The Economics of “Radiator Springs:” Industry Dynamics, Sunk Costs, and Spatial Demand Shifts

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1 Introduction

The construction of the U.S. Interstate Highway System during the second half of the 20th century changed traffic patterns in many local markets, increasing the growth rate of through traffic and shifting it spatially. The size of the spatial shift was small when the new highway was built on top of the intercity route it replaced but large when it was built miles away. The local impact of these traffic changes is a familiar theme in American popular culture. For example, the Interstate’s effect on the fictional town “Radiator Springs” forms the background of the 2005 Disney/Pixar film “Cars.” It has also been a theme of many academic studies; including most recently work in urban economics on the causes of suburbanization (Baum-Snow (2007)).

The periodic opening of new segments of the Interstate Highway System – and the concomitant changes in traffic patterns – offers an analytically advantageous opportunity for a systematic study of industry dynamics. From the perspective of service stations and other businesses that serve highway travelers, the opening of highway segments represents observable, anticipated changes in the level of demand and consumers’ tastes over locations. To exploit this opportunity, we have collected and combined (a) highly detailed data on when narrowly-defined Interstate highway segments opened, (b) county-level data from 1964-1992 describing the number, employment, and size distribution of service stations, and (c) hand-collected measurements of the distance between Interstate highways and the intercity routes they replaced. With these observations, we can observe the timing and spatial taste changes associated with *hundreds* of localized demand shifts taking place throughout the rural United States and relate these to changes in the number and size of service stations in local areas. Casual empiricism reveals obvious ways that new Interstate Highways ultimately affected industry structure: many exits have nearby service stations whose location can clearly be explained by the highway’s presence. However, the industry dynamics associated with the opening of these highways are less clear: How large are the supply-side changes, when and along what margins do they take place, and how do the answers to these questions differ with the size of the spatial demand shift?

We address these questions in this paper. We examine how the number and size distribution of service stations change during the time surrounding the completion of Interstate Highways in rural U.S. counties. We pay particular attention to how changes in locational tastes influence these adjustments. Our results provide evidence on how this industry, which is characterized by high location-specific sunk costs, adjusts to demand changes. We find that the timing and margin of adjustment of industry structure differ considerably with whether the new highway is located close to or far from the old route. When the new highway is close to the old one, there is no evidence that the number of stations changes around the time it opens, but average station size (measured with employees per station) increases by 6%, all of which takes place in the two years leading up to the highway's completion. If instead the new highway is far from the old one (say, 5-10 miles), the number of stations increases by 8% but there is no significant increase in average station size. Unlike the station size adjustment when the new highway is close, all of this increase takes place *after* the highway is completed. We infer from these observations that (a) demand increases with limited spatial effects are preceded by growth of existing stations, and (b) demand increases with large spatial shifts elicit the entry of new stations which begins only after the demand increase occurs. We find no evidence that these outcomes reflect other effects, such as the opening of highway segments in other counties or endogeneity of highway officials' location and construction-sequencing choices. In fact, we find that these effects are particularly large in counties where the volume of through traffic is high relative to the size of the local economy – counties where one would expect the impact of highway openings to be greatest – but find no evidence of these effects in counties where the volume of through traffic is relatively small.

We discuss these findings in light of several theories, including a competitive benchmark motivated by textbook models of perfect competition as well as different imperfect competition models. We show that the timing and margin of adjustment differ from that in our competitive benchmark when the highway is close to the old route; our results are instead consistent with imperfect competition models where equilibrium markups fall with entry (as in, for example, typical Hotelling-style models). In contrast, the timing and margin of adjustment are consistent with our competitive benchmark (and with other models in which markups do not fall with entry, such as typical Chamberlin-style models) when the new highway is far from the old route. Combined, our results illustrate how the way this industry's structure adjusts to permanent, anticipated demand shocks differs depending on where these shocks come in product space, in particular, on whether they create new spatial segments. Accounting for strategic factors that do not appear in our competitive benchmark appears to be important when demand shocks do not create new spatial segments but appears to be less important when demand shocks do so.

Our work is related to several lines of empirical work. Baum-Snow (2007) and Michaels (2008) independently use the same observations of highway opening dates to investigate, respectively, the contribution of highway construction to suburbanization and the effects of decreased transporation costs on wage premiums for skill. Our work focuses on the rural portion of this sample because traffic patterns of rural areas are relatively uncomplicated, making measurement of spatial demand changes possible. Our use of rural areas to investigate industry structure is similar in spirit to Bresnahan and Reiss (1990, 1991) and Mazzeo (2002). We are able to examine industry *dynamics* in a way these papers cannot because we observe both industry demand shocks and industry employment and producer counts over long periods. Nevertheless, our data does have its limitations. Like Bresnahan and Reiss (but unlike Berry (1992)), we observe the number of producers but not their identities. Thus, our results are most informative for models of industry dynamics with limited asymmetries between firms, such as Abbring and Campbell's (2010) dynamic extension of the Bresnahan and Reiss model.

The rest of the paper is organized as follows. Section 2 presents the analytical background to the paper. We develop a competitive benchmark that is inspired by textbook models of perfect competition, and summarize insights from various models of imperfect competition with respect to the margin and timing of an industry's adjustment to a permanent, anticipated demand shock. Section 3 presents the historical context, which we use to help motivate and interpret our empirical work. Section 4 describes the data and shows aggregate relationships between the timing of highway completions and changes in average service station size. Section 5 presents and discusses our main results. Section 6 concludes.

2 Industry Adjustment to Demand Shocks

In this section, we examine theoretically how the ease of entry and difficulty of exit interact with other industry characteristics to shape an industry's response to an anticipated change in demand. Our analysis here helps interpret our empirical results, which reveal *how* local service station industries adjust to anticipated demand increases – at the extensive margin through increases in the number of establishments or at the intensive margin through increases in station size – and *when* the industry adjustment occurs relative to the arrival of demand. Although much of the theoretical discussion is in general terms, we are motivated by an empirical context with several specific features. As we explain in more detail later, building a new service station or adding capacity (i.e., pumps) to an existing one is a straightforward task that requires few scarce inputs and can be accomplished in only a few months once local planning and zoning approval is obtained.[1] Since highways were planned years in advance of their opening, and construction took on the order of one to two years once it started; we conclude that the time to build or expand a service station is generally short

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[1] And as we explain further below, obtaining this approval was generally easy for the locations relevant to our sample: commercially zoned areas near rural Interstate Highways.

relative to the time it takes to plan and build a new segment of highway.[2] Thus, firms could time their entry or expansion to coincide with the highway's opening if they chose to do so. However, much of any new investment was sunk (literally!), because underground storage tanks and pumps are immobile and have little value outside of gasoline retailing.

2.1 A Competitive Benchmark

Models of perfect competition found in most undergraduate economics textbooks describe the short- and long-run industry adjustment to a positive demand shock. These models envision an industry consisting of a large number of price-taking firms that produce a homogeneous product. These firms' common technology features a U-shaped average cost curve with its minimum at $q^\star$. The distinction between the short and long run is that in the long run, the number of firms adjusts so that each firm earns zero profit. The long-run price $p^\star$ equals minimum average cost and each firm produces $q^\star$. The number of operating firms equals total demand at $p^\star$ divided by $q^\star$.

The textbook model's analysis of the short run adjustment illustrates competitive industry dynamics following *unanticipated* demand shocks when firms cannot respond immediately through entry. With greater demand and an upward-sloping short-run supply curve, the price rises above $p^\star$. Each incumbent firm produces more than $q^\star$, and they all earn positive profits in the short run. The length of the "short run" when firms make positive profits depends on how quickly firms can enter. Over time, entry dissipates short run profits, shifts out the short-run supply curve, and restores the price to $p^\star$ and each individual firm's production to $q^\star$.

The comparable analysis of a competitive industry's adjustment to an *anticipated* demand shock depends on how far in advance the shock can be forecast relative to the time required for entry. If firms in the textbook model can forecast the demand shock farther in advance than the time to build, then entrants can time their entry to match the demand expansion, and the model industry adjusts entirely through entry when the demand increase arrives. Prices never rise above $p^\star$, individual firms' production never increases beyond $q^\star$, and no firm makes positive profits at any point in time.

The textbook model's parsimony and the clarity of its implications lend it to our purpose: to provide a benchmark against which to compare empirical results. Nevertheless one might wonder how its implications fare after adding empirically plausible extensions that perserve price-taking behavior and free entry. Campbell (2010) obtains the same *long-run* invariance of firm size and price to demand in a competitive model that allows for firm-specific cost shocks and sunk costs, so our benchmark's long-run implications regarding the margin of adjustment hold in a model with technology shocks and sunk costs. Caballero

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[2] The short time to build for service stations is also revealed by Campbell and Lapham (2005), who document that the number of gasoline service stations in towns along the U.S.-Canada border adjusted within one year following unanticipated demand shocks associated with changes in the real exchange rate.

and Hammour (1994) call the stabilization of the price at $p^\star$ the "insulation effect" of entry, and they show that it operates as in our textbook benchmark in a model with stochastic demand, sunk costs and ongoing technological change.[3] Both of these results reflect the same mechanism as our competitive benchmark. Entry removes excess profits and leads the market to clear always at the competitive price $p^\star$. Active firms' incentives with respect to production do not change in the face of a demand shock, and the industry adjusts entirely through entry. These aspects of our competitive benchmark are fairly robust in the sense that they would change only if one altered the underlying model's key assumptions, particularly assumptions regarding the competitive environment, including short-run price competition and the ease of entry and exit.

We next explore industry adjustment in imperfectly competitive industries. These will help intepret our empirical evidence, which will reveal results inconsistent with our competitive benchmark.

2.2 Imperfect Competition and the Margin of Long-Run Adjustment

The textbook model of perfect competition provides a stark prediction regarding the margin of industries' long-run adjustment: all of the long-run adjustment to an anticipated demand increase should be in the number of firms, not firm size. Models of imperfect competition, in contrast, show how the margin of adjustment to a demand increase depends on the extent to which entry reduces markups. If adding producers has no effect on markups then (as in our competitive benchmark) all of the adjustment should be in the number of firms. In contrast, if adding producers leads markups to fall, some of the long-run adjustment to a demand increase should be in an increase in firm size.

To illustrate this point, consider an industry with S identical consumers, each with a unit demand for the industry's good. [JEFF WE NEED TO DEFINE x.] Suppose that there are many potential suppliers who can produce at fixed cost F and marginal cost c. Competition proceeds in two stages: simultaneous entry followed by price competition. If N firms enter, one chooses p, and all of the others choose $p\prime$, then the (possibly) deviating firm attracts $S \times x(p, p\prime, N)$ customers, where $x(p, p\prime, N)$ is the deviating firm's (output-based) market share. We impose three regularity conditions on this demand system. First, raising p while holding $p\prime$ and N constant reduces x. Second, raising N while holding p and $p\prime$ constant also reduces x. Finally, multiplying N by a positive scalar t while holding both p and $p\prime$ to *the same* constant value divides x by t. This final condition states that doubling the number of producers *while holding their common price constant* cuts each producer's quantity sold in half.

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[3] Their equilibrium analysis of industry-dynamics under aggregate uncertainty differs sharply from that of Dixit and Pindyck (1994), who consider the problem of a firm with an *exclusive and non-expiring* entry option facing demand uncertainty. We discuss the relevance of Dixit and Pindyck's results for interpreting our empirical results below in Section XX.

A symmetric free-entry equilibrium in this industry is a pair $(p^\star, N^\star)$ satisfying two equations, an optimal pricing equation and a zero profit condition:

$$\begin{aligned} \frac{p^\star - c}{p^\star} &= \frac{1}{\eta\left(p^\star, p^\star, N^\star\right)}, \\ F &= S \times x\left(p^\star, p^\star, N^\star\right)\left(p^\star - c\right). \end{aligned}$$

Here,

$$\eta\left(p, p\prime, N\right) \equiv \frac{\partial x\left(p, p\prime, N\right)}{\partial p'} \frac{p'}{x\left(p, p', N\right)}$$

is the residual demand curve's elasticity. We are interested in how this long-run equilibrium changes when we multiply S by $t > 1$. Doing so has no direct effect on the optimal pricing equation: Increases in S rotate firms' residual demand curves outward, leading them optimally to sell more at the same price. However, an increase in S raises post-entry profit, leaving the free-entry condition violated. At issue is how $p^\star$and $N^\star$ adjust to restore equilibrium, and this depends on how changing the number of producers impacts the elasticity of demand.

In many familiar models of Chamberlin-style monopolistic competition, $\eta\left(p^\star, p^\star, t \times N^\star\right) = \eta\left(p^\star, p^\star, N^\star\right)$ for all $t > 1$. Examples include Spence (1976), Dixit and Stiglitz (1978), and Wolinsky (1984). In these models, new entrants can always differentiate themselves enough so that they have no impact on the equilibrium markup of the second-stage pricing game; it is as if entry coincides with an expansion of product space. In this case, multiplying $N^\star$ by t suffices to restore equilibrium. The equilibrium price and each producer's quantity are unchanged, and the analysis of the margin of adjustment is similar to that in perfect competition. On the other hand, models of Hotelling-style monopolistic competition, where product space is fixed, typically imply that $\eta\left(p, p\prime, t \times N\right) > \eta\left(p, p\prime, N\right)$ for all $t > 1$. In these, new entrants produce relatively close substitutes for incumbents' goods. As with Chamberlin-style monopolistic competition, multiplying S by $t > 1$ raises $N^\star$. However, this leads the equilibrium markup to fall. Each producer must sell more at the lower markup to recoup the fixed cost of entry, so the ratio of $N^\star$ to S must fall. That is, the falling markup leads industry adjustment to be an expansion on both the intensive and extensive margins.

