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

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Abstract

Harold Demsetz famously emphasized that the relationship between industry structure and competition runs in both directions. Competition thus can lead industries to adjust to demand increases through larger firms rather than more firms. We investigate this insight empirically by examining how local gasoline retail markets adjusted to interstate highway openings. We find that when a new highway was close to a previous route, average producer size increased beginning 1 year before it opened. If instead the interstate substantially displaced traffic, the number of producers increased beginning only after it opened. These results empirically illustrate how the role of entry in the competitive process depends on whether entry makes product space more crowded.

1. Introduction

How do the number and size of firms change with a foreseeable increase in demand? Textbook perfect-competition models imply that industries should adjust through increases in the number but not the size of firms. Viewed through this lens, entry signals a healthy competitive environment in growing industries. Guided by this logic, antitrust analysis traditionally has used entry as such an indicator, and incumbent producers who expand with their industries have been (sometimes successfully) accused of monopolization. However, as Demsetz (1973, 1974) famously emphasizes, the relationship between industry structure and competition runs in both directions: how firms compete under different industry structures determines their expected profits from production and thereby influences their entry choices. It follows that competition can lead industries to adjust to demand increases through larger firms rather than more firms.

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Predictions from monopolistic competition models regarding long-run industry responses to permanent demand increases sharpen this point. Under Chamberlinian monopolistic competition (see, for example, Dixit and Stiglitz 1977), entry has no impact on residual demand elasticities because product space effectively expands with entry. Since firms' price-cost margins are unchanged, the quantity each must sell to be viable—to recoup its fixed costs—is unchanged. Therefore, each firm's size remains unchanged in equilibrium, and the industry responds to permanent demand shocks only through entry.[1] In contrast, in Hotelling-style (Hotelling 1929) models of imperfect competition (for example, Prescott and Visscher 1977; Salop 1979) with fixed product spaces, entry raises residual demand elasticities and therefore lowers price-cost markups. The quantity that each producer must sell to be viable—to cover fixed costs—is higher, and the industry responds to permanent demand shocks in part through increases in firm size. A general implication of this literature is that how industry structure adjusts to permanent demand increases—through more firms or through larger firms—should depend on where in product space such increases occur because this affects the intensity of competition and thereby the attractiveness of entry.

This paper empirically investigates how industry structure responds to permanent, anticipated demand shocks by examining how local rural markets—in particular, service stations—adjusted to the completion of segments of the US interstate highway system between the mid-1960s and the early 1990s. The construction of the interstate highway system during the second half of the 20th century increased intercity traffic in rural areas and changed traffic patterns in them. Sometimes the new highways shifted demand spatially, but in many cases the interstate followed the same right-of-way as the previous intercity route. In those cases, incumbents remained well positioned to serve intercity travelers. From the perspective of service stations, highway openings changed the level of demand and often consumers' tastes about locations. Incumbents and potential entrants could anticipate these changes (though they could not perfectly forecast the magnitudes of their effects) because the system's planners chose locations long before their construction commenced and because construction took time. In sum, hundreds of permanent, anticipated demand shocks occurred in rural areas of the United States between the late 1950s and the early 1980s, some of which shifted travelers' spatial preferences.[2] These shocks offer a rare opportunity for a systematic study of the dynamics of industry structure in a context in which entry barriers were very low.

We first provide evidence that completion of highway segments in a county was associated with increases in demand at service stations in the county, irre-

[1] Demsetz (1964) shows this result and links it to the analogous prediction from models of perfect competition built from the textbook framework of Viner (1932; see, for example, Jovanovic 1982; Hopenhayn 1992) that all producers operate at the bottom of their (demand-independent) average cost curves in the long run.

[2] Pixar's 2005 film *Cars* famously depicts the impact of highway openings on local economies. In the film, an interstate increases intercity traffic but diverts it from Radiator Springs, a fictional town on Route 66. The present paper's title is a reference to the movie.

spective of whether the new highway was far from or close to the previous intercity route. We then show that new highways had a different long-run effect on industry structure, depending on where they were built. When the new interstate moved consumer demand 5–10 miles from the previous intercity route, the number of firms increased, but their average size did not. When the new highway was instead very close to the old intercity route, so the increase in demand did not coincide with an expansion of product space, average firm size increased, but the number of firms did not.

These results illuminate the role that entry plays in the competitive process in growing industries and how it plays out differently in different contexts. They empirically illustrate the theoretical objection to the inference that a lack of entry indicates a lack of competition: when an expansion of demand takes place in an already-crowded part of product space, entry should affect competition in a way that makes scale more advantageous, and changes in industry structure can come largely in the form of larger firms rather than more firms. Indeed, as Carlton (2004, p. 467) observes, "[F]ar from being an indicator of a lack of competition, [this] can indicate precisely the reverse!" On the other hand, when demand expands into a new region of product space, the primary competitive response comes from entrants producing new variants for different tastes. As Schmalensee (2000) argues, sound competition policy in growing industries is likely to differ depending on whether theory predicts that competitive outcomes should come in the form of larger firms or more firms. In the retail gasoline markets we examine, the relevant margin of industry expansion depends crucially on where in product space the demand shock occurs.

We also provide evidence on the timing of the supply-side response to highway openings. We show that the timing differed depending on whether product space expanded as demand increased. When the new highway was far from the old highway, the supply-side adjustment (that is, entry) did not begin until after the new highway was completed. In contrast, when it was close to the old highway, the adjustment (that is, the increase in average firm size) began before the new highway was completed. This difference may reflect that the highway openings' effects on local demand were more uncertain when they were in new parts of product space. In any case, we find that the short- and long-run adjustments to the demand shocks differed depending on where they took place in product space.

Our work builds on prior investigations of competition and market structure in local markets. Our approach is similar in spirit to Bresnahan and Reiss (1990, 1991) and Mazzeo (2002), which examine the relationship between demand and the number of firms (and who also look at rural areas),[3] and to Campbell and Hopenhayn (2005) and Campbell (2011), which also estimate how producers' av-

[3] See also Abbring and Campbell (2010) and Abbring et al. (2018a, 2018b), which extend the analysis in Bresnahan and Reiss (1990, 1991) to include sunk costs that could potentially be elevated for later entrants.

erage size varies with demand.[4] However, the present paper differs from the existing literature in three substantial ways. First, we characterize both the short-run and the long-run dynamics of industry structure following observed changes in demand. In contrast, the earlier studies examine the long-run relationship between market size and market structure as identified by observations from a cross section of markets at a given moment in time. Second, we examine how the effects of demand shocks differ depending on where in product space they occur. This allows us to examine how the role that entry plays in the competitive process depends on whether entry makes product space more crowded. Third, our empirical approach falls within the difference-in-differences paradigm. This exploits the strengths of our context and data—we observe demand shocks that occurred at different places at different times and have data on industry employment and producer counts over long periods—to estimate the empirical relationship between the demand shocks and changes in industry structure. This approach allows us to establish our main findings: that both the timing and the margin of the changes differed depending on where in product space the demand shock occurred.[5]

The construction of the interstate highway system remains the largest single infrastructure project ever undertaken in the United States, and so its economic implications extend far beyond the rural gasoline markets we examine. Chandra and Thompson (2000), Baum-Snow (2007), and Michaels (2008) independently use the same observations of highway-opening dates to investigate, respectively, the effects of infrastructure on growth, the contribution of highway construction to suburbanization, and the effects of decreased transportation costs on wage premiums for skill. This paper adds to that body of work by demonstrating that interstate construction had important implications for industry structure.

