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COMMUTING COSTS AND THEIR IMPACT ON WAGE RATES

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ABSTRACT

Using data from households across Scotland this research found strong evidence that wage compensation for commuting does occur, though this is only partial. The evidence also appears to suggest that compensation for commuting costs occurs entirely through the wage rate. Additionally, there is evidence to suggest that the marginal level of compensation varies by gender. A key finding of this study is that the complex interaction between wage rates, commuting costs, work and household location decisions and the value of travel time means that, through labour supply effects, transport policy has little impact on wages. The wage appears almost insensitive to transport policy measures as the behavioural response to such measures is to alter commuting distances.

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1 INTRODUCTION

Transport policy has long been viewed by regional policy makers as an important component of economic development policy. From the national perspective transport policy has however been typically viewed as having a more distributive role, and to a certain extent this is still the case – in the absence of other evidence it is normal in transport appraisal to assume no net employment gains at the national level. Within the last ten years the debate surrounding the wider impacts that transport policy can have on the economy and the scale of those impacts at the national and international level has intensified (SACTRA, 1999; van Exel *et al.*, 2002; Laird *et al.*, 2004). The Department of Transport has therefore recently published guidance on the calculation of wider economic benefits and the impacts on GDP (DfT, 2005a), and the Secretary of State for transport has, in conjunction with the Chancellor of the Exchequer, asked Mr Rod Eddington to undertake a study of the long term impact of transport on the economy (the Eddington study). From the current policy perspective there is therefore a need to understand the manner in which transport policy can affect the wider economy and the scale of any impact.

One of the key aspects of the economy that transport policy can affect directly is access to employment. A lowering of commuting costs, by lowering the reservation wage may, in the long run, result in a reduction in the real wage as well as induce an increase in labour market participation. However, this is not the only economic response that may occur due to a reduction in commuting costs. This is because in response to lower commuting costs individuals may just choose to live further away from their workplace. This paper therefore has two objectives. First of all it aims to identify whether a relationship exists between wage rates and commuting costs, and quantify that relationship. Secondly it aims to develop an understanding of whether lower commuting costs can be transmitted through the labour and transport markets into lower real wages and increased labour market participation.

Following this introductory section, section 2 of this paper sets out the existing theory and evidence base on wage rates and commuting costs. Section 3 and sections 4 of this paper present the economic system that describes the relationship between wage rates and commuting costs, introduces the dataset and presents the results of the econometric analysis. Section 5 brings the findings of the research together and draws out some policy conclusions.

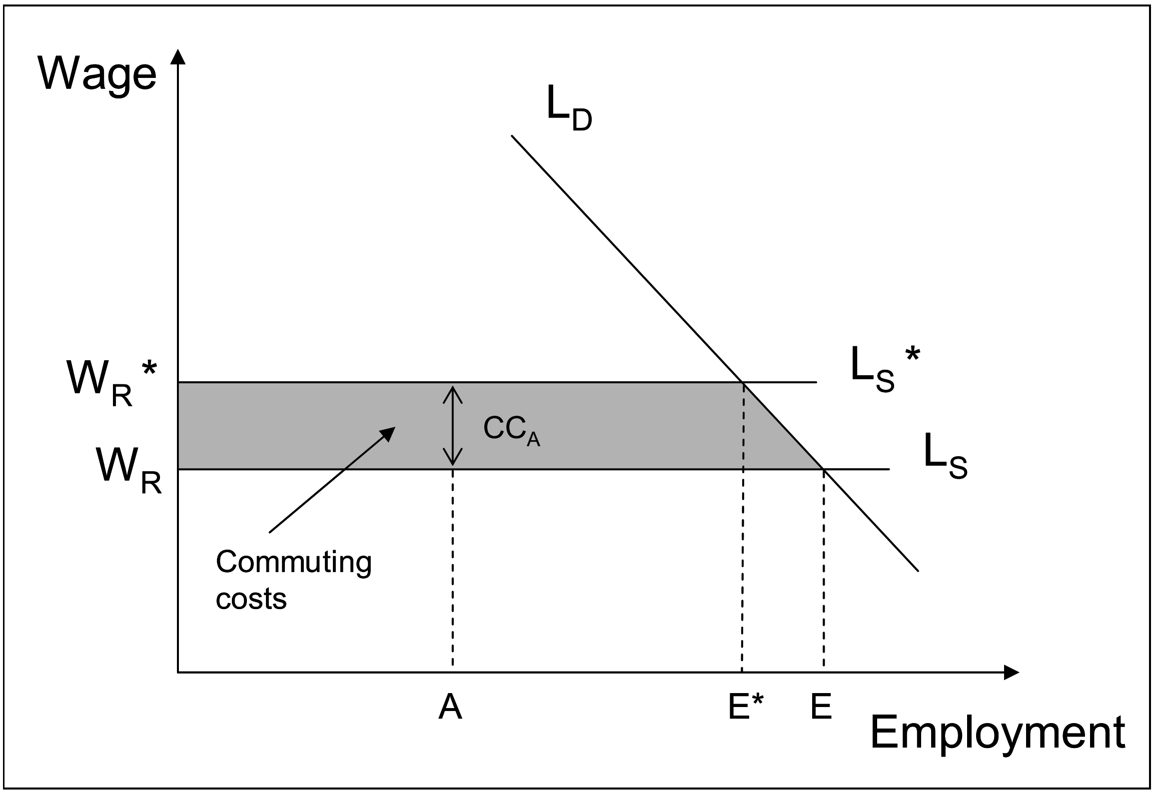
2 THEORY AND EVIDENCE

The relationship between commuting costs and the wage rate is bound up in the theory of labour supply and in the relationship between land values and accessibility. Individuals allocate time between work and leisure subject to a time constraint (24 hrs in a day) and a budget constraint (income, both earned and unearned, equals expenditure). The equilibrium balance between the number of hours allocated to work and to leisure is determined by the wage rate (Becker, 1965). The principle of compensating differentials also implies that if different jobs reward individuals in different ways or offer different working conditions then wage rates will reflect this. In equilibrium the worker will therefore be indifferent between different jobs. The result is that a certain quantity of labour (e.g. 40 hours a week) will only be supplied if the wage offered exceeds a threshold (the reservation wage) – which will vary with working conditions, the number of hours of labour supplied and personal preferences. Furthermore in equilibrium the wage offered to workers, the marginal product of labour, equals the reservation wage of the marginal worker.

Within this model there is no space for commuting between the home and the workplace. Commuting always takes up time and may also have cost implications. Commuting therefore impacts on both the time budget constraint and the money budget constraint - thereby affecting the equilibrium allocation of hours between work and leisure (Oort, 1969; Evans, 1972; De Serpa, 1973). The marginal cost of commuting reflects the sum of: the marginal cost of transferring time from commuting to either work or leisure; plus the out of pocket costs of the commute (Truong and Hensher, 1985; MVA *et al.*, 1987). For workers who face a choice between two jobs, equivalent in every way except for wages and commuting costs, then for the workers to be indifferent between the jobs the wage differential has to be exactly equal (and opposite in sign) to the difference in the commuting costs. Commuting costs therefore form another component of the worker's reservation wage.

Starting from the simplest possible case, consider a situation where all round competition exists and where all workers facing the same commuting costs. In Figure 1 L_S represents the labour supply curve for a situation in which all workers face no commuting costs – i.e. households and workplaces are located at the same point in space (with perfectly elastic labour supply). Labour will be supplied if the wage offered exceeds the reservation wage (W_R) – which reflects the opportunity cost of working and working conditions. If households and workplaces are physically separated, but all workers still experience the same commuting cost (CC) then the labour supply curve would be L_S* and the reservation wage would be W_R*. The difference between W_R and W_R* is the commuting costs (CC). In this situation all workers are fully compensated for their commuting costs through the wage rate. This represents one of the two extreme positions for compensation of commuting costs. The figure also illustrates the labour supply effect of a change in commuting costs - if commuting costs decrease (from CC to zero) employment increases from E* to E.

FIGURE 1 LABOUR SUPPLY WITH FIXED COMMUTING COSTS FOR ALL EMPLOYEES - PERFECTLY ELASTIC LABOUR SUPPLY

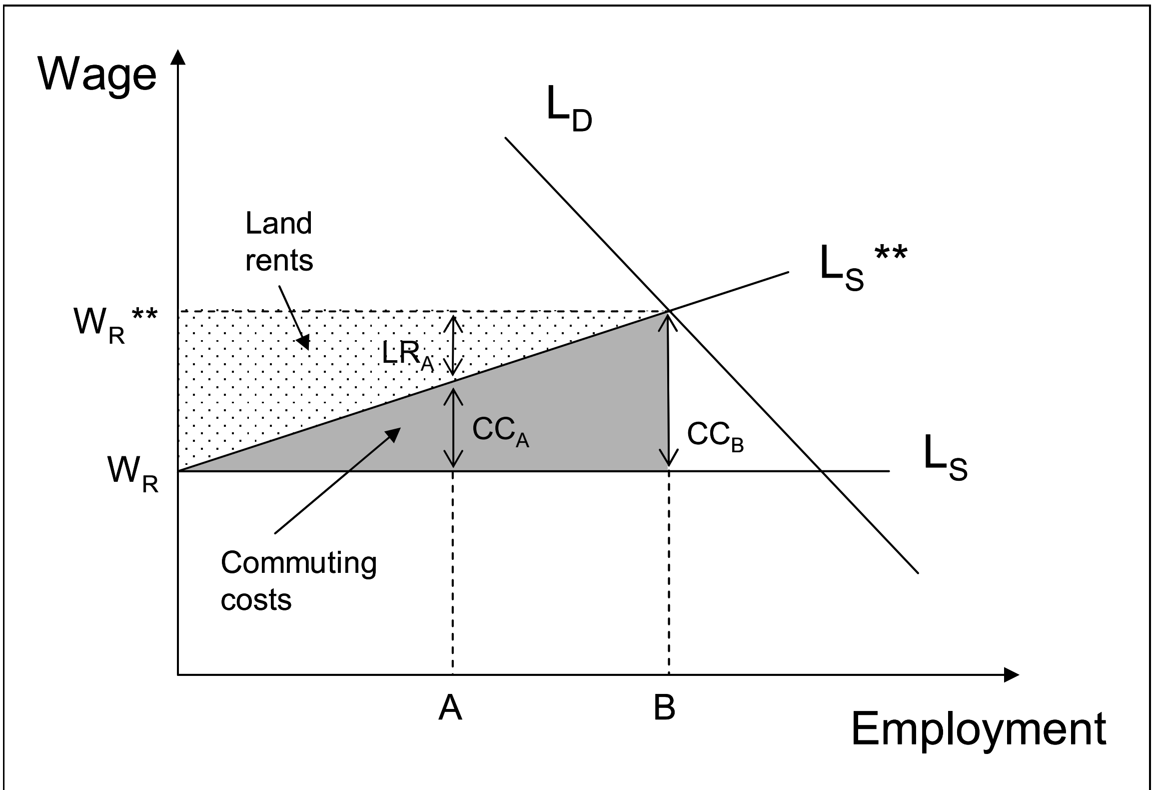


The capitalisation of accessibility, including commuting costs, and other location attributes into urban economic spatial models is well established (Alonso, 1964; Muth, 1969; Mills, 1972) and in fact dates back to the early work of von Thünen (1826) (cited in SACTRA, 1999). Drawing on this literature we can illustrate that workers can receive their compensation for commuting costs entirely through the housing market and not through their wage – the difference with the previous illustration arises due to the different spatial arrangement of dwellings and workplaces. In the simple situation of a mono-centric spatial model all employment is located at one point and land supply is scarce. If the only differentiating feature between different units of land are commuting costs to employment, we would expect a labour supply curve (L_S**) that increases with the commute (see Figure 2[1]). Here the equilibrium wage (W_R**) reflects the worker (B) who has the highest commuting costs (CC_B). Clearly workers, such as A, who live closer to the workplace than B experience lower commuting costs but still enjoy the equilibrium wage. They therefore experience an economic surplus. With a perfectly functioning land market, land rents would exactly offset such a surplus[2], resulting in every worker being indifferent to the location of residence. Thus the difference in commuting costs between A and B (CC_B – CC_A) is equivalent to the difference in the land rents the two workers face (LR_A). As in the simpler example, every worker in this model is fully compensated for their commuting costs. However, this time workers with

[1] In the absence of commuting costs all workers would have the same reservation wage (i.e. perfectly elastic labour supply).
[2] Providing the only difference between different places of residence were commuting costs.

longer commutes are compensated in the land market and do not receive any wage premium for their commutes. The person who receives full compensation via lower land rents is the person who experiences the highest commuting costs. Again we can see that a decrease in CC is associated with an increase in employment.

FIGURE 2: LABOUR SUPPLY WITH COMMUTING COSTS THAT VARY BY EMPLOYEE

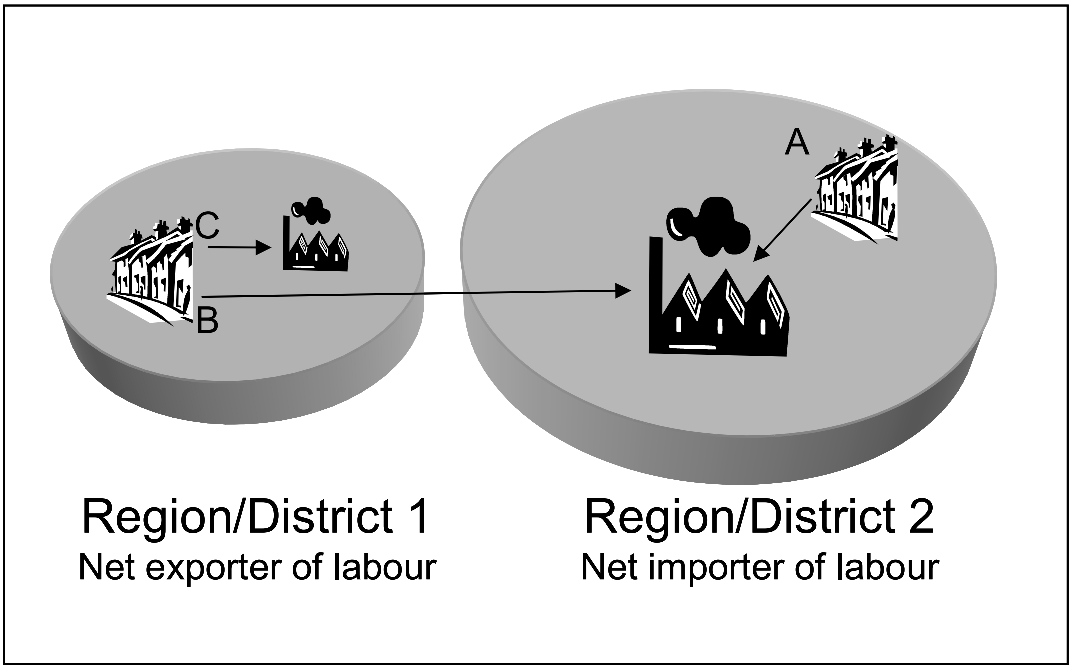


Clearly, workplaces as well as residences can also be located throughout space. In which case, commuting costs must be capitalised into both wages as well as into land rents (Muth, 1969). Workers are still fully compensated but they will receive their compensation in different ways – through their wages, in the housing market or through both. This can be illustrated with reference to Figure 3 and, for ease of explanation, the assumption that the only difference (from the workers' perspective) between workplaces and residences are wages offered, commuting costs and land rents. For the two workers (A and B), who have the same workplace and therefore receive the same wage but live in different locations to be indifferent between place of residence, land rents and commuting costs must offset each other exactly. This is equivalent to the situation depicted in Figure 2. However, for workers (B and C), who live adjacent to each other but work in different locations, to be indifferent between workplaces requires that the wage differential between workplaces be equivalent to the difference in commuting costs. That is workers require a wage premium to commute further. This model illustrates a number of important facets regarding wage rates and commuting behaviour:

- Commuting costs are fully compensated, but can be capitalised into either wage rates and/or land rents;
- Districts and regions that are net importers of labour have to pay higher average wages than the districts and regions from which the labour is exported – otherwise there is no incentive to commute; and
- Wage gradients can exist – that is firms who have to import labour from another locality (e.g. another region or the suburbs of a city) have to pay higher wages than firms who use labour from within the locality.

For the second and third points to exist in equilibrium requires the presence of market failures, such as agglomeration economies - otherwise there would be no reason for firms to concentrate. Agglomeration economies can arise when firms that are located in city centres or a capital city have advantages over and above firms located in suburbs or the regions arising through location (e.g. higher productivity per worker due better worker-job match). Firms that can benefit from agglomerating will bid up wages and property prices in the city centre.

FIGURE 3 COMMUTING WITH MULTIPLE WORKPLACES AND RESIDENCES – INTER-REGIONAL OR INTER-DISTRICT COMMUTING



Clearly there is a lot of heterogeneity within residential location. Some residences have pleasant outlooks, some are affected by air and noise pollution, some are isolated, some are close to shops, schools and other services, some are in good neighbourhoods and some are in bad. In addition to reflecting commuting costs, land rents will also reflect these attributes. Consequently it is possible for workers to trade their commuting costs against other attributes of their residence. In the context of a nation where dwellings and workplaces are dispersed geographically and there is heterogeneity between household locations, aside from accessibility, we may expect that land values may only on average reflect general accessibility levels. Local exceptions to this would only occur if employment is locally concentrated at a single point in space (as in the mono-centric city).

The previous discussion has, apart from the requirement of market failures in order to explain commuting, rested on the premise that the labour market works perfectly and competition exists everywhere. Moving away from that assumption gives rise to situations that may involve amongst others search costs, uncertainty, long term contracts and monopoly or monopsony. From our perspective the important point to note is that in the presence of such labour market imperfections workers may no longer be fully compensated for their commute (Zax, 1991; Van Ommeren *et al.*, 1997; Manning, 2003). Whilst only partially compensated workers may still receive that compensation in either wages, reduced land rents or a mixture of both. Van Ommeren *et al.* and Manning emphasise the role that imperfect information and job search costs play in the relationship between commuting costs and the labour market. Under such conditions workers will voluntarily accept commuting costs which are not compensated by the current characteristics of jobs and residences. This arises for two reasons. Firstly workers realise that commuting costs are temporary as they may change jobs or residences in the future (Van Ommeren *et al.*, 1997), and secondly that labour markets are thin (Manning, 2003). Manning argues that labour markets are thin because job search costs exist and job vacancies only arise periodically. In the presence of thin labour markets Manning demonstrates, theoretically, that the net utility of the worker decreases with increased commuting costs. That is in the presence of thin labour markets workers will not be fully compensated for their commuting costs. This is a similar argument to that espoused by Zax (1991) and Ihlanfeldt (1992), as it is the workers with the least residential mobility (i.e. those who face the thinnest labour market) who receive the least compensation for their commuting costs.