Our empirical analysis measures the margin of adjustment to a permanent increase in demand, and how the margin of adjustment depends on any accompanying change in demanders' locational tastes. We examine the latter by measuring where the new Interstate is located relative to the previous route that through traffic used. In our competitive benchmark, all long-run adjustment occurs on the extensive margin. In contrast, imperfect competition models illustrate how the margin of adjustment can differ with whether the demand increase is accompanied by a spatial shift in tastes. When the new Interstate is built on top of the old route, then new entrants located near highway exits provide close substitutes to incumbent producers' offerings; the new highway creates no new spatial segments. As the distance from the old route increases, the opening of the new highway changes the location of through traffic more, and existing stations become poorer substitutes for a station located near a new highway exit.

One would expect entry to have less of an impact on price-cost margins, and the industry adjustment to be less in terms of station size and more in terms of the number of stations, compared to situations where the opening of a new highway segment creates no new spatial segment.

2.3 Imperfect Competition and the Timing of Adjustment

In our competitive benchmark, entry leads prices to equal minimum average cost and profits to be no greater than zero at any point in time. Therefore, any adjustments to a demand increase occur no earlier than the demand increase begins. Any firm that expanded or entered ahead of the demand increase would receive negative profits before the demand increase – prices would be below competitive levels – but no greater than zero profits in any period after the demand increase.

In contrast, imperfect competition allows for the possibility that the adjustment may begin ahead of an anticipated demand increase, by allowing individual firms to have an incentive to make decisions that trade off lower profits today for higher profits tomorrow. One example is that learning curves can interact with imperfect competition to induce early expansion. If a firm expects that it will sell more in equilibrium after a demand increase, and producing more today can lower its marginal cost in future periods, it can have an incentive to expand ahead of the demand increase because the returns to such investments are larger when firms' scale of operations are greater.[4] This example illustrates how this incentive could arise even if no firm believes that its early expansion affects other firms' decisions.

A large literature in theoretical industrial organization shows how firms can have an incentive to invest ahead of the arrival of demand through its effect on other firms' actions. In many of these, the sunk costs of investment and the concomitant commitment to future production deter the entry or expansion of other firms. Since gasoline retailers literally sink substantial capital into the ground, we find this class of models of particular interest.[5] Fudenberg and Tirole (1986) describe one model with particular relevance for our context. In it, a market is currently supplied by an incumbent monopolist, but the number of potential customers is expected to double at some future date. This demand increase gives rise to an entry opportunity, which may either be filled by the incumbent or an entrant. Fudenberg and Tirole show that if entry lowers total industry profit – monopoly profits are more than twice the duopoly profit – then in equilibrium the incumbent preemptively fills the entry opportunity before demand expands. The incumbent fills this opportuntity just ahead of the time where the entrant is indifferent between entering, earning low duopoly profits until demand arrives, and earning high duopoly profits thereafter.

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[4] The authors tend to believe that learning curves are relatively unimportant in the context they study, but other analogous investments where there exist intertemporal trade-offs and returns to scale (perhaps related to reputations) might be more reasonable.

[5] This literature includes, for example, Spence (1977, 1979), Fudenberg and Tirole (1984), and Bulow, Geanakoplos and Klemperer (1985).

3 The Historical Context

This section describes the historical context in which Interstate Highways were built and the service stations in our sample competed. This discussion places our empirical work in perspective, highlighting the most salient interpretations of our main results.

3.1 Interstate Highway Planning and Construction

The present-day Interstate Highway System is a network of over 40,000 highway miles that serves nearly all of the largest cities in the United States. Its general routing is the direct descendent of a 1947 plan that described a 37,000 mile nationwide network of Interstate Highway routes.[6] These routes corresponded to the existing major roads that connected most population centers, and the plan designated these roads, or alternatively newly-constructed highways along the same route, as part of the Interstate System.[7] Little Interstate Highway construction immediately followed the 1947 plan's publication, in large part because the Federal government did not earmark funds for this purpose.[8]

The vast majority of the Interstate Highway System's construction followed the passage of Federal Aid Highway Act of 1956. The Federal government financed Interstate Highway construction through fuel taxes paid to a Highway Trust Fund that was specifically earmarked for this purpose. Federal funds paid for 90 percent of construction costs, with the states paying for the remainder. The construction was carried out on a "pay as you go" basis, and the Federal Highway Administration (FHA) apportioned each year's available funds to states according to their shares of the total cost of building the entire Interstate system. The legislation's original goal was for each state to steadily build highway mileage until the system's expected completion in 1970. The 1956 Act also set engineering standards for Interstate Highways regarding among other things design speed, alignment, lane width, limited access, and line of sight.

The formula for splitting Federal aid across the states required the FHA to have cost estimates for the *entire system* in place shortly after the passage of the Act. Topography and geology greatly influence the cost of building a road, so the rapid development of cost estimates required a relatively quick selection of Interstate Highways' exact locations. State engineers worked closely with the Federal government, which could veto highway location choices by withholding its 90 percent contribution to construction costs. By 1958, all states had submitted detailed highway location plans.[9] The Federal government had

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[6] Most of the system's remaining mileage was determined in the middle 1950s. *Annual Report, Bureau of Public Roads, Fiscal Year 1956*, U. S. Department of Commerce, Washington, 1956, p. 9.

[7] *Work of the Public Roads Administration 1947*, U. S. Government Printing Office, Washington, 1947, p.5-6.

[8] *Annual Report, Bureau of Public Roads, Fiscal Year 1955*, U. S. Department of Commerce, Washington, 1956, p. 5; *Annual Report, Bureau of Public Roads, Fiscal Year 1956*, U. S. Department of Commerce, Washington, 1956, p. 1.

[9] "Immediately after passage of the act the States undertook the engineering and economic

approved designs and locations for all routes in the system by the middle of 1960.[10]

The states' Interstate Highway plans sometimes describe the logic behind the chosen locations of particular segments. For example, Virginia's report discusses the location of Interstate 66 in the area from its present Exit 6 (Front Royal) to Exit 23 (Delaplane) as follows:

> The present road, an asphalt concrete pavement twenty feet wide, has horizontal alignment, profile grades and sight distance that are all inadequate for a sixty mile per hour design speed. Property along both sides of the road is developed to the point where almost fifty percent of the residents would be displaced by any widening of the right of way... Two Interstate roadways and an additional frontage road would have to be constructed, a more costly procedure than the construction of just two Interstate roadways on a new location. ... Although the number of possible locations for a new route are restricted by mountains in the area, there are no serious topographic or real estate problems along the route selected. It was, therefore, laid out to take the greatest advantage of the terrain and to stay reasonably close to the present road.[11]

As this example indicates, the first step in site selection was the evaluation of the existing road. The obstacles enumerated in the quotation above frequently made its expansion into an Interstate Highway infeasible. Existing roads were expanded for less than one-fourth of the mileage in the system. Most Interstate Highways were instead built as near to the existing road as the local topography allowed.[12]

This discussion illuminates two key aspects of Interstate Highway planning that bear on our empirical results. First, Interstate Highways' locations were determined for most of the rural highway segments in our sample many years before these segments were built. Second, details about the local economy – such as an agglomeration of businesses and residences along the old route – often played an important role in determining whether the new highway was built on

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studies necessary to select definite locations for the routes of the Interstate System, and at the end of the fiscal year locations for about 80 percent of the 40000 mile system had been selected and approved..." *Annual Report, Bureau of Public Roads, Fiscal Year 1957*, U. S. Department of Commerce, Washington, 1957, p. 7.

[10] *Annual Report, Bureau of Public Roads, Fiscal Year 1960*, U. S. Department of Commerce, Washington, 1960, p. 8. Plans with multiple alternative locations were submitted for some segments, but this was the exception rather than the rule. By 1965, the final location of only about 6 percent of system was yet to be determined. *Highway Progress 1965*, U. S. Department of Commerce, Washington, 1965, p. 15.

[11] *Interstate Highway System: Commonwealth of Virginia, Volume V*, Department of Highways, Howard, Needles, Tammen, and Bergendoff, 1956. For this excerpt, see Section 2, "East of Front Royal to South of Delaplane."

[12] Interstate Highway construction and site selection were very contentious issues in urban areas. For example, most of the Interstate Highways planned for Washington D.C. and San Francisco were never constructed. In the rural areas, these plans were much less controversial and were largely implemented as specified.

top of the old one, but played a far less important role in determining where the highway was built, given that it was not on top of the old one. Undeveloped land away from the existing highway was generally available, and highway engineers sought relatively flat terrain with short river crossings where they could build high-speed roads with gradual curves. Where an entirely new highway was built predominantly reflected the location of suitable terrain. Variation across the counties in our sample in how far a new highway is from the old route, given that the new highway is not located on top of an existing road, disproportionately reflects variation in local topography, not other factors such as its expected impact on the local economy. This second aspect of Interstate Highway planning informs one of our empirical exercises below, in which we examine whether the patterns we uncover persist when excluding from our sample counties where the Interstate Highway is extremely close to the old route.

Construction began on Interstate Highways in all states beginning in the late 1950s. Starting from a 2,000-mile base of existing highways (such as the Massachusetts Turnpike) that were grandfathered into the System, construction was extremely rapid, averaging over 2,000 miles per year during the 1960s and early 1970s. Although progress fell short of the initial goal of completion of the entire system by the end of the 1960s, 90% of it was open by the end of 1975 and 96% by the end of 1980.

Interstate Highways were typically completed in segments of 5-15 miles, and the construction of a highway segment generally took three to four years from start to finish.[13] The timing and allocation of Federal funding, guided by the "pay as you go" and "proportionate across states" provisions, kept the pace of construction fairly even across states, and as a consequence there was not a strong tendency for highway construction to be earlier in states with high traffic density or growth. However, each state had wide discretion over which of its Interstate Highways to build first. Within states, construction tended to proceed first in areas where through traffic was causing problems: in traffic corridors, and on highway segments within corridors, where through traffic was causing existing roads to be congested. Construction then progressed to other areas, connecting completed segments until all the highways in the state were complete.[14]

3.2 Service Stations

Service stations are retail outlets primarily engaged in selling gasoline, pumping it from underground tanks into customers' vehicles. The gasoline itself is largely undifferentiated and sold in standard grades, though many customers have brand preferences. Service stations have long offered other services or lines of merchandise as well (hence their name). Although now it is common for service stations to have convenience stores, until the late 1970s most sta-

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[13] *Annual Report, Bureau of Public Roads, Fiscal Year 1957*, U. S. Department of Commerce, Washington, 1957, p. 2.

[14] *Annual Report, Bureau of Public Roads, Fiscal Year 1960*, U. S. Department of Commerce, Washington, 1960, p. 11-17, 51-52.

tions instead supplied simple auto maintenance and repairs such as oil changes, tire replacements, and alignments. Furthermore, unlike today, most stations were "full service" stations at which attendants pumped gasoline for customers. These aspects were interrelated: attendants checked the vehicle's condition while they pumped gas and made service recommendations – this marketing aspect of "full service" was viewed as crucial to stations' profitability because margins on lubricants, maintenance, and repairs were significantly greater than margins on gasoline,[15] and it was common for attendants to be paid commissions for sales of these non-gasoline products and services.[16] It was generally optimal for stations in this era to increase the number of employees when they increased the number of pumps.

During the time of our sample, new service stations were generally financed and constructed by oil companies, who then leased them to operators as independent firms under "lessee-dealer" arrangements. The construction of a new service station involved the acquisition of land, the installation of tanks and pumps, the fabrication of a building and the installation of equipment required for auto repair, such as hydraulic lifts. A 1970 estimate of the (non-land) capital costs of a two-bay, two-island service station was on the order of $40,000.[17] The capital costs of adding a new "island" of pumps at an existing station was a small share of this, if additional land was not required, because it was generally feasible to connect new pumps to existing tanks. The construction of a new service station was usually straightforward, in part because there were standard architectural designs, and generally could be completed in no more than several months.[18] A large share of the costs associated with building a new station were sunk, because much of the capital was not mobile and it was expensive to convert the facilities and land to be used for most other purposes.

Planning and zoning regulations generally restricted the location of service stations to commercially-zoned areas and stipulated such things as minimum lot sizes and how close pumps could be to the right of way, but generally did not have an important impact on the number and size of service stations in an area beyond this. Surveys published by the American Society of Planning Officials in 1973 indicate that planners' main concerns with respect to service stations had to do with the traffic they generated, their appearance, and the problem of abandoned stations. They generally dealt with these by encouraging service

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[15] Guides for running service stations during this period emphasize this. For example, from *Starting and Managing a Service Station* (1961): "How do you make money in this business? First of all, by getting away from limiting your business to just gasoline...Don't let [customers] forget that tires and batteries need replacement, and cars need lubrication." This has since changed: "Self-service completely changed gasoline retail. Gasoline sales were no longer a low-profit adjunct to highly profitable car servicing and tire/battery sales." (Russell, 2007)

[16] Nielsen, Clayton D., *Service Station Management,* University of Nebraska Press, Lincoln, 1957, p. 39; Russell, Tim, *Fill 'er Up: The Great American Gas Station*, Voyageur, Minneapolis, 2007, p. 47.

