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Miquel-Àngel Garcia-López
Luz Yadira Gómez-Hernández
Rosa Sanchis-Guarner

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UAB

Avinguda de l'Eix Central
Edifici B2
Campus de la UAB
08193 Bellaterra
(Cerdanyola del Vallès)
Barcelona · Spain
Tel. +34 93 581 16 80
Fax +34 93 581 22 92
d.econ.aplicada@uab.cat
www.uab.cat/departament/
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Highway traffic in Britain: The effect of road capacity changes*

Miquel-Àngel Garcia-López[‡], Luz Yadira Gómez-Hernández[†], Rosa Sanchis-Guarner[§]

ABSTRACT: This paper provides a theoretical framework to study the relationship between expanded road capacity, traffic volumes and increased economic activity. We build on Anas (2024) to show that increased traffic volumes do not necessarily lead to congestion if adjustments in economic factors, such as population or employment, are not substantial. We test our predictions obtaining key estimates with data from Great Britain between 2001 and 2020, and adopting a shift-share instrumental variable approach. We find that the elasticity of vehicle kilometers traveled to road capacity improvements is positive and statistically different from 1 across different specifications, while the elasticity of population and employment is positive but smaller than 1. In our framework this implies that the cost of driving does not increase above initial levels, resulting in higher consumer surplus through changes in travel demand and time savings.

Keywords: Transportation, road capacity, aggregate travel cost, economic activity.

JEL CLASSIFICATION: H4, R41, R42, R48

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‡Universitat Autònoma de Barcelona and Institut d'Economia de Barcelona (e-mail: miquelangel.garcia@uab.cat; phone: +34 93 581 4584; website: http://gent.uab.cat/miquelangelgarcialopez).

†What Works Centre for Local Economic Growth and Centre for Economic Performance, London School of Economics, United Kingdom. (e-mail: l.gomez-hernandez@lse.ac.uk; website: www.lygomezhernandez.org/).

§Universitat de Barcelona and Institut d'Economia de Barcelona (e-mail: r.sanchis-guarner@ub.edu; website: https://sites.google.com/view/rosasanchisguarner/home).

1. Introduction

Highways attract significant investment as means to promote growth by linking producers and suppliers or workers and jobs, making road building central to any development agenda. At the same time, induced traffic has been associated with potential increases in local congestion, resulting in time lost, pollution, and accidents. For this reason, highway construction has long been the subject of debate among policymakers and researchers, particularly since the 1960s, when Downs (1962) theorized how traffic volumes increased with the creation of new road capacity. Following capacity addition, we can have different scenarios. For a given level of local economic activity, traffic is displaced to the less congested new link due to rerouting. Additionally, if better connections promote employment or population settlements, new traffic flows might arise. The literature has claimed that the positive association between capacity and traffic generates negative externalities because induced demand for travel can result in road congestion. However, local congestion responses would depend on the relative elasticities of traffic volumes and economic activity to expanded road capacity.

This paper shows that adding road capacity increases traffic volumes, local population and employment but does not necessarily lead to congestion. We build upon the theoretical framework of Anas (2024) and estimate key relationships using data for Britain over a 20-year period. The theoretical framework proposed by Anas (2024) suggests that *ceteris paribus*, adding more road capacity lowers the cost of driving, maintaining or even increasing travel speeds in both the short and long run. This occurs because expansions in factors that induce travel demand, such as population and employment, are not large enough to raise the cost of driving (or to reduce speeds). Similar conclusions have been reached empirically by Ossokina, Van Ommeren, and Van Mourik (2023), who found substantial travel time savings due to the widening of new roads in the Netherlands, despite strong increases in traffic flow, creating benefits that cover 40% of the investment in the projects.[1] In our work, we first extend the theoretical analysis of Anas (2024), showing how the equilibrium between travel demand and average cost at a specific capacity determines consumer surplus. This leads us to hypothesize that increasing road capacity might improve consumer surplus.

Our empirical analysis supports our hypothesis. Using longitudinal data for local areas in Great Britain (GB) from 2001 to 2020, we estimate the effect of road capacity improvements on the volume of traffic, measured as vehicle kilometers traveled (VKT).[2] To address endogeneity concerns related to reverse causality, we adopt a shift-share instrumental variable (IV) approach. Our instrument relies on 1870 historical railroads. This allows us to estimate the elasticity of traffic volumes to road infrastructure improvements. To uncover how the elasticity of traffic volume to road capacity relates to underlying economic activity, we explore the effect of road capacity improvements on population and employment. Additionally, we study whether this effect varies by levels of road capacity growth during the period, type of vehicles, and long-run versus short-run adjustments.

Our results show that the elasticity of VKT to road capacity improvements is positive and statistically different from 1 across all specifications. This implies a more than proportional response

[1] Other papers have found positive effects of investing in road infrastructure on the speeds. For instance, Kim (2022) explores the effect of investing in the quality of roads, showing an initial surge in road speed shortly after completion, which lasts about one year.

[2] Our spatial units are travel to work areas (TTWA) explained in Appendix C.

of traffic volume to increases in capacity. Furthermore, in line with Anas (2024) framework, we find that shifts in population and employment are not sizable enough to offset the advantages of constructing road infrastructure. Importantly, we empirically estimate a less-than-proportional growth in population and employment in response to road capacity improvements, which implies that the costs associated with driving do not exceed the positive effects of new capacity. This is relevant because, as shown by Gerritse and Arribas-Bel (2018), highways attract people and increase productivity. Once the population increases, agglomeration benefits thrive through interaction between citizens. Efficient infrastructure, such as a good road network, increases the effective proximity of citizens and should enhance the benefits of population agglomeration.

Moreover, in local areas in the top quartile of road growth, the addition of lane kilometers has a larger impact on employment compared to local areas in the lower three quartiles. The effect on the population does not appear to be heterogeneous. We find a larger elasticity for non-commercial vehicles but observed no differences between long and short-run adjustments.

Our research makes two main contributions. First, our findings provide empirical counterparts to the responses to road capacity exposed in Anas (2024). Our empirical results conclude that employment and population increase in magnitudes lower than proportional to road capacity, confirming that these changes cannot shift the demand for travel enough to generate costs superior to their benefits. In this sense, this chapter adds to the extensive research analyzing the effects of road investment on productivity (Fernald, 1999, Gibbons, Lyytikainen, Overman, and Sanchis-Guarner, 2019), as well as the effectiveness of highway investment as a congestion-relieving policy (Winston and Langer, 2006, Ossokina *et al.*, 2023).

Second, our study is the first to provide evidence on the effects of road capacity on traffic focusing on GB. This is relevant because allocating funds toward road development in GB has been a crucial component of government expenditure. In 2020, over 25% of the total investment devoted to infrastructure construction went to building roads, aiming to mitigate congestion by reducing the volume of traffic (DfT, 2020). Our results, yield lessons relevant to the national highway policy debate. This study then adds to other literature focusing on the wider benefits of highway investments in Britain, such as changes in housing prices (Gibbons and Machin, 2005) and employment and labor productivity (Gibbons *et al.*, 2019).

This paper is organized as follows. In Section 2 we present the theoretical framework. Our empirical strategy is outlined in Section 3. Section 4 presents our main findings, and Section 5 concludes.

2. Theoretical Framework

In this section, we present a theoretical framework demonstrating that the costs associated with driving do not outweigh the positive effects of new capacity. Anas (2024)'s framework shows how the time cost per vehicle trip decreases with higher capacity and can remain fixed with demand shifts resulting from increased employment and population. We extend this framework to consider changes in consumer surplus: if the increases in employment and population are not sufficiently high we show that consumer surplus can rise following capacity increases.

Our analysis stems from the concept of induced travel demand following an increase in road capacity. Most studies define induced traffic as *"the added component of traffic volume which did not previously exist in any form, but which results when new or improved transportation facilities are provided"* (Schmidt and Campbell, 1956, 4). Initially, road improvements stimulate what Downs (1962) termed triple convergence — motorists switch modes, routes, and times of day to exploit available capacity. Among these rearrangements, only mode shifts add new trips and contribute to induced demand.