The rest of the paper is organized as follows. Section 2 presents the analytical background. 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 trends in highway completion, the number and size distribution of service stations, and the relationship between them. Section 5 presents and discusses our main results from panel-data vector autoregressions like those in Campbell and Lapham (2004) and provides evidence on alternative interpretations of these results. Section 6 concludes.

[4] See Berry (1992) and Berry and Waldfogel (2010) for other empirical work that connects competition to industry structure and Sutton (1991) for theory and case studies.

[5] See also Hubbard and Mazzeo (2019), which uses this approach to investigate the relationship between market size and industry structure and how it is affected by the form of quality competition.

2. Industry Adjustment to Demand Shocks

In this section, we examine the question of how the supply side of a market adjusts to permanent, anticipated demand shocks through the lens of theory. This analysis aids the interpretation of our empirical results, which reveal how local retail gasoline markets adjust to anticipated demand increases—at the extensive margin through increases in the number of producers or at the intensive margin through increases in producers' sizes—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. Entry barriers were low, because building a new service station or adding capacity (namely, pumps) to an existing station required few scarce inputs and could be accomplished in only a few months once local planning and zoning approval was obtained.[6] Since highways were planned years in advance of their opening, and construction generally took 1–2 years once it started, we conclude that the time to build or expand a service station was generally short relative to the time it took to plan and build a new segment of highway.[7] 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 gasoline retailing.

2.1. A Competitive Benchmark

We begin with a discussion of industry dynamics in competitive models. While such models are in some sense straw figures in our empirical context in light of previous evidence that gasoline retailing is not perfectly competitive, they provide a useful starting point for understanding the mechanisms through which imperfectly competitive industries adjust to anticipated demand shocks. This adjustment is similar to that for competitive industries in some classes of imperfect-competition models and different for others.

Models of perfect competition in most undergraduate economics textbooks describe the short- and long-run industry adjustment to a positive demand shock (see, for example, Baumol and Blinder 1985, pp. 475–89; Besanko and Braeutigam 2011, pp. 348–58). 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^*. The distinction between the short run and the long run is that in the long run, the number of firms adjusts so that each firm earns profit of 0. The long-run price

[6] As we explain further below, obtaining approval was generally easy for the locations relevant to our sample: commercially zoned areas near rural interstate highways.

[7] The number of gasoline service stations in towns along the US-Canada border adjusted within 1 year following unanticipated demand shocks associated with changes in the real exchange rate (Campbell and Lapham 2004).

p^* equals minimum average cost, and each firm produces q^*. The number of operating firms equals total demand at p^* divided by q^*.

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^*. Each incumbent firm produces more than q^*, 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^* and each firm's production to q^*.

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 further in advance than the time to build, then producers can time their entry to match the demand expansion, and the industry adjusts entirely through entry when the demand increase arrives. Prices never rise above p^*, individual firms' production never increases beyond q^*, and no firm makes positive profits at any point in time.

The textbook competitive model's simplicity and clarity make it a foundational building block in many studies of industry dynamics, including Dunne, Roberts, and Samuelson (1989), Jovanovic and MacDonald (1994), and Cabral and Mata (2003). Since this benchmark model abstracts from a great deal of microeconomic detail and yet is applied widely, one might wonder how its implications fare after adding empirically plausible extensions that maintain its two key assumptions: free entry and an absence of strategic interactions between producers. The model in Campbell (2011), which allows for both firm-specific cost shocks and sunk costs, obtains the same long-run invariance of firm size and price to demand. Caballero and Hammour (1994, p. 1356) call the stabilization of the price at p^* the "insulation effect" of entry, and they show that it operates as in the textbook competitive model in a richer framework with stochastic demand, sunk costs, and ongoing technological change.[8] Both of these results reflect the same mechanism. Entry removes excess profits and leads the market to clear always at the competitive price p^*. Like in the textbook competitive model, active firms' incentives with respect to production do not change in the face of a demand shock, and the industry adjusts entirely through entry.

2.2. *Imperfect Competition and the Margin of Long-Run Adjustment*

Models of imperfect competition, in contrast, show that 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 compet-

[8] The equilibrium analysis of industry dynamics under aggregate uncertainty of Caballero and Hammour (1994) differs sharply from that of Dixit and Pindyck (1994), who consider the problem of a firm with an exclusive and nonexpiring entry option facing demand uncertainty.

itive 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. 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'; then the (possibly) deviating firm attracts $S \times x(p, p', N)$ customers, where $x(p, p', N)$ is the deviating firm's (output-based) market share. We impose three regularity conditions on this demand system. First, raising p while holding p' and N constant reduces x. Second, raising N while holding p and p' constant also reduces x. Finally, multiplying N by a positive scalar t while holding both p and p' 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.

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:

$$\frac{p^\star - c}{p^\star} = \frac{1}{\eta(p^\star,\ p^\star,\ N^\star)}$$

and

$$F = S \times x(p^\star,\ p^\star,\ N^\star)(p^\star - c),$$

where

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

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, which leads them optimally to sell more at the same price. However, an increase in S raises postentry profit, which leaves 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 residual demand.

In many familiar models of Chamberlin-style monopolistic competition, $\eta(p^\star, p^\star, t \times N^\star) = \eta(p^\star, p^\star, N^\star)$ for all $t > 1$. Examples include Spence (1976) and Dixit and Stiglitz (1977). In these models, new entrants differentiate themselves enough that they have no impact on either incumbents' output decisions or the equilibrium markup; it is as if entry coincides with an expansion of product space. Multiplying $N^\star$ by t suffices to restore equilibrium, 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 typically imply that $\eta(p, p', t \times N) > \eta(p, p', N)$ for all $t > 1$. As in Chamberlin-style monopolistic competition, multiplying S by $t > 1$ raises N^*. However, unlike in Chamberlin-style competition, entry makes product space more crowded and leads firms' residual demand curves to become more price elastic. This, in turn, leads individual firms' output to be greater—scale is more advantageous—and markups to be lower than in the initial equilibrium. As a consequence, the industry adjustment to an increase in S comes on the intensive and extensive margins: increases in both the size and the number of firms.