[17] Claus, R. James and David C. Rothwell, *Gasoline Retailing: A Manual of Site Selection and Development*, Tantalus, Vancouver, 1970, p. 75. This is about $225,000 in 2009 dollars.

[18] This remains true today. See http://www.bmconstruction.com/pdf/B&M_Construction_Reprint.pdf, in which a developer reports that it normally takes 90 days to design and build a service station.

stations to be developed on corner lots (which station owners desired in any case), requiring architectural review, and requiring owners of closed stations to empty and remove tanks.[19] In general, although service station operators usually had to obtain a special permit to operate, even in commercial zones, planning and zoning regulations regarding service stations were quite light-handed. Indeed, near highway interchanges, perhaps the most common problem they addressed was encouraging service stations, and not other developments such as strip malls, to be very close to exits so that highway travelers could use them without affecting other traffic.[20]

We next report general trends with respect to service stations during and slightly outside our 1964-1992 sample period, paying particular attention to the period between 1964-1977, the part of our sample period during which most of the highways were built. The numbers are as reported by the U.S. Census in either County Business Patterns or the Economic Census (as part of the Census of Retail Trade or, before 1972, the Census of Business).

3.3 General Trends

Figure 1 presents several series that track the number of service stations in the U.S., and subsets thereof. The top set of points represents all service stations. It shows that the number of service stations increased slowly during the 1960s and early 1970s, growing by 7% from 1963 to its 1972 peak of about 226,000. This number decreased sharply starting in the mid-1970s, falling by more than one-third to about 135,000 in 1982, and has been relatively stable since then. New station openings were exceeding closings during the period when most of the Interstate Highway System was built, but service stations were, on net, exiting the market during the late 1970s.

The second series tracks the number of service stations with positive payroll; the trend of this series is very similar to the first one. This is of note because our main data source tracks only stations with employees.

The other series track the number of "reporting units," as published in County Business Patterns (CBP). The county-level data that we analyze below is from this source. There is a break in this series because the definition of a "reporting unit" changed in the middle of our sample period.[21] Starting in 1974, the CBP reports the number of establishments – in this context, service stations – and the numbers published in the CBP track those published in the Economic Censuses (EC) closely. But before 1974, the CBP reports the number

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[19] Concerns about environmental concerns did not make the list of "major problems." American Society of Planning Officials, *The Design, Regulation and Location of Service Stations*, Chicago, 1973. This may have changed in the 1980s with the onset of environmental regulation of underground storage tanks.

[20] See, for example, *Highway and Land-Use Relationships in Interchange Areas*, Barton-Aschman Associates, January 1968, p. 33.

[21] This change corresponded to a change in how the Internal Revenue Service asked firms to report employment and payroll data. There was also a change in the employment size categories the Census used. Before 1974, the three smallest categories were 1-3, 4-7, and 8-19 employees; after 1974, these were 1-4, 5-9, and 10-19 employees.

of firms competing in the county, not the number of service stations. Firms owning more than one service station in a county are counted once. Time series of CBP data before 1974 capture not only the entry and exit of single-station firms, but also any combinations or spin-offs of service stations within the same county. The ratio of the reporting unit counts and the establishment counts before 1974 indicates the degree to which firms operated multiple stations in the same county. This ratio increased from 1.12 in 1967 to 1.25 in 1972; starting in the late 1960s, it became increasingly common for firms to own multiple stations in the same county.

The size and composition of service stations changed during our sample period. Figure 2 reports time series on average employment size. The EC series show that the average employment size of service stations grew throughout our sample period, increasing by about 125% between 1963 and 1992. Turning to the CBP-derived series, the employment size of the average reporting unit – that is, average within-county firm size – increased by 41% between 1964 and 1972. Employment per station with payroll increased by about 35% during this time; hence, about seven-eighths of the increase in within-county firm size reflects increases in the number of employees per station rather than in the number of stations per firm. The bulk of pre-1974 employment size increases therefore appears to reflect increases in station size.

Other Census figures published on a consistent basis since 1972 show increases in size in other dimensions; we depict these in the first few columns of Table 1. Gallons per station increased steadily between 1972 and 1992, more than doubling during this time. This reflects both an increase in the number of gallons per pump, which grew by 63%, and the number of pumps per station, which grew by 37%. These figures indicate that at the same time average employment per station was increasing, stations' pumping capacity was increasing, and this pumping capacity was being utilized more intensively.

Reports from pre-1972 Census surveys suggest strongly that these trends extend to the beginning of our sample. Evidence from the 1963 Census of Retail implies that gallons per station grew by at least 44% and pumps/station by at least 20% between 1963 and 1972, although the estimates are not directly comparable to those in Table 1 due to reporting bias.[22]

The rest of Table 1 depicts two well-known changes in service stations that occurred during this time. One is the movement toward self-service. This began in the early 1970s, and the share of sales that are self-service exceeded 90% by 1992. The other is the change in service stations' ancillary services away from automotive services and toward convenience stores. These changes did not entirely coincide. The movement away from automotive services was essentially complete by 1982, but the increase in the revenue share of convenience store items – food, alcohol, and tobacco – occurred predominantly after 1982; the revenue share from these categories increased from 5% to 15% between 1982

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[22] The 1963 Census of Retail reports that, among the two-thirds of service stations that responded to the relevant survey questions, stations pumped 250,000 gallons of gasoline and had 4.4 pumps on average. The respondants to this survey disproportionately included larger firms, but the Census did not publish estimates that adjusted for this reporting bias.

and 1992, and has increased since then to about 25%.[23]

This study focuses on periods surrounding when Interstate Highways were being completed, and the phenomena we uncover mainly reflect changes in the number and size distribution of service stations that occured between the early 1960s and the mid-1970s. Throughout this period, service stations were becoming larger in terms of employees. Although some of the increase in service stations' average size likely reflects increases in the number of hours stations were open, it is unlikely that all of it does, because the number of pumps per station was increasing as well, the vast majority of sales was full-service, and the sales of automotive services continued to be important profit sources. Most of the Interstate Highway System was complete when several well-known trends in service stations began, including the diffusion of self-service gasoline and the rise of convenience store-service stations, as well as other innovations such as "pay at the pump" that would tend to decrease the use of labor. Thus, these developments can contribute only little to industry dynamics in our sample period.

4 Data

Our empirical analysis relies on data about highway openings, traffic counts, highway locations, and service stations.

4.1 Data Sources

4.1.1 Highway Openings

Our data on highway openings come from the U.S. Department of Transportation's "PR-511" file. These data describe the milepost, length, number of lanes, pavement type, and opening date of segments of the Interstate Highway System that were open by June 30, 1993 and built using Interstate Highway funds. The data cover nearly the entire System.[24] Highway segments in these data range in length, but the vast majority are less than five miles long and many are less than one mile long. Opening date is described as the month-year in which the segment was open for traffic. The milepost and length variables in the PR-511 indicate where the highway segment is located along the route. We hand-merged these variables with geographic mapping data from the National Highway Planning Network to identify the county in which each of the PR-511

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[23] A third change during this period was the movement from leaded to unleaded gasoline. This, like self-service, began in the early 1970s and was essentially complete by 1992. Many stations offered both leaded and unleaded gas by offering them at different pumps or islands; existing stations often replaced a pump that supplied leaded premium with one that supplied unleaded regular.

[24] A small fraction of the IHS includes highways that were not built with Interstate Highway funds, but were incorporated into the System later. (I-39 in Illinois is an example.) These highways are not in our data.

segments is located.[25] This produced a highly-detailed dataset on the timing and location of Interstate Highway openings.

We then aggregated these data up to the route-county level. For each route-county (e.g., I-75 through Collier County, FL), we calculated the total mileage within the county, the total mileage completed by the end of each calendar year, and the share of mileage completed by the end of each calendar year. Highways were normally completed in segments, so it is not unusual for a route to be partially complete within a county for some period of time, then fully completed within the county a few years later. This cumulative share variable, $csmi_{it}$, is a key independent variable in our analysis.

We also develop a corridor-level version of this variable, $ccsmi_{it}$, which accounts for the possibility that traffic volumes in a county are not only affected by highway openings in the county, but are also affected by highway openings in other counties along the same traffic corridor. For example, traffic in Boone County, Missouri is not only affected when Interstate 70 was completed in Boone County, but also when it was completed in other counties between Kansas City and St. Louis. We describe the details of how we define corridors and how we assign highway segments to corridors in the Appendix. The basic idea is simple, however. Most corridors are defined as highways that connect two central cities with at least 100,000 population; Interstate 70 between Kansas City and St. Louis is an example. For each corridor, we calculate the share of Interstate Highway mileage completed in each year, and assign this variable to each county that lies along the corridor; for example, we calculate the share of Interstate 70 between Kansas City and St. Louis that was opened in each year, and assign this variable to each county through which I-70 passes between these two cities.

4.1.2 Traffic Counts

We utilize traffic count data on Interstates from the U.S. Department of Transportation's Highway Performance Monitoring System (HPMS), to construct a variable that distinguishes among counties by whether the amount of through traffic is large relative to employment in the county. We develop a measure of through traffic in the county by taking the minimum daily traffic count on the Interstate within each of our corridors and assigning it to each county in the corridor. Call this $thru_i$.[26] We then construct a variable $thrushare_i = thru_i/(thru_i + emp_i)$ where emp_i is the county's 1992 employment. The mean value of $thrushare_i$ across our 677 counties is 0.55. The maximum value is

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[25] These data are maintained at: http://www.fhwa.dot.gov/planning/nhpn/. The PR-511 file contains a variable that indicates the county in which the segment is located, but other researchers (Chandra and Thompson, 2000) have noted that this variable contains errors. We use the PR-511 data in checking our construction of this variable.

[26] The HPMS data provide traffic counts measured periodically on the Interstates in our sample. These data are reported consistently starting in 1993. Our measure uses data from 1993-98 to reduce noise in the counts due to sample sizes. We constructed $thru_i$ by first calculating the minimum traffic count on the route*county in each of these years, then averaging this quantity across these years. We then took the minimum value of this county-level average across the corridor.

0.97, which is in Culberson County, TX – a very small county on a fairly heavily traveled stretch of Interstate 10 in west Texas. The minimum value is 0.01 in Kennebec County, ME, the largest county on the corridor which includes the least-traveled stretch on the Interstate Highway System (the northernmost part of I-95).

4.1.3 Highway Locations

We augment these data with a measure of how far the Interstate Highway shifted traffic. We did this via the following procedure. Using mid-1950s road maps, we first designated the route each segment of Interstate Highway likely replaced (the "old route").[27] The general procedure was to look first at the major cities that the current Interstate connects, then assess the most direct major route between these cities as of the mid-1950s. For example, the "old route" for I-95 between Boston and New York is US1. Once the "old route" was established, we measured the "crow flies" distance between each current Interstate exit and the old route. This was done using Google Maps and ancillary tools. Finally, we averaged this distance across the exits within each route-county. This produces a variable $dist_i$ (or "distance from old route") that characterizes the spatial shift in traffic brought about by the Interstate Highway. This measure ranges from zero for many route-counties (where the Interstate merely was an upgrading of the old route) to over 20 miles across the route-counties that we use in our analysis (see below). The median value is 1.25 miles; the 25th and 75th percentile values are 0.5 and 3.0 miles, respectively.

Our data on local market structure for service stations come from County Business Patterns, published annually by the U.S. Bureau of the Census since 1964. CBP contains county-level data on narrowly-defined industries, including "gasoline service stations," SIC 554. We obtained these data in electronic form from 1974-1992; we hand-entered these from published reports from 1964-1973. For each year and county, these data report employment and payroll in the industry within the county. They also report the total number of reporting units (firms until 1973, service stations thereafter) and the number in several employment size categories.

Our data contain missing values for some county-years, especially in the very smallest counties. Missing values arise for industry employment and payroll when the Census deems that publishing these would disclose confidential information regarding individual firms. Such disclosure issues do not arise for the local industry structure variables; these are considered publicly-available information in any case. However, to economize on printing costs, the Census did not publish these data for industry-counties with small numbers of employees (typically fewer than 100); they are available only in electronic versions of the data. We therefore have missing values for these variables in very small counties, particularly in years before 1974.

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[27] The "old routes" were essentially the roads that were designated as part of Interstate system in the 1947 plan.

The CBP data form our dependent variables, the most important of which are the number and average employment size of service stations (before 1974, firms) within the county in an particular year. The bulk of our analysis relates these variables to the timing of highway openings.