Evidence for the existence of wage gradients (e.g. a correlation between wage premiums and high commuting costs) have been found in various studies on North American cities (Madden, 1985; Zax, 1991; Ihlanfeldt, 1992; McMillen and Singell, 1992; Timothy and Wheaton, 2001). There also exists evidence for imperfect markets, that is employers may have monopsony power, workers may be discriminated against by gender and race and some workers may have more market power than others. For example, Ihlanfeldt (1992) finds significant wage gradients for white workers, but insignificant gradients for blacks. Zax (1991) finds evidence of significant variation in the level of compensation for commuting costs by gender and race. Zax partly attributes these results to be a reflection of market power of the different workers. In this context Zax considers labour market power derives from residential mobility "workers with greater residential mobility have access to larger geographic job markets, more job opportunities, and, therefore greater capacity to shift the burden of commuting expenses onto employers". Males, as the most likely primary workers in a household, have the largest degree of residential mobility, whilst females as the most likely secondary worker have less mobility. Manning (2003) found that job separation rates increase with the length of the commute, which is consistent with the theory that workers are only partially compensated for commuting costs in the presence of monopsony power. If workers were fully compensated for commuting costs, there should be no difference in job separation rates by commuting distance.

There is also a growing evidence base within the UK on the impact of transport accessibility on property prices (and therefore land rents). Gibbons and Machin (2005) found that a 1km reduction in distances to tube stations in London increases house prices by more than 1.5%. The accessibility brought about by the Jubilee Line extension in London is thought to have increased property prices in Southwark by £78 million and in Canary Wharf by £2.1 billion (£2 billion to the value of new developments and £73 million to the value of existing properties) (Atisreal and Geofutures, 2005).

The majority of studies examining the relationship between commuting costs and wage rates have been undertaken by labour and urban economists who have been interested in empirical evidence for wage differentiation and labour market imperfections (e.g. Madden, 1985; Zax, 1991; Ihlanfeldt, 1992; McMillen and Singell, 1992; Timothy and Wheaton, 2001; Manning, 2003). It is therefore not surprising that no study has constructed wage equation estimates that have utilised the full costs of commuting – that is all the time costs, (dis)comfort costs, reliability costs and all the out of pocket costs, or what transport economists call the generalised cost of the commute. From the perspective of transport policy it is the relationship between commuting costs (as measured by the generalised cost of the commute) and the wage rate that is of most interest. It is this empirical question which forms the focus of this research.

From the discussion above it can be seen that economic theory is unclear regarding the precise level of compensation that workers will receive from commuting costs. Some workers may receive no compensation in the wage and others may receive full compensation. Market power, the role of the housing market and the spatial pattern of households and workplaces all affect the level of compensation received by the worker in their wage rate. Those studies which have calibrated wage equations also give a wide variation in the level of compensation received. Zax (1991 p202) found wage compensation for time spent commuting that varied from several times the hourly wage rate to negative values. Timothy and Wheaton (2001 p354) find compensation for time spent commuting that varied between 1.6 and 3.0 times the hourly wage. Van Ommeren *et al.*(2000 p561) finds an average value for his dataset of half the hourly wage. Manning (2003 p113) finds a similar average level of between 42% and 57%. Manning's work is the only British research in this subject area and the two results relate to wage equations calibrated on the Labour Force Survey (LFS) and British Household Panel Survey (BHPS) datasets respectively. Whilst these authors' conclusions are clear their research does not answer our policy question. This is for the reasons set out below.

Firstly a causality problem exists. The demand to travel is a function of income –those on higher incomes travel further. This may seem counter-intuitive at first as those with higher incomes have a higher opportunity cost of travel time. However, as travel is both expensive and is a derived demand, those with high incomes have a larger choice set of spatially dispersed activities, than those on lower incomes. The additional benefit associated with undertaking activities in more distant locations often more than offsets the additional travel costs associated which accessing those activities – even when the opportunity cost of time spent travelling increases with income. Consequently the demand for travel is heavily correlated with income (DfT, 2005b; Scottish Executive, 2005a). In the context of commuting the choice faced by those on higher incomes is the choice of residence. Those on high incomes have a larger range of geographic choices of places to live than those on lower incomes – all else being equal. The causality problem gives rise to a high correlation between commuting costs and income which in turn as has two effects on the econometric modelling. The first as Manning demonstrates is that the exclusion of parameters that explain wage setting (e.g. qualifications and occupation) will overestimate the importance of commuting costs in a wage equation, and secondly any results based on Ordinary Least Square regressions (e.g. Zax, Van Ommeren *et al.*and Timothy and Wheaton) will not account for the endogeneity of commuting costs and will therefore develop biased estimates of the elasticity of income to commuting costs.

With only a partial measure of commuting costs (the time element) being included in the wage equation, it is impossible to determine from the existing studies whether wages fully or partially compensate workers for commuting costs. This is exacerbated by the fact that empirical evidence from studies of mode and route choice, both using revealed and stated preference data, consistently identify that marginal value of a saving in commuting time is significantly less than the wage rate[3] (e.g. Mackie *et al.,*2004; Algers et al., 1995, Ramjerdi, et al., 1997, Hague Consulting Group, 1998). The fact therefore that hedonic wage equation regressions identify a marginal willingness to pay for commuting time of less than the wage rate cannot therefore be interpreted as partial compensation for commuting costs (i.e. evidence of imperfect labour markets)[4].

As compensation can also take place through the housing market it is important to take this interaction into account (which only Manning and Zax do).

The objective of this research is therefore to build on the existing evidence base to provide further evidence on the whether wage rates fully or only partially compensate for commuting costs. To fully answer this question requires the econometric process to include all costs associated with a

[3] The transport economics literature (see for example Mackie *et al.*2001) emphasises that the marginal value of a reduction in commuting time is the difference between the marginal value of commuting time and the marginal value of leisure time (which equals the wage rate – Becker (1965)). This arises because travel is an intermediate good (De Serpa, 1973).
[4] It should be noted that Manning also shows that job separation rates are positively correlated with commute time implying that workers are only partially compensated for commuting costs.

commute, the endogeneity of income and commuting costs and the possible interaction between wage rates and land values.

3 THE ECONOMIC MODEL AND DATASET

3.1 The economic system

The economic system relevant to this research can be described by three relationships. The first equation relates to the labour market, the second to commuting costs and the third to the demand for commuting.

3.1.1 The labour market

The classic wage equation is a reduced form equation that includes elements that affect both labour demand and labour supply. On the labour demand side the wage offered by firms is determined by labour productivity and labour costs. Clearly labour productivity is related to employees' skills (qualifications, experience), the industry in which they work and the job they do (occupation). If the industry in which the firm operates is subject to economies of scale and agglomeration economies then we may also expect labour productivity to vary with workplace size and workplace location. Unionised workforces typically receive higher wages than non-unionised workforces – particularly for manual workers - therefore the existence of a collective bargaining system may affect the capital/labour balance of a firm and therefore labour productivity. The fixed costs of employment, particularly those of training and managing employees in addition to differing payroll costs (e.g. the National Insurance threshold) may also imply that the relative value to the firm (per hour) of part-time workers is less than that of full-time workers.

On the labour supply side we would expect the reservation wage to reflect the pleasantness/unpleasantness of the job, other forms of remuneration (e.g. employer's pension contributions) and the opportunity cost of working. We may expect the opportunity cost of working to vary with household structure, household income and number of hours worked (i.e. the scarcity of leisure). We also expect the reservation wage to include an allowance for the costs of accessing a job – whether these are commuting costs only or a mixture of commuting and housing costs (see Figure 2).

We would therefore hypothesise a relationship for the wage of the form:

Wage	=	F(LABOUR DEMAND FACTORS)							(1)
		Human capital	,	Firm specific	,	Location specific	,	Employment status	
		[qualifications] [experience] [occupation]		[Industry] [size of firm/ workplace] [union/ collective bargaining]		[region/ proximity to other firms/ workforce]		[full-time/ part-time]	
	+	G(LABOUR SUPPLY FACTORS)							
		Access Costs	,	Job specific	,	Other forms of remuneration	,	Opportunity cost of working	
		[Commuting costs] [Housing costs due to access to employment]		[Industry] [Occupation]		[Bonus] [Pension] [Company car]		[Household structure] [Hours worked]	

3.1.2 Commuting costs

The consensus within the transport literature is to describe the costs of travel in the form of an equation of generalised cost – in which all components of utility/disutility are summed. The main components of generalised cost are time, comfort/discomfort and out of pocket costs. In some instances the value of time will vary by mode as the comfort/discomfort effects are aggregated with the willingness to pay to transfer time from travel to some other activity. Journey time is obviously dependent on the mode of travel and the location of the origin and destination (i.e. residential and workplace location). Evidence on valuation of travel time also indicates that it varies with income and journey length. Thus we would postulate the following relationships for commuting costs:

Commuting costs	= H(	Value of time	,	Journey time	,	Out of pocket costs [Parking costs] [Fares] [Vehicle operating costs]	) (2)

Where

Journey time = I(commute distance, mode, speed)

Value of time = J(mode, income, journey, length, congestion, overcrowding)

Vehicle operating costs = K(vehicle type, speed and distance)

Speed = L(mode, location)

COMMUTE DISTANCE

In the long run we would expect that employees choose where they work and where they live. They therefore face an implicit trade off between commuting distance (affected by commuting costs), housing costs and quality of area. Households also need to balance the needs of all members of the household. Different members of the household perform different roles and therefore face different constraints. Commuting distance may therefore also vary by gender. The final relationship of the economic system we wish to model may therefore look like:

Commuting distance	= M(	Commuting costs	,	Income [Wage] [Bonus] [Pension] [Company car]	,	Cost of living [Land values] [Other hhold income] [Rent/ mortgage] [land values]	,	Personal and household structure [gender] [age] [children]	,	Niceness of area [Good school] [Shops] [Healthcare] [Recreational facilities] [Crime] [Vandalism] [Social deprivation] [Green space]	)	(3)

Estimation of this model poses a number of challenges of interpretation and specification, but the most fundamental one is the acquisition of data.

3.2 The choice of dataset

A number of datasets have been reviewed for use in this research: the Scottish Household Survey (SHS), the National Travel Survey (NTS), the British Household Panel Survey (BHPS), the Labour Force Survey (LFS), the Annual Survey of Hours and Earnings (ASHE) and the Census 2001. Clearly whichever dataset is to be used has to have both wage/salary data and commuting information. As set out in Table 1 only three datasets have such information: the SHS, the BHPS and the LFS.

TABLE 1: INCLUSION OF WAGE/SALARY AND COMMUTE DATA BY DATASET

	SHS	NTS	BHPS	LFS	ASHE	Census
Wage Data	✓	X	✓	✓	✓	X
Commute Data (some)	✓	✓	✓	✓	X	✓
Potential Dataset	**Yes**	**No**	**Yes**	**Yes**	**No**	**Yes**

We now consider each of these three datasets in more detail with regard to the sample size, the description of the individual's job, remuneration from work, commuting costs, personal information, household and quality of residential area information and location information. This is set out in the attached annex and is summarised and subjectively scored in Table 2. As can be seen from this table the LFS contains relatively little information on the household and as such is weaker than both the SHS and the BHPS. The BHPS is strong on household data, but is weak on data regarding the full costs of the commute and location related information. These two areas of weakness are unfortunately critical if the research is to include the full generalised cost of the commute and dummy variables for urban and rural environments (which can be used to proxy a number of things from agglomeration to quality of environment). The SHS whilst being weaker than the BHPS in a number of areas still contains sufficient information in these areas (for this research), as well as importantly containing more detail regarding commuting costs and location. The SHS was therefore chosen for this research.

TABLE 2: SUMMARY OF DATASETS

	SHS	BHPS	LFS
Sample available	75,000 (5 years). [The travel diary is completed for previous days travel only] Includes Scottish islands and remote areas, but excludes England and Wales	20,000 (individuals) independent observations 80,000 if all waves since 2000/1 are used (includes repeat observations) [panel survey implies each individual is re-interviewed each year] From 2000/1 includes all GB.	22,000 households (approx 33,000 individuals per year). 231,000 based off 7 years data 1997 – 2003). Includes all GB
Job	Good (excludes union membership)	Excellent	Excellent
Remuneration from job	Good (excludes membership of company pension scheme)	Excellent	Good (excludes bonus and membership of company pension scheme)
Commuting costs	Good to excellent (varies by mode) (excludes PT fares)	Weak (only includes commuting time and mode)	Weak (only includes commuting time and mode)
Personal	Excellent	Excellent	Excellent
Household and living area information	Good (Something on all categories needed, but not as much info as in the BHPS)	Excellent	Poor
Location Information	Acceptable (local authority and 8 rural/urban classification based on accessibility)	Weak (areas with populations > 120,000)	Weak to acceptable (local authority)

3.3 The Scottish Household Survey

The Scottish Household Survey (Scottish Executive, 2005b) is a continuous survey based on a sample of the general population in private residences in Scotland. The aim of the survey is to provide representative information about the composition, characteristics and behaviours of Scottish households. There is a particular focus within the survey to inform policy on transport and social inclusion. The sample for the survey is designed to provide nationally representative samples of private households and of the adult population in households. It is also designed to provide data over a two year period for each of the 32 local authorities. The questionnaire is in two parts. The householder or spouse/partner of the householder completes the first part which deals with topics such as household composition, housing and tenure, the vehicles available to the household, household income and housing costs. The second part of the questionnaire is completed by a random adult in the household. This section deals with individuals' housing change, tenure change, neighbourhood problems, transport and use of public transport, public services, income and employment. Importantly for this research this part of the questionnaire also includes a travel diary. There are approximately 15,000 households interviewed each year.

The SHS data from 1999-2003 has data on 75,746 households. In each of these households travel and income data is collected from a 'random adult. As can be seen from Table 3 there are only 34,120 (45%) of the cases where the random adult is in employment. Of these cases further analysis indicates that there are only 25,530 in which the random adult works full-time (23,564 full-time employees and 1,966 full-time self-employed). Thus our dataset is immediately reduced to a third of the SHS's sample size.

TABLE 3: ECONOMIC ACTIVITY OF RANDOM HOUSEHOLD ADULT – INTERVIEWED FOR INCOME AND TRAVEL DATA

		Frequency	Percentage
Valid	Self employed	3,357	4.4%
	Full time employment	23,564	31.1%
	Part time employment	7,199	9.5%
	Looking after home/family	5,766	7.6%
	Permanently retired from work	21,508	28.4%
	Unemployed and seeking work	2,756	3.6%
	At school	615	0.8%
	Higher/further education	2,025	2.7%
	Government work/training scheme	131	0.2%
	Permanently sick or disabled	3,897	5.1%
	Unable to work due to short term ill-health	638	0.8%
	Other	381	0.5%
	Total	71,837	94.8%
Missing data		3,909	5.2%
Total		75,746	100.0%

The data set of full-time 'random adults' has been cleaned by excluding records where:

INCOME DATA

- Income data was of uncertain quality (had either been imputed by the SHS administrators or had been flagged as of poor quality by the SHS administrators);

COMMUTING DATA

- The random adult did not work on the day preceding the day of interview (i.e. there is no commute data in the travel diary);
- The journey to work was between 'home' and 'a place other than the workplace';
- The data on trip length or journey time had been flagged by the SHS administrators as of uncertain quality;
- Journey time was more than 3 hrs;
- Journey distance[5] on outward and return legs differed (implied some form of trip chaining occurred);
- Journey time on the outward and return legs of the commute differed by more than 60 minutes;
- Journey speed was:
    - Slow modes: speed ≤ 1km/h (with journey distance > 1km)
    - Motorised modes: speed ≤ 2km/h (with journey distance > 1km)
    - Motorised modes: speed > 130km/h
- Modes that required payment of a fare (which is not recorded within the travel diary). That is the dataset only contains those who travel by foot, bicycle, car (driver and passenger), motorcycle and works bus. This resulted in no public transport (PT) commuting journeys being included in the analysis. Potentially they could have been included through the calculation of an approximate PT fare. However, it was felt that if such a calculation was undertaken and it was found that there were differences between PT users and other commuters it would not be clear whether this difference had a risen due to the fare imputing process or reflected real differences. For clarity of the results public transport users were therefore excluded from the analysis.

GENERAL

- the random adult works from home or is based from home (with no main workplace);
- single pensioner working households;

[5] Crow-fly distance

This resulted in a dataset of 5,114 full-time workers – which is only 6.7% of the original household dataset. Aside from those not in full-time employment the criteria which excluded the most records were those associated with working from home or with no main workplace; or providing no (or poor) income data. A substantial number of records (16%) were also excluded because the journey to work on the day of the travel diary was not between home and the main place of work[6]. The criteria on journey length, duration and speed did not exclude many records.

Of course this data cleaning and selection represents an enormous reduction in sample size. However, this is not a problem as long as: there are enough observations left for model estimation (which is evidently the case here); and the reduced sample, aside from including only full-time workers, is not selective. The following section demonstrates that this is also the case.

Table 4 presents summary data on the characteristics of full-time workers in the main SHS dataset and the cleaned data. As can be seen from this table the cleaning process has not affected the cross-sectional characteristics of the data. There is a slightly larger proportion of women in the cleaned dataset, a corresponding reduction in skilled tradesmen (and increase in professional occupations) and a reduction in salaries.

As can be seen from Table 5 the lack of data in the SHS on out of pocket costs (fares and car parking charges) has resulted in the exclusion of almost all public transport trips and some car trips. This distorts the mode split of the cleaned data compared to the complete SHS data. However, the relative modal proportions between walk, car (driver and passenger), bicycle, motorcycle and works bus have not been substantially affected by the data cleaning process.

[6] We do not have information on the rationale for trips between "home" and "other workplace". Therefore the wage may reflect unobserved attributes of the job for such trips. Implicitly we rely on the sub-sample of the dataset that travel between "home" and their "workplace" to be representative of the behaviour of all workers travelling to a workplace.