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 used by through traffic. In our competitive benchmark (and in some models of imperfect competition), 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, 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 stations located near new highway exits. 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 with situations in which 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 0 at any point in time. Therefore, any adjustments to a demand increase occur no earlier than when the increase begins. Any firm that expands or enters ahead of the demand increase would receive negative profits before the increase—prices would be below competitive levels—but no more than profits of 0 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 lower profits today for higher profits tomorrow. In some circumstances, doing so can have a direct effect on firms' profits, such as when there is learning by doing. In other circumstances, as a large literature in theoretical industrial organization depicts, the incentive to invest ahead of the arrival of demand arises through the investment's effect on other firms' actions. In many of these models, 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 interest (Spence 1977, 1979; Fudenberg and Tirole 1984; Bulow, Geanakoplos, and Klemperer 1985). For example, Fudenberg and Tirole (1986) model a market that is currently supplied by an incumbent monopolist but in which the number of potential customers is expected to double at some future date. This demand increase gives rise to an entry opportunity, which may be filled by either 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 opportunity just ahead of the time when the entrant is indifferent between entering, earning low duopoly profits until demand arrives and earning high duopoly profits thereafter.

3. The Historical Context

This section describes the historical context in which interstate highways were built and the service stations in our sample were completed. 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.[9] These routes corresponded to the existing major roads that connected most population centers, and the plan designated the roads, or the newly constructed highways along the same route, as part of the interstate system (US Public Roads Administration 1947, pp. 5–6). 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 (US Department of Commerce 1956, pp. 1, 5).

The vast majority of the interstate highway system's construction followed the passage of the Federal Aid Highway Act of 1956. The federal government financed interstate highway construction through fuel taxes paid to the Highway Trust Fund, which was earmarked for this purpose. Federal funds paid for 90 percent of construction costs, with the states paying for the remainder. 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 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 inter-

[9] Most of the system's remaining mileage was determined in the mid-1950s (US Department of Commerce 1956, p. 9).

state highways including design speed, alignment, lane width, access limitations, 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.[10] The federal government had approved designs and locations for all routes in the system by the middle of 1960 (US Department of Commerce 1960, p. 8).[11]

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 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. (Virginia Department of Highways 1956, sec. 2)

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 a road's 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 close to existing roads as the local topography allowed.[12]

This discussion illuminates two key aspects of interstate highway planning that bear on our empirical results. First, locations were determined for most of the rural highway segments in our sample many years before the segments were built.

[10] "Immediately after passage of the act the States undertook the engineering and economic 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" (US Department of Commerce 1957, p. 7).

[11] 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 the system was yet to be determined (US Department of Commerce 1965, p. 15).

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

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 top of the old one but played a far less important role in determining where the highway was built if 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 a 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, when 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 an empirical exercise in which we examine whether the patterns we uncover persist when excluding counties in which the interstate highways are extremely close to the old routes.

Construction began 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 completing the system by the end of the 1960s, 90 percent of it was open by the end of 1975, and 96 percent was open 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 3–4 years from start to finish (US Department of Commerce 1957, p. 2). 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 highways to build first. 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 built (US Department of Commerce 1960, pp. 11–17, 51–52).

3.2. Service Stations

Service stations are retail outlets primarily engaged in selling gasoline, pumping it from underground tanks into customers' vehicles. The gasoline is largely undifferentiated and sold in standard grades, though a customer might display a preference for a particular station because of its brand, location, or other characteristics. Service stations have long offered other services or lines of merchandise (hence their name). Although now it is common for service stations to have convenience stores, until the late 1970s most stations 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 the gasoline. These aspects were interrelated: attendants checked a 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,[13] and it was common for attendants to be paid commissions for sales of these nongasoline products and services (Nielsen 1957, p. 39; Russell 2007, p. 47). 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, which 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 (nonland) capital costs of a two-bay, two-island service station was on the order of $40,000 (Claus and Rothwell 1970, p. 75).[14] The capital cost 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 one could be completed in no more than several months. A large share of the costs associated with building a new station was sunk, because much of the capital was not mobile, and it was expensive to convert the facilities and land for most other purposes.

Entry barriers were generally low during our sample period, especially in the rural areas that we examine. Service stations and other businesses were prohibited from locating on new interstate highways, so new stations occupied sites off, though often near, highway exits.[15] Planning and zoning regulations generally restricted the location of service stations to commercially zoned areas and stipulated such attributes as minimum lot sizes and how close pumps could be to the right-of-way, but they usually did not have an important impact on the number and size of service stations in an area beyond this. Surveys 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 (American Society of Planning Officials 1973). Officials dealt with these by encouraging ser-

[13] Guides for running service stations during this period emphasize this. For example, one read, "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" (US Small Business Administration 1961). This marketing has changed, especially since the emergence of self-service.

[14] This is about $240,000 in current dollars.

[15] Highways that were grandfathered into the system, such as the Massachusetts Turnpike, could continue to have travel plazas with service stations. These highways were completed well before the time period that we study.

vice 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.[16] Although service station operators usually had to obtain a special permit to operate, even in commercial zones, planning and zoning regulations for service stations were quite light-handed. Indeed, near highway interchanges, perhaps the most common problem regulations addressed was ameliorated by 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 (see, for example, Barton-Aschman Associates 1968, p. 33).

We next report general trends with respect to service stations during and slightly outside our 1964–92 sample period, paying particular attention to the period between 1964 and 1977, during which most of the highways were built. The numbers are as reported by the US Census in either County Business Patterns (CBP) or the Economic Census (EC; which was part of the Census of Retail Trade or, before 1972, the Census of Business).

3.3. General Trends

Figure 1 presents several time series that track service stations in the United States. The diamonds represent all service stations reported in the EC. They show that the number of service stations increased slowly during the 1960s and early 1970s, growing by 7 percent from 1963 to the 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 was relatively stable thereafter. New-station openings exceeded 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 trend in the number of service stations with positive payrolls reported in the EC is very similar to the first trend. This is of note because our main data source tracks only stations with employees.

There is a break in the series tracking the number of reporting units, as published in the CBP, because the definition of a reporting unit changed in the middle of our sample period.[17] Starting in 1974, the CBP reports the number of establishments—in this context, service stations—and the numbers track those published in the EC closely. But before 1974, the CBP reports the number 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 in the county. The ratio

[16] Environmental concerns did not make the list of major problems (American Society of Planning Officials 1973). This may have changed in the 1980s with the onset of the environmental regulation of underground storage tanks.

[17] 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 one to three, four to seven, and eight to 19 employees; after 1974, they were one to four, five to nine, and 10–19 employees.