4.2 Sample Criteria

Our empirical approach, which uses highway openings to identify spatial shifts in the demand for gasoline, envisions contexts where these shifts are uncomplicated: for example, a situation where a new highway opens that parallels an existing road that had previously served both local traffic and "through" traffic. This is unreasonable in urban contexts, since the spatial distribution of demand for gasoline is unlikely to be as dependent on the location of the most important "through" roads. We therefore conduct our analysis on a part of our sample that includes only less dense areas where traffic patterns are relatively uncomplicated.[28] First, we use only counties with a single two-digit Interstate and no three-digit Interstates; this is a simple way of eliminating most large cities as well as other counties with complicated traffic patterns. Some populous counties remain after this cut (for example, New York, NY); were therefore eliminate all counties where 1992 employment exceeds 200,000. We also eliminate all counties through which the highway passes but there is no exit; most of these are cases where the highway clips the corner of a county. Finally, we employ in our main analysis a "balanced panel" which includes only counties where the number of service stations is nonmissing in each year between 1964-1992.[29]

Our main sample ultimately includes 677 counties; we depict these counties in Figure 3. This map indicates that our sample counties come from all over the United States, tracing the non-urban parts of the Interstate Highway System. Differences in the shading of these counties indicate differences in when the highways were completed; broadly, they were completed somewhat later in west than in other regions of the country, but the pattern is not strong, reflecting the Federal government's encouragement of proportionate construction in each state. In addition, differences in the shading of the highway indicate counties where the new highway was far from the previous intercity route, defined here as farther than 3 miles. It was more common for western Interstates to be completed close to the previous route than Interstates in other areas of the country, in large part because the population is less dense in the west than in east or south.

4.3 Patterns in the Data

Table 2 presents the timing of "two-digit" Interstate Highway completion as reported in the PR-511 data, and for our balanced panel counties. From the

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[28] And unlike urban counties, the location of highways in these counties was generally uncontroversial.

[29] We retain route-county-years where service station employment is missing, as long as the number of service stations is nonmissing.

left part of the table, 20% of two-digit highway mileage was open by the end of 1960; most of this mileage consisted of toll roads in the east that predated the Interstate Highway System (such as the Pennsylvania Turnpike) and were incorporated into the System once it was established. About 55% of two-digit mileage in the System was completed during the 1960s; the peak construction year was 1965. 90% of the System was completed by 1975, and the final 5% after 1980. The counties in our balanced panel account for 18,833 miles of Interstate Highways, about half of the two-digit mileage in the System as a whole. The timing of highway construction in this subsample mirrors that of the system as a whole, peaking in the mid-1960s, then steadily declining during the years that followed. As noted above, the timing of Interstate Highway construction means that our analysis will center on events that mostly took place in the 1960s and early 1970s, and our creation of a dataset that examines changes in industry structure during this time exploits this.

Table 3 presents time trends in the number and size distribution of firms (starting in 1974, service stations) in our 677 balanced panel counties. The trends in these counties are very similar to those in the U.S. as a whole. The number of firms/county was roughly constant between 1964 and 1973, with the number of large firms increasing relative to the number of small firms. The number of service stations per county then fell by about one-third between 1974 and 1992, reflecting a large decrease in the number of small stations that is partially offset by a small increase in the number of larger stations.

Figure 4 presents some initial evidence on whether the timing of industry structure changes are related to the timing of highway openings. We place counties into three categories according to the year the highway was completed in the county: before 1966, 1966-1971, and after 1971. We then calculate employees per firm (starting in 1974, per station) within these categories.[30] Figure 4 indicates that average firm size was small in "early" and "late" counties early on; in each, there were about three employees per firm. Employment size increases steadily during this period; in 1992, the average gas station in "early" and "late" counties had roughly seven employees. But the timing of this increase differed between the early and late counties. Firm size increased in the "early" counties relative to the "late" counties early in our sample; by the early 1970s, the difference was about 10%. The opposite was true late in our sample, after the mid-1970s, average station size increased in the late counties relative to the early counties. The right part of Figure 4, which depicts the ratios between the "late" and "early" counties each year, shows this pattern. This evidence indicates that increases in the size of service stations corresponded to the completion of Interstate Highways.

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[30] The quantites in Figure 4 use only counties where we observe service station employment in each year, N=470.

5 Empirical Model and Results

Our empirical specifications follow Campbell and Lapham (2004). We estimate vector autoregressive specifications of the form:

$$y_{it} = \alpha_i + \mu_t + \Lambda y_{it-1} + \beta x_{it} + \varepsilon_{it}$$

In the first set of results that we will present, y_{it} is a 2×1 vector containing the logarithms of the number of service stations in county i at time t (n_{it}) (before 1974, the number of firms) and their average employment (a_{it}). The vector x_{it} contains our highway opening variables, including up to three leads and lags; we describe this part of the specification in more detail below. The parameter α_i represents time-invariant factors that lead the number and size of service stations to differ across counties, and μ_t embodies trends and aggregate fluctuations that affect all counties equally. Removing these county-specific and time-specific effects isolates the changes in the number and sizes of service stations around the time of Interstate Highway openings relative to the county's own history and national developments. The specification's autoregressive structure allows the impact of an Interstate's opening to occur gradually. The coefficients of β give the initial impact, while $(I - \Lambda)^{-1}\beta$ measures the long-run change.

Setting aside for now leads and lags, the vector x_{it} includes up to three highway opening variables: $ccsmi_{it}$, $csmi_{it}$, and $csmi_{it}{*}dist_i$. Including $ccsmi_{it}$ accounts for the possibility that the level of demand for gasoline in a county depends on corridor-level construction; the interaction $csmi_{it} * dist_i$ allows for the possibility that the effect of the completion of a highway in given county has a different impact on local industry structure, depending on the size of the spatial shift in demand.

[TO DO – Update this paragraph.] This draft reports results when we estimate our specifications using OLS. Future versions will use estimators that account for the econometric endogeneity of y_{t-1}. Based on our experience with these estimators as applied to CBP data, we expect the results to change little when we do so.

5.1 Basic Results

5.1.1 Number and Average Size of Stations

Table 4 presents results from several specifications.[31] In the top panel, x_t contains no leads or lags, and includes only $csmi_{it}$. Looking first at the autoregressive coefficients, all are positive and significant: the impact of shocks to the number and average size of service stations in a county is therefore distributed over time. The highway opening coefficient is economically and statistically zero for the number of stations, and is positive and significant for the average

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[31] All specifications allow the autoregressive coefficients to vary for the year 1974, to account for the change in the Census definition of reporting units. We have also estimated specifications that allow these coefficients to vary before and after this change, and to vary in each year. The estimates on our highway openings coefficients vary little when we do so.

employment size of stations.[32] The magnitudes of the highway opening coefficients, combined with the autoregressive coefficients, imply that the opening of a highway is associated with no change in the number of firms, but a 6% long run increase in the average employment size of service stations in the county, one-third of which (1.9%) occurs in the year that the highway opens.

The second panel adds a lead and lag to the highway opening vector. The main result is the positive and significant coefficient on the "-1 year" coefficient in the average employment size regression: the increase in average size of service stations begins before the highway opens. The sum of the lagged coefficients is approximately unchanged. The final two panels extend the analysis to two and three leads and lags. While the autoregressive coefficients and the sum of the lagged coefficients – and thus our estimate of the long-run impact of highway openings – are approximately the same as in the other panels, the individual highway opening coefficients are estimated with more noise. The positive estimates of the "zero, one, and two years before" coefficients suggest that average station size increased before opening; the coefficient on the "one year after" coefficient indicates that it fell somewhat the year after the opening.

This first set of results indicates that, unlike in our competitive benchmark, the margin of adjustment is in firm size, not the number of firms, and suggests that the adjustment begins before the demand increase occurs. While we find these general results interesting, these specifications do not differentiate between highway openings with small and large spatial demand shifts. Below we find that once we do, the industry dynamics become richer.

5.1.2 Size Categories

Table 5 presents more detail regarding these patterns by looking at how the number of stations in our size categories changed around the time of highway openings. This table reports results where the dependent variable y_{it} is a vector of the number of stations in each of the four employment size categories reported in Table 3. For brevity, we show results only for zero to two leads and lags; the three leads and lags specification produces results similar to the two leads and lags one.

The results in this Table indicate that highway openings are associated with an increase the average number of "large" stations with 8-19 employees (or, after 1973, stations with 10-19 employees) Our estimates indicate that the number of large stations increased by 0.8 stations during the two years leading up to the highway opening, and in the long run increased by 1.2-1.4 stations. This is fairly large relative to the sample mean of 3.2. However, we find no evidence that highway openings are associated with a change in the number of stations in the other size categories, in particular small stations.

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[32] Before 1974, the unit of observation in the data is the "county-firm." To avoid convoluted language, we will use the term "station" to refer to our unit of observation before and after 1974. This will be supported by empirical evidence that we present below: the results do not appear to differ before and after 1974, suggesting that highway openings were associated with changes in the number and size of stations rather than stations' propensity to be part of multiestablishment firms.

The Table 4 relationship between increases in the average size of service stations and highway completion does *not* appear to be driven by a mechanism in which new highways lead to increases in the number of large stations and decreases in the number of small ones. Small stations are exiting the market throughout our sample period, but there is no evidence that the timing of their exit is related to when highways are built. This pattern is consistent with the hypothesis that sunk costs make exit decisions relatively insensitive to changes in demand, and inconsistent with our competitive benchmark in which firms enter and exit the market with changes in demand.

5.1.3 County Employment

One alternative interpretation of these patterns is that they reflect reverse causation: states could foresee which counties were about to experience a boost in local employment or population (which would also increase the demand service stations faced from locals), and systematically built highway segments so that they were completed at or around the same time as this growth. Although our reading of historical accounts indicates that the timing of Interstate Highway construction in rural counties was much more closely related to through traffic levels – and thus demand for transportation *through* the county – than to local shocks – and thus demand for transportation *in* the county, we nevertheless investigate this interpretation by investigating whether employment in the counties in our sample systematically changes around the time that highways are completed in the county.

Table 6 reports results from this exercise, which uses analogous AR specifications with ln(county employment) as the dependent variable. The estimate in the first row indicates a negative relationship between employment and highway openings that is not statistically different from zero, and adding leads and lags does not change the general picture. We therefore do not find empirical support for this "reverse causation" hypothesis: if state governments built highways around the time that they expected local economies to be growing particularly fast, one would expect to observe a relationship between employment and highway completion, but we do not find such a relationship. Although the timing of highway completion reflects decisions made by policy-makers and politicians, it does not appear to be correlated with other shocks to the local economies of the counties in our sample.

5.1.4 Do These Patterns Differ After 1973?

We next investigate whether our estimates of the relationship between highway openings and industry structure change after 1973. By doing this, we examine several hypotheses. One has to do with whether the patterns we uncover reflect firm-level or station-level effects. Recall that our data are reported at the firm level rather than the station level until 1974. The results in Tables 4 and 5 could either reflect that highway completion is associated with increases in average station size or increases in the number of stations per firm. Examining whether these results differ after 1973 sheds some light on these alternatives. If the results we showed above reflect only increases in station size, and not increases in the number of stations per firm, then one should find no difference in these results when looking through versus after 1973. In contrast, finding that the effects we uncover are significantly weaker after 1973 would provide evidence that the results we presented above reflect increases in the number of stations per firm to some extent.

A second reason for such a test is that, as we discussed above, service stations changed starting around this time – self-service stations became more prevalent, and later on, service stations started to have convenience stores. Finding that the results we uncover are stronger after 1973 would provide evidence consistent with the hypothesis that the changes we uncovered are interrelated with changes in stations' format associated with self-service or convenience stores. Finding no differences would provide no evidence consistent with this hypothesis.

Results are in Table 7. In short, there is no evidence of a significant change in β after 1973. For each specification and each equation, we fail to reject the null that the change in the vector is zero, using Wald tests of size 0.05. We therefore cannot reject the null that the patterns reflect only increases in average station size. To some extent, this reflects the simple fact that close to 90% of two-digit Interstate Highway mileage (both overall and in our subsample) had opened by the end of 1973. However, enough mileage was constructed after this time so that the test has some power, and finding no significant changes provides some evidence that Interstate Highways were having a similar impact on local service station market structure before and after this time.

5.1.5 Discussion

The estimates to this point indicate that on average, local markets adjusted to highway openings through increases in station size, and that this adjustment began two years ahead of the highway's opening. A manifestation of this is in the increase in the number of large stations. They provide a preliminary indication of the industry dynamics associated with Interstate Highway openings. On average, the margin of adjustment is on the intensive margin rather than the extensive margin, and ahead of when highways opened. These dynamics are inconsistent with those in our competitive benchmark and consistent with imperfect competition models where markups fall with entry.

The estimates also suggest that sunk costs shape industry dynamics. Recall that during our sample period, the number of large stations was increasing and the number of small stations was decreasing. Our results indicate that, at least during the time window that we investigate, highway openings are associated with an increase in large stations but there is no evidence that highway openings are associated with a decrease in the number of small stations. This fact is what one might expect in an industry where there are significant industry-specific sunk costs – the fact that it is costly to convert a service station to other purposes would lead exit to be relatively insensitive to demand shocks and competitive conditions.[33]

These patterns, while interesting, mask important differences in the margin and timing of adjustment between situations where the new highway was close to and far from the old route. We present and interpret evidence on these differences in the next section.

5.2 Highway Openings, Spatial Demand Shifts, and Industry Dynamics

We next extend the analysis by examining how the relationship between highway openings and industry structure differs, depending on how far the Interstate is from the old route.