TABLE 4: COMPARISON OF COMMUTER CHARACTERISTICS BETWEEN SHS AND CLEANED DATA – FULL-TIME WORKERS

		SHS	Cleaned Data
Gender	Male	61%	59%
	Female	39%	41%
Age	25% quartile	32	32
	Median	40	40
	75% quartile	49	49
Occupation	Managers and senior officials	16%	16%
	Professional occupations	12%	14%
	Associate professional and technical occupations	13%	13%
	Administrative and secretarial occupations	13%	13%
	Skilled trades occupations	15%	13%
	Personal service occupations	12%	12%
	Sales and customer service occupations	9%	10%
	Process, plant and machine operatives	7%	7%
	Elementary occupations	2%	2%
Income (after tax and other deductions)	Mean	£15,783	£15,229
	25% quartile	£10,525	£10,200
	Median	£14,040	£13,200
	75% quartile	£18,524	£18,000
Rural/Urban classification	Large urban areas	33%	30%
	Other urban	30%	33%
	Small accessible towns	10%	11%
	Small remote towns	2%	2%
	Very remote small towns	3%	4%
	Accessible rural	13%	13%
	Remote rural	2%	2%
	Very remote rural	6%	7%
Household type	Single adult	23%	26%
	Small adult	28%	29%
	Single parent	3%	4%
	Small family	21%	22%
	Large family	9%	8%
	Large adult	12%	8%
	Older smaller	3%	2%
	Single pensioner	1%	1%
Total Records		25,530	5,114

Note 1: The Scottish Executive use an eight category urban-rural classification system based on the following definitions (see Annex F for a map):

Large urban: settlements with a population over 125,000
Other urban: settlements with a population between 10,000 and 125,000
Small towns: settlements with a population between 3,000 and 10,000
Accessible: within a 30 minute drive time from a settlement of 10,000 or more
Remote: between a 30 minute and 60 minute drive time from a settlement of 10,000 or more
Very remote: more than a 60 minute drive time from a settlement of 10,000 or more

Note 2: The Scottish Executive use an eight category household classification system:

Single adult: household contains one adult of non-pensionable age and no children
Single parent: household contains one adult of any age and one or more children
Single pensioner: Household contains one adult of pensionable age (60 for women and 65 for men) and no children

Small family:	household contains two adults of any age and one or two children
Older smaller:	household contains one adult of non-pensionable age, one of pensionable age and no children, or two adults of pensionable age and no children
Large adult:	household contains three or more adults and no children
Small adult:	household contains two adults of non-pensionable age and no children
Large family:	household contains two adults of any age and three or more children, or three or more adults of any age and one or more children

TABLE 5: COMPARISON OF COMMUTE MODE SPLIT PROPORTIONS BETWEEN SHS AND CLEANED DATA – FULL-TIME WORKERS

	SHS	SHS (excluding fare paying modes and those paying parking charges)	Clean Data
Walking	11.2%	14.2%	15.0%
Driver car/van	60.7%	69.2%	66.8%
Passenger car/van	9.7%	12.2%	14.1%
Motorcycle/moped	0.4%	0.6%	0.6%
Bicycle	1.8%	2.2%	2.0%
School bus	0.0%		
Works bus	1.3%	1.7%	1.5%
Ordinary (service) bus	9.6%		
Taxi/minicab	0.5%		
Rail	2.6%		
Underground	0.2%		
Ferry	0.2%		
Aeroplane	0.6%		
Horse-riding	0.0%		
Other	1.3%		
Total records	25,530	18,251	5,114

4 MODEL RESULTS

This section describes the calibration of the conceptual model set out in Section 3 using the SHS dataset. The wage equation and the commuting distance equation are estimated through the process of 2 stage least squares (2SLS), whilst the equation for commuting costs is populated using calibrated models.

4.1 Commuting Costs

As the SHS dataset does not contain information on public transport fares or parking charges, trips that incurred such costs were removed from the analysis. Equation (2) therefore becomes:

$$\text{Commuting costs} = \text{Value of time} * \text{Journey time} + \text{Vehicle operating costs (car/van mode only)} \quad (3)$$

Where:

- Journey time is as reported in the SHS dataset.
- Values of time are sourced from Mackie *et al.*(2003 Table 22 p65) (see also Annex B). Unit values of commuting time are therefore taken to vary with workers' household income and commuting distance. These values are in 1997 prices and values and therefore were growthed to the survey year using data on inflation and income growth. Values of time for walking and cycling were taken to be twice that of car in-vehicle-time – this is consistent with Department for Transport guidance (DfT, 2004).
- Vehicle operating costs (VOC) were calculated using the VOC formula in the Department for Transport's Transport Economic Note (DfT, 2004). All commuters are assumed to drive an average car. Journey speed is sourced from the SHS[7]. For drivers and passengers who travel in a car-sharing scheme, in which they either pay the driver or take a turn driving, the assumption that they pay half the VOC of the car or van is made. This assumption was made in the absence of national data on the average occupancy of shared cars.

Table 6 and Table 7 demonstrate that the average distance commuted is 9.8 km, the average time is 24 minutes and average commuting costs are 188 pence (one-way commute). Analysis of the commuting costs for car drivers also indicates that time costs comprise 51% of total commuting costs whilst total vehicle operating costs comprise the other 49%. The fuel related component of vehicle operating costs comprises 31% (of total commuting costs).

As can also be seen from these tables average earned income after tax and other deductions is £15,229. Earned incomes have steadily increased over

[7] The SHS administrators calculate journey speed from reported journey time and imputed crow-fly distance between work and home. The crow-fly distance is imputed from the addresses of home and workplace.

the five years of the data, as have commuting costs and commuting time. However, over this period commuting distances appear to fluctuate up and down between the survey years. There are also clear gender differences in both commuting behaviour and earnings between men and women. Women earn less, commute less and incur less commuting costs than men.

TABLE 6: ANNUAL INCOME AND COMMUTING COSTS BY SURVEY YEAR – FULL-TIME WORKERS ONLY

	Mean	1999	2000	2001	2002	2003
Commute distance (km)	9.8	9.5	9.9	9.7	9.6	10.2
Commute time (minutes)	24.0	22.9	24.0	23.7	24.0	25.0
Commuting costs (generalised cost) (pence)	188.1	161.8	182.0	183.8	190.9	210.3
Earned income (after tax and deductions)	£15,229	£13,936	£14,108	£15,145	£15,730	£16,554

TABLE 7: ANNUAL INCOME AND COMMUTING COSTS BY GENDER – FULL-TIME WORKERS ONLY

	Mean	Male	Female
Commute distance (km)	9.8	10.9	8.3
Commute time (minutes)	24.0	24.9	22.7
Commuting costs (generalised cost) (pence)	188.1	208.3	159.7
Earned income (after tax and deductions)	£15,229	£16,582	£13,319

4.2 Wage and Distance Equations

4.2.1 Specification and selectivity

Section 3 has set out a conceptual specification for the wage and distance equations against which the different datasets that were available were judged. The actual specification of the equations differs from these concepts due to the availability of the data. The final specification is detailed in Table 8. As section 3 set out, and Table 8 identifies, a number of the explanatory variables in both the distance and the wage equation are endogenous. In such circumstances the coefficients on the endogenous variables will be inconsistent if Ordinary Least Squares (OLS) regression is used to estimate the equations, instead the method of two Stage Least Squares (2SLS) needs to be adopted.

To estimate each equation using the method of 2SLS each equation has to be either exactly or overidentified. As can be seen from Table 9 both equations meet the order condition of identifiability (also known as the exclusion of variables criterion) and are therefore over-identified. Mathematically it can be shown that it is possible that not all equations that meet this criterion are either exactly identified or over-identified. However, the fact that the equations meet the criterion would lead us to believe that they are over-identified.

TABLE 8: WAGE AND DISTANCE EQUATION SPECIFICATION

		Wage Equation	Distance Equation
Income	Annual earned income	Dependent	endogenous[1]
Commute costs	Generalised cost	endogenous[2]	---
	Distance	---	Dependent
	Generalised cost per km	---	endogenous[2]
Job/Firm characteristics	Industrial sector (16 SIC sector variables)	exogenous	---
	Occupation (9 SOC variables)	exogenous	---
	Self-employed	exogenous	---
	Temporary job	exogenous	---
	Works in a small workplace < 25people	exogenous	---
Human capital	Experience (2 variables)	exogenous	---
	Qualifications (3 variables)	exogenous	exogenous
Household/ commuter characteristics	Female	---	exogenous
	Female interaction with occupation (9 variables)	exogenous	---
	Age	---	exogenous
	Household includes a child (<=16yrs old)	exogenous	exogenous
	Household type (8 variables)	---	exogenous
	Housing tenure (home-owner or renting accommodation)	---	endogenous[2]
	Car availability (3 variables)	---	endogenous[2]
	Estimate of annual land value/rent per bedroom (2003 prices)	endogenous[2]	endogenous[2]
Household Location	8 rural/urban classifications	---	exogenous
Workplace location	32 Local authority areas	exogenous	exogenous

Note 1: Function of commuting costs
Note 2: Function of income

TABLE 9: ORDER CONDITION FOR IDENTIFIABILITY

	Wage equation	Distance equation
Total number of exogenous variables in the model including constant (K)	15	15
Number of exogenous variables in the equation (k)	10	7
Number of endogenous variables in equation (m)	3	6
K-k	5	8
m-1	2	5
Is order condition met (K-k=>m-1)?	Yes	Yes

The results of the over-identification test rest on our a priori expectations regarding which variables are included and excluded from the two equations. The rationale for our equations is set out in section 3. Possibly it may be argued that the distance equation should also include variables relating to job/firm characteristics. For example certain industrial sectors (e.g. financial services) can only be found in specific places (e.g. cities and towns), whilst other sectors can be found everywhere (e.g. education). However, it is felt that distance to work reflects the characteristics of the locality (e.g. city or rural) rather than the characteristics of the job. Thus we would expect that commuting distances to education to be longer in remote rural areas than they are in urban areas. Job/firm characteristics are therefore excluded from the distance equation as local variations in commuting distances will be picked up by the geographical variables rural/urban classification and council area[8].

The identification as to which variables are exogenous and which are endogenous also requires justification. Clearly we expect income, generalised cost and distance to be endogenous along with other variables in the commuting cost equation (time, speed, value of time and vehicle operating costs). We also expect housing tenure and car availability to be endogenous as they are functions of income. With respect to housing tenure the size of mortgage is related to income and deposits are also required to secure a mortgage. Car availability will also reflect other factors such as gender (women typically get less access to the car than men in single car owning households) and geography (car ownership is higher in rural areas). Land values[9] are endogenous as they are a function of accessibility (commuting

[8] These a priori expectations were also confirmed as in an F-test on the inclusion of the block of variables associated with including job/firm characteristics in the distance equation the null hypothesis (i.e. that all the coefficients were not significantly different from zero) could not be rejected.

[9] Information on property values was not available in the SHS dataset. Land rents were estimated for home-owners by growthing mortgage payments by the real growth rate in property values (Barker, 2003) and the rate of inflation over the period of time the commuters

distance). They are also endogenous as we would not expect low income workers to live in areas with high land values.

The variables that act as instruments for income in the distance equation are therefore job/firm characteristics. Conversely the variables that act as instruments for commuting costs in the wage equation are household type (we expect all other things being equal that multiple occupancy households to commute more than single adult households) and rural/urban classification (we expect the geographic spread – housing and workplace density – to affect average commuting distance).

The model has been calibrated on data that relates to full-time workers only. This sub-sample is considered not to be representative of the entire population of potential workers. This is because there is substantial evidence to suggest that the participation of women in the full-time labour market is not random. That is an active decision is made to participate in the labour market, and those who chose not to participate may have different characteristics and/or preferences. The model coefficients derived in this research can therefore only be taken to represent the behaviour and preferences of those already in full-time employment - extrapolation to new labour market participants can therefore only be undertaken with caution.

It is expected that unobserved heterogeneity of job types and working conditions will exist within the dataset. For example we have only information in the SHS data at 9 occupation levels and for 16 industries – an economics professor has a very different job with a different remuneration framework from a deputy headmaster at a primary school, however, we cannot distinguish between the two. We also have no information on shift patterns and evening or weekend working. Such unobserved heterogeneity may bias coefficients in either direction (both upwards and downwards). Theoretically any bias introduced by unobserved heterogeneity in the data can be included in an estimation using an additional person-specific random component and estimating its variance (a random effects model). This study's scope did not include an examination of a 2 stage random effects model. Wherever possible therefore this study verified its results against other empirical data.

4.2.2 Wage equation

The calibrated wage equation is set out in Annex C with a summary of the key results contained in Table 10. The final model is a double log model with the dependent variable being the natural log of annual income net of taxes and other deductions. For clarification only personal earned income data were

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have lived in the property. The result was an annual land rent in 2003 prices. For those living in rented accommodation the total annual rent was calculated. These annualised property rents were then divided by the number of bedrooms in the property to give an indicator of domestic unit land rents. Clearly this is only an indicator as: (1) the methodology relies on everyone paying a mortgage/rent related to land rental values (there are therefore problems with the derived values for those who own their property outright or for whom rents are governed through legislation – crofts and social housing); and (2) that the mortgage relates purely to the number of years in which the property has been lived in.

used in the analysis. Several model forms were tested unlogged, semi-log and double log. Variations in the unit of the dependent variable were also calculated. The income variable in the SHS is annual income, however, there is information on the number of hours worked a week in the data. Neither annual salary nor hourly wages are ideal for this research. This is because the unit of income with an explicit relationship to commuting costs is daily income – an estimate of daily income was therefore derived, based on the number of hours worked. The best model fit however was found to the double log model with annual income as the dependent variable. This model formulation was therefore taken as the preferred form.

The first thing to note from the results is that the adjusted r-squared value is around 0.5, implying that our model explains about half the variation in the data. Such r-squared values are not unusual in regression analysis that include such a large number of observations and could have arisen from unobserved heterogeneity of job types and working conditions (as discussed in section 4.2.1). The summary F-statistic indicates that we can reject the hypothesis that all the coefficients in the model are equal to zero. F-tests on each of the blocks of variables (e.g. occupation dummies) also indicate that each block's coefficients differ significantly from zero. A comparison between the 2SLS and the OLS results indicate that coefficients (and t-statistics) on exogenous variables (e.g. occupation dummies, industrial sector dummies and location dummies) are very similar. It is the coefficients and particularly the t-statistics on the endogenous variables (commuting costs and land values) that alter between OLS and 2SLS. This is as expected as it is with endogenous variables that the OLS estimates of a coefficient are inconsistent.

All three models (both sexes, male and female) exhibit similar characteristics in that:

- The most important explanatory variables are experience, followed by occupation and then qualifications.
- With increasing experience[10] annual salaries increase until around age 50, after which they begin to decline.
- The ranking of wages by occupation is intuitive, the lowest wages are those associated with elementary and administrative/secretarial occupations, whilst the highest are those associated with professionals and managers.
- A substantial wage premium is associated with having a degree, whilst those who have no qualifications receive the lowest wages.
- Women in all occupations, other than elementary occupations, earn less than men. It should be noted that as this dataset only contains full-time workers, this is not a facet of part-time/full-time status.
- People who work in the mining and quarrying sector (includes the oil sector) earn the highest wages (all other things being equal), whilst the

[10] Age minus 16 was used as a proxy for experience.

lowest wages are obtained in hotels and restaurants and wholesale and retail.

- Self-employed people earn more than employees and permanent workers more than temporary. The latter may seem counter-intuitive as due to the fact that temporary workers have less employment rights they may require a higher compensation to do a job than if they did the job on a permanent contract. However, if we think of temporary workers as those who face the least job opportunities for reasons of either discrimination or lack of residential mobility then such a result is consistent with the imperfect labour market arguments
- Those who work in small workplaces earn less than those in large workplaces. This can be a result of different levels of productivity with firm size and also that there may be better opportunities for promotion in large workplaces (Kalleberg and Van Buren, 1996; Gilbert , 2004) .
- Those who have a child in the household, typically earn more than those who do not. As can be seen from the models by gender this wage premium is mainly associated with male workers and is considered to reflect the higher reservation wage of those with children. That is a man who has a child will not be satisfied with a job that a similar man, but without children, would be content with.
- People who work in Aberdeen City, Moray, Edinburgh and the Shetland Islands receive a wage premium compared to others in Scotland. This wage premium is a reflection of either labour market imperfections (e.g. tight labour market) and/or some form of agglomeration effect. There are oil industry clusters in Aberdeen and the Shetland Islands, financial and bio-technology clusters in Edinburgh and a food and drink cluster in Moray. Shetland and Moray also have low unemployment, whilst Edinburgh and Aberdeen have shortages of workers with key skills. The lowest wages are in the Scottish Borders, Dumfries and Galloway and Perth and Kinross. These three areas are rural and, in parts, geographically isolated.

Table 10 reproduces the results for the elasticity of annual income to commuting costs and the coefficient on land values. For each of the OLS gender models the coefficient on land values is the correct sign and significant. However, under 2SLS the coefficient on land values becomes insignificant. The implication of this is that land values do not form part of the reservation wage – as would be hypothesised in a mono-centric urban model (see Figure 2). Clearly the pattern of residences and workplaces in Scotland has no relation to a mono-centric model, because employment is spread throughout the country. We would also expect that whilst residential land values reflect accessibility they reflect the general accessibility of the property, rather than the accessibility of a property to an individual's workplace. Under such general conditions we may expect that workers are principally compensated for their commuting costs through the wage, rather than through land values – which is as the model suggests.

TABLE 10: KEY RESULTS OF WAGE EQUATION (FULL-TIME WORKERS)

Model	Natural Log of generalised cost of commute	Estimated unit land values (2003 prices)	Adjusted R-squared	F-stat	Sample size
2SLS - both sexes	0.044 (2.46)	0.00001 (0.33)	0.494	59.17	4405
OLS - both sexes	0.057 (13.19)	0.00001 (4.13)	0.505	61.71	4405
2SLS - male	0.058 (2.98)	-0.00001 (-0.24)	0.437	31.32	2539
OLS - male	0.059 (9.96)	0.00001 (2.57)	0.450	33.01	2539
2SLS - female	0.051 (1.54)	0.00008 (1.42)	0.486	28.11	1866
OLS - female	0.050 (7.61)	0.00002 (3.45)	0.517	31.66	1866

Note 1: Coefficient (t-stat)
Note 2: Dependent variable - natural log of annual income (net of tax and deductions)
Note 3: Model calibrated from 4,405 cases of the 5,114 due to missing data existing for one or more of the regressors in 709 of the cases.

Under an OLS regression the elasticity of income to commuting costs is highly significant for all three models. However, once the endogeneity of commuting costs is controlled for within the 2SLS regression the statistical significance of the elasticity drops quite dramatically. In the case of women the elasticity to commuting costs in fact becomes insignificant. The average elasticity of income to commuting costs across the dataset (both sexes) is 0.044. The implication is that for the average worker, with a net salary of £15,229 incurring a one-way commute cost of 188.1pence, a 10% increase in commuting costs would require a salary increase of £67.01 for compensation. This reflects only a partial level of compensation (at 77%) as a 10% increase in commuting costs means that the worker has incurred an additional £86.53 in costs[11].

A similar calculation can be undertaken for male workers. The elasticity to commuting costs is 0.059. A 10% increase in commuting costs would require a salary increase of £97.83 in compensation. With 460 one-way commutes in a year the 10% increase in commuting costs would have increased total commuting costs by £95.81. That is male workers are over-compensated by 2%. Bearing in mind the uncertainty in the number of commuting journeys made in a year[12] and the statistical uncertainty in the estimate of the elasticity, we cannot reject the hypothesis that wages fully compensate (not over-compensate) workers for their commute.

[11]Assuming 460 one-way commutes in a year – 10 per week for 46 weeks of the year (i.e. 6 weeks annual leave/bank holidays per year).
[12] For example if we assume an average 5 weeks annual leave/bank holidays per year (i.e. 470 one-way commuting trips) commuting costs are exactly compensated.

In contrast the annual salaries that women receive do not appear to include an allowance for commuting costs. This difference between men and women is attributed to the arguments associated with imperfect labour markets (Zax, 1991; Manning, 2003). As a result of lower residential mobility compared to men women have less market power and fewer job opportunities.