Although route and schedule switches may reduce some of the travel time savings conferred by a project, they do not create new vehicle travel. Trips might also lengthen as motorists travel farther due to free-flowing traffic. Additionally, suppressed (and presumably lower-value) trips are unleashed by faster-moving traffic, also known as latent demand. Ultimately, new roads induce structural shifts, including the realignment of land development and a tendency toward higher car ownership due to more auto-centric landscapes and the decline in transit services. Thus, mode shifts, new and longer trips, as well as long-run changes, are elements of induced travel generated by the addition of lane kilometers (Cervero, 2002, Hsu and Zhang, 2014). In recent work, Anas (2024) provides a theory formalizing Downs (1962)'s law, which we use as a base for our theoretical setup.[3]

We illustrate our framework in Figure 1. Here, we define the time-cost of a car trip that travels on a unit-length road as C (travel time multiplied by a unitary value of time, for simplicity). On congestion function 1 (curve A'), when traffic flow (cars per hour), T, is congestion-free, the time-cost is C_0 and the speed is $1/C_0$. Congestion starts at a critical traffic flow, T_{01}, after which the time-cost rises convexly, reaching maximum flow T_1, permitted by the highway's design at a time-cost per car of C_1 (or design optimal speed $1/C_1$). By "...congestion rises to meet maximum capacity," Downs meant that equilibrium occurred at this highest traffic level T_1, often called "maximum capacity" or maximum possible flow. For higher time costs (lower speed), A' becomes vertical at T_1. In this case, the demand is high enough to intersect A' at its vertical portion where flow is maximum. When this happens, C_1 is the time-cost of traveling the length of the road, and the additional time-cost, Δ_1, is the cost of the time-in-queue to access the road. This forces the average speed of the trip, $1/(C_1 + \Delta_1)$, below the on-the-road flow speed of $1/C_1$. When the road is widened, A' shifts to A''.[4]

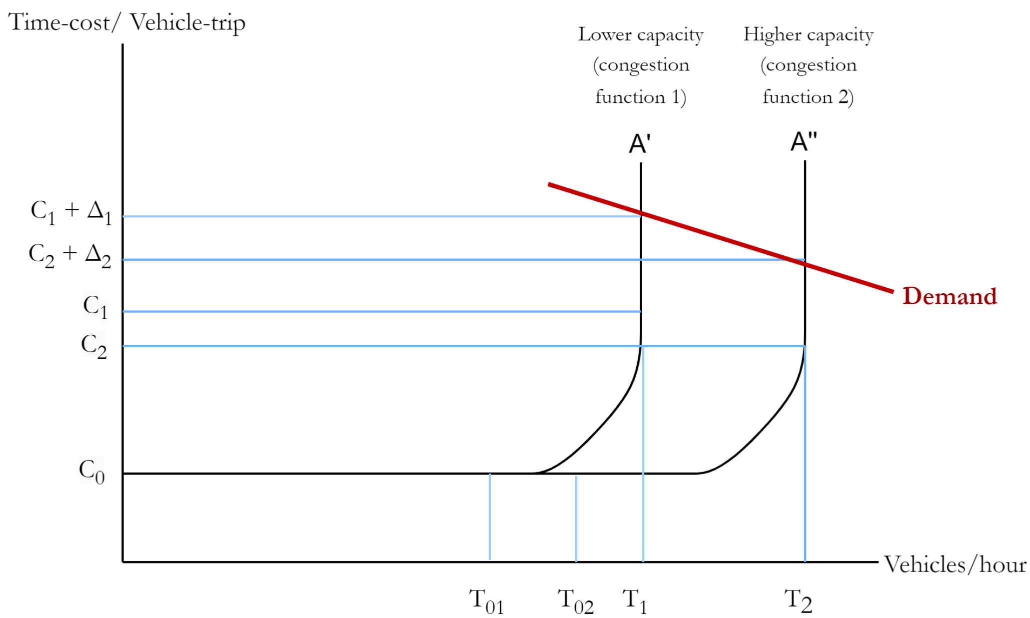
On A'', congestion starts at $T_{02} > T_{01}$. Higher flow occurs at any speed, with the maximum flow T_2 being higher than T_1, and the flow speed is $1/C_2 > 1/C_1$. This increase in flow speed is partly due to the availability of more lanes, allowing for more passing and maintaining higher average speeds. With the downward-sloping travel demand function in Figure 1, the new equilibrium time-cost $C_2 + \Delta_2$ is lower than $C_1 + \Delta_1$, resulting in a higher average trip speed: $1/(C_2 + \Delta_2) > 1/(C_1 + \Delta_1)$.

Let's now consider the effect of widenings in the steady state and the influence of demand shifters in Figure 2. Here, the road's capacity (width) is denoted as K, with its length assumed to be unity, and the steady-state flow of car trips per hour represented by T. The curve A' represents the flow

[3]Down's law established that "On urban commuter expressways, peak-hour traffic congestion rises to meet maximum capacity" (Downs, 1962, p.399).

[4]As Anas (2024) shows, the same analysis holds when the length of the road increases.

Figure 1: Down's congestion model



Note: The figure displays the formalization of Downs' congestion model by Anas (2024).

congestion function $C = G(T,K)$. In this setup, T can increase without limit at a decreasing rate. The variable $D(C,X)$ denotes the travel demand in trips per hour, where $DC < 0$. X is a vector of demand shifters. At equilibrium, $T = D(C,X)$, and congested traffic equilibrium occurs at point E. When the road is widened by increasing capacity K, the congestion function shifts from A' to A''. Assuming that X remains unchanged by the increase in K, there is a downward movement along the demand function, leading to a new equilibrium at point E'. Consequently, the cost of travel falls from CE to CE', and traffic volume rises from TE to TE'.

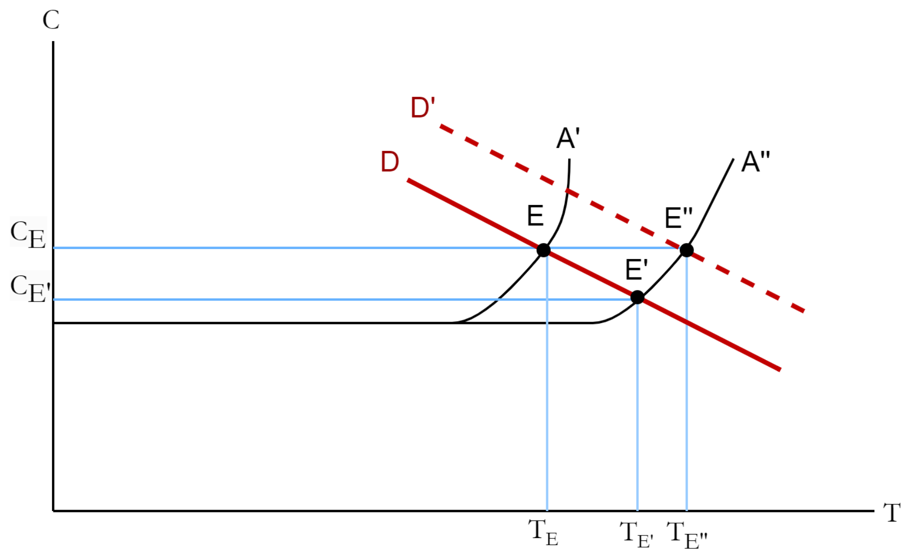
In this case, an equilibrium in C and T is determined by Equation 1 and Equation 2. A detailed comparative static analysis concerning K can be found in Anas (2024). However, our focus lies on the implications of the resulting elasticities. Assuming X remains constant, if the demand function is perfectly inelastic (depicted by a vertical D in Figure 2), then a road widening in a congested state leads to a reduction in equilibrium travel cost but does not increase traffic volume. On the other hand, if the demand tends toward perfect elasticity (illustrated by a horizontal D in Figure 2), then widening the road results in increased traffic volume without lowering travel cost.

$$T - D(C,X) = 0 \quad (1)$$

$$G(T,X) - C = 0 \quad (2)$$

In the aggregate, the travel cost is denoted as ATC (Equation 3). For a congested state, ATC decreases with increased capacity unless the travel cost elasticity of demand is unitary or higher. However, estimates of the travel time and monetary cost elasticities of the demand for car trips are very low (for a review see Litman (2024)).

Figure 2: Effect of road capacity changes and demand shifts on traffic equilibrium



Note: The figure displays an aggregation of roads at the TTWA level. The steady-state flow of car trips per hour is T. In this general result, as we assume that T can rise without limit at a decreasing rate, there is no need for a vertical portion of the congestion curve. Road capacity improvements move the congestion function from A' to A''. Demand shifters (population and employment in our case) move the demand curve from D to D'.

$$ATC = G(T, K) * T \tag{3}$$

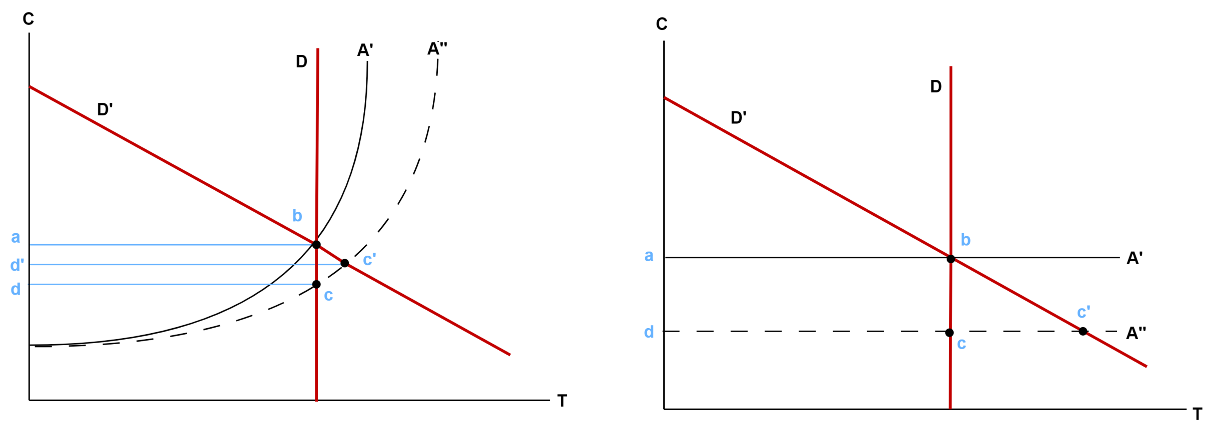
Now, an indirect effect of the added capacity can change X to X', thereby shifting the travel demand function from $D \equiv D(C, X)$ to $D' \equiv D(C, X')$ or higher. Consequently, the new equilibrium would be at E'' or a higher cost level for the time-cost to not decrease after the capacity addition. Such a shift can indirectly impact the population level or the labor market, leading to changes in incomes or the cost of travel to acquire goods. In each case, Anas (2024) demonstrates that the long-run demand shifts up insufficiently, thus congested travel times are lowered when road capacity is increased. This means that adding more road capacity reduces congestion in the short run when the population is fixed and also lowers congestion in the long run, despite induced travel, population or employment growth. This is because the commuting population cannot increase enough to cause travel times to rise above the level that prevailed before the road capacity was increased.

