Chapter 19
Structural Models in Transportation Economics

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Abstract This chapter reviews the historical development of structural econometric models in transportation economics and illustrates how methodological advances have been driven by the increasing recognition of endogeneity and strategic interactions in transportation markets. Beginning with early aggregate demand systems and reduced-form analyses of costs, regulation, and competition, the chapter shows how these approaches provided valuable empirical insights but proved increasingly inadequate in industries characterized by product differentiation, imperfect competition, and complex institutional arrangements. It then examines the emergence of discrete-choice demand models, structural models of incentive regulation under asymmetric information, models of market conduct and dynamic oligopoly, and structural auction models for transportation procurement. This chapter highlights the economic questions that motivated each methodological innovation, discusses the limitations of earlier approaches, and explains how richer structural models expanded the scope for counterfactual policy analysis. The evolution of transportation econometrics mirrors the broader development of empirical industrial organization: a gradual shift from reduced-form correlations to structural models capable of explaining the economic mechanisms that generate observed market outcomes.

19.1 Introduction

Transportation economics has long been one of the principal application areas for structural econometrics. Transportation industries combine many of the features that make empirical analysis particularly challenging: differentiated products, network effects, large fixed costs, imperfect competition, public regulation, and complex procurement mechanisms. These characteristics have repeatedly motivated the devel-

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opment of new econometric methods, making transportation a natural laboratory for methodological innovation in empirical industrial organization. At the same time, the evolution of the field illustrates an important lesson: empirical models have progressively become more structural because researchers increasingly recognized that many of the variables they sought to explain—prices, market concentration, regulation or procurement mechanisms—are themselves endogenous outcomes of economic decisions.

This chapter reviews the historical development of structural models in transportation economics through four major applications: demand estimation, cost estimation and regulation, competition, and procurement auctions. Rather than providing an exhaustive survey of the literature, the objective here is to explain why successive generations of empirical models emerged, what limitations they addressed, and which challenges remain today. Throughout the chapter, emphasis is placed on the interaction between economic theory, econometric methods and the institutional characteristics of transportation markets.

The estimation of transport demand provides a first illustration of this evolution. During the 1970s and 1980s, empirical work relied largely on aggregate demand systems designed to estimate own- and cross-price elasticities for forecasting traffic, evaluating infrastructure investments and assessing pricing policies. These models were well suited to analysing competition between a limited number of transport modes but became increasingly inadequate as deregulation transformed transportation industries into highly differentiated markets. The development of multinomial logit, nested logit and random-coefficient models during the 1990s introduced explicit microeconomic foundations for consumer choice while addressing the endogeneity of prices and making counterfactual policy analysis possible. More recently, the widespread availability of individual-level data has shifted attention towards modelling traveller heterogeneity and dynamic travel behaviour.

A similar progression characterizes the estimation of operating costs. Early studies focused primarily on recovering technological characteristics such as economies of scale and economies of density, providing important insights into the cost structure of network industries. As governments introduced privatization, competitive tendering and incentive regulation, the empirical question gradually shifted from describing technologies to evaluating the effects of regulatory institutions. Reduced-form analyses were progressively replaced by structural models based on asymmetric information, which explicitly model the strategic interaction between regulators and firms. This literature also illustrates a broader methodological debate between positive and normative modelling, emphasizing that one of the central objectives of structural econometrics is to confront competing economic theories with observed data rather than simply implement theoretical models.

The empirical analysis of competition followed an equally important transformation. Early studies, largely inspired by the Structure–Conduct–Performance paradigm, related prices to measures of market concentration in order to assess the consequences of deregulation. Although these analyses produced valuable evidence on airline pricing, they generally treated market concentration as exogenous. The New Empirical Industrial Organization subsequently shifted the focus towards estimating firms' conduct directly from market equilibrium conditions. More recent structural models go one step further by recognizing that prices, entry, mergers and network configurations are jointly determined through firms' strategic decisions. Dynamic models of airline competition now provide a unified framework for analysing entry, market power, mergers and network formation.

Finally, transportation has provided some of the richest applications of structural auction models. Competitive tendering for bus services, highway construction and other transport infrastructure has stimulated the development of econometric models capable of recovering bidders' costs, detecting collusion and evaluating alternative procurement mechanisms. More recent work has extended the analysis to combinatorial auctions, incomplete contracts and the choice between auctions and negotiated procurement, highlighting both the potential and the limitations imposed by available data.