We first run a series of simple specifications to examine whether the *margin* of adjustment differs with how far the new Interstate is from the old route, and if so whether any effects we find are nonlinear in distance from old route. Results are in Table 8; these are analogous to those in the top panel in Table 4 that include no leads or lags. We report here only the coefficients on the cumulative share of miles completed in the county and interactions between this variable and "distance from old route," since the estimates of the autoregressive coefficients are similar to those reported in the other tables. The estimates in the top panel indicate that highway openings are associated with a greater increase in the number of stations when the Interstate is farther from the old route. The estimate on the interaction in the second column is positive and significant. In the third column, we allow the distance effect to be nonlinear by including an interaction with the square of distance; the estimate on this coefficient is negative, but is not statistically significant. Within the range of our data, the linear and quadratic specifications have similar implications: no evidence of a relationship between highway openings and changes in the number of firms when "distance from old route" = 0, but a relationship that gradually increases in magnitude to about 0.025 as "distance from old route" increases to 10 miles (which is the 95th percentile "distance from old route" in our data). The bottom panel shows analogous results when examining the average employment size of service stations. In contrast to the top panel, there is no evidence of an effect that differs with "distance from old route." The long run increase of 5-6% we report above holds irrespective of distance.

Combined, these specifications indicate a systematic difference in how these local markets adjust to demand shocks: when the spatial demand shift is minimal, the industry adjusts through changes the average size but not in the number of stations. In contrast, when there is a significant spatial shift, it adjusts mainly in the number of stations. These patterns are consistent with the implications of imperfect competition models described in Section 2: demand increases that do not create new spatial segments primarily lead to increases

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[33] It is also what one might expect from watching the movie "Cars:" after all, the Radiator Springs service station had not yet exited the market, even though there apparently had been no through traffic in the town for many years.

in average firm size, but demand increases that do so are absorbed mainly by increases in the number of firms.

Table 9 shows how the *timing* of adjustment varies with the magnitude of spatial demand shifts. These results are from specifications that include leads and lags, and allow the highway opening variables to interact with "distance from old route." In addition to the coefficient estimates, we show estimates of the sum of the leads and lags, evaluated at distance = 0 and distance = 10, in the right part of the table. The main finding from these specifications is that the timing as well as the margin of adjustment is different when comparing situations where the Interstate was close to or far from the old route. This is suggested by the coefficient estimates in the middle panel: in particular, by the positive and significant coefficient estimates on the "+1 year" interaction in the number of stations regression and on the "-1 year" coefficient in the average station size regression. But it can be seen more easily in the impulse-response functions associated with these specifications, which we display in Figure 5 and which use results from the middle specification. In each of these, the three lines represent impulse-response functions evaluated at three distances: 0 miles, 1.25 miles, and 10 miles; these are at the 5th, 50th, and 95th percentiles of the distance distribution in our sample. The functions for 0 and 1.25 miles are similar: there is little change in the number of stations, but an increase in the average size of 6% during the two years leading up to the highway opening. Thereafter, the average size levels off. The function is much different for 10 miles. There is an increase in the number of stations of about 8%, starting after the highway is complete, but no significant increase in the size of stations.

The evidence in Figure 5, which concerns both the timing and margin of adjustment, reveals an interesting pattern in light of Section 2's theoretical discussions. Figure 5 indicates that, when highways do not create new spatial segments, local markets adjust through increases in firm size, and the adjustment begins before highways open. This is inconsistent with the implications of our competitive benchmark, and consistent with models of imperfect competition in which entry leads markups to fall and entry does not immediately dissipate rents associated with the demand increase. In contrast, Figure 5 indicates that, when highways are built far from the previous route and thus create new spatial segments, the adjustment is consistent with our competitive benchmark: the adjustment is in the number of firms rather than firm size, and the adjustment only begins once the new highway opens.[34] Our competitive benchmark therefore provides a reasonable depiction of industry adjustment when highways create new spatial segments: the opening of new spatial segments leads the industry to adjust through the entry of new firms that are not close substitutes to existing ones and therefore leave incumbents' pricing incentives unchanged, and entry occurs only once the demand increase begins. But it does not provide a reasonable depiction of industry adjustment when new highways increase demand without creating new spatial segments. The lessons

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[34] The fact that the margin of adjustment is in firm size and not the number of firms is also consistent with imperfect competition models (e.g., as discussed earlier, "Chamberlin-style" models) in which markups do not fall with entry.

of imperfect competition models, as outlined in Section 2, explain why: entry can lead markups to fall in the long run, thereby leading firm size to increase in equilibrium, and firms can have an incentive to expand ahead of demand either to better exploit scale effects or to influence competitors' strategic decisions.

5.3 Do the Results Change When Looking Only at Counties Where a New Highway Was Added?

In Section 4 we discussed the determinants of the location of Interstate Highways, relative to the roads they replaced. A central point of this discussion was that details of the local economy sometimes played a significant role in determining whether the new highway was built atop the old route, but played a minimal role relative to the local terrain in determining how far the new highway was from the old route, given that it did not use the old right of way. We therefore examined whether the patterns we uncover change when we look only at counties where "distance from old route" was greater than 0.5 miles – counties where little if any of the old right of way was used for the new highway. We found that the coefficient estimates were almost the same when using this 518 county sample as when we used the full sample of of 677 counties, though some of the coefficients that were statistically significant when using a test of size 0.05 are now statistically significant only when using a test of size 0.10. We report these estimates in Table A2 in the Appendix. We conclude that differences in the local economy that are correlated with highway placement are unlikely to explain our results, as these results appear when only looking at counties where the highway was located away from the old route.

5.4 Does The Timing of Adjustment Reflect Highway Openings In Other Counties in the Corridor?

The results above indicate that the adjustments to industry structure are earlier when new highway openings involve a small spatial demand shift than when they involve a large one, and that these adjustments take place before the highway opens when there is only a small spatial demand shift. One interpretation of the latter result is that it reflects highway openings in other counties along the same corridor: the demand for gasoline in a county may increase before the highway in the county is completed because the highway has been completed elsewhere in the corridor, and this has led traffic in the corridor to increase. If so, the latter result would not be evidence of expansion ahead of demand changes.

We investigate this by including $ccsmi_i$ in our specification. Table 10 shows the results. The top panel shows specifications with no leads and lags. The coefficient on $ccsmi_i$ in the number of stations regression is economically and statistically zero: the results are essentially the same as in our base specification. The story is somewhat different in the station size regression. The point estimate on $csmi_i$ declines to 0.016 (down from 0.020 in the base specification) and becomes not statistically significant; the point estimate on $ccsmi_i$ is 0.014 and not statistically significant. This specification indicates that it is difficult to separately identify the impact on station size of highway openings in a county and in a corridor.

The bottom panel, however, provides evidence that our "expansion ahead of the demand change" result does not reflect highway openings in other counties. Here we include a lead and a lag. We find that the results on $csmi_i$ are almost identical to those in Table 9; in particular, there is a positive and significant coefficient on the one-year lead that is nearly identical in magnitude to our previous result. The fact that average station size in a county increases take place ahead of highway openings in the county does not appear to reflect the opening of highway sections outside of the county.

5.5 Do Our Results Differ With the Importance of Through Traffic In the County?

Table 11 presents results where we interact $(1 - thrushare_i)$ and $thrushare_i$ with x_{it}. We find that the estimates on interactions between $thrushare_i$ and $csmi_{it}$ and $csmi_{it} * dist_i$ are similar to what we show in Table 9. In contrast, the estimates on interactions between $(1 - thrushare_i)$ and these variables look quite different; indeed, the coefficient on $csmi_{it}$ in the number of stations regression is negative and significant. As one might expect, our main results reflect changes in industry structure in counties where highway traffic is large relative to local employment. There is no evidence that either the number or size of service stations in a county increased with the highway opened in the county in counties where highway traffic is small relative to local employment, and there is some evidence that the number of stations actually decreased.

This fact lends additional evidence in support of the experiment that we envision in this paper: that highway openings represent observable, permanent demand shifts for highway-related services and that changes in market structure for service stations around the time of these openings reflect the supply response to these demand shifts. We observe changes in industry structure only in counties where through traffic is important, and thus demand changes are large. This pattern is not what one would expect if instead the relationships we revealed earlier between changes in industry structure and highway openings had other explanations that are unrelated to through-traffic-related demand changes. Along with the fact that there is no evidence that county employment changed around the time of highway openings, this provides evidence against the alternative interpretation that state officials timed highway construction such that highways were completed when local economies were receiving positive demand shocks that were unrelated to the highway.

6 Conclusion

As described in the introduction, the opening of Interstate Highway segments provides a fertile environment for studying how industries adjust to demand shocks. This paper presents evidence on the margin, timing, and magnitude of these adjustments in the case of service stations. We show how this industry, one in which a significant share of capital investments is sunk to the industry and market, adjusts and how the adjustment process differs depending on whether demand shifts spatially.

Our empirical analysis reveals that local retail gasoline markets adjusted differently, depending on whether the new highway was built far from or close to the existing route, and thus did or did not create new spatial segments. When the new highway was built far from the old route, the industry adjusted mainly through the entry of new firms, and this adjustment started only after the highway was built. This adjustment pattern corresponds closely the implications of a competitive benchmark model where firms are price takers and entry maintains prices at competitive levels at every point in time, and the margin of adjustment is consistent with typical "Chamberlin-style" imperfect competition models in which entry does not lead price-cost markups to fall. In contrast, when the new highway was built close to the old route, and thus did not create new spatial segments, the adjustment pattern was very different. The industry adjustment was mainly through increases in the size rather than the number of firms, and this adjustment began well ahead of when the new highway opened. This pattern of adjustment is consistent with imperfect competition models where markups fall with entry.

The contrast in how the industry adjusted to demand increases when new highways did and did not create new spatial segments illustrates differences in how the industry dynamics play out in these circumstances. It suggests that demand increases are strategically important – in the sense that they create new incentives with respect to pricing and entry – in circumstances where they do not create new spatial segments. In our sample, they led firms to increase their size, and do so ahead of the demand increase. It suggests that they are less strategically important in circumstances where they do create new spatial segments. In our sample, firms became no bigger, and entry tended to track the timing of the increase in demand. Strategic incentives with respect to pricing and entry vary across the different models that economists apply to understand industry structure and how it evolves. Along with illustrating how retail gasoline markets adjusted to the largest highway building project in U. S. history, our analysis provides a first set of systematic evidence that can guide the application of these models more broadly. It indicates that models where strategic factors are important potentially apply well to understanding how industries where product space has well-defined boundaries, and thus new products are close substitutes to existing products, adjust to permanent, anticipated demand shocks but models where strategic factors are less important – such as our competitive benchmark – potentially apply well to understanding the adjustment of industries where the boundaries of product space is less defined and thus new products need not be close substitutes to existing ones.

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8 Appendix

8.1 Definition of Corridors

Defining corridors first involves establishing the locations where corridors begin and end. These locations include most prominently major cities. After various trial definitions, we found that a useful and parsimonious way to generate a set of cities that serve as corridor endpoints is to look at the U.S. map in a standard road atlas. We found that cities listed in bold provided reasonable endpoints in the vast majority of cases. We spoke to cartographers at the firm that produced the map, and asked the criteria for including a city in bold. We learned that all cities in bold have at least 100,000 population (for the map we use, in 1996), but not all cities that exceed this level are included on the map – suburban cities (e.g., Fullerton, CA) are excluded both because they are not major destinations and because including them would make the map cluttered. We asked the criteria for including these cities and were told "cartographic license."

In any case, this rule produces a very useful set of cities; central cities with at least 100,000 population. A list of these cities is in Table A1.

In addition, we included the beginning and end of interstate highways as corridor endpoints, when the beginning or end of a highway (a) was not in a endpoint city, and (b) did not end at a junction with an interstate with the same orientation. One example of a corridor endpoint that satisfies this is Interstate 5's northern terminus at the Canadian border. Another is Interstate 4's northern terminus at its intersection with Interstate 95; this is an intersection between a (even-numbered) east-west route and an (odd-numbered) north-south route.

Within cities, we defined the beginning/end of the corridor to be at major intersections. The most common situation is where two interstates intersect near the heart of a city; when this occurs we use the interstate intersection as the placement for the node. (Sometimes the interstate intersection close to downtown is with a 3-digit highway.) In cities where there is a "dual-signed" segment where a single road is part of two two-digit interstate highways (e.g., Interstate 5-Interstate 10 in downtown Los Angeles), we use one of the endpoints of this dual-signed section. Where there is no interstate intersection near downtown, we use an important intersection close to downtown.

This produces an easy division of some Interstate Highways into distinct corridors. For example, it divides Interstate 25 into 4 corridors: start-Albuquerque, Albuquerque-Colorado Springs, Colorado Springs-Denver, and Denver-end. This is simple because every mile of Interstate 25 belongs to only one corridor.

8.2 Highway Segments and Multiple Corridors

Some segments of the interstate highway system belong to multiple corridors. The most common examples of this occur when an east-west interstate divides into two east-west interstates, and this division takes place outside one of our city endpoints: forks in the road. For example, Interstate 10 west of Tucson divides between Interstate 8, which goes to San Diego, and Interstate 10, which goes to Phoenix. The stretch of Interstate 10 that is west of Tucson but east of this fork is part of two corridors: Phoenix-Tucson and San Diego-Tucson. Another example of this is when highways merge then separate. For example, Interstate 70 and Interstate 76 come together southeast of Pittsburgh, continue together for a long stretch, then split. The "I70-I76" stretch is part of four corridors: Pittsburgh-Philadelphia, Pittsburgh-Baltimore, Columbus-Philadelphia, and Columbus-Baltimore. The adjacent segments are each part of two corridors; for example, the stretch of Interstate 76 west of this dual signed stretch is part of Pittsburgh-Philadelphia and Pittsburgh-Baltimore. This pattern is common within metropolitan areas, albeit for much shorter stretches than I70-I76; as noted above, Interstate 5-Interstate 10 in Los Angeles is an example.