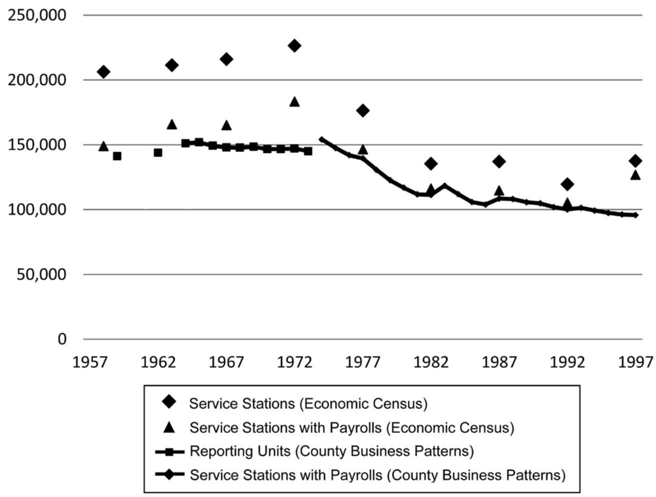

Figure 1. Number of service stations in the United States

of the reporting-unit counts to 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 for average number of employees (hereafter, employment size). The EC series show that the average employment size of service stations grew throughout our sample period, increasing by about 125 percent between 1963 and 1992. In the CBP-derived series, the employment size of the average reporting unit—that is, the average within-county firm size—increased by 41 percent between 1964 and 1972. Employment per station with payroll increased by about 35 percent during that 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 the pre-1974 employment increases therefore appear to reflect increases in station size.

Other census figures published on a consistent basis since 1972 show increases in size in other dimensions; we report data from the Census of Retail Trade in Table 1. The number of gallons per station increased steadily between 1972 and 1992, more than doubling during that time. This reflects an increase in both the number of gallons per pump, which grew by 63 percent, and the number of pumps per station, which grew by 37 percent. These figures indicate that while average employment per station was increasing, stations' pumping capacity was also increasing, and 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

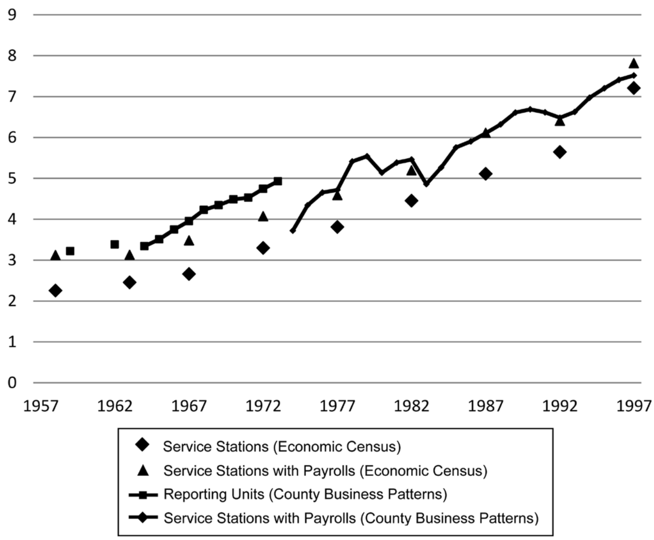

Figure 2. Average employment size of service stations

that the number of gallons per station grew by at least 44 percent and the number of pumps per station grew by at least 20 percent between 1963 and 1972, although the estimates are not directly comparable to those in Table 1 because of reporting bias.[18]

Table 1 also shows two well-known changes in service stations that occurred during this time. One is the movement toward self-service that began in the early 1970s; the share of sales that is self-service exceeded 91 percent 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 percent to 15 percent between 1982 and 1992 and has increased since then to about 25 percent.[19]

This study focuses on periods surrounding the completion of interstate highways, and the phenomena we uncover mainly reflect changes in the number and size distribution of service stations between the early 1960s and the mid-1970s.

[18] The 1963 Census of Retail Trade 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 respondents to the survey disproportionately include larger firms, but the census did not publish estimates that adjusted for this reporting bias.

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

Table 1
Statistics for Service Stations

						Share of Revenue by Category (%)			
	Gallons per Station (1,000s)	Gallons per Pump (1,000s)	Pumps per Station	Employees per Pump	Self-Service Revenues (%)	Fuel and Oil	Tires and Parts	Food, Alcohol, and Tobacco	Other
1972	360.7	68.0	5.3	.77		82	10	2	6
1977	508.8	97.4	5.2	.88	30	85	5	4	6
1982	543.1	90.2	6.0	.86	63	88	3	5	4
1987	697.4	97.1	7.2	.85	75	81	2	12	6
1992	802.8	110.8	7.2	.88	91	79	2	15	5
Change 1972–92 (%)	123	63	37	15					

Throughout this period, service stations were becoming larger in terms of employees. Although some of the increase in service stations' average size may reflect 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 were full service, and 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 stores and other innovations such as paying at the pump that would tend to decrease the use of labor. Thus, these developments can contribute only a little to industry dynamics in our sample period.

4. Data

4.1. Data Sources

4.1.1. Highway Openings

Our data on highway openings are from the US 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 were built using interstate highway funds. The data cover nearly the entire system.[20] Highway segments in the data range in length, but the vast majority are less than 5 miles long, and many are less than 1 mile long. The opening date is the month-year the segment was open for traffic. The milepost and length variables in the PR-511 file 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 segments is located.[21] This produced a highly detailed data set on the timing and location of interstate highway openings.

We aggregated these data up to the route-county level. For each route-county (for example, I-75 through Collier County, Florida), we calculated the total mileage in 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 in a county for some period of time and then fully completed a few years later. The cumulative share variable $CSMI_{it}$ is a key independent variable in our analysis.

[20] A small fraction of the system 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.

[21] For the data, see National Bureau of Economic Research, Transportation Economics in the 21st Century—Highway Data (https://www.nber.org/research/data/transportation-economics-21st-century-highway-data). The PR-511 file contains a variable that indicates the county in which the segment is located, but other researchers (Chandra and Thompson 2000) note that the variable contains errors. We use the PR-511 data in checking our construction of this variable.

4.1.2. Highway Locations

We augment these data with a measure of how far the interstate highway shifted traffic. Using mid-1950s road maps, we first designate the route each segment of interstate highway likely replaced (the old route).[22] The general procedure is to look first at the major cities that the current interstate connects and 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 is established, we measure the direct distance between each current interstate exit and the old route using Google Maps and ancillary tools. Finally, we average the distance across the exits in each route-county. This produces the variable $DIST_i$, which characterizes the spatial shift in traffic brought about by the interstate highway. This measure ranges from 0 for many route-counties (where the interstate merely upgraded the old route) to over 20 miles (see Section 4.2). The median value is 1.25 miles; the 25th and 75th percentile values are .5 and 3.0 miles, respectively.

4.1.3. Service Stations

Our data on local market structures for service stations are from the CBP, published annually by the US Bureau of the Census since 1964. The CBP contains county-level data on narrowly defined industries, including gasoline service stations (Standard Industrial Classification code 554). We obtained these data in electronic form for 1974 to 1992; we hand entered them from published reports from 1964 to 1973. For each year and county, these data report employment and payroll in the industry in a county. They also include the 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 them 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 before 1974.

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) in the county in a particular year. The bulk of our analysis relates these variables to the timing of highway openings.

[22] The old routes were essentially the roads that were designated as part of the interstate system in the 1947 plan.