Taken together, these developments reveal a common pattern. The history of empirical transportation economics is not simply one of increasingly sophisticated econometric techniques. Rather, it reflects a continuous effort to replace reduced-form correlations with structural models grounded in economic theory whenever endogeneity, strategic interaction or institutional design became central to the empirical question. Although modern structural models are considerably more demanding in terms of computation, identification and data requirements, they provide a coherent framework for conducting policy evaluation and counterfactual analysis. The evolution reviewed in this chapter therefore illustrates not only the remarkable progress of structural econometrics, but also the continuing dialogue between economic theory, empirical evidence and public policy that has shaped transportation economics over the past five decades.

The common thread running through these developments is the progressive recognition that demand, costs, market structure and procurement institutions cannot be treated as exogenous objects of analysis. Instead, they emerge from the interactions of consumers, firms and regulators, and must therefore be modelled jointly within coherent structural frameworks. In this sense, the history of transportation econometrics mirrors the broader evolution of applied econometrics itself: the gradual replacement of reduced-form relationships by models capable of explaining the economic mechanisms that generate the observed data.

The remainder of the chapter is organized as follows. Section 19.2 reviews the evolution of demand estimation, from aggregate demand systems and elasticity analysis to discrete-choice models, random-coefficient demand systems and the exploitation of large-scale individual-level data. The discussion emphasizes how increasingly differentiated transportation markets required progressively richer models of consumer behaviour. Section 19.3 turns to the estimation of operating costs and the evaluation of regulation. It follows the literature from early studies of economies of scale and density to structural models of incentive regulation under asymmetric information, highlighting the distinction between positive and normative approaches to regulatory modelling. Section 19.4 examines the empirical analysis of competition. Beginning with reduced-form studies relating prices to market concentration, it describes the transition towards structural models of market conduct, airline entry, mergers and dynamic network formation. Section 19.5 reviews the development of structural auction models in transportation procurement, discussing their application to bus franchising, highway construction and procurement design, as well as the challenges associated with modelling incomplete contracts and endogenous procurement mechanisms. Finally, Section 19.6 provides an overview of our general discussion about what did age well, or not so well, in the different empirical frameworks presented in this chapter. Section 19.7 concludes.

19.2 Demand Estimation

The evolution of demand estimation in transportation economics closely mirrors the development of empirical industrial organization over the last four decades. Each generation of models emerged in response to a specific economic question and to the limitations of its predecessors. During the 1970s and 1980s, linear demand systems were developed primarily to estimate price elasticities for forecasting and policy evaluation. Following airline deregulation and the emergence of increasingly differentiated transport markets, discrete-choice models became the preferred framework for analysing substitution patterns among products. The introduction of random-coefficient models subsequently allowed researchers to account for consumer heterogeneity and to perform richer welfare analyses. More recently, the availability of large-scale individual-level data has shifted attention towards modelling travel behaviour at an unprecedented level of detail.

This historical evolution also illustrates a broader lesson. Improvements in econometric methods have generally been driven not only by advances in econometric theory, but also by changes in the economic questions being asked and by the increasing richness of available data.

19.2.1 Linear Demand Models

The first generation of empirical studies of transport demand relied almost exclusively on systems of demand equations estimated from aggregate data. During the 1970s and 1980s, the principal objective was not to model firms' strategic behaviour, but to forecast traffic demand and evaluate public policies. Governments and transport operators required reliable estimates of own-price, cross-price and income elasticities to assess the effects of fare changes, fuel taxes, congestion pricing and infrastructure investments. Because detailed individual-level data were generally unavailable, aggregate demand systems estimated from market-level observations became the standard empirical tool.

Transportation demand presents several features that make its empirical analysis particularly challenging. As emphasized by Oum, Waters and Yong (1992), transport is a derived demand: individuals demand transportation because they wish to undertake other economic or social activities. Moreover, transport modes differ along several dimensions beyond price, including travel time, reliability, comfort, frequency and accessibility, making them imperfect substitutes. Finally, behavioural responses differ substantially between the short and the long run. While travellers can adjust departure times or travel modes relatively quickly, changes in residential location, workplace choice or vehicle ownership occur only gradually, leading to much larger long-run elasticities. Transportation demand presents several features that make its empirical analysis particularly challenging. Transport is a derived demand: individuals demand transportation because they wish to undertake other economic or social activities. Moreover, transport modes differ along several dimensions beyond price, including travel time, reliability, comfort, frequency and accessibility, making them imperfect substitutes. Finally, behavioural responses differ substantially between the short and the long run. While travellers can adjust departure times or travel modes relatively quickly, changes in residential location, workplace choice or vehicle ownership occur only gradually, leading to much larger long-run elasticities.