4.2.3 Distance Equation

The calibrated distance equation is set out in Annex D with a summary of the key results in Table 11. This model, like the wage equation, is also a double log model as this gives the best model fit. There is a lot of unexplained variation in the data with an adjusted r-squared of 0.279 (for the 2SLS model). This unexplained variation could arise due to a lack of information within the dataset regarding the qualities of residential location and the commuter's personal preferences for residence (e.g. does the individual value accessibility or remoteness). We would expect that individual's may trade commuting distance against non-pecuniary benefits in the housing market. The SHS contains a series of questions on the perceived attributes of and problems with the neighbourhood in which the commuter lives. At the outset of the research it was intended that this data on perceptions and attitudes of the neighbourhood would be incorporated into the model. However, on analysis, the data did not give objectivity required for this analysis – for example 50% of respondents rated their neighbourhood as a very good place to live. It was also found that instead of the number of attributes to an area being inversely correlated with the 'bads' of an area they were in fact correlated. Deciles from the Scottish Index of Multiple Deprivation (SIMD) were therefore also obtained. The SIMD is a poverty index which calculates a score for an area based on income, employment, health, education, housing and geographic and telecommunication access. This data was also found to be unsuitable as it is very heavily correlated with income - which is one of the key determinants of the score. Additionally it was not possible to obtain an aggregate score that excluded income data.

Notwithstanding the lack of data on preferences for residential location the results from the distance equation are very plausible and consistent with other empirical findings. The summary F-stat indicates that we can reject the hypothesis that all the coefficients in the model are equal to zero. F-tests on each of the blocks of variables (e.g. household location dummies) also indicate that each block's coefficients differ significantly from zero. As with the wage equation a comparison between the 2SLS and the OLS results indicate that coefficients (and t-statistics) on exogenous variables (e.g. household dummies and location dummies) are very similar. It is the coefficients and particularly the t-statistics on the endogenous variables (income and commuting cost per km) that alter between OLS and 2SLS.

The most important explanatory variables are - in order of importance[13] - commuting costs per km, income, car availability, location, household type and finally personal characteristics (self-employed, female, etc.). The

[13] Order of importance is determined by the beta coefficient in the regression output

elasticity of commuting distance to generalised cost is -0.9. As the fuel related component of generalised cost (for car drivers) comprises 31% of commuting costs this gives an indicative elasticity to fuel price of -0.28. The results are sensitive to the choice of instrument used within the 2SLS and, as set out in Annex E, a potential range from -0.5 to -1.0 was found for the elasticity of commuting distance to generalised cost. The elasticities are consistent with other empirical evidence on destination choice. The elasticities relate to destination choice, as it is through varying either the location of the home or the workplace that the commuter alters commuting distance. De Jong and Van de Riet (2004) report that the empirical evidence on destination choice suggests an elasticity in the range of -0.6 to -1.1 to generalised cost, whilst an elasticity to fuel price of -0.3 is also often cited (see for example De Jong and Gunn, 2001; Goodwin, Dargay and Hanly, 2004; Graham and Glaister, 2004). The implication of an elasticity of -0.9 to generalised cost is that a 10% reduction in commuting costs per kilometre would be associated with a 9% increase in commuting distance (i.e. an increase of 0.88km on the average commute).

The second most important determinant to commuting distance is income. The model indicates an elasticity to income of 0.81 – though again the results are sensitive to the choice of instrument and a range of 0.74 to 0.84 was found. This too is consistent, though slightly higher, than other empirical evidence. Based on a meta-analysis of published studies Goodwin, Dargay and Hanly found long run elasticities to income of 0.49 and 0.73 for car vehicle-kms (depends on the estimation method). Possibly our slightly higher than expected income elasticity has been biased upwards by the lack of data with which to control for the ‘niceness of the area’ in which the household live. Typically ‘nicer’ areas may be further from employment centres and therefore residents of such areas incur higher commuting costs than residents in other areas. As higher income households may cluster in such areas they may have higher commuting costs compared to lower income households than would be explained by a pure income effect. In the absence of data on niceness of area the regression may therefore attribute all the correlation to income. An elasticity of 0.81 to income implies that a 10% increase in average income would increase average commute distances by 0.79km.

The sensitivity of commuting distance to changes in generalised cost and income growth with elasticities approaching -1 and 1 respectively has close parallels to the constant travel budget hypothesis (Zahavi and Talvitie, 1980; Metz, 2005). Metz using data collected in the Great Britain National Travel Survey (NTS) over the last 30 years demonstrates that travel time is invariant when averaged across the population. Similarly the proportion of household expenditure that is spent on transport has been relatively invariant through time despite income growth over that period. Under such circumstances any improvements in the transport system are absorbed through increased travel.

TABLE 11: KEY RESULTS OF DISTANCE EQUATION (FULL-TIME WORKERS)

Model	Natural Log of annual income	Natural Log of generalised cost per km	Natural Log of estimated unit land values (2003 prices)	Adjusted R-squared	F-stat	Sample size
2SLS - both sexes	0.811	-0.893	-0.00027	0.279	33.2	4652
	(7.94)	(-4.71)	(-0.01)			
OLS - both sexes	0.564	-1.044	-0.00392	0.475	80.4	4652
	(16.5)	(-40.62)	(-0.7)			

Note 1: Coefficient (t-stat)
Note 2: Dependent variable natural log of commute distance (metres)
Note 3: Model calibrated from 4,652 cases of the 5,114 due to missing data existing for one or more of the regressors in 462 of the cases.

As with the wage equation the land values in the distance equation are not statistically significant. This is thought to occur for the same reasons, in that land values typically reflect levels of general accessibility rather than the accessibility to an individual's workplace.

Location is a key driver in determining the commuting distance, primarily as the spatial density of dwellings and workplaces varies with location. The data suggests that those who live in remote rural areas and accessible rural areas commute the greatest distances – all else being equal – whilst those who live in very remote small towns commute the least distance. This is consistent with research based on the Census for Scotland 2001 (Scottish Executive, 2005d). With respect to work place location those who work in Glasgow City, East Renfrewshire, Edinburgh and East Lothian travel the greatest distance to work. Each of these authorities lies in the travel to work area of either Edinburgh or Glasgow the largest employment centres in Scotland. We would therefore expect that the longest commutes would occur to businesses located in such authorities. On the other hand people who work in Moray, Dumfries and Galloway, Aberdeenshire and Angus travel the least. These authorities are geographically isolated [14] and therefore commuting opportunities between residences and different employment centres are limited

Car availability is an important determinant in workers' mobility. Those who have access to a car can travel much further more easily than those who do not.

We find that larger households typically commute further than small households (though not all the coefficients are significant). This is expected for two reasons. Firstly for larger households in which two or more people work it will be difficult for the household to locate close to the work places of all the workers. If such households have families there may also be 'social' costs associated with moving house, for example children changing school, that may also act as a deterrent to moving house. We would therefore expect

[14] Aside from the parts of Aberdeenshire close to Aberdeen

that members of larger households to have a larger commute compared to adults in the single adult households. We may also expect that different household types may exhibit different preferences which cannot be observed in this dataset. Single adult households may for example prefer ‘city-living’ which, as a secondary effect, may give rise to a short commute, whilst family households may seek a suburban lifestyle which, again as a secondary effect, may give rise to longer commutes.

Personal characteristics: gender, age, qualifications, self-employed status, occupation and housing tenure do not play a significant role in determining commuting distance. Of these variables only age and self-employed status are statistically significant. Research consistently identifies that men travel more than women (see also Table 7), those with degrees are more mobile than those without and those with high level occupations travel further than those of elementary occupations (Scottish Executive, 2005d, Nielsen *et al.,*2005; Benito and Oswald, 2000) and anecdotal evidence exists that those who wish to buy a house have to commute further than those who rent. This research, however, ascribes these different behaviour patterns to differences in personal income and car availability - rather than some built-in preference by such individuals to travel further.

5 IMPLICATIONS FOR TRANSPORT POLICY

5.1 Model Interpretation

The calibrated wage equation provides information regarding the level of wage compensation a full-time worker would require should commuting costs alter. As set out earlier, for the average full-time worker this level of compensation is 77% of the change in the commuting costs. The nature of the model (double log) does not allow us to infer what the total level of compensation is (as opposed to marginal level of compensation).

Transport policy will typically impact on commuting costs and therefore wage rates through one of two mechanisms: a change in journey speed and a change in transport prices. The former may occur through either an infrastructure improvement (journey speeds increase) or through traffic management (journey speeds by car may fall). A road user charging policy would have a significant impact on transport prices, however, fuel cost changes would also affect transport prices. To understand the impact that such policies have on wages we therefore need to determine elasticities of the wage to journey speed and transport price. This requires some manipulation of the calibrated wage and distance equations due to the presence of second and higher order effects as the system reaches a new equilibrium - once it has been 'shocked' by the transport policy. We can illustrate this as follows:

> An increase in journey speeds lowers commuting costs. Wages will therefore adjust downwards and average commuting distances increase. The increase in commuting distance then increases commuting costs. The change in wage and the change in commuting distance will affect the value of time, which also affects commuting costs. The process then repeats itself until an equilibrium is reached.

As set out in Annex H there is no set of simple transformations that can express the wage equation and the distance equation purely in terms of journey speed and transport prices. A numeric approach to deriving the equilibrium values of wages and commuting distance was therefore adopted (see Annex H for the details). The elasticities derived from this method are set out in Table 12. As can be seen from this table, in contrast with the wage and distance equation models, the elasticities are not constant – the elasticity varies with the scale of the 'shock' with lower elasticities associated with increases in the policy variables. It can also be seen that the elasticities of wages are much lower than those of distance and are also lower, by a factor of more than 10, compared to the commuting cost elasticity of wages in the wage equation (0.044). This latter affect is attributed to the policy shock's second and higher order effects dampening down the response in the wage rate.

TABLE 12: JOURNEY SPEED AND PRICE ELASTICITIES OF WAGES AND DISTANCE

	Elasticity associated with the following change in journey speed or price		
	-50%	Point	+100%
Journey speed elasticity of wages	-0.00311	-0.00199	-0.00120
Transport price elasticity of wages	0.00235	0.00214	0.00183
Journey speed elasticity of distance	0.493	0.363	0.244
Transport price elasticity of distance	-0.477	-0.390	-0.0283

Note 1: All elasticities are calculated from the output of the numerical optimisation model. The point elasticity is an average of the elasticities with a 0.1% change and a -0.1% change in journey speed or price.

The sensitivity of the above elasticities of wages and distance to a different specification of the wage and distance equation was also examined. The wage and distance equation was populated with elasticities relating to the upper and lower bounds of the 95% confidence intervals of the coefficients of the double log models. The results from this sensitivity analysis are set out in Table 13. As can be seen from this analysis there is some sensitivity of the results to the different specifications but the resultant elasticities of wages and distance to journey speed and price are in the main of a similar order of magnitude. The lowest elasticities of wages are obtained if the elasticity to commuting costs in the wage equation is low for obvious reasons. The highest elasticity is obtained when the elasticity of commuting distance is as close to zero as possible. Clearly if commuting distance is insensitive to the transport policy measures then a larger proportion of the benefits of the transport initiative will be transmitted into the wage equation. An interesting

TABLE 13: POINT ELASTICITIES FOR DIFFERENT ELASTICITY ASSUMPTIONS IN THE WAGE EQUATION AND DISTANCE EQUATION

	Central estimate	Sensitivity to 95% confidence interval bounds in the:					
		Commuting cost elasticity of wages		Income elasticity of distance		Commuting cost per km elasticity of distance	
		Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Calibrated elasticity		*0.044*	*0.044*	*0.811*	*0.811*	*-0.893*	*-0.893*
Elasticity sensitivity tested to		*0.009*	*0.079*	*0.611*	*1.011*	*-1.265*	*-0.521*
Journey speed elasticity of wages	-0.00199	-0.00038	-0.00391	-0.00131	-0.00261	0.00385	-0.01162
Price elasticity of wages	0.00214	0.00045	0.00371	0.00305	0.00133	-0.00617	0.00792
Journey speed elasticity of distance	0.363	0.347	0.382	0.241	0.473	0.406	0.267
Price elasticity of distance	-0.390	-0.416	-0.364	-0.562	-0.240	-0.652	-0.183

Note 1: All elasticities are calculated from output of the numerical optimisation model. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

result occurs when the commuting cost per km elasticity of distance is less than -1. In such a situation commuting costs increase at a faster rate than unit commute costs (i.e. per km) change. The implication is that a fall in unit commute costs (e.g. journey speed increases and price decreases) actual increases total commuting costs and, ultimately, wages.

5.2 Impacts of transport policy

Figure 4 and Figure 5 illustrate the impact of changes in transport price and journey speed on commuting distance and wages. The most striking aspect of the figures is that commuting distance is very sensitive to the policy change but wages are almost inelastic. A 10% increase in journey speeds will only give a £4 reduction in a net annual salary of nearly £20,000 (i.e. a 0.02% reduction), whilst a doubling of journey speeds will only reduce it by £24. This apparent inelasticity occurs despite reductions in unit commute costs (e.g. through price reductions or journey speed increases). The sensitivity analysis to the specification of the wage and distance equation (see Annex H) also indicates that wage rates are mainly insensitive to transport policy.

The reason for this is that ultimately commuting costs almost return to their original 'pre-transport shock' level as a result of the increased length of the commute and the corresponding increase in values of time. We would associate an increased length of commuting journeys with workers either moving house or changing jobs. The latter in particular is associated with an increase in the size of the labour market and potentially better worker/firm job matches. Such effects form part of the group that arise due to agglomeration economies. The wage equation developed in this research does not capture agglomeration economies in a dynamic way. It uses a set of dummy variables for local authority areas which capture the manner that wages vary systematically from one area to another. One of the reasons for this systematic variation is agglomeration effects, others could be skill shortages or tight labour markets. In application the model assumes that these effects are fixed, that is the transport policy impact cannot affect the underlying cause for this systematic variation.

There is, however, a growing evidence base that, through agglomeration economies, changes in regional density through for example increased journey speeds can have a significant effect on regional productivity (Rosenthal and Strange, 2004; Rice and Venables, 2004; Graham, 2005). Rice and Venables estimate that the agglomeration economies from a 10% reduction in commuting time will lead to an increase of 1.12% in labour productivity. If we assume that this increase in productivity translates through to an increase in wages then agglomeration economies associated with larger labour markets would lead wages to increase by 1.12%. The effect of agglomeration on wages therefore appears to be in the region of 50 times larger than the labour supply effect - as estimated in this paper.

FIGURE 4: IMPACT OF TRANSPORT PRICE ON WAGES AND COMMUTING DISTANCE

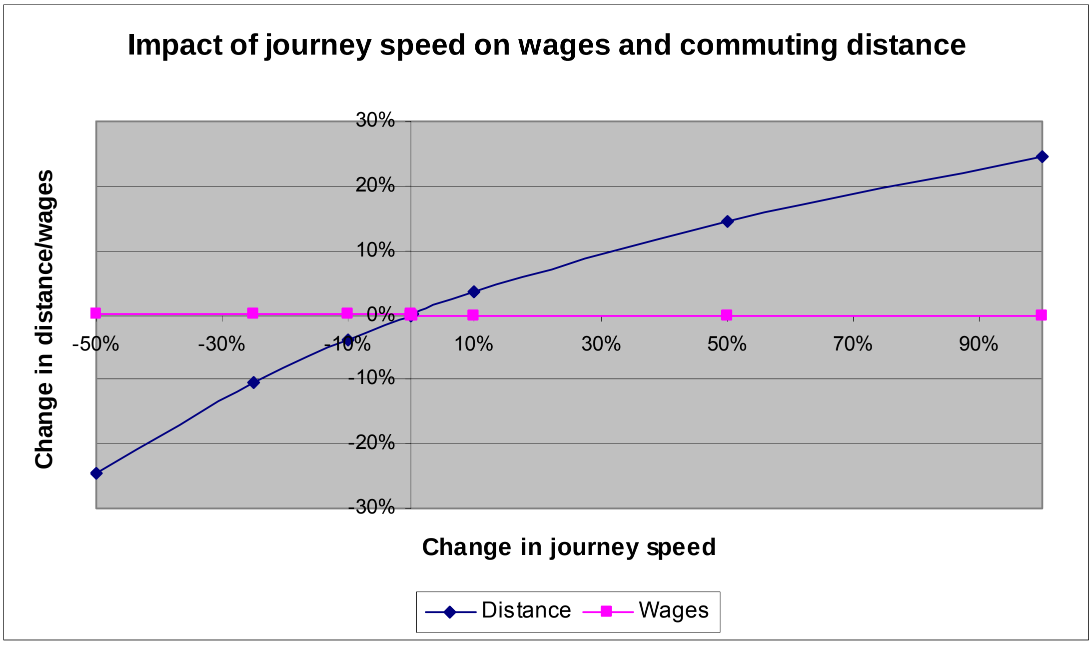
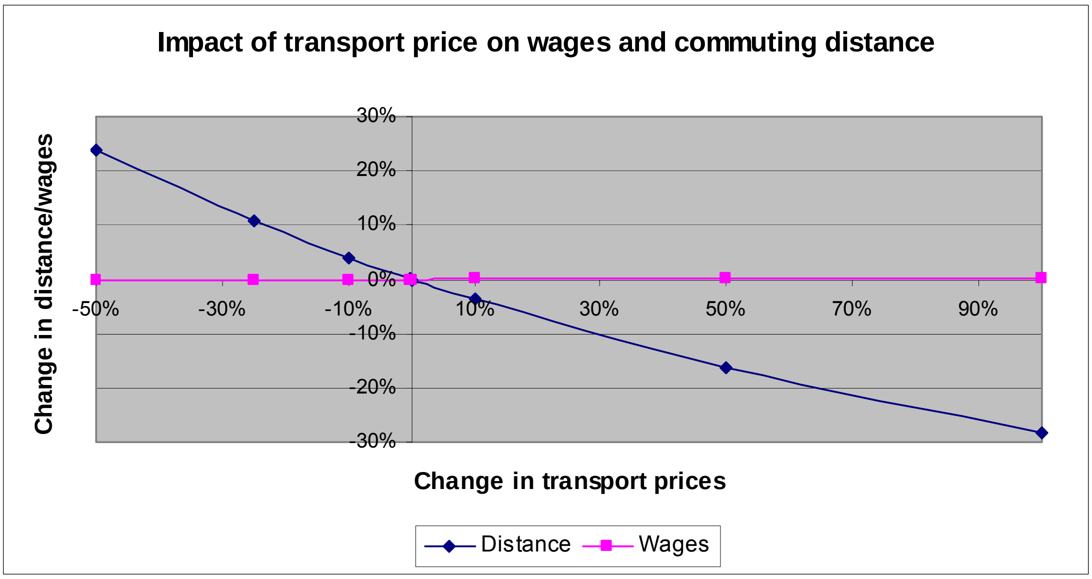


FIGURE 5: IMPACT OF TRANSPORT PRICE ON WAGES AND COMMUTING DISTANCE



The above discussion has focused exclusively on the transport policy impacts of those who are already in full-time employment. Strictly speaking as the wage equation has not been corrected for selectivity bias we cannot apply it to those who are not in full-time work. However, it is informative to do such an application if only to get a feeling for the scale of the labour market response if all workers and those who choose not to work had the same preferences as full-time workers[15]. In such a situation those on the margin of the labour market participation decision require 77% of the change in commute costs as

[15] See discussion on selectivity bias in §4.2.1

compensation. A 10% reduction in commuting costs would therefore, for the last new worker to enter the labour market (i.e. the marginal worker), lower the reservation wage by £67 per year. Using an elasticity to earned income of 0.1 (DfT, 2004 p52) this would imply that 687 unemployed people across Scotland would be induced into full-time work by a 10% reduction in commuting costs. This does not seem a particularly large number of new workers when set against the costs of an infrastructure investment programme needed to bring about a 10% reduction in commuting costs across Scotland. This reinforces the view that transport policy is not the best policy tool to encourage general labour market participation.

