelling for LP	-0.0105***	-0.00574***	-0.0808***
	0.000814	0.00165	0.0083
Minutes spent watching TV	0.00272**		
	0.00129		
Wald Chi-sq. - Goodness Fit	300.89***		
Wald Chi-sq. - Independence	7.76***		
Observations	9638		

Note: statistical significance is shown as *** for p<0.01, **for p<0.05 and * for p<0.1.

Table 6 – Switching model estimation results – 2012 – Travel - HH

Variable name	Discretionary dummy	Minutes travelling (Discretionary)	Minutes travelling (Non-discretionary)
	Equation one	Equation two	Equation three
Constant	-4.566***	117.0***	202.8***
	0.323	5.748	14.35
Tuesday dummy variable	0.0874	5.838	1.061
	0.168	3.86	2.885
Wednesday dummy variable	0.0329	4.838	-0.316
	0.156	3.684	3.033
Thursday dummy variable	-0.343*	9.299**	8.345***
	0.185	3.937	3.226
Friday dummy variable	-0.186	17.89***	10.26***
	0.15	3.916	2.968
Saturday dummy variable	0.00958	5.231*	3.185
	0.126	2.977	3.218
Sunday dummy variable	0.232*	1.886	-0.843
	0.125	2.92	3.625
Rural Area dummy variable	0.134	-1.699	-0.0951
	0.092	1.896	2.546
Child dummy variable	0.0897***	-0.827	2.160**
	0.0308	0.879	0.846
Single Parent dummy variable	0.017	-2.728	-3.086
	0.116	3.022	2.713
Female dummy variable	0.154**	2.820*	-0.231
	0.0675	1.521	1.986
Part-time Emp. dummy variable	0.139*	0.288	-9.320***
	0.0832	2.338	2.43
Unemployed dummy variable	0.00252	-1.791	-10.25*
	0.152	3.12	5.854
Student dummy variable	-1.236***	-4.553	-34.15***
	0.157	3.513	4.779
Retired dummy variable	0.0711	-2.006	0.46
	0.102	1.797	6.188
High Income dummy variable	-0.129*	5.596***	7.202***
	0.0741	1.949	2.085
Low Income dummy variable	0.0488	-5.605***	-9.127***
	0.0834	1.688	2.485
Minutes spent working	-0.00899***	-0.106***	-0.205***
	0.000407	0.0111	0.0152
Minutes spent on HH duties	-0.00927***	-0.0568***	-0.173***
	0.000448	0.00934	0.0187
Minutes spent on LP activities	0.0173***	-0.0961***	-0.178***
	0.000792	0.00622	0.0166
Minutes travelling for Work	-0.0148***	-0.144*	-0.263***
	0.00252	0.0868	0.0273
Minutes travelling for LP	-0.00902***	-0.0968***	-0.116***
	0.000686	0.0172	0.0291
Minutes spent watching TV	0.00289**		
	0.00117		
Wald Chi-sq. - Goodness Fit	426.05***		
Wald Chi-sq. - Independence	181.46***		
Observations	9638		

Note: statistical significance is shown as *** for p<0.01, **for p<0.05 and * for p<0.1.