One popular specification was the log-linear demand system, described by Deaton and Muellbauer (1980), in which the logarithm of demand for each product is modelled as a linear function of the logarithms of all prices and consumer income. The coefficients associated with each price variable measure own- and cross-price elasticities. The popularity of this specification stemmed from its simplicity and transparency. The estimated coefficients have a direct economic interpretation, estimation can be carried out using standard econometric techniques, and only aggregate market-level data are required. These features made the approach particularly attractive in transportation economics, where detailed micro-data were rarely available before the 1990s. The comprehensive survey by Oum et al. (1992), reviewing several hundred elasticity estimates for air, rail, urban transit and freight transportation, illustrates both the richness of this literature and the central role played by elasticity estimation in transport planning and policy evaluation.

With hindsight, however, the limitations of linear demand systems became increasingly apparent. First, the number of parameters grows rapidly with the number of products J. Estimating a complete demand system for an industry with hundreds of differentiated products, such as commercial aviation after deregulation, quickly becomes infeasible since the number of cross-price elasticities increases approximately with J^2. Second, substitution patterns are entirely determined by the estimated coefficients and need not be consistent with an underlying model of consumer choice. Unless additional theoretical restrictions are imposed, the estimated demand system may violate the regularity conditions implied by utility maximization. Third, prices are generally endogenous because firms adjust them in response to demand conditions. Ignoring this simultaneity leads to biased elasticity estimates unless appropriate instrumental variables are available.[1]

Interestingly, the principal weakness of linear demand systems was not statistical but conceptual. These models were well suited to analysing competition between a small number of transport modes, but became increasingly inadequate as transportation

[1] For a more detailed discussion, see the Endogeneity and Simultaneity chapter of this book.

industries evolved towards highly differentiated markets. Airline deregulation, for example, transformed competition from a choice between a few transport modes into a choice among hundreds of differentiated airline products, varying in schedules, airports, frequencies, service quality and fares. Researchers therefore needed models whose complexity depended primarily on consumer heterogeneity rather than on the number of products.

The emergence of discrete-choice models during the early 1990s represented precisely such a shift. Rather than modelling aggregate demand directly, these approaches derive market demand from the utility-maximizing decisions of individual consumers. Besides providing stronger microeconomic foundations, they dramatically reduce the dimensionality of the estimation problem and offer a natural framework for dealing with differentiated products, endogenous prices and welfare analysis. McFadden (1974) and Berry (1994) provided seminal contributions that transformed empirical demand estimation in transportation economics. More recent contributions such as Hensher, Rose and Greene (2015) or Small, Verhoef and Lindsey (2024) provide a very useful state of the art overview of the implementation of these techniques in transportation sectors.

19.2.2 The Multinomial Logit Model

The first major conceptual breakthrough in demand estimation came with the introduction of random utility models by McFadden (1974). Rather than citemodelling market demand directly, these models describe the decision process of individual consumers. Each consumer is assumed to choose the alternative that provides the highest utility among a finite set of available products. Aggregate demand is then obtained by aggregating these individual choices across the population. This change in perspective represented a major departure from the aggregate demand systems discussed in the previous section, providing demand estimation with explicit microeconomic foundations based on utility maximization.

Transportation economics rapidly became one of the principal fields of application of these models. Individual travel decisions naturally involve discrete choices: travellers select among transport modes, routes, destinations, departure times or ticket types, making random utility models particularly well suited to analysing travel demand. The seminal book by Ben-Akiva and Lerman (1985) established discrete-choice models as the standard framework for transportation demand analysis and demonstrated their applicability to a wide range of decisions, including mode choice, destination choice, route choice and vehicle ownership. During the following decades, discrete-choice models became the dominant empirical tool for forecasting travel demand and evaluating transport policies.

Under the multinomial logit model, the utility that a consumer derives from choosing an alternative consists of an observable component, determined by the characteristics of the product and the consumer, and an unobservable random component. Assuming that the unobserved utility follows an extreme-value distribution leads to a closed-form expression for the probability that a consumer chooses a particular alternative. This analytical solution made the multinomial logit remarkably attractive from a computational perspective, especially at a time when computing power and data availability were limited.

The popularity of the multinomial logit model also stems from its flexibility. Product characteristics such as travel cost, travel time, frequency, comfort or reliability can be incorporated directly into the utility specification, while consumer characteristics allow researchers to explain systematic differences in travel behaviour. As emphasized by Train (1986), the model offered an economically coherent and computationally tractable framework that could be estimated using standard maximum likelihood techniques. More than two decades later, Train (2009) showed how advances in simulation methods had considerably expanded the range of discrete-choice models that could be estimated, while preserving the random utility framework introduced by McFadden.