Notwithstanding that transport policy may form an important part of an economic development package, where significant step changes in accessibility can be targeted towards areas with low labour market participation and high transport costs. For example, the replacement of a ferry with a toll-free causeway to the Isle of Berneray in the Outer Hebrides has been associated with an increase in labour market participation by women on Berneray from 50% to 76% - though the numbers involved are small and a substantial reduction in transport costs occurred (SQW, 2004). The Department for Transport already recognises this and a key component of an economic impact report focuses on the number of jobs that become accessible to people living in regeneration areas as a consequence of a transport proposal (DfT, 2003).

Unfortunately, the wage equation does not lend itself to an understanding of the full GDP impacts of transport policy. The model is only a partial model of the economy and therefore implicitly assumes that the excluded economic sectors and variables (e.g. prices for goods) remain unaffected by transport policy. Notwithstanding that it is possible to make some observations on the expected direction and scale of change. Firstly, we would expect any increase in labour market participation, no matter how small, to have a positive impact on GDP. Secondly it appears that wages, through supply side effects, are almost inelastic to changes in transport policy. We therefore would not expect GDP to be affected by transport policy through supply side effects on the existing workforce. However, if the transport policy had agglomeration impacts - which are not modelled in our system of equations - we would expect some positive changes in GDP to occur.

5.3 Transferability of results to other areas of Great Britain

The model has been developed from the Scottish Household Survey dataset. Trips that have involved the payment of a fare (e.g. public transport trips) have had to be excluded from the analysis. The transferability of the model and its findings is therefore dependent on how representative travel and labour market behaviour is between Scotland and other areas of Great Britain.

Firstly with respect to travel behaviour it is common place to transfer results between England and Scotland, particularly if adjustments are made for income differences. For example, values of time derived in England are used in Scotland. Similarly transport model parameters are often transferred between the countries with adequate levels of fit being achieved. For example within the DELTA land use transport interaction model parameters have been developed through applications of the model to both Scotland and England. We also find that average travel times in Scotland are similar to those in England with the exception of London, and that model parameters (such as the generalised cost elasticity of demand) are similar to other empirical travel behaviour findings.

A key issue in transferability of the results is the exclusion of public transport data from the analysis. This raises a question mark on the applicability to large urban areas – particularly London. In the main this question mark is associated with the wage equation as the distance equation appears consistent with other travel behaviour literature. With respect to the wage equation we may find that the commuting cost elasticities of wages varies between this model and large urban areas and we may find that such areas may act much more like a mono-centric city than other parts of the UK. In a mono-centric city we may find that the commuting cost elasticity of wages is much lower and that the land value elasticity of wages becomes significant.

Whilst we may question whether the parameters of the wage equation are appropriate for large cities with developed public transport networks - such as London – we can use evidence from the sensitivity tests to draw out some tentative implications for such cities. The sensitivity tests included commuting cost elasticities of wages that were almost inelastic ($\xi=0.009$) to one in which workers receive more compensation for a change in commuting costs than the actual cost increase ($\xi=0.079$). In both tests it was found that the level of wage compensation for a change in commuting costs was very small – once again this is attributed to changes in travel behaviour. Thus whilst the model parameters themselves may not be transferable to places like London the policy conclusions do appear transferable.

6 CONCLUSION

This research had two objectives. First of all it aimed to identify whether a relationship existed between wage rates and commuting costs, and quantify that relationship. Secondly it aimed to develop an understanding of whether lower commuting costs can be transmitted through the labour and transport markets into lower real wages and increased labour market participation.

The relationship between commuting costs and the wage rate is bound up in the theory of labour supply and the demand to travel. In conditions of perfect competition we would expect the worker to receive full compensation for any commuting costs incurred. However, the form that this compensation takes, as a wage premium or a reduction in land rents, will vary with the spatial distribution of housing and workplaces. Contrastingly, in situations where labour markets work imperfectly, theory indicates that workers may only be partially compensated for their commute costs. By identifying the level of compensation associated with full cost of commuting and the form that this takes, this research has added significantly to the existing evidence base on wage rates and commuting costs. Strong evidence has been found that compensation for commuting costs does occur. The evidence also appears to suggest that this compensation occurs entirely through the wage rate. The marginal level of wage compensation for a change in commuting costs incurred by full-time workers is however only partial – at 77% of the change in the commuting costs. There is also evidence to suggest that the marginal level of compensation varies by gender. This lends further support to the arguments that certain segments of the labour force face thin labour markets due to a lack of personal and residential mobility. The estimates of travel demand elasticities to commuting costs, -0.9, and to income, 0.8, are consistent with the existing evidence base, though the income elasticity is at the upper end of the expected range. This gives confidence in the research findings.

Strictly speaking the models developed in this research can only be applied to full-time workers who already participate in the labour market. However, tentative findings can be drawn regarding the impact of transport costs on labour supply. These findings indicate that the impact is limited, which is consistent with existing transport appraisal practice. Only substantial changes in commuting costs would be expected to give a significant change in labour market participation.

A key finding of this study is that the complex interaction between wage rates, commuting costs, work and household location decisions and the value of travel time means that, through labour supply effects, transport policy has little impact on wages. A 10% increase in journey speeds will only give a £4 reduction in a net annual salary of nearly £20,000 (i.e. a 0.02% reduction), whilst a doubling of journey speeds will only reduce it by £24. This apparent inelasticity occurs as ultimately commuting costs almost return to their original 'pre-transport shock' level as a result of the increased length of the commute and the corresponding increase in values of time. We would associate an increased length of commuting journeys with workers either moving house or changing jobs. The apparent inelasticity of wages contrasts quite strikingly with the empirical evidence on labour productivity and wages. Such evidence suggests that the effect of changes in transport costs on wages through agglomeration economies may be 50 times larger than the impact on wages through labour supply effects. The inter-relationship between labour supply, commuting distance and agglomeration economies has not been addressed in this paper. Whilst being a complex area, research in this area would usefully build on this study's findings and further contribute to the debate on the impacts of transport policy on the wider economy.

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ANNEX A

Comparison of Datasets

ANNEX A – COMPARISON OF DATASETS

		SCOTTISH HOUSEHOLD SURVEY	NATIONAL TRAVEL SURVEY	BRITISH HOUSEHOLD PANEL SURVEY	LABOUR FORCE SURVEY	ANNUAL SURVEY OF HOURS AND EARNINGS	CENSUS 2001
Geographic coverage		Scotland (all incl. islands)	Great Britain (excl. Scottish islands, Isles of Scilly)	Great Britain and Northern Ireland (incl. islands)	Great Britain and Northern Ireland (incl. islands)	Great Britain	UK
Sample size	Households	30,000 (15,000 p.a.)	15,000 (5,000 p.a.)	10,000 (10,000 p.a.)	57,000 (but only 22,000 asked income data)	N/A	All
	Individuals - travel and income information	30,000	22,000 (from fully responding households)	20,000	JJL estimates about 33,000 adults	1% of work force 160,000 employees	All
Time period sample collected over		2 years	3 years	1 year	1 year	April of each year	1 day (every 10 yrs)
Sampling method		Postcodes	Postcodes everywhere except north of Caledonian Canal where the telephone directory is used	Postcodes everywhere except north of Caledonian Canal where the telephone directory is used	Postcodes everywhere except north of Caledonian Canal where the telephone directory is used	All companies	Addresses
Travel diary information		Yes (1 day)	Yes (1 week)	No	No	No	No
Latest dataset		2001/2 (2003/4 becomes available in Oct 2005)	1999/2001	2003/4 (Wave 13)	March 2005 (But travel-to-work data is only available annually up to 2003 and then every third year from then. Last available year is 2003)	2004	2001
No. of datasets available		2 (3 from Oct 2005)	14 years worth (from 1988)	13 years (waves) (from 1991/2) (NB Only sampled north of Caledonian Canal from 2000/1)	From 1992 to 2003	From 1998 (Due to replacement of NES by ASHE)	N/A

	SCOTTISH HOUSEHOLD SURVEY	NATIONAL TRAVEL SURVEY	BRITISH HOUSEHOLD PANEL SURVEY	LABOUR FORCE SURVEY	ANNUAL SURVEY OF HOURS AND EARNINGS	CENSUS 2001
REMUNERATION FROM JOB						
Wage/salary	Yes - to £	No (only total income from earned and un-earned sources is recorded and then it is banded)	Yes - to £	Yes	Yes	No
Bonus scheme	included in wage data	No	Yes	No	Yes	No
Pension scheme	No	No	Yes (only membership of employer's pension scheme, not employer's contribution)	No	Yes	No
Company car	Yes (Up to 2002 - but cannot identify if journey to work is undertaken in company car)	Yes (But cannot identify if journey to work is undertaken in company car)	Yes (But cannot identify if journey to work is undertaken in company car)	Yes	No	No
Other	None	None	None	None	No	None
COMMUTING COSTS						
Mode	Yes	Yes	Yes	Yes	No	Yes
Time	Yes (total journey and stages)	Yes (total journey and stages)	Yes	Yes	No	No
Distance	Yes (derived - crow-fly distance)	Yes	No	No	No	Yes (derived)
Stage breakdown	Yes	Yes	No	No	No	No
Parking costs	Yes	Yes	No	No	No	No

	SCOTTISH HOUSEHOLD SURVEY	NATIONAL TRAVEL SURVEY	BRITISH HOUSEHOLD PANEL SURVEY	LABOUR FORCE SURVEY	ANNUAL SURVEY OF HOURS AND EARNINGS	CENSUS 2001
Fares	No (Derived fares maybe available from a study undertaken by MVA for the Executive)	Yes	No	No	No	No
Road congestion/ Road Delays	Yes - Delays Yes - Congestion	No	No	No	No	No
Overcrowding/PT delays	Yes - Delays No - Overcrowding	No	No	No	No	No
Who pays for travel-to-work costs?	No	Yes (company car information and self-employed car information)	No	No	No	No
Other purpose for commute journey (e.g. drop kids at school)	No (introduced in 2005/6) [possibly derive from stage data]	No [possibly derive from stage data]	No	No	No	No
Work from home/teleworking	(i) Work mainly from home	(i) Work mainly from home	(i) Work mainly from home	(i) Work mainly from home (ii) Worked mainly away from home but worked at home for at last one day in previous week	No	(i) Work mainly from home
JOB						
Industry	Yes - SIC	Yes - SIC	Yes - SIC	Yes	Yes	Yes
Occupation	Yes - SOC	Yes - SEG	Yes - SOC	Yes	Yes	Yes
Size of firm/workplace	No - size of firm Yes - size of workplace (1-24, 25 or more)	No - size of firm Yes - size of workplace (1-24, 25 or more)	No - size of firm Yes - work place (9 categories)	No - size of firm Yes - work place	Yes	No

	SCOTTISH HOUSEHOLD SURVEY	NATIONAL TRAVEL SURVEY	BRITISH HOUSEHOLD PANEL SURVEY	LABOUR FORCE SURVEY	ANNUAL SURVEY OF HOURS AND EARNINGS	CENSUS 2001
Union member	No	No	Yes	Yes	No - union member Yes - pay set through collective bargaining	No
Public sector/private sector	No (can be derived from SIC/SOC?)	No (can be derived from SIC/SEG?)	Yes	Yes	[Could be derived]	No
Full-time/Part-time	Yes	Yes	Yes	Yes	Yes	Yes
Managerial duties	Yes	No	Yes	Yes	No	Yes
PERSONAL						
Gender	Yes	Yes	Yes	Yes	Yes	Yes
Age	Yes	Yes	Yes	Yes	Yes	Yes
Social class	Yes	No	Yes	Yes	No	Yes
Qualifications	Yes	No	Yes	Yes	No	Yes
Experience	Yes - last job information	No	Yes - Employment history	Yes - info on last job	Yes	Yes (former occupation)
HOUSEHOLD AND LIVING AREA INFORMATION						
Household composition	(i) Household type - 6 cats (ii) Household working status - 5 cats (iii) HIH information	(i) Household structure - 33 cats (ii) HoH information	(i) Household type - several different categorisations (ii) HoH information	(i) Household type (ii) HoH information	No	(i) Household type (ii) HoH information

	SCOTTISH HOUSEHOLD SURVEY	NATIONAL TRAVEL SURVEY	BRITISH HOUSEHOLD PANEL SURVEY	LABOUR FORCE SURVEY	ANNUAL SURVEY OF HOURS AND EARNINGS	CENSUS 2001
Location information	(i) Local authority (ii) 8 classifications for Rural/Urban by size and accessibility (iii) Drive time in mins to nearest population centre > 10,000 (iv) Detailed ward/postcode level geographic reference is suppressed for confidentiality	(i) Local authority (ii) Population density of sampling area (iii) Type of area (Inner London to small urban and rural) - 16 cats (iv) Detailed ward/postcode level geographic reference is suppressed for confidentiality	(i) Aggregations of local authorities to populations of > 120,000	(i) Local authority (maybe districts) (ii) Detailed ward/postcode level geographic reference is suppressed for confidentiality	(i) Local authority (previously under NES other geograhic groupings were possible) (ii) Detailed postcode information on workplace and and residence location is held, but this is subject to disclosure permission.	(i) Varies for different data types/disaggregations - lowest output level is census output area.
Quality of area information	(i) Rating of neighbourhood as place to live (crime, vandalism, schools, neighbours, etc.) (ii) Scottish Index of Multiple Deprivation (unemployment, overcrowding, access to services) (iii) Satisfaction with schools (for children at school) (iv) Convenience of services - 7 services (v) Access to public transport (vi) 8 category rural/urban as above (vii) MOSIAC - Scottish geodemographic classification	(i) Access time to 6 different amenities (by walking or bus) (ii) Access time to bus stop (iii) Rural/urban classification (in location information) (iv) Index of Multiple Deprivation (English records only) (v) ACORN - geodemographic classification	(i) Crime and vandalism in neighbourhood (ii) Likes neighbourhood and whether neighbourhood is a good or bad place to live. (iii) Standard of local services (schools, medical, transport, shopping, leisure) (iv) Importance of house being in catchment area of a good school.	None	No	None

	SCOTTISH HOUSEHOLD SURVEY	NATIONAL TRAVEL SURVEY	BRITISH HOUSEHOLD PANEL SURVEY	LABOUR FORCE SURVEY	ANNUAL SURVEY OF HOURS AND EARNINGS	CENSUS 2001
Household financial situation	(i) Total household income - to £ (ii) Mortgage/rent - to £ (iii) Overall financial situation of household - 5 cats	(i) Total household income - banded	(i) Household income - to £ (ii) Mortgage/rent - to £ (iii) Other household costs (e.g. heating and power costs) - to £ (iii) Conversion factors for needs analysis (from household income)	(i) Earned income for household adults (no unearned income data)	No	None
Household transport	(i) No. of cars/vans available for private use (by household and individual) (ii) Cost of transport to household	(i) No. of cars/vans available for private use (by household and individual) (ii) Cost of transport to household	(i) No. of cars/vans available for private use (by household and individual)	(i) No. of motor vehicles available to household	No	(i) No. of motor vehicles available to household
Accommodation	(i) Accommodation type (detached, terrace, flat, etc.) (ii) No. of bedrooms (iii) Rooms shared with other hholds (iv) Tenure	(i) Accommodation type (detached, terrace, flat, etc.) (ii) Length of residence	(i) Accommodation type (detached, terrace, flat, etc.) (ii) No. of rooms (iii) Rooms shared with other hholds (iv) Garden (iv) Tenure (v) Length of residence at address (can be calculated from year moved to present address)	(i) Tenure (ii) Length of time at current address	No	(i) Tenure (ii) No. of rooms (iii) No. of bedrooms
Other			(i) How satisfied with amount of leisure time available.			

ANNEX B

Marginal value of a commuting travel time saving (1997 pence per minute)

ANNEX B – MARGINAL VALUE OF A COMMUTING TRAVEL TIME SAVING (1997 PENCE PER MINUTE)

	Journey distance (miles)											
Income £000 per annum	**<1**	**1 to 2**	**2 to 3**	**3 to 5**	**5 to 10**	**10 to 15**	**15 to 25**	**25 to 35**	**35 to 50**	**50 to 100**	**100 to 200**	**200 and over**
<1	0.33	0.56	0.7	0.84	1.11	1.39	1.68	2.01	2.33	2.92	3.91	4.9
1 to 2	0.41	0.69	0.86	1.02	1.36	1.7	2.06	2.47	2.86	3.58	4.79	6.01
2 to 3	0.49	0.83	1.04	1.23	1.63	2.04	2.48	2.96	3.43	4.3	5.75	7.22
3 to 4	0.55	0.93	1.17	1.39	1.84	2.31	2.8	3.34	3.87	4.85	6.49	8.15
4 to 5	0.6	1.02	1.28	1.52	2.01	2.52	3.06	3.66	4.23	5.31	7.1	8.92
5 to 6	0.65	1.1	1.38	1.63	2.16	2.71	3.29	3.93	4.55	5.7	7.63	9.58
6 to 7	0.69	1.16	1.46	1.73	2.29	2.88	3.49	4.18	4.83	6.05	8.11	10.17
7 to 8	0.72	1.23	1.54	1.83	2.42	3.03	3.68	4.4	5.09	6.37	8.53	10.71
8 to 9	0.76	1.28	1.61	1.91	2.53	3.17	3.85	4.6	5.32	6.66	8.93	11.2
9 to 10	0.79	1.33	1.67	1.99	2.63	3.3	4	4.79	5.54	6.94	9.29	11.66
10 to 12.5	0.84	1.42	1.78	2.11	2.79	3.51	4.25	5.08	5.88	7.37	9.87	12.39
12.5 to 15	0.9	1.52	1.91	2.27	3	3.77	4.57	5.46	6.32	7.92	10.61	13.31
15 to 17.5	0.95	1.62	2.03	2.41	3.19	4	4.85	5.8	6.71	8.41	11.26	14.13
17.5 to 20	1	1.7	2.14	2.54	3.36	4.21	5.11	6.11	7.07	8.85	11.85	14.88
20 to 25	1.07	1.82	2.28	2.71	3.58	4.5	5.46	6.52	7.54	9.45	12.66	15.88
25 to 30	1.15	1.95	2.45	2.91	3.85	4.83	5.86	7.01	8.11	10.16	13.6	17.07
30 to 35	1.22	2.07	2.6	3.09	4.09	5.13	6.23	7.44	8.61	10.78	14.44	18.12
35 to 40	1.29	2.18	2.74	3.25	4.3	5.4	6.55	7.83	9.06	11.35	15.2	19.08
40 to 50	1.38	2.33	2.93	3.47	4.59	5.76	7	8.36	9.67	12.12	16.23	20.37
50 to 74	1.55	2.62	3.29	3.91	5.17	6.49	7.87	9.41	10.88	13.63	18.26	22.91
>=75	1.79	3.03	3.81	4.52	5.98	7.5	9.1	10.88	12.59	15.77	21.12	26.5

Source: Mackie *et al.*(2003 Table 22, p65)

The average value of time recommended by Mackie *et al*. for the average journey distance over all modes is 6.6 pence/min (1997 prices and values) (see p85 of Mackie *et al.*, 2003). Updating this value for real growth in value of time and for inflation gives the 2002 values recommended in webTAG.