4.2. *Criteria for the Sample*

Our empirical approach, which uses highway openings to identify spatial shifts in the demand for gasoline, envisions contexts in which these shifts are uncomplicated: for example, a new highway opens that parallels an existing road that had 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 simple. First, we use only counties with a single one- or two-digit interstate (for example, I-5, I-90) and no three-digit interstates (for example, I-290); this eliminates most large cities and counties with complicated traffic patterns. Some populous counties remain after this cut (for example, New York County); we therefore eliminate counties in which 1992 employment exceeds 200,000. We also eliminate counties through which a highway passes but there is no exit; in most of these cases the highway clips the corner of a county. Finally, we employ in our main analysis a balanced panel that includes only counties for which the number of service stations is nonmissing in each year between 1964 and 1992.[23]

Our main sample ultimately includes the 677 counties shown in Figure 3. This map indicates that our sample counties are located all over the United States, tracing the nonurban parts of the interstate highway system. Figure 3 indicates when the highways were completed; broadly, they were completed somewhat later in the West than in other regions of the country, but the pattern is not strong, which reflects the federal government's encouragement of proportionate construction in each state. In addition, Figure 3 indicates where a new highway was more than 3 miles from the previous intercity route. 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 the 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 our balanced-panel counties. By the end of 1960, 20 percent of two-digit highway mileage was open; most consisted of toll roads in the East that predated the interstate highway system (such as the Pennsylvania Turnpike) and were later incorporated into it. About 55 percent of two-digit mileage in the system was completed during the 1960s; the peak construction year was 1965. By 1975, 90 percent of the system was completed, and the final 5 percent was finished 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

[23] We retain route-county-years where service station employment is missing (about 5 percent of route-county-years) as long as the number of service stations is nonmissing.

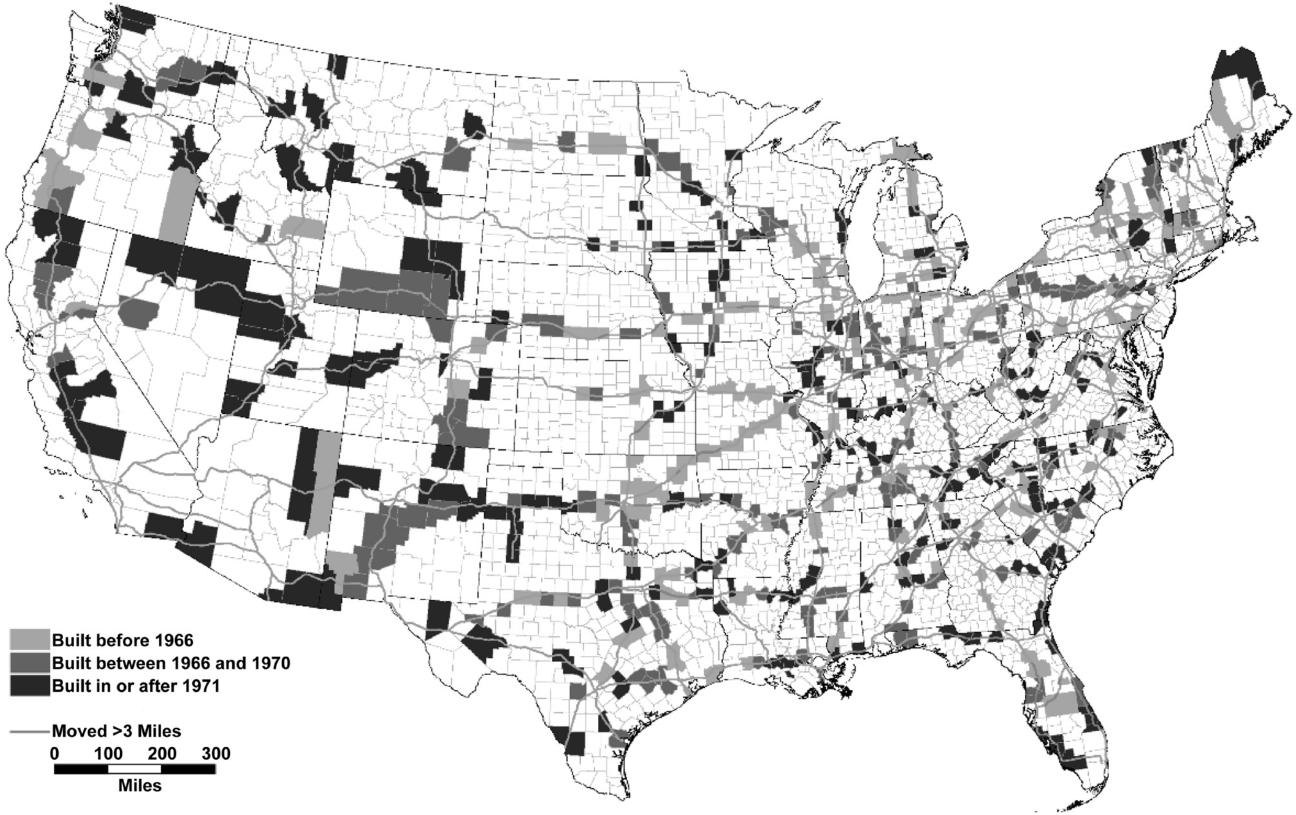

Figure 3. Sample counties, highway completion, and distance from old routes

Table 2
Completion of Two-Digit Interstate Highways

	All		Balanced-Panel Counties	
	Cumulative Miles	Share of Total (%)	Cumulative Miles	Share of Total (%)
1960	7,732	20	3,494	19
1965	19,423	50	9,273	49
1970	29,260	76	14,334	76
1975	34,884	90	17,138	91
1980	37,238	96	18,119	96
1985	38,065	98	18,571	99
1990	38,597	100	18,785	100
1992	38,665	100	18,833	100

Note. Shares are rounded.

that of the system as a whole: peaking in the mid-1960s and then steadily declining. As noted above, the timing of interstate highway construction means that our analysis centers on events that mostly took place in the 1960s and early 1970s, and our creation of a data set that examines changes in industry structure during that 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 are very similar to overall trends in Figure 1. The number of firms per 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, which reflects a large decrease in the number of small stations that is partially offset by a small increase in the number of larger stations.

Table 4 and Figure 4 present some initial evidence on whether the timing of changes in industry structure is 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 (early counties), 1966–71, and after 1971 (late counties). We then calculate the number of employees per firm (starting in 1974, per station) in each category.[24] Table 4 indicates that average firm was small in early and late counties initially; in each, there were about three employees per firm. The number of employees increased steadily; in 1992, the average gas station had roughly seven employees. But the timing of the increase differed between the early and late counties. Firm size increased in early counties relative to late counties at the start of the sample period; by the early 1970s, the difference was about 10 percent. The opposite is true after the mid-1970s, when average station size increased in the late counties relative to the early counties. Figure 4, which plots the ratios between counties per year, shows this pattern. This evidence indicates

[24] The quantities in Figure 4 include only counties where we observe service station employment in each year ($N = 470$).