Table 7 – Switching model estimation results – 2012 – Travel - LP

Variable name	Discretionary dummy	Minutes travelling (Discretionary)	Minutes travelling (Non-discretionary)
	Equation one	Equation two	Equation three
Constant	-4.380***	94.45***	145.3***
	0.326	5.772	12.65
Tuesday dummy variable	0.0711	1.132	0.896
	0.171	3.184	2.005
Wednesday dummy variable	-0.0138	1.988	4.086*
	0.158	3.169	2.466
Thursday dummy variable	-0.305	4.241	2.966
	0.187	3.366	1.892
Friday dummy variable	-0.135	5.939*	6.966***
	0.15	3.24	2.192
Saturday dummy variable	-0.055	10.03***	10.82***
	0.124	2.789	2.516
Sunday dummy variable	0.219*	-2.57	6.686**
	0.125	2.646	3.063
Rural Area dummy variable	0.117	1.237	-1.857
	0.0922	1.747	1.672
Child dummy variable	0.0887***	0.65	0.483
	0.03	0.789	0.592
Single Parent dummy variable	-0.0213	2.423	-0.866
	0.118	2.987	2.414
Female dummy variable	0.179***	0.61	-1.643
	0.0684	1.397	1.766
Part-time Emp. dummy variable	0.124	-1.27	-3.550*
	0.0842	2.027	2.038
Unemployed dummy variable	-0.00181	-3.624	-5.116
	0.152	2.523	4.689
Student dummy variable	-1.272***	4.364	-30.52***
	0.16	3.423	3.681
Retired dummy variable	0.105	-3.642**	7.584
	0.103	1.741	6.568
High Income dummy variable	-0.127*	4.964***	5.314***
	0.0759	1.815	1.634
Low Income dummy variable	0.0258	-4.739***	-2.31
	0.0842	1.601	2.225
Minutes spent working	-0.00966***	-0.0952***	-0.157***
	0.000422	0.00966	0.0131
Minutes spent on HH duties	-0.00914***	-0.129***	-0.190***
	0.000438	0.00934	0.0159
Minutes spent on LP activities	0.0177***	-0.0734***	-0.120***
	0.000819	0.00601	0.0144
Minutes travelling for Work	-0.0151***	-0.121**	-0.190***
	0.00252	0.0565	0.0215
Minutes travelling for HH	-0.00930***	-0.0793***	-0.0853***
	0.000624	0.0152	0.0201
Minutes spent watching TV	0.00281**		
	0.00118		
Wald Chi-sq. - Goodness Fit	313.35***		
Wald Chi-sq. - Independence	182.03***		
Observations	9638		

Note: statistical significance is shown as *** for p<0.01, **for p<0.05 and * for p<0.1.

Figure 5 – Difference in travel between a discretionary and a non-discretionary day – 2012