Given these conclusions, we build upon the previous theoretical framework to show that changes in consumer surplus when road capacity increases remain positive in two scenarios presented in Figure 3: one where the cost of travel rises with increased flow, T, leading to congestion, and another where the cost of travel remains constant despite higher T. Unlike previous figures, where the congestion function had flat and vertical sections (Figure 1 and Figure 2), the congestion function here is either elastic or flat for the sake of our explanation. In both cases, we analyze the implications for an elastic and inelastic demand for travel. The results of the analysis area analogous for a single road and a system of roads. Our consumer surplus analysis is based on the assumption that spatial restructuring of the economy due to road capacity is minor, hence the main welfare effects are through changes in travel demand and time savings. This assumption is supported by the findings of Ossokina *et al.* (2023).

In the scenario where the cost of driving increases with more T, and thus roads are susceptible to congestion (Figure 3a), for instance, due to changes in demand shifters discussed earlier, the impact of increasing road capacity is represented by a downward shift of the congestion function curve from A' to A'', and reducing the time-cost of driving C. If the demand curve is inelastic, like D, the resulting increase in consumer surplus from the improved capacity is shown by the rectangle $abcd$. On the other hand, if the demand curve is elastic, like D', induced traffic reduces the benefit to the smaller area $abc'd'$.

Now, consider an extreme case where the average cost of driving does not increase with T, and thus A' is flat as in Figure 3b. A downward shift from A' to A'', implies an increased consumer surplus shown by the rectangle $abcd$. With an elastic demand for travel, the consumer surplus increases to the bigger area $abc'd$. In this scenario, an elastic demand curve implies a greater benefit than the inelastic case, with the effect potentially amplified when supply curves are downward-sloping due to economies of scale.

Figure 3: Welfare analysis of capacity improvements



(a) Cost of driving increases with T

(b) Cost of driving remains constant

Two important lessons can be drawn from our theoretical analysis. First, increased road capacity decreases the cost of driving unless demand shifters are sufficiently strong to raise time costs above their levels prior to the capacity addition. Second, this reduction in time costs occurs both in scenarios where the cost of driving increases with traffic flow and when it remains constant. For demand shifters to be high enough to increase the cost of driving above their initial level, reducing the consumer surplus, the elasticity of population and employment with respect to road capacity must be higher than one. If the elasticity is less than one, the overall traffic volume increases at a slower rate than the available road space. As a result, the additional capacity effectively absorbs the increased demand without causing significant congestion, and consequently, the cost of driving does not increase or goes down. As a result, consumer surplus increases with a road capacity addition.

3. Empirical Strategy

To measure the volume of traffic, we use VKT, which represents the kilometers traveled by motor vehicles on the highway network. This measure has been used in previous studies to quantify traffic volume. VKT measures flow and is considered to correlate strongly with the social costs of automobile travel. However, it is an imperfect measure as it ignores some elements of trip redistribution. Nonetheless, for our main purpose, VKT is sufficient. Our traffic data comes from the Department for Transport (DfT). Appendix A explains the construction of our main outcome variable and presents more details on other data sources.

The Census geographies we use are the Travel To Work Areas (TTWAs) calculated using 2011 census data by the Office for National Statistics (ONS). Considering most of the trips made in our period of analysis in GB are for commuting, selecting TTWAs helps us account for a significant portion of the variation in VKT due to changes in the highway network. Furthermore, larger geographic areas capture the impacts the additional traffic on feeder routes within a tributary. Additionally, Cervero and Hansen (2002) suggest that when studying changes in traffic at a national level, larger geographies help account for redistributions and understand the total response of traffic when road capacity changes. This approach, however, has its caveats, as redistributions can lead to zero effects and we cannot capture the nature of specific local displacement effects. Despite these limitations, for our purpose of understanding the broader effects of road capacity, the granularity of our data is sufficient. Appendix C.

For our baseline estimations, we index TTWA by i and years by t, and estimate a form of Equation 4.

$$\begin{aligned} ln(VKT_{it}) = \beta_0 + \beta_1 Ln(LaneKm_{it}) + \beta_2 Ln(Population_{it}) \\ + \beta_4 Socioeconomy_i + \beta_4 Geography_i + \mu_{it} \end{aligned} \tag{4}$$

where VKT_{it} is our traffic measure, and the coefficient β_1 is our parameter of interest, representing the road elasticity of VKT. $LaneKm_{it}$ refers to the number of highway lane kilometers (length of each segment multiplied by the number of lanes), from the DfT.

As covariates in the estimation we include the logarithm of the Census 2001 $(Population)i$. $Socieconomyi$ includes a set of Census 2001 characteristics: the share of individuals in skilled occupations, the share of individuals aged 16 to 74 working in the manufacturing sector, the share of households renting from the council and housing associations, the share of individuals usually traveling to work by private mode, the logarithm of the average distance (km) traveled to work or study in 2001, and the share of urban postcodes per TTWA. All variables from the Census 2001 come from the ONS.

The reason for using the value at the beginning of the period instead of the time-varying values is to avoid endogeneity issues that might arise when control variables change over time. These variations could be influenced by unobserved factors that also affect the dependent variable. Using the initial values, which are predetermined and fixed, helps mitigate this problem as well as simultaneity bias. Additionally, using initial values helps avoid introducing measurement errors.

The data from the Census, which provides these initial values, tends to be more reliable, thus reducing the potential for such errors and leading to more robust estimates.

$Geography_i$ represents a vector of Travel To Work Area (TTWA) geographic characteristics, including the logarithm of the elevation range, the logarithm of the distance from the centroid of each TTWA to the coast, and the proportion of each TTWA covered by lakes. Detailed information regarding the specific sources of all geographic data and GIS analysis is provided in Appendix A.

For the initial OLS estimates to be consistent, we require the road capacity to be uncorrelated to the unobserved error term in Equation 4. However, the stock of roads per TTWA might be partially determined by VKT or be correlated with unobserved TTWA and time characteristics that can affect VKT. In such case, road capacity becomes endogenous, violating the orthogonality assumption required for consistently estimating the elasticity β_1. Then, we add time and TTWA Fixed-Effects (FE) to our baseline estimation.

To address the further concerns of endogeneity due to reverse causality between VKT and $LaneKm$, we rely on IV estimations. We construct an instrument based on historical railroads in England, Scotland, and Wales, using the digital vector maps used by Garcia-López (2019). Historical railroads are time-invariant, therefore, to create a time-variant instrument, we adopt a "shift-share" approach (Bartik, 1991), using each historical railroad as the "share" component and the growth of the highway network as the "shift" component. Specifically, we compute each time-variant historical instrument by multiplying its historical length (in kilometers) by the growth of the highway network in each year outside each specific TTWA.[5]