A full list of highway stretches that are part of multiple corridors, and the corridors to which they are assigned, is available upon request from the authors.

8.3 Measuring Corridor Completion When Segments Are Part of Multiple Corridors

An issue arises with respect to how to quantify how much of the corridor is complete in a county when highway segments are part of multiple corridors. For example, consider a county on Interstate 10 west of Tucson. This stretch of Interstate 10 is part of both Phoenix-Tucson and San Diego-Tucson. We construct our measure of corridor completion by first calculating the cumulative share of construction along each corridor, then weighting construction along the two corridors according to the traffic volume on each of the branches, measured at a point as close as possible to the "fork in the road;" in this case, traffic volumes on Interstate 8 and Interstate 8 just west of where Interstate 10 splits into these two roads. We compute corridor-level construction variables analogously for all counties that are part of multiple corridors.

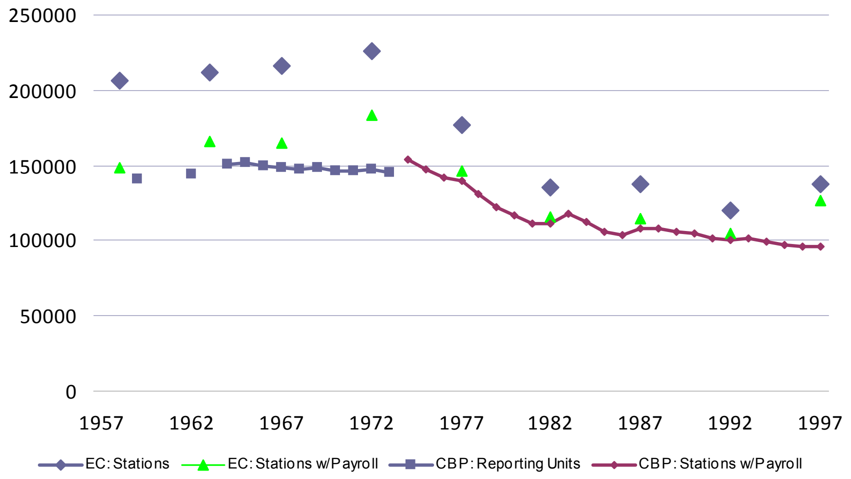


Figure 1. Service Stations in the United States. This Figure depicts Census counts of the number of service stations in the United States, and subsets thereof; these come from the Economic Census (EC) and County Business Patterns (CBP). The EC series show that the number of stations increased from the late 1950s to the early 1970s, then dropped sharply from then until the early 1980s. The CBP figures report the number of firms operating in each county before 1974, then the number of stations thereafter. The former falls relative to the EC-reported number of stations during the late 1960s and early 1970s, indicating that an increasing share of stations were owned by firms that operated other stations in the same county.

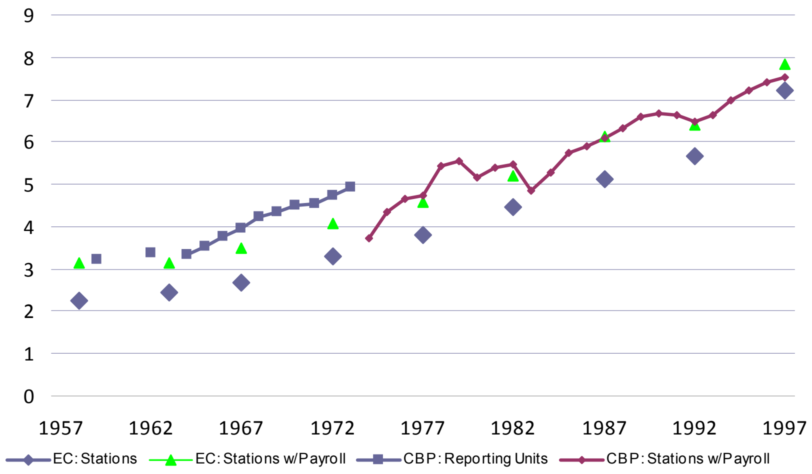


Figure 2. The Employment Size of Service Stations in the United States. This Figure depicts various measures of the employment size of service stations using data from the Economic Census (EC) and County Business Patterns (CBP). The EC series, which report employees per station using all stations and only stations with positive payroll, show that station size increased steadily throughout our sample period, increasing from 2.5 in 1964 to 5.6 in 1992. The CBP series report employees per "reporting unit" (firm*county) before 1974, then employees per station thereafter. The former increases by more than employees per station during the late 1960s and early 1970s. Combined, the Figure indicates that stations' employment size roughly doubled between 1964-1992, and that about 1/4 of the increase in within-county firm size between 1964-1973 is accounted for by an increase in the share of firms that operated multiple stations in the same county.

Service Station Size, Characteristics

	Gallons/ Station	Gallons/ Pump	Pumps/ Station	Employees/ Pump	Share Self-Service Sales
1972	360.7	68.0	5.3	0.77	
1977	508.8	97.4	5.2	0.88	30%
1982	543.1	90.2	6.0	0.86	63%
1987	697.4	97.1	7.2	0.85	75%
1992	802.8	110.8	7.2	0.88	91%
Change 1972-1992	123%	63%	37%	15%	

Share of Revenues by Product Category

	Fuel, Oil	Tires, Parts	Food, Alcohol, Tobacco	Other
1972	82%	10%	2%	6%
1977	85%	5%	4%	6%
1982	88%	3%	5%	4%
1987	81%	2%	12%	6%
1992	79%	2%	15%	5%

Source: Census of Retail Trade, Various Years.

Table 1. Service Station Size, Characteristics, and Revenue Sources. This Table reports how service stations' business and characteristics have changed between 1972-1992, using data from the Economic Census. Gallons per station more than doubled, reflecting increases in both gallons per pump and pumps per station. Employees per pump was constant starting in 1977. The self-service share of sales steadily increased to 91% by 1992. Automotive parts and accessories' share of station revenues decline between 1972-1982. The increase in convenience store-related sales increased sharply starting in 1982.

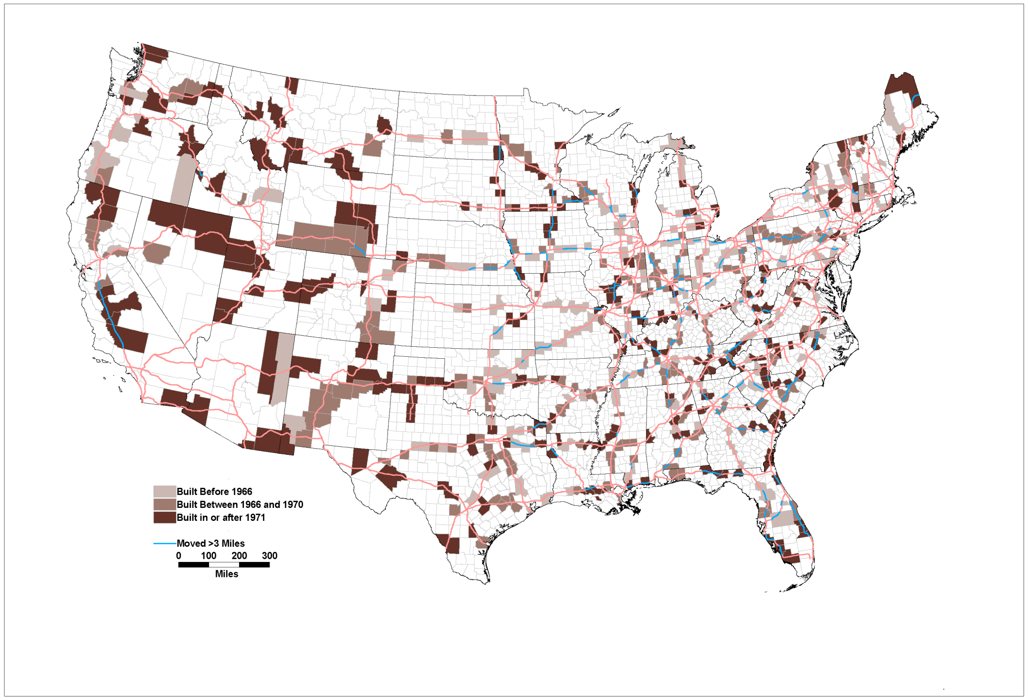


Figure 3. Sample Counties, Timing of Highway Completion, Distance from Old Route.

	All Two-Digit Highways		*Two-Digit Highways In Balanced Panel Counties*	
Year	Cumulative Miles	Share of Total	Cumulative Miles	Share of Total
1960	7732	20%	3494	19%
1965	19423	50%	9273	49%
1970	29260	76%	14334	76%
1975	34884	90%	17138	91%
1980	37238	96%	18119	96%
1985	38065	98%	18571	99%
1990	38597	100%	18785	100%
1992	38665	100%	18833	100%

Table 2. Two-Digit Interstate Highway Completion. This Table depicts cumulative completed mileage of construction of "two-digit" Interstate Highways in all U.S. counties, and for the 677 counties in our balanced panel. Most of the mileage was completed during the 1960s and 1970s. The pace of highway completion in our balanced panel counties was similar to that overall.

Number of Firms/County

		by Employment Size Category			
	Total	1-3	4-7	8-19	20 or more
1964	45.8	35.7	7.6	2.2	0.4
1965	45.9	34.7	8.4	2.4	0.5
1966	45.8	33.4	9.1	2.8	0.5
1967	45.2	31.8	9.8	3.0	0.6
1968	45.2	30.3	10.7	3.5	0.7
1969	46.0	30.2	11.4	3.8	0.7
1970	45.3	29.2	11.5	3.9	0.7
1971	45.3	29.1	11.7	3.8	0.8
1972	45.7	27.9	12.6	4.3	0.8
1973	44.9	26.4	12.8	4.8	0.9

Number of Service Stations/County

		by Employment Size Category			
	Total	1-4	5-9	10-19	20 or more
1974	47.4	37.9	7.4	1.6	0.6
1975	44.9	33.3	9.0	2.0	0.6
1976	43.5	31.4	9.2	2.3	0.6
1977	43.3	30.8	9.7	2.2	0.6
1978	40.4	26.4	10.3	3.0	0.8
1979	37.6	23.7	10.2	2.8	0.9
1980	35.6	24.0	8.6	2.2	0.9
1981	33.8	22.2	8.7	2.2	0.7
1982	33.7	21.5	9.0	2.5	0.8
1983	35.9	23.0	9.7	2.5	0.7
1984	34.0	20.5	10.1	2.5	0.8
1985	32.1	18.3	9.9	3.0	1.0
1986	31.5	17.6	9.7	3.2	1.0
1987	33.6	18.2	10.6	3.6	1.1
1988	34.1	16.8	12.0	4.2	1.1
1989	33.4	15.8	11.8	4.5	1.3
1990	33.3	15.1	12.1	4.7	1.3
1991	32.4	14.9	11.7	4.5	1.4
1992	31.9	13.8	12.3	4.6	1.2

Table 3. Number of Firms and Service Stations per County, Overall and by Employment Size Category. This Table depicts the average number of firms per county (in 1964-1973) and service stations per county (in 1974-1992) for counties in our balanced panel. Between 1964 and 1973, there is a decrease in the number of small firms and an increase in the number of larger firms. Between 1974 and 1992, the average number of service stations decreased by one-third, reflecting a large decrease in the number of small stations and a smaller increase in the number of large ones.

	Date of Highway Completion	
	Before 1966	After 1971
1964	3.0	2.9
1965	3.2	3.1
1966	3.5	3.2
1967	3.6	3.4
1968	3.9	3.6
1969	4.0	3.7
1970	4.2	3.9
1971	4.3	3.9
1972	4.4	4.2
1973	4.7	4.4
1974	3.6	3.4
1975	4.2	4.0
1976	4.5	4.3
1977	4.7	4.3
1978	5.4	5.1
1979	5.6	5.3
1980	5.3	5.0
1981	5.4	5.2
1982	5.5	5.3
1983	4.8	4.8
1984	5.2	5.2
1985	5.6	5.8
1986	5.7	6.0
1987	6.0	6.2
1988	6.4	6.5
1989	6.7	6.9
1990	6.9	7.0
1991	6.7	7.1
1992	6.7	7.0

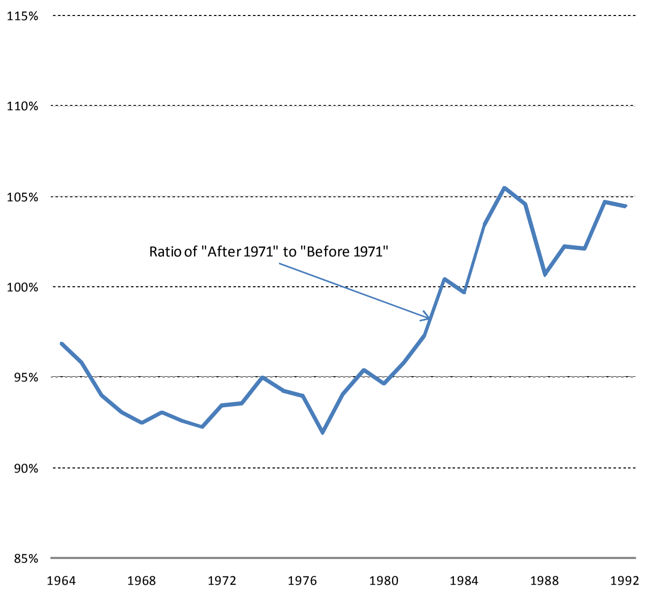


Figure 4. Average Employment Size of Firms/Stations, by Year and Date of Highway Completion in County. This Table depicts average employment per firm (in 1964-1973) and employment per station (in 1974-1992) for counties in our balanced panel with nonmissing employment for each sample year (N = 470). Highway completion is "early" if completed in the county before 1966, and "late" if completed after 1971. N=167 and 153 for early and late counties, respectively. The Table shows that while the employment size of firms and stations increased in each of these categories, it took place earlier for the "early" counties than the "late" counties.