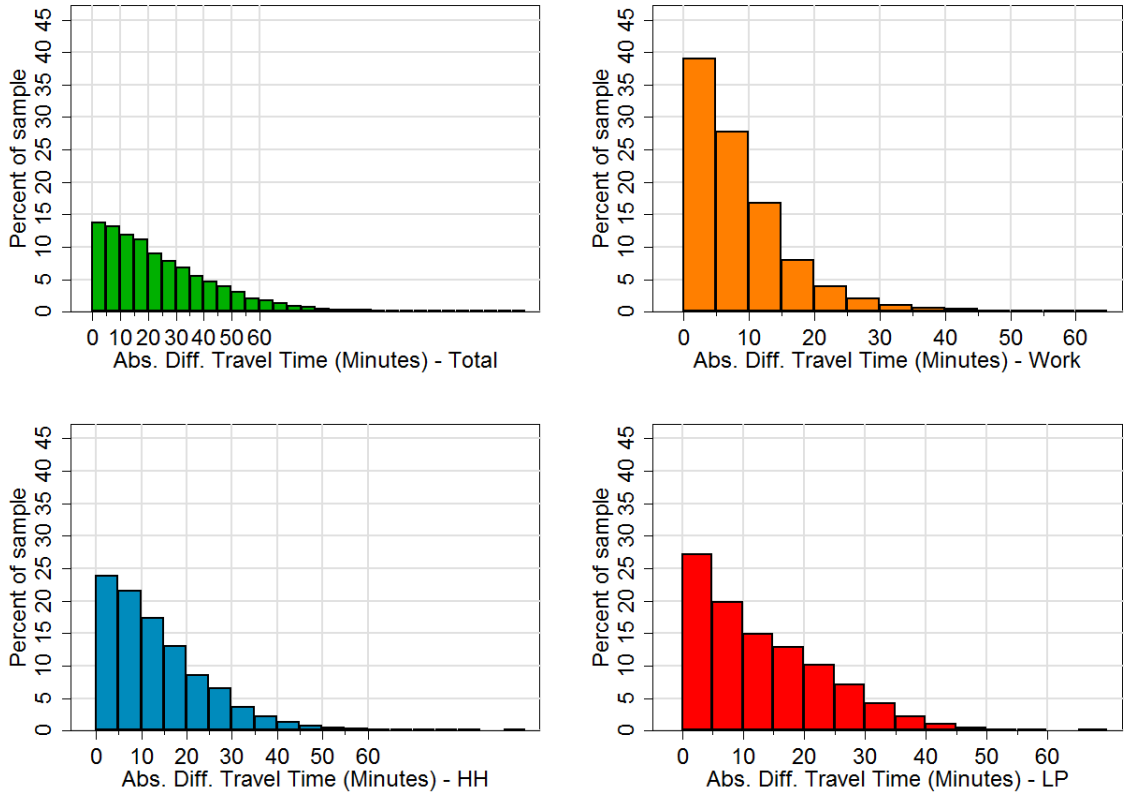


Table 8 – Statistics of the absolute difference in travel time – 2012

	Mean	Median	10th percentile	90th percentile	Inter-quantile range
Abs. difference in travel time – Total	25.573	20.227	3.694	54.537	26.928
Abs. difference in travel time – Work	8.955	6.858	1.210	19.270	9.053
Abs. difference in travel time – HH	14.088	11.124	2.034	30.045	14.753
Abs. difference in travel time – LP	13.634	11.056	1.920	28.873	15.864

Table 9 – Percent of sample with an absolute difference in travel time less than or equal to ten minutes

Year	Total	Work	HH	LP
2012	26.51	65.70	45.87	46.11
2011	23.88	57.36	42.84	39.29
2010	18.39	65.26	31.11	31.32
2009	18.39	59.07	34.47	30.74
2008	21.59	53.95	31.06	41.62
2007	20.63	54.28	31.77	35.05
2006	20.47	57.82	35.14	37.94
2005	17.49	51.91	31.57	26.82

Section 4 – Discussion

This section discusses issues relevant to the findings of this paper. Section 4.1 focuses on the discussion of consistent average travel times as a transferable assumption that can be used in a range of applications and the modelling of travel demand. Section 4.2 discusses whether a consistent average is important when the shape of the distribution has a large range of values and introduces some literature that has asked a similar question in other contexts. Section 4.2 then concludes with a discussion of avenues for future research and the type of data that can be applied to these avenues of investigation.

4.1 – Modelling using transferable travel characteristics

A noted proponent of travel budgets, Yacov Zahavi reviewed whether the development of transport models could utilise travel characteristics that are generally transferable and consistent based on key factors. Zahavi (1982) focused on the regularity of daily travel time expenditures per traveller and whether this foundation was more transferable than one that focused on something more irregular, such as trip-rates. Within the paper, Zahavi was careful to note that he did not seek to establish whether daily travel times were actually fixed, as this would not allow for heterogeneity between socio-economic groups and other factors such as mode of travel, but sought to establish "whether regularities exist at a useful level of disaggregation that are transferable in space and time" (Zahavi (1982): 206). As an example, this transferability was utilised by Schafer and Victor (2000) when they projected total mobility for eleven aggregate world regions up until 2050. These studies were important in developing this article as they led to the question of what are the travel characteristics that are transferable and stable, as opposed to those that are highly variable and extreme. This led to my interest in travel behaviour across different days of the week and a focus on discretionary days.

When focusing on stable travel times, Schafer and Victor (2000) also considered income, speed and distance as important factors related to the amount of time used for travel and noted that these

variables were likely to depend on the mode of vehicle and living arrangements. These issues led Schafer and Victor (2000) to contend that future mobility will include more extreme travel behaviour and conclude that the amount of commuting between different cities or local areas would depend on high-speed transport options. Related to this, Metz (2008) discussed the consistency of average travel time and the lack of evidence for travel time saving from improved infrastructure. Metz (2008) noted that an "improvement in the transport system allows further access to desired destinations, within the more or less constant time people allow themselves on average for travel" (Metz (2008): 333). This paper and those that focus on differences across types of days, such as Bhat and Misra (1999); Yamamoto and Kitamura (1999), Holden and Linnerud (2011) and Stopher et al. (2016), are relevant to this discussion as a focus on everyday travel has meant that transport policy and research have not fully considered the implications of the different travel patterns that occur between discretionary and non-discretionary days. For example, the literature on the value of travel time has tended to focus on variations based on the time of the day on weekdays (Small, 2012), even though early work had focused on differences between weekdays and weekends (Horowitz, 1978). This paper has shown that how people commute to work and travel for leisure does matter and the variance of this travel is important when modelling or producing forecasts. While this paper has focused on differences in travel times for different types of days, there are important underlying factors that explain these differences. Unfortunately, a review of the mode and distance of travel cannot be tackled using this dataset. It is acknowledged that further disentangling the differences between days needs to be a question of future research.