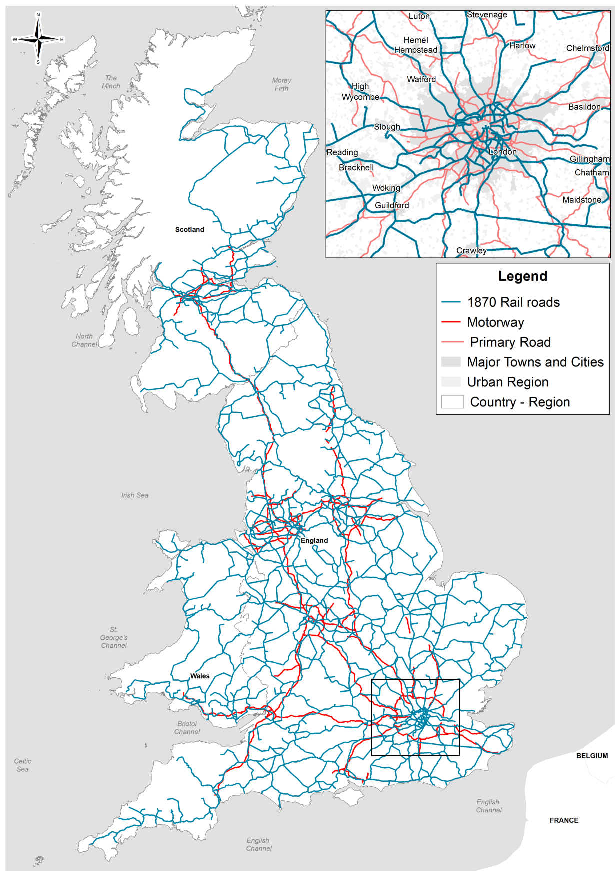
For the shift-share instrument to be valid and yield consistent estimates of the effects of road capacity improvements on traffic volume, it must satisfy two conditions. First, it needs to be relevant, meaning it must be sufficiently correlated with the variable it predicts. Second, it must be conditionally exogenous, meaning it should be uncorrelated with unobserved shocks. As pointed out by Duranton and Turner (2011) and Garcia-López, Pasidis, and Viladecans-Marsal (2022), historical transportation networks serve as relevant instruments because modern networks are not built in isolation from them: it is easier and cheaper to build new infrastructures close to old ones. As depicted in Figure 4 historical railroads align closely with primary roads and motorways in GB, indicating a strong correlation between past and present transportation infrastructure. Furthermore, we confirm the relevance of the instrument in each estimation with the F-statistic of the instrument in the first stage of the 2-stage-least-squares (2SLS) regressions. This provides additional evidence of the instrument's ability to predict variations in road capacity.

For the exogeneity condition to be satisfied, both components used in the construction of the instrument must be orthogonal to local shocks related to the outcome variable, conditional on control variables. Our "shift" component is exogenous by construction as it refers to the yearly stock of highways that would have existed had governments allocated highway construction uniformly across Britain. The "share" component of our IV, the length 1870 historical railroads, may be exogenous because its construction was not aimed at anticipating current traffic congestion levels but to

[5] To ensure that all Travel To Work Areas (TTWAs) in Great Britain have a value for our instrument, even those without railroads in 1870, we imputed the average kilometers of railroads in 1870 to those TTWAs without them. This approach ensures that each TTWA has a non-zero value for our instrument.

achieve military, administrative, and commercial goals between different regions of GB. Instrument validity also requires that,after controlling for relevant covariates, rail routes are correlated with the dependent variable only through contemporaneous highways. Since geography has influenced both, the evolution of TTWAs and their transportation networks, the exogeneity of our instrument depends on controlling for those characteristics, represented by the vector of variables $Geography_i$. After appropriately controlling for these characteristics, it becomes unlikely that railroads could have anticipated the demand for vehicle travel in TTWAs many years later.

Figure 4: Historical railroads, motorways, and primary roads in Great Britain



3.1 Effects of traffic in Population and Employment

Our analysis of the effects of road capacity addition on population and employment aims to shed light on the hypothesis that increasing road capacity does not result in a significant increase in the commuting population, thereby preventing congested travel times from surpassing pre-expansion levels. As suggested in section 2, in the long run, shifts in population and income (due to employment) are not substantial enough to create congestion and and offset the advantages of constructing road infrastructure. Thus, if this proposition holds true, we expect the elasticity of both population and employment to road capacity additions to be smaller than 1, as we anticipate the response will be less than proportional.

In the population analysis, the data for the outcome variable corresponds to the estimates for Middle Super Output Areas (MSOAs) from the Office for National Statistics (ONS), which we agreggated to TTWAs. Our estimating equation in this case takes the form of:

$$\begin{aligned} ln(Population_{it}) = \beta_0 + \beta_1 Ln(LaneKm_{it}) + \beta_2 Geography_i \\ + \beta_3 Socioeconomy_{it} + \delta_t + \eta_{it} \end{aligned} \tag{5}$$

$Employment_{it}$ comes from NOMIS, which reports yearly Middle Super Output Area (MSOA) employment data across all sectors. Using this information, we aggregated the data to the Travel To Work Area (TTWA) level. Our estimation equation is:

$$\begin{aligned} ln(Employment_{it}) = \beta_0 + \beta_1 Ln(LaneKm)_{it} + \beta_2 Geography_i \\ + \beta_4 Socioeconomy_{it} + \delta_t + \eta_{it} \end{aligned} \tag{6}$$

In this case, both estimations face the same reverse causality problem as in Equation 4. As population movement responds to changes in infrastructure, distinguishing whether population and employment growth stem from new roads or if roads were built in areas with higher population and employment becomes challenging. Hence, we also employ our instrumental variable approach in this estimation.

3.2 Descriptive statistics

Figure 5 shows the evolution of the aggregated investment in roads and traffic in the UK since 2000[6]. In GB up to the day, a big part of public spending is devoted to the construction of roads. In 2020, over 25% of the total investment in infrastructure construction was allocated to building roads, mostly to add capacity to the network as GB has a mature highway infrastructure (DfT, 2020). Figure 5a shows evidence of the two distinctive periods that the expansion of roads in Britain had in recent decades. Following the economic growth and rapid rise of traffic volumes in the 80s, major road investments were planned. However, due to protests and environmental concerns in the late 1990s, the Government decided to cut back its road-building program substantially. Several schemes were canceled until 1997 when a new integrated transport policy was established. Spending on highway infrastructure remained relatively low until 2010 when the second period started. In 2011 the government decided to expand its road-building program again. The same year several road schemes were approved. In June 2013, the Government announced a £15 billion investment in roads, the biggest in a generation (Melia, 2019).

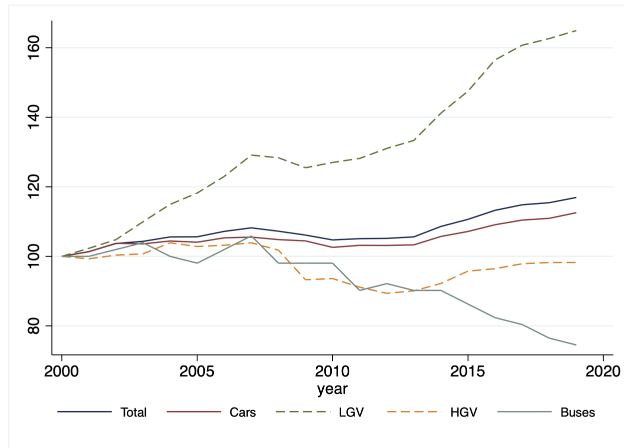
Traffic has grown constantly since 2000. According to the DfT (2020), traffic growth slowed during the 2000s but increased during the next 10 years. Effectively, the overall growth of all motor vehicle traffic was 6% in the 2000s and went up 18% in the 2010s. The slower growth at the beginning of the period (Figure 5a) was influenced by increasing fuel prices and the economic downturn (DfT, 2020). The changes in traffic by vehicle type (Figure 5b) show a slower growth for cars and taxis (red line) when compared to the growth in light goods vehicles (LGV). However, the number of trips in private modes has lengthened over the last 20 years, with the distance traveled

[6]UK investment data comes from `https://data.oecd.org/transport/infrastructure-investment.htm`, while VKT for GB comes from the Department for Transport (DfT).

by cars and taxis increasing by 29.8% (DfT, 2020). The estimated average annual kilometers per car in Great Britain has decreased. This decline has coincided with an increase in the number of cars per household. In 2002, the average was around 9,200 miles, but by 2020, it had fallen to 7,400 miles. This reduction imposes a high price on households in terms of commute times. Consequently, car traffic has increased (DfT, 2020).

Figure 5: Aggregate road investment and traffic (vehicle kilometers traveled) since 2000

(a) Road investment and traffic



(b) Road traffic by vehicle type

In GB, the predominant commuting modes are cars and taxis. Car trips accounted for 77% of the total distance traveled in 2020. 61% of trips were made by car, either as a driver or passenger. In rural areas, nearly three-quarters (73.4%) of workers travel by car, many of them going to the urban areas. This method of travel also dominates the commute in urban areas (outside of London) with 67.1% of people either driving themselves or catching a lift. Even in London, 29.8% of workers commute by car. The traffic by buses and coaches decreased while the traffic by Heavy Good Vehicles (HGV) decreased from 2008 to 2012 when it started growing again. This is partly influenced by the crisis and also, as pointed out by Browne, Rizet, and Allen (2014), by 2010 there was already a substitution of HGV for LGV in order to avoid some regulations associated with vehicles over 3.5 tonnes gross weight. During the next decade, this substitution continued. During 2000 and 2020, the kilometers traveled by LGV grew by over 60%.

Regarding the evolution of roads by 2020, there were about 398,313 kilometers of roads in Great Britain. From those, 77% belonged to England, 15% to Scotland, and 9% to Wales. 87% of the roads in Great Britain are minor roads, while 13% are major roads. Overall, between 2000 and 2020, the total length of highways in GB changed by only 2,1% meaning that road construction focused on capacity instead of coverage. Figure C.1 shows the evolution of the highway network between 2000 - 2001.