Table 4
VARs of the Number and Average Employment Size of Service Stations on Highway Openings

	Autoregressive Coefficients		Cumulative Share of Highway Opened in County Distributed Lag: Years From Highway Opening							Sum of Lag Coefficients
	ln(nit-1)	ln(ait-1)	-3	-2	-1	0	1	2	3	
No Leads or Lags										
ln(nit)	**0.768**	**0.029**				0.002				0.002
	(0.005)	**(0.004)**				(0.005)				(0.005)
ln(ait)	**0.032**	**0.638**				**0.019**				**0.019**
	(0.007)	**(0.006)**				**(0.007)**				**(0.007)**
One Lead and Lag										
ln(nit)	**0.766**	**0.032**			-0.006	-0.003	0.011			0.003
	(0.005)	**(0.004)**			(0.011)	(0.014)	(0.010)			(0.006)
ln(ait)	**-0.035**	**0.635**			**0.030**	0.002	-0.010			**0.022**
	(0.007)	**(0.006)**			**(0.015)**	(0.019)	(0.013)			**(0.008)**
Two Leads and Lags										
ln(nit)	**0.754**	**0.033**		-0.010	0.003	-0.001	0.009	0.002		0.002
	(0.005)	**(0.005)**		(0.013)	(0.016)	(0.015)	(0.014)	(0.010)		(0.007)
ln(ait)	**0.040**	**0.618**		0.011	0.018	0.007	-0.036	0.025		**0.025**
	(0.008)	**(0.007)**		(0.018)	(0.022)	(0.021)	(0.019)	(0.013)		**(0.009)**
Three Leads and Lags										
ln(nit)	**0.737**	**0.032**	-0.022	0.019	-0.013	0.000	0.015	0.007	-0.012	-0.007
	(0.006)	**(0.005)**	(0.015)	(0.019)	(0.018)	(0.016)	(0.015)	(0.014)	(0.009)	(0.008)
ln(ait)	**0.039**	**0.598**	-0.001	0.013	0.016	0.013	-0.055	0.032	0.006	**0.024**
	(0.008)	**(0.007)**	(0.021)	(0.026)	(0.025)	(0.023)	(0.021)	(0.020)	(0.013)	**(0.012)**

These results are from county-level VAR specifications that relate the number of service stations and the average employment size of service stations to Interstate highway openings.
The specifications also include county and year fixed effects (not reported). We also allow the autoregressive coefficients to differ in year 1974 to accommodate Census' change in reporting units between 1973 and 1974.

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, N=677.
Standard errors are in parentheses; bold indicates that the estimates is statistically significantly different zero using a test of size 0.05.

Table 5
VARs of the Number of Service Stations in Employment Size Categories on Highway Openings

	Autoregressive Coefficients				Cumulatiive Share of Highway Opened in County Distributed Lag: Years from Highway Opening					Sum of Lag Coefficients
	s1	s2	s3	s4	-2	-1	0	1	2	
No Leads or Lags										
s1	**0.802**	**0.149**	-0.017	-0.063			0.179			0.179
	(0.004)	**(0.007)**	(0.015)	(0.036)			(0.156)			(0.156)
s2	**0.077**	**0.650**	**0.271**	**0.114**			0.080			0.080
	(0.003)	**(0.006)**	**(0.011)**	**(0.026)**			(0.110)			(0.110)
s3	**-0.005**	**0.082**	**0.579**	**0.325**			**0.234**			**0.234**
	(0.002)	**(0.003)**	**(0.006)**	**(0.015)**			**(0.064)**			**(0.064)**
s4	**-0.002**	-0.001	**0.063**	**0.519**			0.010			0.010
	(0.001)	(0.001)	**(0.003)**	**(0.006)**			(0.028)			(0.028)
One Lead and Lag										
s1	**0.794**	**0.158**	-0.001	-0.021		0.214	-0.401	-0.450		0.263
	(0.004)	**(0.008)**	(0.016)	(0.038)		(0.333)	(0.429)	(0.295)		(0.172)
s2	**0.079**	**0.640**	**0.268**	**0.144**		0.008	-0.088	0.193		0.113
	(0.003)	**(0.006)**	**(0.011)**	**(0.027)**		(0.236)	(0.303)	(0.208)		(0.122)
s3	**-0.004**	**0.086**	**0.573**	**0.293**		**0.304**	-0.052	0.038		**0.290**
	(0.002)	**(0.003)**	**(0.006)**	**(0.016)**		**(0.136)**	(0.175)	(0.121)		**(0.070)**
s4	**-0.004**	**-0.003**	**0.064**	**0.545**		0.020	-0.031	0.031		0.020
	(0.001)	**(0.001)**	**(0.003)**	**(0.007)**		(0.058)	(0.074)	(0.051)		(0.030)
Two Leads and Lags										
s1	**0.778**	**0.172**	0.010	-0.007	0.035	0.336	-0.428	0.273	0.017	0.232
	(0.004)	**(0.009)**	(0.017)	(0.040)	(0.384)	(0.489)	(0.459)	(0.431)	(0.298)	(0.206)
s2	**0.082**	**0.622**	**0.277**	**0.179**	-0.058	-0.143	-0.071	0.358	0.031	0.117
	(0.003)	**(0.006)**	**(0.012)**	**(0.029)**	(0.271)	(0.345)	(0.325)	(0.305)	(0.210)	(0.145)
s3	**-0.006**	**0.083**	**0.569**	**0.303**	**0.408**	0.022	-0.016	-0.183	0.226	**0.457**
	(0.002)	**(0.004)**	**(0.007)**	**(0.016)**	**(0.156)**	(0.198)	(0.186)	(0.175)	(0.121)	**(0.083)**
s4	**-0.003**	0.002	**0.059**	**0.525**	-0.065	0.104	-0.031	-0.040	0.052	0.021
	(0.001)	(0.002)	**(0.003)**	**(0.007)**	(0.066)	(0.084)	(0.079)	(0.074)	(0.051)	(0.035)

These results are from county-level VAR specifications that relate the number of service stations in different size categories to the share of interstate highway mileage in the county that had opened by year t. S1, S2, S3, and S4 consist of firms with 1-3, 4-7, 8-19, and 20 or more employees in the county (these categories are 1-4, 5-9, 10-19, and 20 or more after 1974).

Table 6
Regressions of County Employment on Highway Openings

	Autoregressive Coefficients	Cumulative Share of Highway Opened in County Distributed Lag: Years From Highway Opening							Sum of Lag Coefficients
	ln(county employment, it-1)	-3	-2	-1	0	1	2	3	
No Leads or Lags									
ln(county employment, it)	**0.916**				-0.004				-0.004
	(0.003)				(0.003)				(0.003)
One Lead and Lag									
ln(county employment, it)	**0.913**			0.007	-0.009	0.000			-0.002
	(0.003)			(0.006)	(0.008)	(0.005)			(0.003)
Two Leads and Lags									
ln(county employment, it)	**0.906**		-0.002	0.006	-0.005	-0.012	**0.015**		0.000
	(0.003)		(0.007)	(0.008)	(0.008)	(0.007)	**(0.005)**		(0.004)
Three Leads and Lags									
ln(county employment, it)	**0.894**	0.003	-0.008	0.010	-0.001	-0.019	0.013	0.003	0.004
	(0.004)	(0.008)	(0.010)	(0.010)	(0.009)	(0.008)	(0.008)	(0.006)	(0.009)

These results are from county-level AR specifications that relate county employment to Interstate Highway openings.

The specifications also include county and year fixed effects (not reported). We also allow the

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, N=677.
Standard errors are in parentheses; bold indicates that the estimate is statistically significantly different zero using a test of size 0.05.

Table 7

VARs of the Number and Average Employment Size of Service Stations on Highway Openings

Interactions with Post 73 Dummy

Autoregressive Coefficients			Cumulative Share of Highway Opened in County Distributed Lag: Years from Highway Opening					Post 73*Cumulative Share of Highway Opened in County Distributed Lag: Years from Highway Opening				
	ln(nit-1)	ln(ait-1)	-2	-1	0	1	2	-2	-1	0	1	2
No Leads or Lags												
ln(nit)	**0.768**	**0.029**			-0.001					0.013		
	(0.005)	**(0.004)**			(0.005)					(0.011)		
ln(ait)	**0.032**	**0.638**			**0.020**					-0.007		
	(0.007)	**(0.006)**			**(0.007)**					(0.016)		
One Lead and Lag												
ln(nit)	**0.766**	**0.032**		-0.006	-0.003	0.009			0.009	0.002	0.008	
	(0.005)	**(0.004)**		(0.012)	(0.015)	(0.010)			(0.017)	(0.021)	(0.017)	
ln(ait)	**0.039**	**0.617**		**0.035**	0.002	-0.013			-0.024	0.002	0.020	
	(0.008)	**(0.007)**		**(0.016)**	(0.020)	(0.014)			(0.023)	(0.029)	(0.023)	
Two Leads and Lags												
ln(nit)	**0.754**	**0.033**	0.005	-0.008	-0.001	0.008	0.000	-0.043	0.040	0.001	0.000	0.010
	(0.005)	**(0.005)**	(0.014)	(0.017)	(0.016)	(0.015)	(0.010)	(0.017)	(0.022)	(0.021)	(0.021)	(0.017)
ln(ait)	**0.039**	**0.618**	0.004	0.029	0.008	-0.032	0.017	0.025	-0.038	-0.003	-0.009	0.044
	(0.008)	**(0.006)**	(0.019)	(0.024)	(0.022)	(0.021)	(0.014)	(0.024)	(0.030)	(0.030)	(0.029)	(0.025)

These results are from county-level VAR specifications that relate the number of service stations and the average employment size of service stations to Interstate highway openings.
The specifications also include county and year fixed effects (not reported). We also allow the autoregressive coefficients to differ in year 1974 to accommodate Census' change in reporting units between 1973 and 1974.

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, N=677.
Standard errors are in parentheses; bold indicates that the estimates is statistically significantly different zero using a test of size 0.05.

Table 8
Interaction Specifications with Distance From Old Route: No Leads or Lags

Dependent Variable: ln(nit)			
Cumulative Share of Highway Opened ("CSHO")	0.002	-0.006	-0.013
	(0.005)	(0.006)	(0.008)
CSHO*distance from old route		**0.0027**	**0.0076**
		(0.0012)	**(0.0035)**
CSHO*(distance from old route)^2			-0.0004
			(0.0002)

Dependent Variable: ln(ait)			
Cumulative Share of Highway Opened ("CSHO")	**0.019**	**0.019**	0.016
	(0.007)	**(0.008)**	(0.011)
CSHO*distance from old route		-0.0002	0.0022
		(0.0017)	(0.0049)
CSHO*(distance from old route)^2			-0.0002
			(0.0003)

These results are from county-level interactions that relate the number of service stations and the average employment size of service stations to interstate highway openings.

The first column is the same as the top panel of Table 4. The second and third interact the cumulative share of highway opened in the county (CSHO) with the average distance between the interstate and the old route that it replaced in the county.

The results indicate that highway openings have a stronger effect on the number of firms when the old route is farther from the interstate, and that distance has a diminishing incremental effect. In contrast, there is no evidence the relationship between average service station size and highway openings varies with distance from old route.