4.2 – Going beyond the average

A consistent average daily travel time may not be interesting or a transferable value if there is a notable skew in the distribution or key factors combine to determine the average. For example, applying the average to the total number of observations to estimate the total amount of travel will result in an appropriate estimate. However, this estimate may be inappropriate for other applications, such as travel related to certain activities or certain days of the week. This paper has focused on using

an endogenous switching model to show that travel on discretionary days is highly variable and that this is a complexity that should be accounted for as the three equations were found to be dependent. This means that the average daily travel time is likely to have limited transferability. The econometric literature has developed estimation techniques that account for endogeneity and others that model the entire distribution with an aim of going beyond the mean when distributions are skewed. Examples of these distributional techniques include parametric methods and distributional models. Jones, Lomas, and Rice (2015) contains an overview of these techniques with an application to healthcare costs on the health economics literature. These approaches have also been used to calculate counterfactual distributions and review differences in the dispersion of wages.

Further research in this area is planned by the author and the MTUS provides data on a range of countries that can be used to replicate the findings of this paper for the UK, Spain, France and Canada. And while utilising estimation techniques that focus on the entire distribution is likely to assist in the understanding of the consistency and extremes of travel behaviour, the issue of endogeneity has meant that this paper has focused on producing estimates using a switching model rather than a distributional approach. This paper has made a start by estimating differences in travel using counterfactual estimates and focusing on the consistency of the whole distribution across years. Further research on the consistency of travel times that looks beyond the mean is warranted and replicating these findings for other countries and data sets will be an important step in establishing the importance of considering travelling on discretionary days and non-discretionary days.