ANNEX C

Wage Equation

ANNEX C – WAGE EQUATION

TABLE C-1: WAGE EQUATION – BOTH SEXES (FULL-TIME WORKERS ONLY)

		2SLS		OLS	
		Coefficient	t-statistic	Coefficient	t-statistic
	(Constant)	9.289	(66.26)	9.228	(204.32)
Labour supply factors	Natural Log of generalised cost of commute	0.044	(2.46)	0.057	(13.19)
	Estimated unit land values (2003 prices)	0.00001	(0.33)	0.00001	(4.13)
	Household includes a child (<=16yrs old)	0.030	(2.22)	0.029	(2.7)
Human capital	Potential experience	0.019	(6.67)	0.019	(8.64)
	Potential experience squared	-0.00028	(-4.37)	-0.00027	(-6.3)
	School certificate or nothing	-0.140	(-8.34)	-0.137	(-9.79)
	Other qualification	---	---	---	---
	Degree	0.161	(8.67)	0.157	(11.17)
Occupation	Managers and senior officials	---	---	---	---
	Professional occupations	-0.003	(-0.12)	-0.002	(-0.07)
	Associate professional and technical occupations	-0.167	(-6.81)	-0.166	(-6.82)
	Administrative and secretarial occupations	-0.416	(-12.69)	-0.411	(-13.85)
	Skilled trades occupations	-0.253	(-10.54)	-0.249	(-11.83)
	Personal service occupations	-0.306	(-10.89)	-0.301	(-11.76)
	Sales and customer service occupations	-0.339	(-12.69)	-0.332	(-14.31)
	Process, plant and machine operatives	-0.392	(-13.05)	-0.386	(-14.29)
	Elementary occupations	-0.416	(-9.94)	-0.411	(-10)
Female and occupation (interaction)	Female Managers and senior officials	-0.265	(-10.85)	-0.262	(-10.83)
	Female Professional occupations	-0.097	(-3.64)	-0.095	(-3.69)
	Female Associate professional and technical occupations	-0.071	(-2.53)	-0.067	(-2.53)
	Female Administrative and secretarial occupations	-0.106	(-3.62)	-0.104	(-3.57)
	Female Skilled trades occupations	-0.260	(-6.16)	-0.252	(-6.11)
	Female Personal service occupations	-0.280	(-9.78)	-0.277	(-10.18)
	Female Sales and customer service	-0.261	(-7.04)	-0.256	(-7.22)

	occupations				
	Female Process, plant and machine operatives	-0.390	(-8.82)	-0.386	(-8.83)
	Female Elementary occupations	-0.064	(-0.81)	-0.058	(-0.77)
Industrial sector	Agriculture, hunting and forestry	-0.153	(-3.1)	-0.152	(-3.14)
	Fishing	-0.091	(-1.41)	-0.094	(-1.46)
	Mining and quarrying	0.179	(3.43)	0.171	(3.45)
	Manufacturing	---	---	---	---
	Electricity, gas and water supply	0.134	(3.3)	0.133	(3.32)
	Construction	0.009	(0.43)	0.009	(0.42)
	Wholesale and retail trade; repair trades	-0.179	(-9.04)	-0.177	(-9.37)
	Hotels and restaurants	-0.197	(-6.78)	-0.193	(-6.9)
	Transport, storage and communication	-0.007	(-0.35)	-0.007	(-0.36)
	Financial intermediation	0.054	(1.81)	0.052	(1.83)
	Real estate, renting and business activities	-0.090	(-4.62)	-0.089	(-4.58)
	Public administration and defence; compulsory social security	0.012	(0.59)	0.010	(0.53)
	Education	-0.110	(-4.52)	-0.106	(-4.53)
	Health and social work	-0.051	(-2.5)	-0.050	(-2.45)
	Other community, social and personal service activities	-0.129	(-4.76)	-0.126	(-4.89)
	Private households and extra-territorial	0.037	(0.64)	0.037	(0.63)
Job/Firm characteristics	Self-employed	0.284	(7.43)	0.289	(7.62)
	Employee	---	---	---	---
	Temporary job	-0.118	(-4.51)	-0.117	(-4.64)
	Permanent job	---	---	---	---
	Works in a small workplace < 25people	-0.067	(-6.18)	-0.066	(-6.22)
	Work in a large workplace => 25 people	---	---	---	---
Location of workplace (council area)	Aberdeen City	0.173	(5.1)	0.168	(5.2)
	Aberdeenshire	0.071	(1.86)	0.069	(1.81)
	Angus	0.032	(0.76)	0.033	(0.79)
	Argyll & Bute	0.078	(1.69)	0.078	(1.71)
	Clackmannanshire	0.066	(1.32)	0.066	(1.32)
	Dundee City	0.012	(0.31)	0.009	(0.23)
	Dumfries and Galloway	---	---	---	---
	East Ayrshire	0.064	(1.59)	0.060	(1.5)
	East Dunbartonshire	0.022	(0.37)	0.014	(0.24)
	East Lothian	0.000	(0)	-0.009	(-0.16)
	East Renfrewshire	0.038	(0.58)	0.031	(0.47)
	Edinburgh, City of	0.119	(3.16)	0.112	(3.7)
	Eilean Siar	0.102	(1.97)	0.107	(2.46)
	Falkirk	0.081	(2.12)	0.079	(2.1)
	Fife	0.054	(1.69)	0.051	(1.6)

	Glasgow City	0.081	(2.29)	0.071	(2.3)
	Highland	0.046	(1.21)	0.046	(1.26)
	Inverclyde	0.044	(0.95)	0.043	(0.93)
	Midlothian	0.046	(0.99)	0.044	(0.96)
	Moray	0.141	(2.91)	0.141	(3.07)
	North Ayrshire	0.102	(2.25)	0.098	(2.19)
	North Lanarkshire	0.080	(2.34)	0.076	(2.25)
	Orkney Islands	0.086	(1.88)	0.089	(2.2)
	Perth & Kinross	-0.008	(-0.21)	-0.012	(-0.31)
	Renfrewshire	0.084	(2.04)	0.078	(2.05)
	Scottish Borders	-0.003	(-0.07)	-0.005	(-0.11)
	Shetland Islands	0.138	(3.4)	0.138	(3.93)
	South Ayrshire	0.072	(1.73)	0.067	(1.64)
	South Lanarkshire	0.070	(1.99)	0.066	(1.92)
	Stirling	0.104	(2.52)	0.097	(2.41)
	West Dunbartonshire	0.079	(1.51)	0.074	(1.43)
	West Lothian	0.096	(2.49)	0.090	(2.38)
	Council area could not be derived	0.081	(2.23)	0.078	(2.14)
Sample size		4405		4405	
Adjusted R-squared		0.494		0.505	
F-stat		59.17		61.71	

Note 1: Dependent variable is Natural Log of Annual Income (after tax and deductions)

Note 2: Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Dumfries and Galloway.

TABLE C-2: WAGE EQUATION – MALE (FULL-TIME WORKERS ONLY)

		2SLS		OLS	
		Coefficient	t-statistic	Coefficient	t-statistic
	(Constant)	9.204	(65.32)	9.163	(151.18)
Labour supply factors	Natural Log of generalised cost of commute	0.058	(2.98)	0.059	(9.96)
	Estimated unit land values (2003 prices)	-0.00001	(-0.24)	0.00001	(2.57)
	Household includes a child (<=16yrs old)	0.040	(2.5)	0.044	(3.2)
Human capital	Potential experience	0.026	(7.63)	0.025	(8.52)
	Potential experience squared	-0.00040	(-5.69)	-0.00038	(-6.7)
	School certificate or nothing	-0.121	(-6.01)	-0.117	(-6.72)
	Other qualification	---	---	---	---
	Degree	0.177	(8.05)	0.173	(8.84)
Occupation	Managers and senior officials	---	---	---	---
	Professional occupations	0.013	(0.47)	0.012	(0.43)
	Associate professional and technical occupations	-0.155	(-6.09)	-0.156	(-6.19)
	Administrative and secretarial occupations	-0.416	(-11.96)	-0.410	(-13.38)
	Skilled trades occupations	-0.255	(-9.7)	-0.249	(-11.29)
	Personal service occupations	-0.291	(-9.64)	-0.286	(-10.64)
	Sales and customer service occupations	-0.343	(-11.93)	-0.339	(-13.84)
	Process, plant and machine operatives	-0.395	(-12.34)	-0.390	(-13.78)
	Elementary occupations	-0.417	(-9.5)	-0.413	(-9.76)
Industrial sector	Agriculture, hunting and forestry	-0.163	(-2.97)	-0.159	(-2.94)
	Fishing	-0.091	(-1.2)	-0.084	(-1.13)
	Mining and quarrying	0.165	(2.97)	0.165	(3.05)
	Manufacturing	---	---	---	---
	Electricity, gas and water supply	0.107	(2.24)	0.111	(2.36)
	Construction	0.015	(0.65)	0.017	(0.7)
	Wholesale and retail trade; repair trades	-0.139	(-5.67)	-0.137	(-5.68)
	Hotels and restaurants	-0.242	(-5.34)	-0.240	(-5.49)
	Transport, storage and communication	-0.015	(-0.62)	-0.014	(-0.6)
	Financial intermediation	0.026	(0.6)	0.023	(0.54)
	Real estate, renting and business activities	-0.105	(-4.27)	-0.106	(-4.33)
	Public administration and defence; compulsory social security	0.002	(0.08)	0.004	(0.14)
	Education	-0.152	(-4.52)	-0.151	(-4.53)
	Health and social work	-0.049	(-1.36)	-0.055	(-1.62)
	Other community, social and personal service activities	-0.135	(-3.63)	-0.128	(-3.8)
	Private households and extra-territorial	0.043	(0.52)	0.037	(0.45)
Job/Firm	Self-employed	0.275	(6)	0.272	(6.02)

characteristics	Employee	---	---	---	---
	Temporary job	-0.172	(-4.64)	-0.173	(-4.7)
	Permanent job	---	---	---	---
	Works in a small workplace < 25people	-0.093	(-6.12)	-0.091	(-6.28)
	Work in a large workplace => 25 people	---	---	---	---
Location of workplace (council area)	Aberdeen City	0.177	(3.4)	0.170	(3.66)
	Aberdeenshire	0.115	(2.02)	0.110	(2.02)
	Angus	0.010	(0.16)	0.005	(0.09)
	Argyll & Bute	0.101	(1.44)	0.086	(1.38)
	Clackmannanshire	0.095	(1.37)	0.095	(1.39)
	Dundee City	-0.003	(-0.05)	-0.001	(-0.02)
	Dumfries and Galloway	---	---	---	---
	East Ayrshire	0.039	(0.66)	0.040	(0.7)
	East Dunbartonshire	-0.003	(-0.04)	-0.003	(-0.03)
	East Lothian	-0.014	(-0.18)	-0.026	(-0.38)
	East Renfrewshire	-0.046	(-0.51)	-0.058	(-0.66)
	Edinburgh, City of	0.097	(1.7)	0.083	(1.87)
	Eilean Siar	0.021	(0.34)	0.029	(0.49)
	Falkirk	0.093	(1.73)	0.094	(1.78)
	Fife	0.014	(0.29)	0.012	(0.27)
	Glasgow City	0.057	(1.09)	0.049	(1.1)
	Highland	-0.003	(-0.06)	0.003	(0.06)
	Inverclyde	0.014	(0.2)	0.010	(0.14)
	Midlothian	0.061	(0.92)	0.054	(0.85)
	Moray	0.108	(1.68)	0.113	(1.78)
	North Ayrshire	0.099	(1.53)	0.101	(1.59)
	North Lanarkshire	0.057	(1.1)	0.054	(1.11)
	Orkney Islands	0.077	(1.3)	0.084	(1.47)
	Perth & Kinross	-0.045	(-0.8)	-0.048	(-0.88)
	Renfrewshire	0.066	(1.04)	0.054	(1)
	Scottish Borders	0.063	(0.94)	0.064	(0.97)
	Shetland Islands	0.117	(2.29)	0.125	(2.57)
	South Ayrshire	0.070	(1.16)	0.065	(1.13)
	South Lanarkshire	0.015	(0.28)	0.009	(0.18)
	Stirling	0.045	(0.69)	0.035	(0.59)
	West Dunbartonshire	0.024	(0.32)	0.020	(0.27)
	West Lothian	0.076	(1.41)	0.076	(1.46)
	Council area could not be derived	0.072	(1.39)	0.071	(1.41)
Sample size		2539		2539	
Adjusted R-squared		0.437		0.450	
F-stat		31.32		33.01	

Note 1: Dependent variable is Natural Log of Annual Income (after tax and deductions)

Note 2: Constant relates to a male employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Dumfries and Galloway.

TABLE C-3: WAGE EQUATION – FEMALE (FULL-TIME WORKERS ONLY)

		2SLS		OLS	
		Coefficient	t-statistic	Coefficient	t-statistic
	(Constant)	8.924	(35.72)	9.052	(138.17)
Labour supply factors	Natural Log of generalised cost of commute	0.051	(1.54)	0.050	(7.61)
	Estimated unit land values (2003 prices)	0.00008	(1.42)	0.00002	(3.45)
	Household includes a child (<=16yrs old)	0.020	(0.7)	-0.005	(-0.28)
Human capital	Potential experience	0.007	(1.19)	0.012	(3.48)
	Potential experience squared	-0.00003	(-0.22)	-0.00015	(-2.11)
	School certificate or nothing	-0.167	(-5.33)	-0.177	(-7.43)
	Other qualification	---	---	---	---
	Degree	0.117	(3.6)	0.138	(6.87)
Occupation	Managers and senior officials	---	---	---	---
	Professional occupations	0.154	(4.57)	0.145	(4.58)
	Associate professional and technical occupations	0.023	(0.8)	0.019	(0.72)
	Administrative and secretarial occupations	-0.249	(-7.91)	-0.263	(-10.77)
	Skilled trades occupations	-0.231	(-4.56)	-0.224	(-4.95)
	Personal service occupations	-0.301	(-7.89)	-0.321	(-12.01)
	Sales and customer service occupations	-0.288	(-5.31)	-0.309	(-7.84)
	Process, plant and machine operatives	-0.488	(-9.78)	-0.497	(-11.4)
	Elementary occupations	-0.147	(-1.78)	-0.184	(-2.74)
Industrial sector	Agriculture, hunting and forestry	-0.033	(-0.26)	-0.072	(-0.59)
	Fishing	-0.063	(-0.44)	-0.031	(-0.23)
	Mining and quarrying	0.012	(0.06)	0.134	(0.99)
	Manufacturing	---	---	---	---
	Electricity, gas and water supply	0.195	(2.31)	0.181	(2.27)
	Construction	-0.018	(-0.22)	-0.046	(-0.7)
	Wholesale and retail trade; repair trades	-0.202	(-5.42)	-0.212	(-6.7)
	Hotels and restaurants	-0.145	(-3.38)	-0.151	(-3.95)
	Transport, storage and communication	0.014	(0.31)	0.006	(0.15)
	Financial intermediation	0.065	(1.48)	0.080	(1.99)
	Real estate, renting and business activities	-0.054	(-1.52)	-0.056	(-1.71)
	Public administration and defence; compulsory social security	0.032	(0.97)	0.029	(0.91)
	Education	-0.057	(-1.43)	-0.058	(-1.64)
	Health and social work	-0.022	(-0.67)	-0.030	(-1.04)
	Other community, social and personal service activities	-0.115	(-2.62)	-0.115	(-2.77)
	Private households and extra-territorial	0.070	(0.78)	0.048	(0.57)
Job/Firm	Self-employed	0.344	(4.47)	0.356	(4.85)

characteristics	Employee	---	---	---	---
	Temporary job	-0.031	(-0.71)	-0.056	(-1.63)
	Permanent job	---	---	---	---
	Works in a small workplace < 25people	-0.036	(-2.17)	-0.034	(-2.2)
	Work in a large workplace => 25 people	---	---	---	---
Location of workplace (council area)	Aberdeen City	0.152	(3.23)	0.147	(3.28)
	Aberdeenshire	0.045	(0.75)	0.022	(0.42)
	Angus	0.090	(1.19)	0.052	(0.89)
	Argyll & Bute	0.110	(1.21)	0.064	(0.92)
	Clackmannanshire	0.024	(0.32)	0.023	(0.31)
	Dundee City	0.035	(0.58)	0.013	(0.24)
	Dumfries and Galloway	---	---	---	---
	East Ayrshire	0.106	(1.77)	0.083	(1.5)
	East Dunbartonshire	0.030	(0.38)	0.032	(0.42)
	East Lothian	0.004	(0.04)	0.030	(0.33)
	East Renfrewshire	0.177	(1.67)	0.139	(1.4)
	Edinburgh, City of	0.130	(2.73)	0.148	(3.61)
	Eilean Siar	0.293	(2.92)	0.222	(3.41)
	Falkirk	0.061	(1.04)	0.045	(0.84)
	Fife	0.123	(2.45)	0.099	(2.21)
	Glasgow City	0.098	(2.05)	0.099	(2.31)
	Highland	0.106	(1.72)	0.079	(1.55)
	Inverclyde	0.083	(1.28)	0.090	(1.46)
	Midlothian	0.011	(0.15)	0.005	(0.08)
	Moray	0.208	(2.44)	0.164	(2.45)
	North Ayrshire	0.121	(1.78)	0.101	(1.61)
	North Lanarkshire	0.127	(2.32)	0.105	(2.25)
	Orkney Islands	0.127	(1.58)	0.071	(1.26)
	Perth & Kinross	0.051	(0.88)	0.029	(0.54)
	Renfrewshire	0.097	(1.78)	0.101	(1.93)
	Scottish Borders	-0.042	(-0.51)	-0.087	(-1.34)
	Shetland Islands	0.193	(2.68)	0.145	(2.83)
	South Ayrshire	0.095	(1.49)	0.068	(1.18)
	South Lanarkshire	0.138	(2.81)	0.134	(2.84)
	Stirling	0.187	(3.1)	0.159	(2.91)
	West Dunbartonshire	0.147	(1.92)	0.142	(1.94)
	West Lothian	0.099	(1.62)	0.111	(1.99)
	Council area could not be derived	0.086	(1.52)	0.076	(1.42)
Sample size		1866		1866	
Adjusted R-squared		0.486		0.517	
F-stat		28.11		31.66	

Note 1: Dependent variable is Natural Log of Annual Income (after tax and deductions)

Note 2: Constant relates to a female employee with a qualification other than a degree working full-time as a manager or senior official in manufacturing. Has a permanent job, works in a workplace with 25 or more other people in Dumfries and Galloway.