Table 1 presents the top 20 TTWAs with the highest initial levels of traffic, as measured by VKT in 2001 (expressed in millions of kilometers). Notably, the TTWAs exhibiting the largest initial traffic volumes are those situated in major urban areas. Regarding growth in road capacity, four TTWAs, namely Glasgow, Birmingham, Blyth and Ashington, and Aberdeen, stand out for more than doubling their road infrastructure during the period under consideration.

Table 1: Highest VKT in 2001 and road increments 2001-2020

VKT 2001 ('000,000)			Road increments (p.p.)		
1	London	104789	1	Glasgow	281
2	Manchester	25070	2	Birmingham	214
3	Slough and Heathrow	7781	3	Blyth and Ashington	146
4	Birmingham	5981	4	Aberdeen	112
5	Glasgow	3786	5	Liverpool	89
6	Newcastle	3329	6	Northallerton	88
7	Warrington and Wigan	3053	7	Wolverhampton and Walsall	79
8	Guildford and Aldershot	2705	8	London	69
9	Leicester	2677	9	Leeds	67
10	Leeds	2603	10	Newcastle	65
11	Cambridge	2401	11	Blackpool	64
12	Crawley	2275	12	Exeter	64
13	Southampton	2217	13	Portsmouth	63
14	Liverpool	2209	14	Huntingdon	58
15	Bristol	2049	15	Edinburgh	58
16	Oxford	1793	16	Mansfield	57
17	Nottingham	1671	17	Motherwell and Airdrie	55
18	Stoke-on-Trent	1621	18	Bedford	51
19	Wolverhampton and Walsall	1610	19	Hull	50
20	Edinburgh	1598	20	Warrington and Wigan	49

Figure C.2b illustrates the aggregate value of VKT for each TTWA in 2001 (a) and the growth of lane kilometers between 2001 and 2020 (b). While Duranton and Turner (2011) observed that roads are allocated to Metropolitan Statistica Areas (MSAs) in the United States with little consideration for existing traffic levels, in Britain, there is a positive correlation between road growth and the VKT levels of each TTWA in 2001. This correlation becomes even more pronounced when excluding London and its adjacent TTWAs.

4. Results

4.1 Effects of road capacity expansion on traffic volume

In this section, we discuss the estimation of the elasticity when regressing the $ln(VKT)$ on the log of highway $LaneKM$, specifically, on the baseline estimates of β_1 in Equation 4. Table 2 presents the results of estimating Equation 4 using ordinary least squares (OLS). Columns [1] to [5], add covariates and different levels of fixed effects (FE). Column [1] reports the specification using only population as a covariate and Year-Region fixed effects. Using time-region fixed effects allows us to better account for spatial correlation in traffic growth, as traffic patterns and infrastructure developments in neighboring TTWAs within the same region are likely to be correlated. Regional fixed effects capture these spatial spillovers and interactions more effectively than individual TTWA fixed effects. Since regions are larger geographies than TTWAs, they encompass broader geographic and economic dynamics that may influence traffic patterns.[7] By encompassing multiple TTWAs, regions capture regional policies, economic trends, and infrastructural developments that transcend individual TTWAs but still impact the entire region. This helps account for factors that affect

[7] There are 11 regions in GB: Scotland and Wales each constitute their own region, while the other 9 regions are in England, representing the highest tier of sub-national division.

the entire region, such as regional policies and economic trends. Many transportation policies and infrastructural projects are implemented at the regional level rather than the TTWA level. Therefore, using regional fixed effects aligns our model more closely with the scale at which policy interventions occur, providing more relevant insights for policymakers.

Table 2: Baseline results. The effect of road capacity changes on traffic - OLS and IV results

Dependent variable:	ln(VKT)					
	OLS					IV
	[1]	[2]	[3]	[4]	[5]	[6]
ln(laneKm)	1.583^a	1.546^a	1.664^a	1.782^a	1.638^a	1.843^a
	(0.094)	(0.112)	(0.074)	(0.060)	(0.161)	(0.117)
Observations	4,360	4,360	4,360	4,360	4,360	4,360
R-squared	0.890	0.892	0.951	0.948	0.224	
lnPopulation	Yes	Yes	Yes	-	Yes	-
Geography	-	Yes	Yes	Yes	-	Yes
Census 2001 Ch	-	-	Yes	Yes	-	Yes
Year-Region FE	Yes	Yes	Yes	Yes	-	Yes
TTWA FE	-	-	-	-	Yes	-
Year FE	-	-	-	-	Yes	-
F-S F-stat						23.53
Instrument B-Railroads						Yes

Note: Number of TTWAs - 218. Geography variables encompass the logarithm of the elevation range per TTWA, the logarithm of the distance from the centroid of each TTWA to the coast, and the proportion of each TTWA covered by lakes. Census 2001 characteristics consist of the share of individuals in skilled occupations, the share of individuals aged 16 to 74 working in the manufacturing sector, the share of households with housing rented by social services, the share of households with housing rented from the council and housing association, the share of individuals usually traveling to work by private mode, the logarithm of the average distance (km) traveled to place of work or study in 2001, and the share of urban postcodes per TTWA.
Standard errors clustered at the TTWA level are in parentheses.
^{a} p<0.01, ^{b} p<0.05, ^{c} p<0.1

In Columns [2] and [3] we add the *Socioeconomic* and *Geography* covariates, respectively. While in Column [4] we keep all of our covariates, taking out *Population*. Previous research has controlled for population levels, however, as we believe that higher traffic might lead to population growth, while population growth can also lead to increased traffic thus leading to a problem of bad controls, we are interested in testing whether the results are statistically different from the ones estimated using all the controls and year-region fixed effects. We found no statistically significant difference between estimations, suggesting that the inclusion or exclusion of *Population* does not affect the results when using all other controls and year-region fixed effects.

Column [5] includes year and TTWA fixed-effects. The time fixed-effects control for national shocks such as economic conditions, changes in transportation policies or regulations, and technological advancements influencing travel behavior that affect traffic volume but are constant across TTWAs. TTWA fixed-effects control for specific unobserved characteristics that are time-invariant but may affect traffic volume, such as levels of urbanization, population density, infrastructure quality, and local transportation policies. We found that this estimation is not statistically different from our estimations using time-region fixed effects. Therefore, in our preferred specification, we use the latter, as it captures broader geographic and economic dynamics that may influence traffic patterns and aligns more closely with the scale at which policy interventions occur.

With these results, we found that our preferred specification for the IV estimation will include year-region fixed effects instead of year and TTWA fixed effects. As explained earlier, while year and TTWA fixed effects provide detailed control for specific local characteristics and national trends, time-region fixed effects offer a balanced approach that captures broader regional influences, spatial correlations, and policy impacts more effectively. Furthermore, our OLS estimations yield no difference whether or not we include population as a covariate. However, including population could induce concerns about endogeneity and simultaneity bias in our estimations.

In Column [6], we report the IV estimates of the road elasticity of VKT, instrumenting $LaneKM$ with the log of the time-variant length of Historical Railroads. In the second to last row, we show the F-Statistics. According to Murray (2006), valid instruments should have significant effects on modern highway lane kilometers and high First-stage F-Statistics. First-stage results show that historic railroads predict the traffic volumes when we follow a panel fixed-effects regression approach. Results also show First-Stage F-statistics that are above the critical values proposed by Stock and Yogo (2005). This is the specification that we will use in our following estimations.

Our elasticity estimates indicate that in GB, there is a more than proportional increase in traffic when road capacity increases, as the elasticity of VKT to $LaneKm$ is higher than 1. In all cases, our β_1 was statistically different from 1. Our estimates align closely with those found by Garcia-López *et al.* (2022) for the Functional Urban Areas (FUAs) of Europe.

4.2 Effects of road capacity expansion on population and employment

In this section, we discuss the estimate of the impact of road capacity additions on population and employment levels, the demand shifters proposed by Anas (2024). With this, we aim to test whether the proposition that increasing road capacity does not result in a significant increase in the commuting population, thereby preventing congested travel times from surpassing pre-expansion levels, is true. Existing literature suggests that new and improved roads stimulate local economic activity, which may result in population growth. In addition to stimulating economic activity in specific areas, an improved road network can enhance their appeal relative to other regions by reducing transportation costs. This can prompt changes in population distribution, particularly among highly mobile populations.

Duranton and Turner (2012) further support this notion by analyzing US Metropolitan Statistical Areas (MSAs) between 1980 and 2000. They find that a 10 percent increase in the extent of the road network leads to a 1.3 percent increase in MSA population over 10 years and a 2 percent increase over 20 years. This direct evidence suggests that expanding the road network contributes to population growth in urban areas.

Our results for GB are presented in Table 3. We provide both OLS and IV estimations; however, we focus on the results for the latter. In both cases, we observe that the addition of road capacity increased both population and employment. Nevertheless, these increments were lower than proportional, as the elasticity is lower than 1. This suggests, as established in section 2, that population and employment shifts do not sufficiently increase travel demand to result in higher levels of congestion at the new equilibrium.