Table 9

VARs of the Number and Average Employment Size of Service Stations on Highway Openings

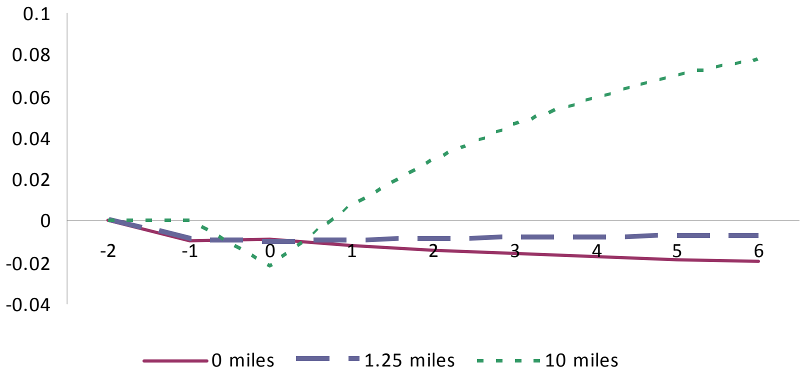
Distance Interactions, Two Leads and Lags

	Autoregressive Coefficients		Cumulative Share of Highway Opened in County Distributed Lag: Years from Highway Opening					Distance*Cumulative Share of Highway Opened in County Distributed Lag: Years from Highway Opening					Sum of Lag Coefficients	
	ln(nit-1)	ln(ait-1)	-2	-1	0	1	2	-2	-1	0	1	2	d=0	d=10
No Leads or Lags														
ln(nit)	**0.768**	**0.030**			-0.006					**0.003**			-0.005	**0.021**
	(0.005)	**(0.004)**			(0.006)					**(0.001)**			(0.006)	**(0.010)**
ln(ait)	**0.039**	**0.617**			**0.020**					0.000			**0.020**	0.018
	(0.008)	**(0.007)**			**(0.009)**					(0.002)			**(0.009)**	(0.014)
One Lead and Lag														
ln(nit)	**0.765**	**0.032**		-0.010	0.007	-0.005			0.001	-0.003	**0.005**		-0.007	**0.024**
	(0.005)	**(0.004)**		(0.015)	(0.018)	(0.013)			(0.003)	(0.005)	**(0.002)**		(0.007)	**(0.011)**
ln(ait)	**0.039**	**0.617**		**0.054**	-0.016	-0.011			-0.008	0.006	0.000		**0.028**	0.010
	(0.008)	**(0.007)**		**(0.020)**	(0.026)	(0.017)			(0.005)	(0.005)	(0.003)		**(0.010)**	(0.015)
Two Leads and Lags														
ln(nit)	**0.754**	**0.033**	-0.010	-0.010	0.016	-0.010	-0.003	0.000	0.001	-0.005	0.006	0.001	-0.008	0.024
	(0.005)	**(0.005)**	(0.017)	(0.021)	(0.020)	(0.188)	(0.013)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)	(0.009)	(0.013)
ln(ait)	**0.039**	**0.617**	0.025	0.038	-0.011	-0.028	0.010	-0.005	-0.007	0.006	-0.002	0.005	**0.035**	0.005
	(0.008)	**(0.007)**	(0.024)	(0.030)	(0.028)	(0.026)	(0.018)	(0.005)	(0.006)	(0.006)	(0.005)	(0.003)	**(0.012)**	(0.018)

These results are from county-level VAR specifications that relate the number of service stations and the average employment size of service stations to Interstate highway openings.
The specifications also include county and year fixed effects (not reported). We also allow the autoregressive coefficients to differ in year 1974 to accommodate Census' change in reporting units between 1973 and 1974.

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, N=677.
Standard errors are in parentheses; bold indicates that the estimates is statistically significantly different zero using a test of size 0.05.

Number of Service Stations and
Year From Interstate Highway Opening



Average Service Station Employment Size and
Year From Interstate Highway Opening

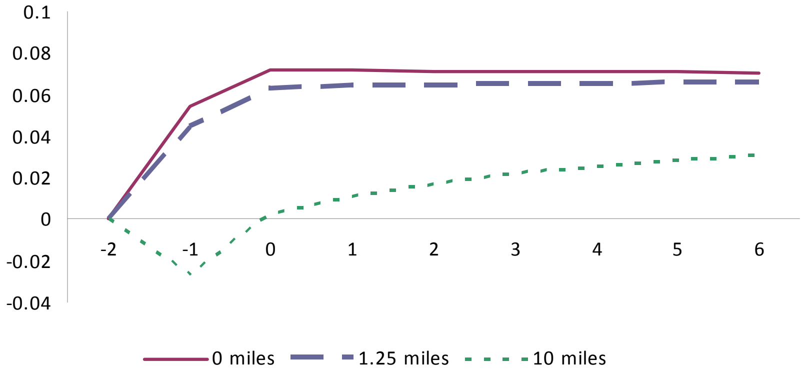


Figure 5. Impulse-Response Functions for Highway Openings on Market Structure of Service Stations, by Distance from Old Route. These graphs depict how the number and average size of service stations change around the time that Interstate Highway segments are completed in a county, and how this differs with how close the Interstate is from the previous route. The vertical axes scaled in log-points; 0.04 represents a 4% increase. The horizontal axis is years from segment completion; "-2" means two years before a segment is completed. These graphs illustrate that when the Interstate was close to the old route, the industry adjustment was in an increase in average station size during the two years preceding the new highway's completion. When it was far, the adjustment was an increase in the number of stations that took place after the new highway was completed.

Table 10

VARs of the Number and Average Employment Size of Service Stations on Highway Openings

Distance Interactions, One Lead and Lag

	Autoregressive Coefficients		Cumulative Share of Highway Opened in Corridor			Cumulative Share of Highway Opened in County			Cumulative Share of Highway Opened in County*Distance			Sum of Lag Coefficients	
	ln(nit-1)	ln(ait-1)	-1	0	1	-1	0	1	-1	0	1	d=0	d=10
No Leads or Lags													
ln(nit)	**0.768**	**0.030**		0.005			-0.008			**0.003**		0.005	0.019
	(0.005)	**(0.004)**		(0.010)			(0.007)			**(0.001)**		(0.010)	(0.010)
ln(ait)	**0.031**	**0.637**		0.014			0.016			0.000		0.016	0.012
	(0.007)	**(0.006)**		(0.014)			(0.010)			(0.002)		(0.010)	(0.015)
One Lead and Lag													
ln(nit)	**0.765**	**0.032**	-0.025	0.009	0.011	-0.006	0.009	-0.008	0.001	-0.002	0.005	-0.004	**0.026**
	(0.005)	**(0.004)**	(0.019)	(0.022)	(0.016)	(0.015)	(0.019)	(0.013)	(0.003)	(0.004)	(0.002)	(0.008)	**(0.012)**
ln(ait)	**0.034**	**0.634**	0.001	0.009	0.009	**0.052**	-0.013	-0.019	-0.008	0.006	0.000	0.021	0.001
	(0.007)	**(0.006)**	(0.027)	(0.031)	(0.023)	**(0.020)**	(0.026)	(0.018)	(0.005)	(0.006)	(0.003)	(0.012)	(0.016)

These results are from county-level VAR specifications that relate the number of service stations and
the average employment size of service stations to Interstate highway openings.
The specifications also include county and year fixed effects (not reported). We also allow the
autoregressive coefficients to differ in year 1974 to accommodate Census' change in reporting units between 1973 and 1974.

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, N=677.
Standard errors are in parentheses; bold indicates that the estimates is statistically significantly different zero using a test of size 0.05.

Table 11
VARs of the Number and Average Employment Size of Service Stations on Highway Openings

Distance Interactions, One Lead and Lag

	Autoregressive Coefficients		Cumulative Share of Highway Opened in County			Cumulative Share of Highway Opened in County*Distance			Sum of Dist. Lags: County	
	ln(nit-1)	ln(ait-1)	-1	0	1	-1	0	1	d=0	d=10
No Leads or Lags										
				Interactions with "thrushare"						
ln(nit)	**0.766**	**0.029**		0.017			**0.005**		0.017	**0.071**
	(0.005)	**(0.004)**		(0.012)			**(0.003)**		(0.012)	**(0.020)**
ln(ait)	**0.030**	**0.636**		**0.067**			-0.005		**0.067**	0.019
	(0.007)	**(0.006)**		**(0.017)**			(0.004)		**(0.017)**	(0.028)
				Interactions with (1-"thrushare")						
ln(nit)				**-0.034**			-0.001		**-0.034**	-0.044
				(0.015)			(0.003)		**(0.015)**	(0.026)
ln(ait)				-0.037			0.006		-0.037	0.019
				(0.020)			(0.005)		(0.020)	(0.035)
One Lead and Lag										
				Interactions with "thrushare"						
ln(nit)	**0.764**	**0.032**	0.011	-0.020	0.029	0.003	-0.001	0.004	0.019	**0.079**
	(0.005)	**(0.004)**	(0.030)	(0.039)	(0.026)	(0.007)	(0.008)	(0.005)	(0.014)	**(0.022)**
ln(ait)	**0.032**	**0.633**	0.077	-0.023	0.024	**-0.023**	0.012	0.002	**0.077**	-0.016
	(0.007)	**(0.006)**	(0.042)	(0.054)	0.036	**(0.009)**	(0.010)	(0.007)	**(0.018)**	(0.031)
				Interactions with (1-"thrushare")						
ln(nit)			-0.030	0.038	-0.046	-0.003	-0.004	0.005	**-0.038**	-0.049
			(0.038)	(0.049)	(0.033)	(0.009)	(0.011)	(0.007)	**(0.016)**	(0.028)
ln(ait)			0.018	0.004	-0.057	0.014	-0.003	-0.003	-0.036	0.044
			(0.053)	(0.068)	(0.046)	(0.012)	(0.015)	(0.011)	(0.023)	(0.039)

These results are from county-level VAR specifications that relate the number of service stations and the average employment size of service stations to Interstate highway openings.
The specifications also include county and year fixed effects (not reported). We also allow the autoregressive coefficients to differ in year 1974 to accommodate Census' change in reporting units between 1973 and 1974.

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, N=677.
Standard errors are in parentheses; bold indicates that the estimates is statistically significantly different zero using a test of size 0.05.

Table A1
Cities that Are Corridor Endpoints

Abilene, TX
Akron, OH
Albany, NY
Albuquerque, NM
Allentown, PA
Amarillo, TX
Ann Arbor, MI
Atlanta, GA
Austin, TX
Baltimore, MD
Baton Rouge, LA
Beaumont, TX
Birmingham, AL
Boise, ID
Boston, MA
Bridgeport, CT
Buffalo, NY
Charlotte, NC
Chattanooga, TN
Chicago, IL
Cincinnati, OH
Cleveland, OH
Colorado Springs, CO
Columbia, SC
Columbus, OH
Corpus Christi, TX
Dallas, TX
Dayton, OH
Denver, CO
Des Moines, IA
Detroit, MI
Durham, NC
El Paso, TX
Erie, PA
Eugene, OR
Flint, MI
Fort Lauderdale, FL
Fort Wayne, IN
Fort Worth, TX
Gary, IN
Grand Rapids, MI
Greensboro, NC
Hartford, CT
Houston, TX
Indianapolis, IN
Jackson, MS
Jacksonville, FL
Kansas City, MO
Knoxville, TN
Lafayette, LA
Lansing, MI
Laredo, TX
Las Vegas, NV
Lexington, KY
Lincoln, NE
Little Rock, AR
Los Angeles, CA
Louisville, KY
Lubbock, TX
Macon, GA
Madison, WI
Memphis, TN
Miami, FL
Milwaukee, WI
Minneapolis, MN
Mobile, AL
Montgomery, AL
Nashville, TN
New Haven, CT
New Orleans, LA
New York, NY
Newark, NJ
Norfolk, VA
Oklahoma City, OK
Omaha, NE
Orlando, FL
Peoria, IL
Philadelphia, PA
Phoenix, AZ
Pittsburgh, PA
Portland, OR
Providence, RI
Raleigh, NC
Reno, NV
Richmond, VA
Rockford, IL
Sacramento, CA
Salem, OR
Salt Lake City, UT
San Antonio, TX
San Bernardino, CA
San Diego, CA
San Francisco, CA
Savannah, GA
Seattle, WA
Shreveport, LA
Sioux Falls, SD
South Bend, IN
Spokane, WA
Springfield, IL
Springfield, MO
St. Louis, MO
Stockton, CA
Syracuse, NY
Tacoma, WA
Tallahassee, FL
Tampa, FL
Toledo, OH
Topeka, KS
Tucson, AZ
Tulsa, OK
Waco, TX
Washington, DC
Wichita, KS
Winston Salem, NC

Table A2

VARs of the Number and Average Employment Size of Service Stations on Highway Openings

Distance Interactions, Includes Only Counties Where Distance From Old Route Is Greater Than 1/2 Mile

	Autoregressive Coefficients		Cumulative Share of Highway Opened in County Distributed Lag: Years from Highway Opening					Distance*Cumulative Share of Highway Opened in County Distributed Lag: Years from Highway Opening					Sum of Lag Coefficients	
	ln(nit-1)	ln(ait-1)	-2	-1	0	1	2	-2	-1	0	1	2	d=0	d=10
No Leads or Lags														
ln(nit)	**0.767**	**0.032**			-0.006					0.002			-0.006	0.018
	(0.006)	**(0.005)**			(0.007)					(0.001)			(0.007)	(0.010)
ln(ait)	**0.027**	**0.635**			0.020					-0.001			0.020	0.013
	(0.008)	**(0.007)**			(0.010)					(0.001)			(0.010)	(0.014)
One Lead and Lag														
ln(nit)	**0.766**	**0.035**		-0.018	0.025	-0.014			0.002	-0.006	**0.006**		-0.007	0.020
	(0.006)	**(0.005)**		(0.017)	(0.021)	(0.014)			(0.003)	(0.004)	**(0.003)**		(0.008)	(0.011)
ln(ait)	**0.030**	**0.632**		**0.060**	-0.014	-0.019			-0.009	0.006	0.001		**0.026**	0.003
	(0.008)	**(0.007)**		**(0.023)**	(0.030)	(0.020)			(0.005)	(0.006)	(0.003)		**(0.011)**	(0.015)

These results are from county-level VAR specifications that relate the number of service stations and the average employment size of service stations to Interstate highway openings.
The specifications also include county and year fixed effects (not reported). We also allow the autoregressive coefficients to differ in year 1974 to accommodate Census' change in reporting units between 1973 and 1974.

These results use all counties with non-missing reports for number of firms/establishments from 1964-1992, and for which distance from old route > 1/2 mile, N=518.
Standard errors are in parentheses; bold indicates that the estimates is statistically significantly different zero using a test of size 0.05.