ANNEX D

Distance Equation

ANNEX D – DISTANCE EQUATION

TABLE D-1: DISTANCE EQUATION (FULL-TIME WORKERS ONLY)

		2SLS		OLS	
		Coefficient	t-statistic	Coefficient	t-statistic
	(Constant)	4.079	(3.32)	7.054	(20.45)
	Natural Log of annual income	0.811	(7.94)	0.564	(16.5)
	Natural Log of generalised cost per km	-0.893	(-4.71)	-1.044	(-40.62)
	Natural Log of estimated unit land values (2003 prices)	-0.0003	(-0.01)	-0.004	(-0.7)
Commuter and household characteristics	Self-employed - Full-time	-0.634	(-5.41)	-0.296	(-3.69)
	Employed - Full-time	---	---	---	---
	Male	---	---	---	---
	Female	-0.036	(-0.85)	-0.057	(-1.94)
	Age of commuter	-0.006	(-2.14)	-0.006	(-4.37)
	No car in household	-0.580	(-1.71)	-0.879	(-19.58)
	Car available	---	---	---	---
	Household has a car, but potentially unavailable to commuter	-0.637	(-2.07)	-0.918	(-24.69)
	Single adult household	---	---	---	---
	Small adult household	0.187	(2.05)	0.178	(4.69)
	Single parent household	-0.050	(-0.61)	-0.037	(-0.49)
	Small family household	0.193	(2.18)	0.176	(4.32)
	Large family household	0.098	(1.1)	0.080	(1.42)
	Large adult household	0.114	(1.04)	0.076	(1.31)
	Older smaller household	0.127	(0.9)	0.096	(0.9)
Location of household (Rural/urban classification)	Large urban	---	---	---	---
	Other urban	0.275	(5.09)	0.233	(5.44)
	Small accessible towns	0.552	(6.74)	0.469	(8.64)
	Small remote towns	0.242	(1.8)	0.146	(1.21)
	Very remote small towns	-0.447	(-3.12)	-0.374	(-2.88)
	Accessible rural	0.767	(7.48)	0.675	(12.99)
	Remote rural	1.142	(7.15)	1.079	(9.13)
	Very remote rural	0.589	(4.11)	0.547	(4.58)
Location of workplace (council area)	Aberdeen City	-0.507	(-6.67)	-0.475	(-6.74)
	Aberdeenshire	-0.866	(-7.88)	-0.842	(-8.79)
	Angus	-0.865	(-6.75)	-0.864	(-7.88)
	Argyll & Bute	-0.684	(-4.54)	-0.653	(-4.61)
	Clackmannanshire	-0.861	(-5.88)	-0.866	(-6.29)
	Dundee City	-0.364	(-3.58)	-0.380	(-4.01)
	Dumfries and Galloway	-0.911	(-8.02)	-0.854	(-8.85)
	East Ayrshire	-0.715	(-6.5)	-0.743	(-7.03)
	East Dunbartonshire	-0.260	(-1.53)	-0.301	(-1.86)
	East Lothian	-0.155	(-0.97)	-0.112	(-0.73)
	East Renfrewshire	-0.230	(-1.18)	-0.326	(-1.79)
	Edinburgh, City of	-0.244	(-3.25)	-0.174	(-2.81)
	Eilean Siar	-0.862	(-4.83)	-0.927	(-5.85)
	Falkirk	-0.744	(-7.06)	-0.716	(-7.48)

	Fife	-0.645	(-8.11)	-0.651	(-8.69)
	Glasgow City	---	---	---	---
	Highland	-0.798	(-6.85)	-0.833	(-8.17)
	Inverclyde	-0.725	(-5.53)	-0.721	(-5.74)
	Midlothian	-0.787	(-6.14)	-0.854	(-6.92)
	Moray	-0.965	(-5.78)	-0.859	(-6.86)
	North Ayrshire	-0.742	(-5.85)	-0.749	(-6.17)
	North Lanarkshire	-0.499	(-5.86)	-0.517	(-6.63)
	Orkney Islands	-0.801	(-5.03)	-0.833	(-5.49)
	Perth & Kinross	-0.619	(-5.81)	-0.594	(-6.1)
	Renfrewshire	-0.270	(-2.77)	-0.300	(-3.2)
	Scottish Borders	-0.802	(-5.77)	-0.809	(-6.58)
	Shetland Islands	-0.750	(-5.03)	-0.808	(-5.78)
	South Ayrshire	-0.600	(-5.3)	-0.621	(-5.72)
	South Lanarkshire	-0.502	(-5.67)	-0.482	(-5.88)
	Stirling	-0.529	(-4.89)	-0.534	(-5.01)
	West Dunbartonshire	-0.451	(-3.05)	-0.434	(-3.13)
	West Lothian	-0.454	(-4.48)	-0.394	(-4.18)
	Council area could not be derived	-0.536	(-5.65)	-0.513	(-5.73)
Sample size		4652		4652	
Adjusted R-squared		0.279		0.475	
F-stat		33.16		80.37	

Note 1: Dependent variable is Natural Log of Commute Distance (metres)

Note 2: Constant relates to full-time male employee with a car available living in a large urban area in a single adult household and working in Glasgow City

ANNEX E

2SLS SENSITIVITY TO CHOICE OF INSTRUMENT

ANNEX E - 2SLS ROBUSTNESS AND SENSITIVITY

Wage Equation

We apply two statistical tests to the wage equation: the Wu-Hausman test for endogeneity in a regression with instrumental variables and the Sargan test of overidentifying restrictions.

The result of the Wu-Hausman test ($F_{2,4328} > 0.51$; p-value=0.60) implies that the regressors in the wage equation are probably exogenous, and therefore a 2SLS estimation could be viewed as excessive (an OLS regression would suffice). However given that the commuting costs in the wage equation were constructed as a function of income, we know they are endogenous. Additionally commuting costs are endogenous to the economic system we are modelling. We would therefore consider that the most appropriate econometric method to estimate the wage equation is 2SLS, rather than OLS. We also note that the main conclusions of this research would be robust if drawn from the OLS regression results.

The exogenous variables that are excluded from the wage equation but appear in other equations in the economic system are household type (we expect all other things being equal that multiple occupancy households to commute more than single adult households) and rural/urban classification (we expect the geographic spread – housing and workplace density – to affect average commuting distance). The justification for excluding these variables is set out in the main body of the paper. The result of the Sargan test of overidentifying restrictions ($17.8 > \chi^2_{(10)}$; p-value = 0.06) would also lead us to believe that these excluded variables are valid instruments for commuting costs.

Table E-1 demonstrates the effect on the 2SLS estimate of excluding each of the two blocks of instruments in turn. The results demonstrate significant variability, with the exclusion of the urban-rural classification resulting in a very poor model fit. In this situation we are relying on the household type variable to explain commuting costs, when as we can see from the distance equation set out in section 4.2.3 and Annex D it has only weak explanatory power (in both the OLS and 2SLS regressions).

TABLE E-1 SENSITIVITY OF WAGE EQUATION CO-EFFICIENTS TO CHOICE OF INSTRUMENTS

2SLS with instruments	Natural Log of generalised cost of commute	Estimated unit land values (2003 prices)
All instruments	0.044 (2.46)	0.00001 (0.33)
Without urban-rural classification	-0.011 (-0.23)	-0.00007 (-1.02)
Without household classification	0.065 (2.22)	0.00016 (1.48)

Note 1: Coefficient (t-stat)

Note 2: Dependent variable natural log of annual income (net of tax and deductions)

Distance Equation

The result of the Wu-Hausman test ($F_{5,4302}$ < 3.46; p-value=0.004) implies that the regressors in the distance equation (income, commuting costs, land rents and car availability) are probably endogenous. A 2SLS estimation is therefore required. This is consistent with the economic system as set out in the main body of this paper.

The variables that act as instruments for income in the distance equation are job/firm characteristics (occupation, industrial sector, workplace size), human capital (qualifications and experience) and gender (interacted with occupation). The Sargan test on these variables however indicates that, despite our theoretical expectations of the economic system, there appears to be some correlation between these variables and the error term in the regression. This test result casts doubt on the validity of these instruments for income in the distance equation. The implication being that we need to treat, with a degree of caution, the coefficients of the endogenous variables in the 2SLS. That is the elasticity to income, elasticity to generalised cost, elasticity to land rents and the coefficients on the car available dummy variables. It should be noted that this degree of caution does not extend to the coefficients of the exogenous variables (household type, rural-urban classification) as these are unbiased.

Drawing on the transport economics literature in which there exist reviews of demand elasticities to income and generalised costs (De Jong and Gunn, 2001; Goodwin, Dargay and Hanly, 2004; Graham and Glaister, 2004) we find that the distance equation, despite failing the Sargan test, gives estimates of elasticities to income and generalised cost that are eminently plausible and within the observed range. Therefore whilst we note the fact that there is some doubt over the validity of the instruments used in the 2SLS, in drawing the main policy conclusions of this paper together, we do not have any concerns regarding utilising the derived elasticity to generalised cost, -0.9, as this is entirely consistent to the existing evidence base.

In terms of the sensitivity of the 2SLS estimation to the exclusion of different instruments, we do not find the same sensitivity as seen in the wage equation. In part this is attributed to the fact that each of the variables is a strong determinant of income. As can be seen from Table E-2 the commute distance (demand) elasticity to income has a range of 0.74 to 0.84, whilst the elasticity to unit generalised cost has a range of -0.5 to -1.0. In all instances the land values coefficient is insignificant.

TABLE E-2 SENSITIVITY OF DISTANCE EQUATION CO-EFFICIENTS TO CHOICE OF INSTRUMENTS

2SLS with instruments	Natural Log of annual income	Natural Log of generalised cost per km	Natural Log of estimated unit land values (2003 prices)
All instruments	0.811	-0.893	-0.00027
	(7.94)	(-4.71)	(-0.01)
Without occupation	0.824	-0.927	0.00261
	(7.5)	(-4.48)	(0.07)
Without industry	0.844	-0.480	0.00375
	(5.77)	(-1.91)	(0.08)
Without interaction between female and industry	0.772	-0.879	-0.01623
	(6.88)	(-3.42)	(-0.42)
Without experience	0.790	-0.959	0.03798
	(7.54)	(-4.81)	(0.61)
Without qualifications	0.737	-0.991	0.00478
	(6.92)	(-5.12)	(0.13)
Without workplace size	0.778	-0.884	-0.00531
	(7.56)	(-4.54)	(-0.14)
Without temporary/permanent worker	0.789	-0.937	0.00158
	(7.72)	(-4.92)	(0.04)

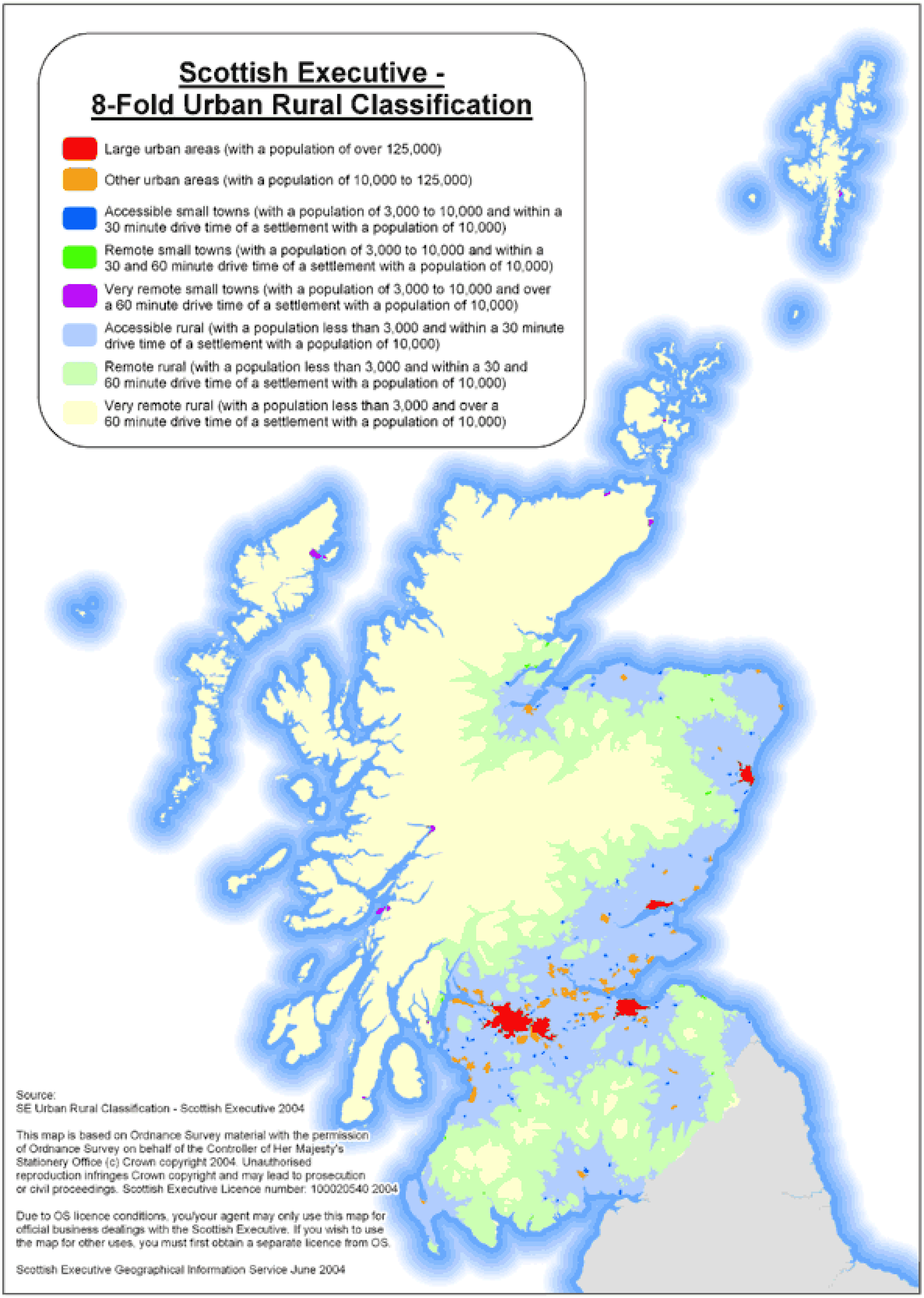
Note 1: Coefficient (t-stat)

Note 2: Dependent variable natural log of commute distance (metres)

ANNEX F

SCOTTISH EXECUTIVE 8-FOLD URBAN RURAL CLASSIFICATION

ANNEX F - SCOTTISH EXECUTIVE 8-FOLD URBAN RURAL CLASSIFICATION



Source: Scottish Executive Urban Rural Classification
http://www.scotland.gov.uk/library5/rural/seurc-03.asp

ANNEX G

RELATIONSHIP BETWEEN GDP AND SALARY COSTS

ANNEX G - RELATIONSHIP BETWEEN GDP AND SALARY COSTS

	1995	1996	1997	1998	1999	2000	2001	2002	2003	1999 to 2003 Average
GDP	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Indirect taxes	10%	11%	11%	11%	11%	11%	11%	11%	11%	11%
GVA	**90%**	**89%**	**89%**	**89%**	**89%**	**89%**	**89%**	**89%**	**89%**	**89%**
Factor income capital	*35%*	*36%*	*35%*	*35%*	*34%*	*32%*	*32%*	*32%*	*33%*	*33%*
Profits	33%	34%	34%	33%	32%	31%	30%	31%	31%	31%
Cap gains tax	3%	4%	4%	4%	4%	3%	3%	3%	3%	3%
Corp tax +	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Direct taxes	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Factor income labour	*54%*	*53%*	*54%*	*54%*	*55%*	*56%*	*57%*	*57%*	*56%*	*56%*
Employers' NI	7%	7%	7%	7%	8%	8%	8%	8%	8%	8%
Wages and salaries	47%	46%	47%	47%	48%	48%	49%	49%	48%	48%
Income taxes and NI	10%	9%	10%	10%	10%	11%	11%	11%	10%	11%

Source: UK National Accounts - The Blue Book 2005 (National Statistics, 2005)

Net to gross salary:	77.9%
Net salary to gross labour costs	66.8%
Net salary to GDP	37.5%

ANNEX H

CALCULATION OF PRICE AND JOURNEY SPEED ELASTICITIES OF DISTANCE AND WAGES

ANNEX H: CALCULATION OF PRICE AND JOURNEY SPEED ELASTICITIES OF DISTANCE AND WAGES

The problem

For a given individual with a car available, the three equations describing the economic system are:

[Wage equation] $Ln(W) = 0.044Ln(C) + Ln(x)$ (1)

[Distance equation]

$Ln(D) = -0.893Ln(K) + 0.811Ln(W) + Ln(y)$ (2)

[Commuting costs] $C = V.T + P$ (3)

Note:
- W = net wages
- D = commuting distance
- C = commuting costs
- K = commuting cost per km
- T = commuting time
- V = value of time
- P = out of pocket costs
- S = speed
- F = out of pocket costs per km
- x, y and z are constants

To analyze the impact of transport policy (i.e. changes in speed and price) on wages and commuting distance we need to express equations (1), (2) and (3) in terms of only exogenous parameters – that is speed (S) and price per kilometre (F).

An analytical solution

Defining K, commuting costs per km:

$$K = \frac{C}{D} \qquad (4)$$

Substituting for C gives:

$$K = \frac{V.T + P}{D}$$

$$K = \frac{V.T}{D} + \frac{P}{D}$$

$$K = \frac{V}{S} + F \qquad (5)$$

From Mackie *et al.* (2003) (p39) the marginal value of travel time is a function of household income and distance. If we assume that the ratio between household income and earned personal income remains constant the recommended value of time model proposed by Mackie *et al.* can be expressed as follows:

$$V = z.\left(\frac{W}{W_0}\right)^{0.359}\left(\frac{D}{D_0}\right)^{0.421}$$

Where z, W_0 and D_0 are constants.