Table 3: Mechanisms. The effect of road capacity changes on population and employment - OLS and IV results

Dependent Variable:	ln(Population)		ln(Employment)	
	OLS	IV	OLS	IV
	[1]	[2]	[3]	[4]
lmlanekm	0.669^a	0.723^a	0.627^a	0.698^a
	(0.077)	(0.107)	(0.114)	(0.165)
Observations	4,360	4,360	4,360	4,360
R-squared	0.779	0.778	0.830	0.829
Geography	Yes	Yes	Yes	Yes
Census 2001 Ch	Yes	Yes	Yes	Yes
Year-Region FE	Yes	Yes	Yes	Yes
F-S F-stat	-	23,53	-	23,56
Instrument B-Railroads	Yes	Yes	Yes	Yes

Note: Number of TTWAs - 218. Geography variables and Census 2001 characteristics are consistent with the definitions provided in Table 2.
Standard errors clustered at the TTWA level are in parentheses.
^{a} p<0.01, ^{b} p<0.05, ^{c} p<0.1

4.3 Heterogeneity by road capacity growth, type of vehicle and long-run adjustments

In this section, we explore into the heterogeneity of our results. First by road capacity growth. To accomplish this, we use $Ln(Lanekm_{it})$ as our variable of interest and introduce an interaction with a binary variable set to 1 for TTWAs in the top quartile (Q4) of road growth between 2001 and 2020. This specification enables us to capture the differentiated effects of road capacity on each outcome variable for TTWAs for TTWAs with the highest road construction during the period. In essence, it elucidates whether the effect of adding road capacity is magnified, diminished, or unchanged in areas experiencing significant road expansion over the period.

Our findings reveal a larger effect on traffic and employment in TTWAs experiencing greater road growth during the period. We found no effect on the population. This could be attributed to several factors. First, adding road capacity may not immediately prompt changes in residential location choices, even in areas with substantial road growth. Population dynamics typically evolve more slowly and gradually compared to traffic and employment patterns. Consequently, it may take time for the effects of increased road capacity to translate into noticeable shifts in population. Additionally, population changes are influenced by factors other than road infrastructure, including housing availability, cost of living, educational facilities, and other amenities. Furthermore, these regions may also serve as destinations for commuters from other areas.

Next, we focus on the heterogeneity by type of traffic. The differences on the response of commercial and non-commercial vehicles to road capacity is important because it allows us to understand the underlying drivers of increased traffic volumes. The results can have policy implications as they

Table 4: Heterogeneuos effect of road capacity changes on VKT, Population and Employment - OLS and IV results

Dependent variable:	ln(VKT)		ln(Population)		ln(Employment)	
	[1]	[2]	[3]	[4]	[5]	[6]
	OLS	IV	OLS	IV	OLS	IV
ln(lanekm)	1.680[a]	1.681[a]	0.598[a]	0.624[a]	0.466[a]	0.520[b]
	(0.076)	(0.165)	(0.095)	(0.144)	(0.143)	(0.214)
ln(lanekm) x Q4	0.180	0.317[b]	0.168	0.230	0.395[a]	0.391[b]
	(0.110)	(0.152)	(0.129)	(0.170)	(0.121)	(0.158)
Observations	4,360	4,360	4,360	4,360	4,360	4,360
R-squared	0.950		0.781		0.838	
Geography	Yes	Yes	Yes	Yes	Yes	Yes
Census 2001 Ch	Yes	Yes	Yes	Yes	Yes	Yes
Year-Region FE	Yes	Yes	Yes	Yes	Yes	Yes
F-S F-stat Instrument		29.85	-	29.85	-	29.88
F-S F-stat Interaction		38.98	-	38.98	-	38.98
F-S F-stat	-	7.53	-	7.53	-	7.54
Instrument B-Railroads	-	Yes	-	Yes	-	Yes
Instrument Interaction	-	Yes	-	Yes	-	Yes

Note: Number of TTWAs - 218. Geography variables and Census 2001 characteristics are consistent with the definitions provided in Table 2.
Standard errors clustered at the TTWA level are in parentheses.
[a] p<0.01, [b] p<0.05, [c] p<0.1

might help infrastructure policies to address specific needs. For example, if the increase is driven by commercial traffic, policies could focus on improving freight efficiency or creating dedicated lanes for trucks. Furthermore, as explained by Fernald (1999): ”there are no direct measures of industry road use. But given the complementarity between roads and vehicles, vehicle use provides an indirect measure of road intensity”. When the road capacity is enhanced, there could be more commercial vehicles accessing previously underutilized segments of the highway network, thereby resulting in a higher elasticity of commercial traffic.

We define commercial vehicles as heavy goods vehicles (HGVs) and light goods vehicles (LGVs), while non-commercial vehicles encompass cars, taxis, buses, and coaches. Table 5 presents our findings, showing a higher elasticity among non-commercial vehicles compared to commercial ones. This heterogeneity may be attributed to the surge in longer trips undertaken via private modes over the past two decades, evidenced by a notable 29.8% increase in the distance traveled by cars and taxis.

Finally, Table 6 presents the results for both long and short-run periods. Our interest in these estimates stems from the need to compare our results with studies such as Duranton and Turner (2011) and Garcia-López *et al.* (2022), which use a 10-year delta in their panel data analysis, while we have yearly data. According to Cervero (2002), panels with longer deltas should exhibit larger effects. Column [2] shows the estimates when using only the data from 2001 and 2010, a delta of 20 years in our panel. Interestingly, these results are not statistically different from our baseline analysis. Furthermore, there is no significant difference in the estimates when using different deltas,

Table 5: Heterogeneuos effect of road capacity changes on commercial vs non-commercial vehicles - OLS and IV results

Dependent variable:	ln(VKT)			
	Commercial		Non-Commercial	
	OLS	IV	OLS	IV
Dependent variable: ln(VKT)	[1]	[2]	[3]	[4]
lmlanekm	1.767^{a}	1.816^{a}	1.838^{a}	1.943^{a}
	(0.059)	(0.116)	(0.066)	(0.124)
Observations	4.,360	4,360	4,360	4,360
R-squared	0.949		0.939	
Geography	Yes	Yes	Yes	Yes
Census 2001 Ch	Yes	Yes	Yes	Yes
Year-Region FE	Yes	Yes	Yes	Yes
F-S F-stat		23.54	-	23.54
Instrument B-Railroads	Yes	Yes	Yes	Yes

Note: Number of TTWAs - 218. Geography variables and Census 2001 characteristics are consistent with the definitions provided in Table 2. Commercial vehicles consist of Heavy Goods Vehicles (HGVs) and Light Goods Vehicles (LGVs), whereas non-commercial vehicles comprise cars and buses.
Standard errors clustered at the TTWA level are in parentheses.
[a] p<0.01, [b] p<0.05, [c] p<0.1

Table 6: Effect of road capacity changes on VKT - OLS and IV estimations by periods

Dependent variable:	ln(VKT)					
	2001 - 2020		2001 - 2010 -2020		2001 - 2005 - 2010 - 2015 - 2020	
	[1]	[2]	[3]	[4]	[5]	[6]
	OLS	IV	OLS	IV	OLS	IV
ln(lanekm)	1.785^{a}	1.868^{a}	1.785^{a}	1.857^{a}	1.782^{a}	1.852^{a}
	(0.060)	(0.130)	(0.060)	(0.124)	(0.060)	(0.120)
Observations	436	436	654	654	1,090	1,090
R-squared	0.946		0.947		0.948	
Geography	Yes	Yes	Yes	Yes	Yes	Yes
Census 2001 Ch	Yes	Yes	Yes	Yes	Yes	Yes
Year-Region FE	Yes	Yes	Yes	Yes	Yes	Yes
F-S F-stat	-	23.21	-	23.26	-	23.43
Instrument B-Railroads	Yes	Yes	Yes	Yes	Yes	Yes

Note: Number of TTWAs - 218. Geography variables and Census 2001 characteristics are consistent with the definitions provided in Table 2.
Standard errors clustered at the TTWA level are in parentheses.
[a] p<0.01, [b] p<0.05, [c] p<0.1

as depicted in Columns [4] and [6]. This suggests that there is no heterogeneity in our results introduced by analyzing a yearly panel versus a long-run adjustment in road capacity and traffic.

5. Conclusions

This paper highlights a crucial aspect of the travel demand literature: the increase in travel demand following road capacity additions does not necessarily lead to congestion. Building on the theoretical framework of Anas (2024), we provide empirical evidence supporting his propositions, showing that the impacts of road capacity improvements on employment and population growth are moderate. Although these factors could potentially increase congestion, their effects are not sizable enough to raise the cost of driving. While the resulting increases in population and employment are not sufficient to create congestion, they can still generate agglomeration benefits. Hence, road capacity expansions have the potential to lead to sustainable improvements in mobility while fostering local economic activity.