Section 5 – Conclusion

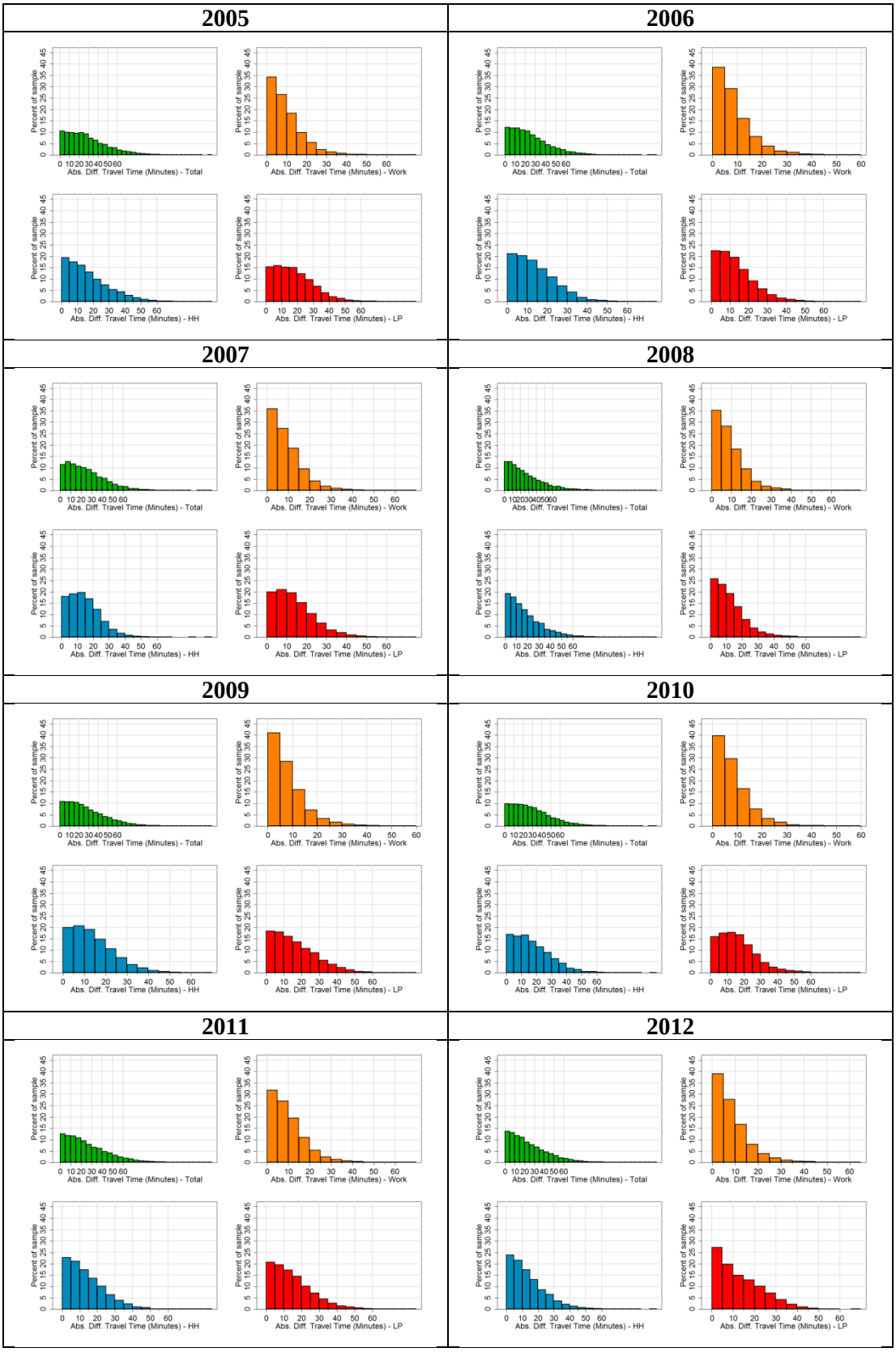
This paper has focused on travel times related to a variety of activities with the aim of investigating how they differ between discretionary and non-discretionary days. The intention was to unite literature focused on the purpose of travel and the resulting travel patterns that occur with literature that focuses on consistent travel time expenditures. Accordingly, this paper finds that average travel time expenditures can be consistent across multiple years even though there is notable heterogeneity across individuals based on their particular situation or decisions of how to spend their time on discretionary days. This suggests that consistent average travel times are not a result of similar budgets across individuals, but that travel time budget planning and actual travel time expenditure are likely to involve a trade-off between a range of factors, including the mode of travel, traffic/congestion and the location of residence, work and recreation. Differences between discretionary and non-discretionary days infer that people tend to minimise their travel to work based on long term planning and their location of residence, while being willing to extend their travel times on discretionary days for household duties and leisure/personal activities.

By estimating an endogenous switching model, this paper finds that differences in travel time related to work on a discretionary and non-discretionary day are less than or equal to ten minutes for more than 50% of the sample. In comparison, only about 18-27% of the people in the sample have total travel times that differ by ten minutes or less. This confirms the hypothesis that consistent travel times correspond with travel related to work as it tends to be determined by long-term planning of regular commutes, while irregular travel times tend to coincide with leisure/personal activities on discretionary days of the week. So while evidence of consistent travel time expenditures is found, notable heterogeneity occurs based on the activity that the travel is related to and the type of day the travel occurs.

These results have notable implications for the travel time budget literature and raises questions for future research. The main question is whether these results hold in different contexts (i.e. at the country, community and individual levels) and are replicated in various data sets that have been devoted to measuring consistent average travel expenditures. The explanation for relatively small differences in travel related to work (i.e. long term planning of travel based on the location of residence and work) should be further explored and the validity of the claim tested with regards to differences in travel times between discretionary and non-discretionary days. Within this paper, changes of location have not been considered as daily travel time diaries do not capture such occurrences. In relation to this, how the rational locator hypothesis, or alternatively the co-location hypothesis, fares when discretionary and non-discretionary days are accounted for is of interest.

Appendix

Figure 1A – Difference in travel between a discretionary and a non-discretionary day – 2005 to 2012



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