Substituting for V in (5) therefore gives:

$$K = \frac{z}{S}.\left(\frac{W}{W_0}\right)^{0.359}\left(\frac{D}{D_0}\right)^{0.421} + F$$

Substituting for K in (4) gives

$$C = D.\left[\frac{z}{S}.\left(\frac{W}{W_0}\right)^{0.359}\left(\frac{D}{D_0}\right)^{0.421} + F\right] \qquad (6)$$

(1) and (2) can also be expressed as:

$$W = x.C^{0.044} \qquad (7)$$

$$D = y.K^{-0.893}W^{0.811} \qquad (8)$$

Substituting for C and K in (6) and (7) gives:

$$W = x.D^{0.044}.\left(\frac{z}{S}.\left(\frac{W}{W_0}\right)^{0.359}\left(\frac{D}{D_0}\right)^{0.421} + F\right)^{0.044} \qquad (9)$$

$$D = y.\left[\frac{z}{S}.\left(\frac{W}{W_0}\right)^{0.359}\left(\frac{D}{D_0}\right)^{0.421} + F\right]^{-0.893} W^{0.811} \qquad (10)$$

There is no simple analytical solution to this problem. That is it is not possible to express wages (W) and distance (D) purely as a function of speed (S) and cost per kilometre (F) through simple transformations.

To find the equilibrium conditions under different transport policy scenarios – that is to find D and W for different S and F – two approaches can be used. For large network problems Taylor approximations to the can be usefully employed, however, for smaller 'more tractable' problems such as the problem set out above a simple numeric approach is often sufficient. A weakness of the numeric approach is that the system of equations that describe the economic system may have multiple solutions in equilibrium. It is therefore important to test the system to see if such multiple equilibria exist.

A numerical solution

To solve the problem numerically we need to re-define the problem such that an approach such as Newton-Raphson can be used to solve for the equilibrium conditions. In equilibrium the left hand side and right hand side of equation (6) equal each other. This is also true for equation (7). We can therefore re-express equations (6) and (7) as follows:

$$0 = W - x.C^{0.044} \tag{11}$$
$$0 = D - y.K^{-0.893} W^{0.811} \tag{12}$$

Squaring equations (11) and (12) and summing them gives:

$$0 = \left(W - x.C^{0.044}\right)^2 + \left(D - y.K^{-0.893} W^{0.811}\right)^2 \tag{13}$$

Where:

$$C = D.K$$
$$K = \frac{V}{S} + F$$
$$V = z.\left(\frac{W}{W_0}\right)^{0.359} \left(\frac{D}{D_0}\right)^{0.421}$$
$$D \geq 0$$
$$W \geq 0$$

For a given S, F, x, y and z an optimisation methodology such as Newton-Raphson will be able to find a D and W that satisfies the equilibrium condition set out in equation (13) – if such a solution exists.

The constants, x and y vary with the personal attributes of the worker. The numeric solution presented below has been developed using worker attributes that form, in the main, the largest percentage of the sample. These are reflected by the constant terms in both the wage and distance equations. That is the numeric solution has been developed for a full-time worker who is:

- Male;
- 40 years old with 24 years of work experience;
- Has a qualification other than a degree or a school certificate;
- Is a manager or senior official;
- Works in the manufacturing sector;
- Is an employee;
- Works in a workplace with 25 or more other people;
- Workplace is located in Glasgow City (local authority area);
- Lives in a large urban area;
- In a single adult household; and
- Has a car available.

Using the wage equation for both male and females and the distance equation, the constants x and y for a worker with the above characteristics can be derived as follows:

$$x = e^{\left[9.289 + 0.081 + (24 * 0.019) + \left(24^2 * -0.00028\right)\right]} = 15{,}752$$

$$y = e^{(4.079 + 40 * 0.006)} = 46.5$$

The constants z, W_0 and D_0 can be calculated from Mackie et al (p39, p58) and from analysis of the SHS dataset.

D_0 = *12.12 km (=7.58 miles)*

z = *inflation effect between 1994 and 2002 ** β_T/β_c

= *4.99*

W_0 = Inc_0 */ ratio of household to personal income * ratio of net to gross salaries*inflation*

= *35 / 1.67 *0.78 * 1.223*

= *20.0 (£000)*

For full-time workers who drive to work the average speed (S), average out of pocket costs per km (F) and average value of time (V) in the Scottish Household Survey dataset are:

$$S = 27.6km/hr = 0.46km/\min$$

$$F = 10.0pence/km$$

The Excel 'solver' utility using the Newton search methodology and a precision of 0.00001 on the target value was used to derive the equilibrium commute distance and wage. In the optimisation process the starting values for *D*, *W*, *S*, *F*, *x* and *y* were altered. As no other equilibrium solutions were found this gives confidence that the above equilibrium point is unique within the constraints imposed on the process (i.e. distance and wages must be greater than zero). The equilibrium wage and commute distance for the worker, with the characteristics set out above is detailed in Table H.1.

Table H.1 Equilibrium values for income and distance

	SHS dataset average (men)	SHS Mean for managers and senior officials (men)	SHS Median for managers and senior officials (men)	Numeric model equilibrium values
Net earned income	£16,600	£21,400	£19,200	£19,867
Commute distance	10.9km	14.1km	8.3km	10.1km

The equilibrium value for distance is similar to the average for the whole SHS dataset, whilst that for income is substantially higher than that for the average male worker. However, the equilibrium values for income, and distance, lie part way between the mean and median values that are observed in the SHS dataset for people whose occupations are managers or senior officials. This gives confidence in that the numeric analysis has a robust basis for forecasting policy impacts.

The primary impacts of transport policy is to change journey speed and/or transport prices. The numerical model can be used to find equilibrium solutions of wages and commuting distance for different levels of transport prices and journey speed. The results of some tests are detailed in Table H.3. As can be seen from these results commuting distance is very sensitive to a change in price and to a change in journey speed, whilst wage rates are almost completely insensitive. A doubling of journey speed only reduces wages by £24 a year off a £20,000 net annual salary, whilst simultaneously increasing the average commuting distance by 2.5km. Similar effects occur with a change in transport price.

It is useful to consider the sensitivity of these results to the uncertainty within the estimated elasticities of the wage and distance equation (see Table H.2). Tables H.4 to H.9 set out the results of repeating the previous transport policy tests with the re-defined wage and distance equations.

TABLE H.2: 95% CONFIDENCE INTERVALS FOR WAGE EQUATION AND DISTANCE EQUATION ELASTICITIES

	Model coefficient	T-Stat	Standard error	95% Confidence Interval		
				+/-	Lower bound	Upper bound
Wage equation						
Commuting cost elasticity	0.044	2.46	0.0179	0.0351	0.0089	0.0791
Distance equation						
Income elasticity	0.811	7.94	0.102	0.200	0.611	1.011
Commuting cost per km elasticity	-0.893	-4.71	0.190	0.372	-1.265	-0.521

TABLE H.3: IMPACT OF JOURNEY SPEED AND TRANSPORT PRICES ON WAGES AND COMMUTING DISTANCE

	Change in journey speed								
	-50%	**-25%**	**-10%**	**-0.1%**	**0%**	**0.1%**	**10%**	**50%**	**100%**
Journey speed elasticity of distance	0.493	0.417	0.383	0.364	0.363	0.363	0.346	0.291	0.244
Distance (m)	7,615	9,050	9,716	10,099	10,103	10,107	10,452	11,575	12,571
Percentage change in distance	-25%	-10%	-4%	0%	0%	0%	3%	15%	24%
Journey speed elasticity of wages	-0.00311	-0.00242	-0.00214	-0.00200	-0.00199	-0.00198	-0.00188	-0.00149	-0.00120
Net wages (£)	19,897	19,879	19,871	19,867	19,867	19,867	19,863	19,852	19,843
Percentage change in wages	0.16%	0.06%	0.02%	0.00%	0.00%	0.00%	-0.02%	-0.07%	-0.12%
	Change in transport price								
	-50%	**-25%**	**-10%**	**-0.1%**	**0%**	**0.1%**	**10%**	**50%**	**100%**
Price elasticity of distance	-0.477	-0.430	-0.405	-0.390	-0.390	-0.390	-0.376	-0.329	-0.283
Distance (m)	12,511	11,188	10,512	10,107	10,103	10,099	9,723	8,442	7,239
Percentage change in distance	24%	11%	4%	0%	0%	0%	-4%	-16%	-28%
Price elasticity of wages	0.00235	0.00224	0.00219	0.00214	0.00214	0.00215	0.00210	0.00197	0.00183
Net wages (£)	19,843	19,855	19,862	19,867	19,867	19,867	19,871	19,886	19,903
Percentage change in wages	-0.12%	-0.06%	-0.02%	0.00%	0.00%	0.00%	0.02%	0.10%	0.18%

Note 1: All elasticities are calculated from output of the numerical optimisation model. The point elasticity is an average of the elasticities with a 0.1% change and a -0.1% change in journey speed and transport prices.

TABLE H.4: SENSITIVITY TEST TO LOWER BOUND OF 95% CI OF COMMUTING COST ELASTICITY OF WAGES

	Change in journey speed				
	-50%	**-10%**	**0%**	**10%**	**100%**
Journey speed elasticity of distance	0.476	0.366	0.347	0.329	0.229
Distance (m)	6,933	8,766	9,099	9,398	11,186
Percentage change in distance	-24%	-4%	0%	3%	23%
Journey speed elasticity of wages	-0.00081	-0.00040	-0.00038	-0.00036	-0.00011
Net wages (£)	16,496	16,490	16,490	16,489	16,488
Percentage change in wages	0.04%	0.00%	0.00%	0.00%	-0.01%
	Change in transport price				
	-50%	**-10%**	**0%**	**10%**	**100%**
Price elasticity of distance	-0.516	-0.433	-0.416	-0.400	-0.296
Distance (m)	11,444	9,492	9,099	8,735	6,402
Percentage change in distance	26%	4%	0%	-4%	-30%
Price elasticity of wages	0.00049	0.00046	0.00045	0.00044	0.00038
Net wages (£)	16,486	16,489	16,490	16,490	16,496
Percentage change in wages	-0.02%	0.00%	0.00%	0.00%	0.04%

Note 1: All elasticities are calculated from output of the numerical optimisation 'Elasticity of wage sensitivity'. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

TABLE H.5: SENSITIVITY TEST TO UPPER BOUND OF 95% CI OF COMMUTING COST ELASTICITY OF WAGES

	Change in journey speed				
	-50%	**-10%**	**0%**	**10%**	**100%**
Journey speed elasticity of distance	0.509	0.400	0.382	0.363	0.260
Distance (m)	8,397	10,813	11,264	11,674	14,194
Percentage change in distance	-25%	-4%	0%	4%	26%
Journey speed elasticity of wages	-0.00600	-0.00416	-0.00391	-0.00365	-0.00236
Net wages (£)	24,292	24,229	24,219	24,210	24,162
Percentage change in wages	0.30%	0.04%	0.00%	-0.04%	-0.24%
	Change in transport price				
	-50%	**-10%**	**0%**	**10%**	**100%**
Price elasticity of distance	-0.438	-0.377	-0.364	-0.352	-0.270
Distance (m)	13,729	11,689	11,264	10,868	8,227
Percentage change in distance	22%	4%	0%	-4%	-27%
Price elasticity of wages	0.00404	0.00378	0.00371	0.00365	0.00321
Net wages (£)	24,170	24,210	24,219	24,228	24,297
Percentage change in wages	-0.20%	-0.04%	0.00%	0.04%	0.32%

Note 1: All elasticities are calculated from output of the numerical optimisation 'Elasticity of wage sensitivity'. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

TABLE H.6: SENSITIVITY TEST TO LOWER BOUND OF 95% CI OF INCOME ELASTICITY OF DISTANCE

	Change in journey speed				
	-50%	**-10%**	**0%**	**10%**	**100%**
Journey speed elasticity of distance	0.362	0.257	0.241	0.225	0.145
Distance (m)	1,413	1,681	1,725	1,764	1,975
Percentage change in distance	-18%	-3%	0%	2%	14%
Journey speed elasticity of wages	-0.00217	-0.00141	-0.00131	-0.00122	-0.00074
Net wages (£)	18,157	18,140	18,138	18,136	18,124
Percentage change in wages	0.11%	0.01%	0.00%	-0.01%	-0.07%
	Change in transport price				
	-50%	**-10%**	**0%**	**10%**	**100%**
Price elasticity of distance	-0.770	-0.593	-0.562	-0.531	-0.359
Distance (m)	2,389	1,828	1,725	1,634	1,105
Percentage change in distance	38%	6%	0%	-5%	-36%
Price elasticity of wages	0.00354	0.00313	0.00305	0.00296	0.00242
Net wages (£)	18,106	18,132	18,138	18,143	18,182
Percentage change in wages	-0.18%	-0.03%	0.00%	0.03%	0.24%

Note 1: All elasticities are calculated from output of the numerical optimisation 'Elasticity of wage sensitivity'. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

TABLE H.7: SENSITIVITY TEST TO UPPER BOUND OF 95% CI OF INCOME ELASTICITY OF DISTANCE

	Change in journey speed				
	-50%	**-10%**	**0%**	**10%**	**100%**
Journey speed elasticity of distance	0.590	0.490	0.473	0.455	0.350
Distance (m)	38,720	52,218	54,912	57,411	74,141
Percentage change in distance	-29%	-5%	0%	5%	35%
Journey speed elasticity of wages	-0.00388	-0.00274	-0.00261	-0.00247	-0.00167
Net wages (£)	21,853	21,816	21,810	21,805	21,774
Percentage change in wages	0.19%	0.03%	0.00%	-0.02%	-0.17%
	Change in transport price				
	-50%	**-10%**	**0%**	**10%**	**100%**
Price elasticity of distance	-0.269	-0.246	-0.240	-0.235	-0.196
Distance (m)	62,306	56,260	54,912	53,621	44,125
Percentage change in distance	13%	2%	0%	-2%	-20%
Price elasticity of wages	0.00140	0.00135	0.00133	0.00132	0.00121
Net wages (£)	21,795	21,808	21,810	21,813	21,837
Percentage change in wages	-0.07%	-0.01%	0.00%	0.01%	0.12%

Note 1: All elasticities are calculated from output of the numerical optimisation 'Elasticity of wage sensitivity'. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

TABLE H.8: SENSITIVITY TEST TO LOWER BOUND OF 95% CI OF COMMUTING COST PER KM ELASTICITY OF DISTANCE

	Change in journey speed				
	-50%	**-10%**	**0%**	**10%**	**100%**
Journey speed elasticity of distance	0.548	0.426	0.406	0.385	0.270
Distance (m)	2,927	3,860	4,032	4,187	5,121
Percentage change in distance	-27%	-4%	0%	4%	27%
Journey speed elasticity of wages	0.00606	0.00413	0.00385	0.00357	0.00227
Net wages (£)	18,876	18,926	18,934	18,940	18,976
Percentage change in wages	-0.30%	-0.04%	0.00%	0.04%	0.23%
	Change in transport price				
	-50%	**-10%**	**0%**	**10%**	**100%**
Price elasticity of distance	-0.863	-0.686	-0.652	-0.619	-0.422
Distance (m)	5,771	4,308	4,032	3,782	2,331
Percentage change in distance	43%	7%	0%	-6%	-42%
Price elasticity of wages	-0.00681	-0.00628	-0.00617	-0.00606	-0.00518
Net wages (£)	18,998	18,945	18,934	18,922	18,835
Percentage change in wages	0.34%	0.06%	0.00%	-0.06%	-0.52%

Note 1: All elasticities are calculated from output of the numerical optimisation 'Elasticity of wage sensitivity'. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

TABLE H.9: SENSITIVITY TEST TO UPPER BOUND OF 95% CI OF COMMUTING COST PER KM ELASTICITY OF DISTANCE

	Change in journey speed				
	-50%	-10%	0%	10%	100%
Journey speed elasticity of distance	0.369	0.282	0.267	0.253	0.177
Distance (m)	22,837	27,215	28,003	28,712	32,959
Percentage change in distance	-18%	-3%	0%	3%	18%
Journey speed elasticity of wages	-0.01776	-0.01239	-0.01162	-0.01084	-0.00704
Net wages (£)	21,187	21,026	21,000	20,978	20,852
Percentage change in wages	0.89%	0.12%	0.00%	-0.11%	-0.70%
	Change in transport price				
	-50%	-10%	0%	10%	100%
Price elasticity of distance	-0.209	-0.187	-0.183	-0.178	-0.147
Distance (m)	30,926	28,528	28,003	27,504	23,900
Percentage change in distance	10%	2%	0%	-2%	-15%
Price elasticity of wages	0.00859	0.00804	0.00792	0.00780	0.00689
Net wages (£)	20,910	20,983	21,000	21,017	21,145
Percentage change in wages	-0.43%	-0.08%	0.00%	0.08%	0.69%

Note 1: All elasticities are calculated from output of the numerical optimisation 'Elasticity of wage sensitivity'. The point elasticity is an average of the elasticities with a 10% change and a 10% change in journey speed and transport prices.

FIGURE H.1: SCREENSHOT OF NUMERICAL OPTIMISATION MODEL

Gap = $(W\text{-}xC^{0.044})^2+(D\text{-}yK^{-0.893}W^{0.811})^2$

Gap	0.000000

$(W\text{-}xC^{0.044})^2$	$(D\text{-}yK^{-0.893}W^{0.811})^2$
0	0

Commuting costs (pence): C=(D/1000).K — C 195.28 — Dataset average 236.1

Generalised cost per km (pence/km): K=V/S+F — K 19.33 — Dataset average 20.3

Value of time (pence/min): $V=z.(W/W_0)^{0.359}.(D/D_0)^{0.421}$ — V 4.29

z	4.993	B_T/B_C	4.083	B_T	-0.101	B_C	-0.025
Income elasticity	0.359	Distance elasticity	0.421				
Reference household income (£000) INC_0	35.000	Reference distance (km) D_0	12.121	=100/8.25	(source Mackie et al. p58)		
1994 RPI	144.1	2002 RPI	176.2	Inflation effect	1.223		

Source: http://www.statistics.gov.uk/STATBASE/tsdataset.asp?vlnk=7172&More=N&All=Y

Household to individual income	1.666	Source: dataset average ratio of personal to household income
Gross to net salaries	0.779	Source annex G of working paper
W_0 (£000)	20.017	INC_0 adjusted for inflation, individual not hhold and net not gross salaries (£000)

VTTS	4.291	Dataset average GC/km	4.70

	Exogenous		Multiplicative Factor
Speed (km/min)	S	0.460	1
Out of pocket costs (pence/km)	F	10.010	1
	x	15752.0	
	y	46.5	

Mean speed in dataset	27.6	km/hr		0.460	km/min
Mean out of pocket costs (car drivers) =	116.5	p/trip	=	10.0	pence/km
Constant + work in Glasgow + 24 yrs experience	15752.0	=exp(9.289+0.081+(24*0.019)+(24^2*-0.00028))			
Constant + 40 years old	46.5	=exp(4.079-40*0.006)			

						% in price	% in speed	Elas to price	Elast to speed
Distance (metres)	D	10,103	0.00000000	10,103	0.000%	0%	0%	#DIV/0!	#DIV/0!
Net earned income (£)	W	19,867	0.00000000	19,867	0.000%	0%	0%	#DIV/0!	#DIV/0!