Our study is the first to focus on the effects of road capacity improvements in GB, adding to the existing literature on the long-run and short-run effects of building highways (Duranton and Turner, 2011, Hsu and Zhang, 2014, Garcia-López *et al.*, 2022, Ossokina *et al.*, 2023). We found no significant difference between short-term and long-term traffic adjustments following road capacity expansions. According to Cervero (2002), panels with longer time intervals should exhibit larger effects; however, our estimated elasticity is similar to the long-run results of Garcia-López *et al.* (2022) for European cities.

We find that a significant portion of the employment response is attributable to TTWAs that experienced substantial road capacity increases during our study period. This heterogeneity in the induced traffic effect suggests that investments in roads can impact local economies. In contrast, there is no observable heterogeneity in the population results. This difference could arise because population dynamics typically evolve more slowly and gradually compared to traffic and employment patterns. Hence, it may take time for the effects of increased road capacity to translate into noticeable shifts in population. Additionally, population changes are influenced by factors beyond road infrastructure, such as housing availability and cost of living.

These findings provide valuable insights for future infrastructure investment decisions and emphasize the importance of policy coordination. It is essential that infrastructure planning tools incorporate a comprehensive evaluation of all relevant factors, including the sources of demand and the potential for induced traffic. While expanding road capacity can be an effective policy tool for mitigating congestion, it must be carefully integrated with complementary policies to avoid negative outcomes. Specifically, road construction should align with broader local development strategies, such as land development.

Our analysis is limited by the granularity of the data we use. Larger geographical units make it hard to identify the nature and magnitude of local displacement effects, which in this case could help identify whether increased employment in areas with larger road capacity growth is due to commuters from other TTWAs. These questions remain open for future research on travel demand in Great Britain. Despite these limitations, for the purpose of understanding the broader effects of road capacity and testing our hypothesis regarding the magnitude of changes in employment and population induced by road capacity, the granularity of our data is sufficient.

References

Anas, Alex. 2024. “Downs’s Law” under the lens of theory: Roads lower congestion and increase distance traveled. *Journal of Urban Economics* 139: 103607. URL https://www.sciencedirect.com/science/article/pii/S0094119023000773.

Bartik, Timothy. 1991. *Who Benefits from State and Local Economic Development Policies?* Kalamazoo (MI): W.E. Upjohn Institute for Employment Research.

Browne, M, C Rizet, and J Allen. 2014. A Comparative Assessment of the Light Goods Vehicle Fleet and the Scope to Reduce its CO2 Emissions in the UK and France | Elsevier Enhanced Reader. *Procedia - Social and Behavioural Sciences* .

Cervero, Robert and Mark Hansen. 2002. Induced travel demand and induced road investment: A simultaneous equation analysis. *Journal of Transport Economics and Policy* 36.

Cervero, Roberto. 2002. Induced travel demand and induced road investment: A simultaneous equation analysis. *Journal of Transport Economics and Policy* 36(3): 469–490.

DfT. 2020. *Road traffic estimates: Great Britain 2019*. Statistical Report.

Downs, Anthony. 1962. The law of peak-hour expressway congestion. *Traffic Quarterly* 16: 393–409.

Duranton, Giles and Mathew Turner. 2011. The fundamental law of highway congestion: Evidence form us cities. *American Economic Review* 101(6): 2616–52.

Duranton, Gilles and Matthew A. Turner. 2012. Urban growth and transportation. *The Review of Economic Studies* 79(4): 1407–1440. URL https://doi.org/10.1093/restud/rds010.

Fernald, John G. 1999. Roads to Prosperity? Assessing the Link between Public Capital and Productivity. *The American Economic Review* 89(3): 619–638. URL https://www.jstor.org/stable/117036. Publisher: American Economic Association.

Garcia-López, Miquel-Àngel. 2019. All roads lead to rome...and to sprawl? evidence from european cities. *Regional Science and Urban Economics* 79: 103467.

Garcia-López, Miquel-Àngel, Ilias Pasidis, and Elisabet Viladecans-Marsal. 2021. Congestion in highways when tolls and railroads matter:evidence from european cities. *Journal of Economic Geography* X.

Garcia-López, Miquel-Àngel, Ilias Pasidis, and Elisabet Viladecans-Marsal. 2022. Congestion in highways when tolls and railroads matter: evidence from European cities. *Journal of Economic Geography* 22(5): 931–960. URL https://academic.oup.com/joeg/article/22/5/931/6333639.

Gerritse, Michiel and Daniel Arribas-Bel. 2018. Concrete agglomeration benefits: do roads improve urban connections or just attract more people? *Regional Studies* 52(8): 1134–1149. URL https://doi.org/10.1080/00343404.2017.1369023. Publisher: Routledge _eprint: https://doi.org/10.1080/00343404.2017.1369023.

Gibbons, Stephen, Teemu Lyytikainen, Henry Overman, and Rosa Sanchis-Guarner. 2019. New road infrastructure: The effects on firms. *Journal of Urban Economics* 110: 35–50.

Gibbons, Stephen and Stephen Machin. 2005. Valuing rail access using transport improvements. *Journal of Urban Economics* 57(1): 148–169.

Hsu, WenTai and Hongliang Zhang. 2014. The fundamental law of highway congestion revisited: Evidence from national expressways in japan. *Journal of Urban Economics* 81: 65–76.

Kim, Jinwon. 2022. Does roadwork improve road speed? Evidence from urban freeways in California. *Regional Science and Urban Economics* 93.

Litman, Todd. 2024. Understanding transport demands and elasticities: How prices and other factors affect travel behavior. URL https://www.vtpi.org/elasticities.pdf.

Melia, Steve. 2019. Why did the uk governments cut road building in the 1990s and expand it after 2010? *Transport Policy* 81: 242–253.

Murray, Michael P. 2006. Avoiding invalid instruments and coping with weak instruments. *Journal of Economic Perspectives* 20(4): 111–132. URL https://www.aeaweb.org/articles?id=10.1257/jep.20.4.111.

Ossokina, Ioulia V, Jos Van Ommeren, and Henk Van Mourik. 2023. Do highway widenings reduce congestion? *Journal of Economic Geography* 23(4): 871–900. URL https://academic.oup.com/joeg/article/23/4/871/6901322.

Schmidt, R. and M. Campbell. 1956. *Highway traffic estimation*. Eno Foundation.

Stock, J.H and M Yogo. 2005. Testing for weak instruments in liner iv regressions. In D.W Andrews and J.H Stock (eds.) *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*. Cambridge: Blackwell Publishing, 80–108.

Winston, Clifford and Ashley Langer. 2006. The effect of government highway spending on road users' congestion costs. *Journal of Urban Economics* 60(3): 463–483.

Appendix

A. Data Appendix

Our data on traffic comes from a data set collected yearly by the Department for Transport[8], between 2001 and 2020. Data is available for each junction-to-junction link on the major road network (motorways and A roads), and for a sample of points on the minor road network (B, C, and unclassified roads). The traffic flow counts are based on information from count points (CPs). These automatic points count and classify vehicles passing over them 24 hours a day, every day of the year, making them well-suited to provide data on flow variation. The yearly aggregation of these CP counts contributes to the calculation of the Average Annual Daily Traffic (AADT). To achieve this, we rely on the same methodology used by the Department for Transport (DfT) to convert AADTs into traffic volume (See Equation A 1). This is the same source for the number of highway lane kilometers (length of each segment multiplied by the number of lanes).

$$\begin{aligned} Traffic_{CP} &= AADT_{CP} \times lenght_{link} \times *365 \\ TotalTrafficorVKT &= \sum Traffic_{CP} \end{aligned} \tag{A 1}$$

The frequency of our traffic data set our study apart from previous papers. For example, Duranton and Turner (2011) used data for 1983, 1993, and 2003; Hsu and Zhang (2014) used panel data collected non-periodically from 1990 to 2005, and Garcia-López, Pasidis, and Viladecans-Marsal (2021) used data for 1985, 1995, and 2005. More recently, Ossokina *et al.* (2023) used longitudinal data to evaluate the effects on the short run, defined as 6 years.

$Geography_i$ encompasses the logarithm of the elevation range per TTWA, the logarithm of the distance from the centroid of each TTWA to the coast, and the proportion of each TTWA covered by lakes. The base layer for our GIS analysis was the TTWA 2011 boundary coming from the ONS's Open Geography Portal [9], from this we calculated the centroid of each centroid as well as the distance to the coast. The elevation across GB that allowed to calculate the elevation range in each TTWA, comes from Ordenance Survey [10]. The data on lakes comes from the UK's Department for Environment Food and Rural Affairs [11].

In section 3.1, our data on population comes from the ONS[12] while the employment data comes from NOMIS[13].

[8]Data comes from https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra

[9]Retreived from:https://geoportal.statistics.gov.uk/, October 2023

[10]Data from: https://www.ordnancesurvey.co.uk/, October 2023.