Table 3
Firms and Service Stations per County by Number of Employees

	Total	1–3 Employees	4–7 Employees	8–19 Employees	20 or More Employees
Firms:					
1964	45.8	35.7	7.6	2.2	.4
1965	45.9	34.7	8.4	2.4	.5
1966	45.8	33.4	9.1	2.8	.5
1967	45.2	31.8	9.8	3.0	.6
1968	45.2	30.3	10.7	3.5	.7
1969	46.0	30.2	11.4	3.8	.7
1970	45.3	29.2	11.5	3.9	.7
1971	45.3	29.1	11.7	3.8	.8
1972	45.7	27.9	12.6	4.3	.8
1973	44.9	26.4	12.8	4.8	.9
Service stations:					
1974	47.4	37.9	7.4	1.6	.6
1975	44.9	33.3	9.0	2.0	.6
1976	43.5	31.4	9.2	2.3	.6
1977	43.3	30.8	9.7	2.2	.6
1978	40.4	26.4	10.3	3.0	.8
1979	37.6	23.7	10.2	2.8	.9
1980	35.6	24.0	8.6	2.2	.9
1981	33.8	22.2	8.7	2.2	.7
1982	33.7	21.5	9.0	2.5	.8
1983	35.9	23.0	9.7	2.5	.7
1984	34.0	20.5	10.1	2.5	.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

that increases in the size of service stations corresponded to the completion of interstate highways.

5. Empirical Model and Results

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

$$\boldsymbol{y}_{it} = \alpha_i + \mu_t + \Lambda y_{it-1} + \beta \boldsymbol{x}_{it} + \varepsilon_{it}.$$

In our first set of results, $\boldsymbol{y}_{it}$ is the 2×1 vector $[\ln n_{it}, \ln a_{it}]'$, where n_{it} is the number of service stations (before 1974, the number of firms) divided by total county employment in county i at time t, and a_{it} is the average employment at these service stations (before 1974, firms). The vector $\boldsymbol{x}_{it}$ contains our highway-opening

Table 4
Average Employment Size by Highway Completion Date

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

Note. Values are employees per firm (1964–73) or station (1974–92) for counties in the balanced-panel sample with nonmissing employment for each year ($N = 470$). Highway completion before 1966 is early ($N = 167$) and after 1971 is late ($N = 153$).

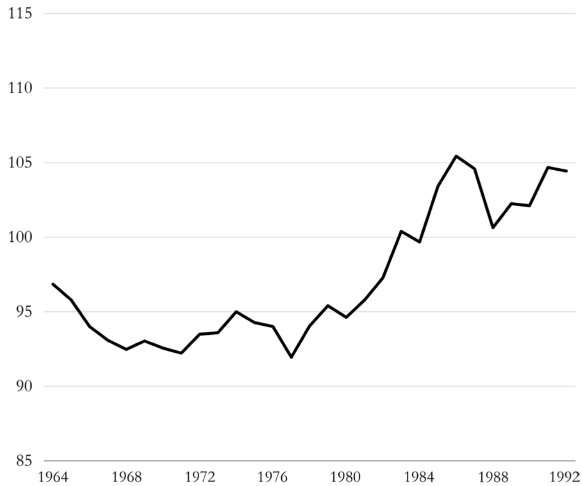

Figure 4. Ratio of late counties to early counties by firm size

variables, CSMI_{it}, $\text{CSMI}_{it} \times \text{DIST}_i$, and sometimes leads and lags of the variables. The interaction $\text{CSMI}_{it} \times \text{DIST}_i$ allows for the possibility that the effect of the completion of a highway in a given county has a different impact on local industry structure, depending on the size of the spatial shift in demand. The county fixed effect α_i represents time-invariant factors that lead the number and size of

Table 5

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

	Autoregressive Coefficient		Years from Highway Opening			Sum of Lead and Lag
	$\ln n_{i,t-1}$	$\ln a_{i,t-1}$	−1	0	1	
No leads or lags:						
$\ln n_{it}$	.768*	.029*		.002		.002
	(.005)	(.004)		(.005)		(.005)
$\ln a_{it}$	.032*	.638*		.019*		.019*
	(.007)	(.006)		(.007)		(.007)
One lead and one lag:						
$\ln n_{it}$	.766*	.032*	−.006	−.003	.011	.003
	(.005)	(.004)	(.011)	(.014)	(.010)	(.006)
$\ln a_{it}$	−.035*	.635*	.030*	.002	−.010	.022*
	(.007)	(.006)	(.015)	(.019)	(.013)	(.008)

Note. Standard errors are in parentheses. $N = 677$.
* $P < .05$.

service stations to differ across counties, and the year fixed effect 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 size of service stations around the time of interstate highway openings relative to the county's own norm and national developments. Without the autoregressive term Λy_{it-1}, the panel vector autoregression reduces to a standard difference-in-differences equation. With it, the specification parsimoniously captures the empirical regularity that deviations of the market structure from its mean persist from year to year and so allows us to exploit our data's high-frequency variation more effectively. The autoregressive structure also allows the impact of an interstate's opening to occur gradually, so the estimates can characterize both the long-run and the short-run impacts of highway openings on industry structure. Our estimates of β give the initial impact, while those of $(I - \Lambda)^{-1}\beta$ measure the long-run change.

5.1. Basic Results

5.1.1. Number and Average Size of Stations

Table 5 presents results from ordinary least squares estimates of two specifications.[25] For the results with no leads or lags, the highway-opening coefficient is economically and statistically 0 for the number of stations and is positive and

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

significant for the average employment size of stations.[26] The autoregressive coefficients are all positive and significant, so the impact of shocks on the number and average size of service stations in a county is distributed over time. The magnitudes of the highway-opening coefficients, combined with the autoregressive coefficients, provide no evidence that the opening of a highway is associated with a change in the number of firms but imply a 6 percent long-run increase in the average employment size of service stations in the county, one-third of which (1.9 percent) occurs in the year that the highway opens.

Table 5 also presents results that add a lead and lag to the highway-opening vector. The main result is the positive and significant coefficient in the average-employment-size regression: the increase in the average size of service stations begins before the highway opens. The sum of the coefficients on the leads and lags is approximately unchanged.[27]

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

5.1.2. Size Categories

Table 6 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. The results are from regressions in which the dependent variable $\boldsymbol{y}_{it}$ is a vector of the number of stations in each of the four employment-size categories reported in Table 3.

Table 6 indicates that highway openings are associated with an increase in the average number of stations with between eight and 19 employees (or, after 1973, stations with 10–19 employees). Our estimates indicate that the number of large stations increased by .3 during the year leading up to the highway opening, and combined with the autoregressive coefficients this implies a long-run increase of 1.1 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. Small stations exit the market throughout our sample period, but there is no evidence that their exits are related to when highways are built. This pattern is consistent

[26] To avoid convoluted language, we use the term "station" both before and after 1974. This is supported by empirical evidence that we present below: the results do not appear to differ before and after 1974, which suggests that highway openings were associated with changes in the number and size of stations rather than stations' propensity to be part of multiestablishment firms.