[11]Retreived from: https://environment.data.gov.uk/dataset/76b02c00-d465-11e4-a772-f0def148f590, November 2023

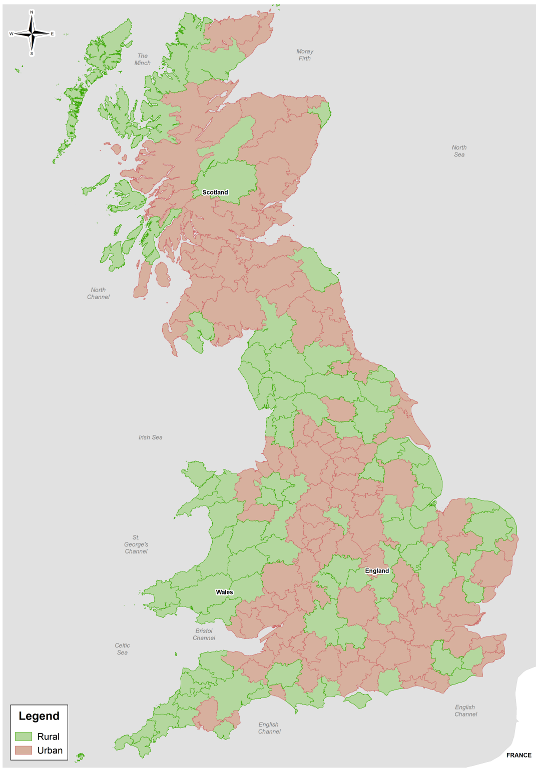
[12]https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/middlesuperoutp

[13]Information from https://www.nomisweb.co.uk/query/select/getdatasetbytheme.asp?opt=3&theme=&subgrp=

B. Spatial units

TTWAs were created to approximate labor market areas. They are derived to reflect self-contained regions where at least 75% of people both live and work. They divide the island into 218 Census Areas, including 149 TTWAs in England, 45 in Scotland, 18 in Wales, and 6 cross-border TTWAs. Based on the predominant type of population, 94 are defined as mainly rural and 124 as mainly urban (see Figure B.1).

Figure B.1: Urban and rural TTWA2011



C. Evolution of roads in Great Britain

Figure C.1: Evolution of road network in Great Britain

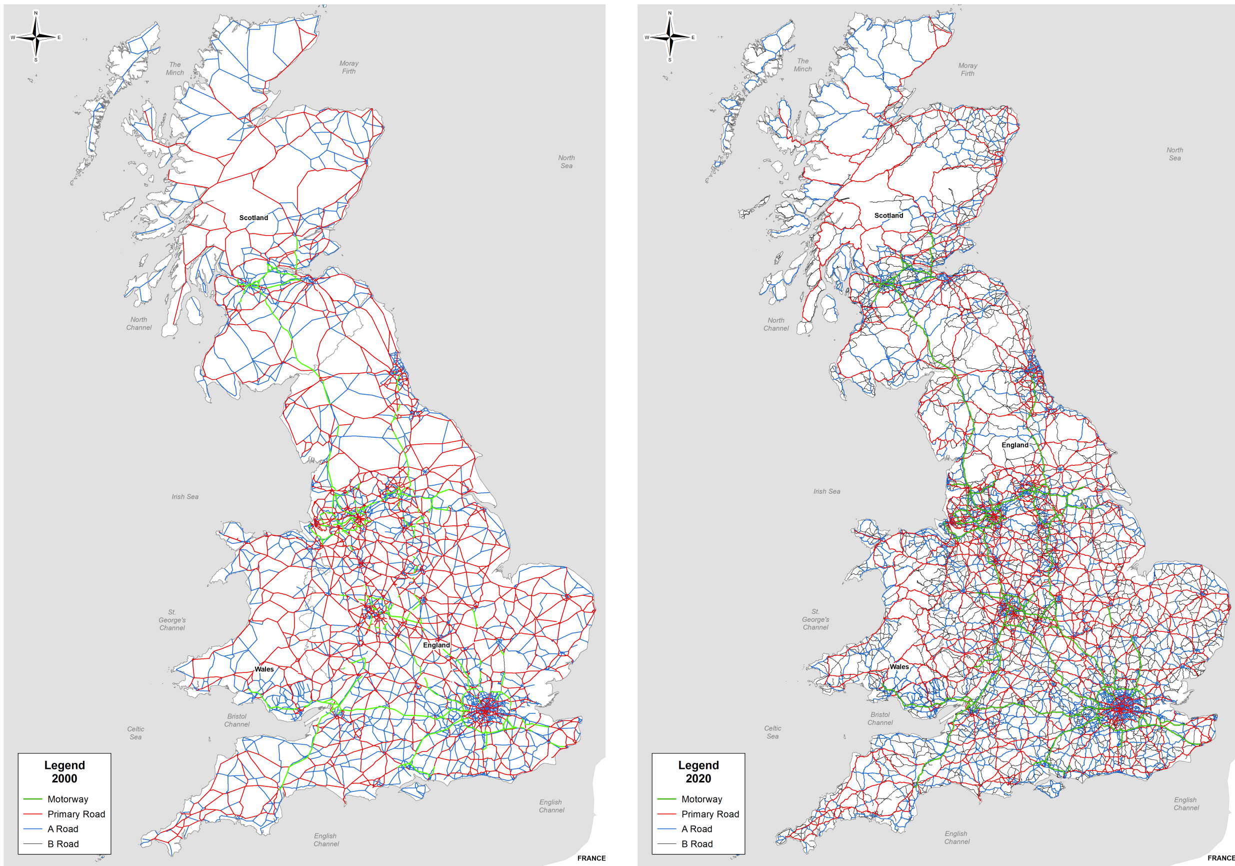
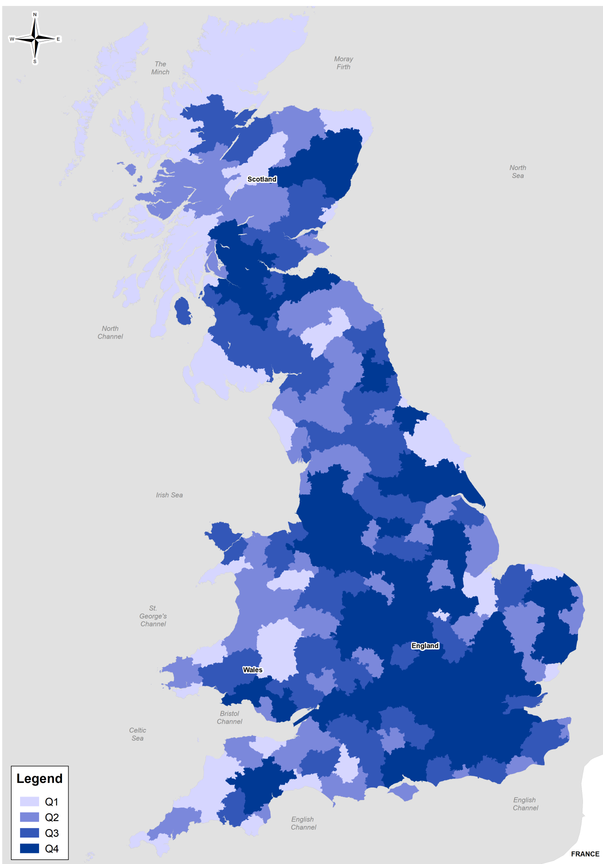
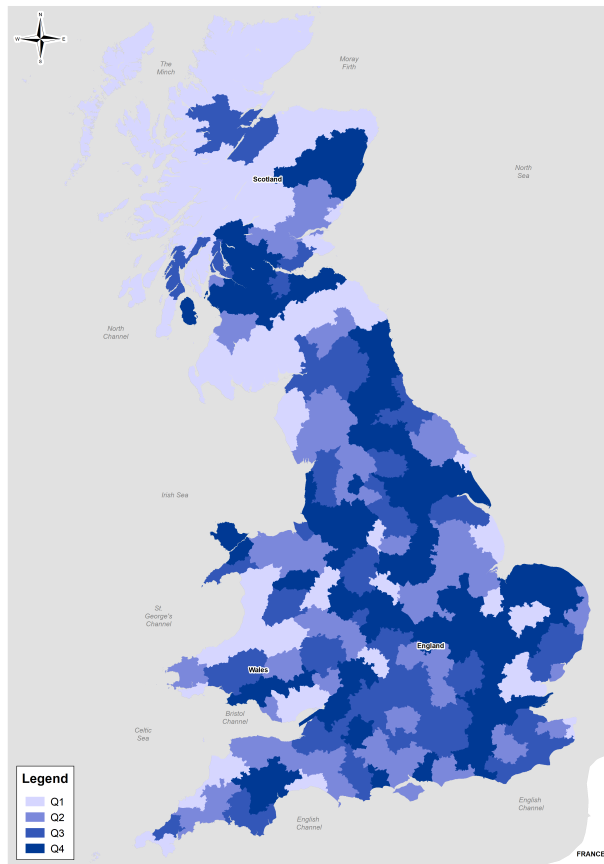


Figure C.2: VKT 2001 and road growth in the TTWAs of GB



(a) VKT levels in 2001



(b) Road capacity growth 2001-2020

Note: The figure displays the quartiles of VKT levels in 2001 (a) and the quartiles of road growth in our period of analysis (2001 - 2020).

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