[27] We also estimated versions of these regressions including two and three leads and lags (see Campbell and Hubbard 2016); doing so increases the standard errors on all of our coefficients, which indicates that our ability to identify a longer time structure than that of a single lead and single lag is limited. We therefore report only results from specifications with no more than one lead and one lag.

Table 6

Vector Autoregressions of the Number of Service Stations in Employment-Size Categories on Highway Openings

	Autoregressive Coefficient				Years from Highway Opening			Sum of Lead and Lag
	S1	S2	S3	S4	−1	0	1	
No leads or lags:								
S1	.802*	.149*	−.017	−.063		.179		.179
	(.004)	(.007)	(.015)	(.036)		(.156)		(.156)
S2	.077*	.650*	.271*	.114*		.080		.080
	(.003)	(.006)	(.011)	(.026)		(.110)		(.110)
S3	−.005*	.082*	.579*	.325*		.234*		.234*
	(.002)	(.003)	(.006)	(.015)		(.064)		(.064)
S4	−.002*	−.001	.063*	.519*		.010		.010
	(.001)	(.001)	(.003)	(.006)		(.028)		(.028)
One lead and one lag:								
S1	.794*	.158*	−.001	−.021	.214	−.401	.450	.263
	(.004)	(.008)	(.016)	(.038)	(.333)	(.429)	(.295)	(.172)
S2	.079*	.640*	.268*	.144*	.008	−.088	.193	.113
	(.003)	(.006)	(.011)	(.027)	(.236)	(.303)	(.208)	(.122)
S3	−.004	.086*	.573*	.293*	.304*	−.052	.038	.290*
	(.002)	(.003)	(.006)	(.016)	(.136)	(.175)	(.121)	(.070)
S4	−.004*	−.003*	.064*	.545*	.020	−.031	.031	.020
	(.001)	(.001)	(.003)	(.007)	(.058)	(.074)	(.051)	(.030)

Note. The terms S1, S2, S3, and S4 denote the number of firms with one to three, four to seven, eight to 19, and 20 or more employees in the county (one to four, five to nine, 10–19, and 20 or more employees after 1974), respectively. Standard errors are in parentheses. $N = 677$.

* $P < .05$.

Table 7
Regressions of County Employment on Highway Openings

	Autoregressive Coefficient	Years from Highway Opening −1	0	1	Sum of Lead and Lag
No leads or lags	.916*		−.004		−.004
	(.003)		(.003)		(.003)
One lead and one lag	.913*	.007	−.009	.000	−.002
	(.003)	(.006)	(.008)	(.005)	(.003)

Note. The natural log of county employment is the dependent variable. Standard errors are in parentheses. $N = 677$.
* $P < .05$.

with the hypothesis that sunk costs make exit decisions relatively insensitive to 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 that service stations faced from locals) and systematically built highway segments so that they were completed at or around the same time as the 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 testing whether employment in the counties in our sample systematically changed around the time that their highways were completed.

Table 7 reports results from this exercise, which uses analogous autoregressive specifications with ln(County Employment) as the dependent variable. The estimate without leads or lags indicates a negative relationship between employment and highway openings that is not statistically different from 0, and adding a lead and a lag does not change the result. We therefore do not find empirical support for the 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 one. 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 (after 1973) effects. The results in Tables 5 and 6 could reflect that highway completion is associated with either 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 to this point reflect only increases in station size and not increases in the number of stations per firm, then we should find no difference in the results through 1973 versus after 1973. In contrast, finding that the effects we uncover are significantly weaker after 1973 would provide evidence that the results to this point 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 are interrelated with changes in stations' format associated with self-service or convenience stores. Finding no differences would provide no evidence consistent with that hypothesis.

Results are in Table 8. 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 hypothesis that the change in the vector is 0, using Wald tests of .05. We therefore cannot reject the null hypothesis that the patterns indicate only increases in average station size. To some extent, this reflects the simple fact that close to 90 percent 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 that time 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 1973.

5.1.5. Discussion

The estimates thus far indicate that, on average, local markets adjusted to highway openings through increases in station size and that this adjustment began ahead of highway openings. A manifestation of this is in the increase in the number of large stations, which provides a preliminary indication of the industry dynamics associated with interstate highway openings. These dynamics are consistent with imperfect-competition models in which markups decrease with entry and inconsistent with competitive and monopolistically competitive models in which they do not.

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 examine, 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

Table 8

Vector Autoregressions of the Number and Average Employment Size of Service Stations on Highway Openings after 1973

	Autoregressive Coefficient		Years from Highway Opening			Years from Highway Opening after 1973		
	$\ln n_{i,t-1}$	$\ln a_{i,t-1}$	−1	0	1	−1	0	1
No leads or lags:								
$\ln n_{it}$	.768*	.029*		.001			.013	
	(.005)	(.004)		(.005)			(.011)	
$\ln a_{it}$	.032*	.638*		.020*			−.007	
	(.007)	(.006)		(.007)			(.016)	
One lead and one lag:								
$\ln n_{it}$	.766*	.032*	−.006	−.003	.009	.009	.002	.008
	(.005)	(.004)	(.012)	(.015)	(.010)	(.017)	(.021)	(.017)
$\ln a_{it}$	.039*	.617*	.035*	.002	−.013	−.024	.002	.020
	(.008)	(.007)	(.016)	(.020)	(.014)	(.023)	(.029)	(.023)

Note. Standard errors are in parentheses. $N = 677$.
* $P < .05$.

might expect in an industry with significant industry-specific sunk costs—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.[28]

These patterns, while interesting, mask important differences in the margin and timing of adjustments based on whether a new highway is close to or far from the old route. We present and interpret evidence on these differences in Section 5.2.

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 depends on how far the interstate is from the old route. We do so by including $\text{CSMI}_{it} \times \text{DIST}_i$, which allows the relationship between highway openings and our dependent variables to differ depending on the distance to the new highway from the old route. Table 9 first reports results from specifications in which we include no leads and lags. The estimates 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 with distance is positive and significant. The coefficient estimate on CSMI_{it} evaluated at 10 miles is .021 and is statistically significantly different from 0. When the new highway was far from the old route, the industry adjusted to the increase in demand with entry.

Table 9 also reports results from specifications that include a lead and a lag and thus shows how both the margin and the timing of adjustment vary with the magnitude of spatial demand shifts. The main finding from these specifications is that the timing and the margin of adjustment are different when comparing the interstate's distance to the old route. This is indicated by the positive and significant coefficient estimates on the interaction in the number of stations at 1 year and on the regression for average station size before highway completion. But it can be seen more easily in the impulse-response functions associated with these specifications.

Figure 5 plots these impulse-response functions. The impulse-response functions are evaluated at 0, 1.25, and 10 miles and are at the 5th, 50th, and 95th percentiles of the distance distribution in our sample, respectively. The functions for 0 and 1.25 miles are similar: Figure 5*A* shows that there is little change in the number of stations, but there is an increase in the average size of 6 percent during the 2 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 percent, starting after the highway is complete, but no significant increase in the size of stations.

These results indicate a systematic difference in how local markets adjust to demand shocks. Figure 5*B* indicates that when highways do not create new spatial

[28] 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.

Table 9

Vector Autoregressions of the Number and Average Employment Size of Service Stations on Highway Openings by Distance from Old Routes

	Autoregressive Coefficient		Years from Highway Opening			Years from Highway Opening × Distance			Sum of Lead and Lag	
	$\ln n_{i,t-1}$	$\ln n_{i,t-1}$	−1	0	1	−1	0	1	0 Miles	10 Miles
No leads or lags:										
$\ln n_{it}$	.768*	.030*		−.006			.003*		−.005	.021*
	(.005)	(.004)		(.006)			(.001)		(.006)	(.010)
$\ln a_{it}$	.039*	.617*		.020*			.000		.020*	.018
	(.008)	(.007)		(.009)			(.002)		(.009)	(.014)
One lead and one lag:										
$\ln n_{it}$	.765*	.032*	−.010	.007	−.005	.001	−.003	.005*	−.007	.024*
	(.005)	(.004)	(.015)	(.018)	(.013)	(.003)	(.005)	(.002)	(.007)	(.011)
$\ln a_{it}$	.039*	.617*	.054*	−.016	−.011	−.008	.006	.000	.028*	.010
	(.008)	(.007)	(.020)	(.026)	(.017)	(.005)	(.005)	(.003)	(.010)	(.015)

Note. Standard errors are in parentheses. $N = 677$.
* $P < .05$.

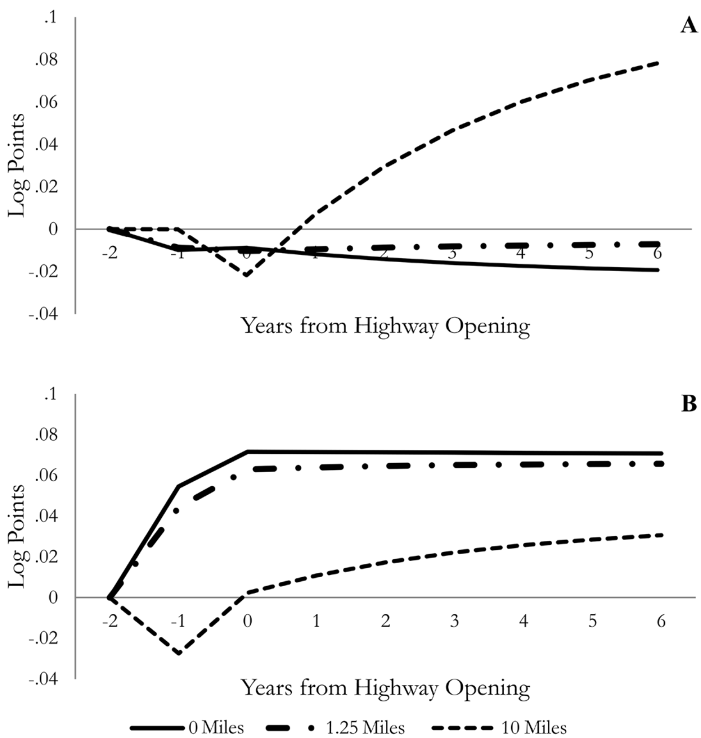

Figure 5. Impulse-response functions for highway openings by distance from the old route. *A,* Service stations; *B,* average employment.

segments, local markets adjust through increases in firm size, and the adjustment begins before the highways open. In contrast, when highways are built far from the previous routes (thereby creating new spatial segments), the number of firms increases. Consistent with the initial insight of Demsetz (1974) and the literature on monopolistic competition that followed, our results illustrate that entry's role in the competitive process depends on where in product space demand shocks occur and therefore whether entry is likely to make product space more crowded. They also illustrate the importance of allowing for such factors as product differentiation and sunk costs—central in the field of industrial organization but sometimes not as central in other fields that examine industry dynamics, such as macroeconomics—when modeling or analyzing industry dynamics (such as many other retail industries), even though it may be analytically convenient to abstract from these factors.

5.3. *Other Results*

In Campbell and Hubbard (2016), we report the results of several other empirical exercises. In one, we investigate whether differences in local economies that are correlated with highway placement explain our results. In Section 4, we explained that details of the local economy sometimes played a significant role in determining whether a new highway was built atop the old route but played a minimal role relative to the local topography conditional on the new highway not using the old right-of-way. We therefore reran our main specifications using only counties in which the distance from the old route was greater than .5 of a mile and find little change in the coefficient estimates. In another, we investigate whether our results—particularly our evidence that average station size increased in the year before the highway opened—reflect increases in demand-associated highway openings outside the county but in the same transportation corridor. We did so by rerunning our specification, including controls for the completed share of the highway corridor in the county. Once again, we find no change in our results. Finally, we investigate whether our results are stronger in areas where through-traffic levels are high relative to local employment—where one would expect highway openings to have a greater impact on our county-level measures of the number and size of gas stations. Our results are stronger in such counties and weaker in counties where through-traffic levels are low relative to local employment.

6. Conclusion

The opening of interstate highway segments provides an unusually fertile environment for the empirical examination of industry adjustment to permanent demand shocks, both because we can observe their timing and because the long available time series allows us to observe short-run and long-run outcomes. Our evidence from gasoline retailing indicates that how this industry adjusted depended on whether highway construction spatially moved demand. When a new highway was built close to an existing route, the industry grew mainly through increases in firm size instead of by adding firms, and this growth began well ahead of the new highway's completion. In contrast, when a new highway was built far from a previous intercity route, the industry adjusted mainly through the entry of new firms and only after the highway's completion.

Textbook perfect competition predicts that long-run industry adjustment to demand increases occurs entirely through entry. From that perspective, a lack of entry and an increase in the size of firms in an industry in which demand is increasing implies that the competitive process is not working well. However, that line of reasoning leads to misleading conclusions when applied to markets with product differentiation. If entrants would be close competitors to existing firms, then an industry adjustment primarily through increases in firm size is completely consistent with a well-working competitive process without entry barriers. Our study, which examines a context with no significant entry barriers and shows that demand increases were met by increases in firm size when they occurred in existing parts of product space but by increases in the number of firms when they occurred in new parts of product space, illustrates this point.

The observation in Demsetz (1974) that the relationship between industry structure and competition runs in both directions made economics more rigorous and the formation of antitrust policy more difficult.[29] The literature that has followed theorizes that this bidirectional relationship decreases realized entry rates exactly where entry—when it does occur—should have the greatest impact on price-cost margins. We believe that our evidence provides a textbook empirical illustration of this central implication of the simultaneous determination of industry structure and competition.

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[29] Demsetz (1974, p. 170) writes, "[N]o good theoretical link has been forged between the structure of the industry and the degree to which competitive pricing prevails, because no good explanation has been provided for how present and potential rivals are kept from competing without some governmentally provided restrictions on competitive activities." The subsequent literature on market structure closes this loop by allowing for competition and entry.

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