Despite its success, the multinomial logit model imposes a strong behavioural restriction known as the Independence of Irrelevant Alternatives (IIA). Because substitution patterns depend only on market shares, the introduction or removal of one alternative affects all remaining alternatives proportionally. This implication is often unrealistic in transportation markets. For example, the introduction of a new high-speed rail service should primarily attract passengers from conventional rail rather than equally from airlines and private cars. Likewise, the entry of a low-cost airline is expected to divert demand mainly from other airlines serving the same route.

These shortcomings motivated the development of richer discrete-choice models such as the mixed logit model, see for instance Behrens and Pels (2012) which focuses on travelers' choices between high speed rail and airline services. Nested logit models relaxed the IIA assumption by allowing products sharing similar characteristics to be grouped together, while the random-coefficient models of Berry, Levinsohn and Pakes (1995) introduced flexible patterns of consumer heterogeneity. Together, these innovations transformed discrete-choice analysis from a model primarily designed for travel demand forecasting into the dominant framework for empirical studies of differentiated product markets and modern empirical industrial organization.

While linear demand systems modelled aggregate quantities directly, the multinomial logit model fundamentally changed the object of analysis by modelling the decisions of individual consumers.

19.2.3 Nested Logit and Random Coefficient Models

The early 1990s marked a fundamental turning point in the empirical analysis of transportation demand. The deregulation of the airline industry in the United States and Europe profoundly changed the nature of competition. Instead of choosing between a small number of transport modes, consumers increasingly faced a large number of differentiated products offered by competing firms. Airline tickets differed not only in price, but also in departure time, flight frequency, airport location, number of connections, loyalty programmes and service quality. Traditional linear demand systems were ill-equipped to analyse such markets. Researchers therefore required a new modelling framework capable of accommodating large product spaces while retaining a clear economic interpretation.

The solution came from discrete-choice models derived from random utility theory. Rather than specifying demand directly at the market level, these models assume that each consumer chooses the alternative providing the highest utility among a finite set of competing products. Aggregate demand is then obtained by integrating these individual choices across consumers. This seemingly simple change in perspective transformed empirical demand estimation. It provided explicit microeconomic foundations, guaranteed theoretically consistent substitution patterns and dramatically reduced the dimensionality of the estimation problem.

Berry (1994) demonstrated how differentiated-product demand models could be estimated using aggregate market shares rather than individual-level data. This contribution was particularly important for transportation economics, where detailed information on individual travellers was still largely unavailable. Berry also showed how the endogeneity of prices could be addressed using instrumental variables while recovering the mean utility associated with each product through an inversion of observed market shares. These methodological innovations made it possible to estimate demand in industries containing dozens or even hundreds of differentiated products, something that had proved impractical using traditional demand systems.

The nested logit model represented an important intermediate step between linear demand systems and more flexible demand specifications. By grouping similar products into nests, the model relaxes the restrictive substitution patterns implied by the simple multinomial logit model while remaining computationally tractable. In transportation applications, nests naturally correspond to transport modes, airline alliances, cabin classes or other groups of products sharing common characteristics. Consumers are allowed to substitute more easily between products belonging to the same nest than between products belonging to different nests, providing a substantially more realistic description of demand than earlier approaches, as illustrated for instance by Peters (2006).

Although nested logit represented a major improvement, it still imposed restrictive assumptions on substitution patterns within each nest. In particular, consumers sharing the same observable characteristics were assumed to exhibit identical preferences. Berry et al. (1995) overcame this limitation by introducing random coefficients into the utility function, allowing tastes to vary continuously across individuals. Consumer heterogeneity became an integral part of demand estimation rather than a residual source of unexplained variation.

The random-coefficient logit model considerably expanded the range of questions that could be addressed empirically. Researchers could estimate heterogeneous willingness-to-pay for travel time, service frequency or comfort, recover realistic own- and cross-price elasticities, and perform welfare analyses under alternative pricing or regulatory scenarios. More importantly, the model generated substitution patterns that depended on the similarity of products in the characteristics space rather than solely on arbitrary nesting structures. This proved particularly valuable in transportation industries where products differ simultaneously along numerous dimensions.

These methodological advances profoundly influenced empirical transportation economics. Structural demand models based on the Berry (1994) and Berry et al. (1995) framework rapidly became the standard approach for analysing airline competition, merger simulations, pricing strategies and market entry, see Berry and Jia (2010) for instance. They also provided the demand component required for estimating complete models of oligopoly behaviour, thereby linking consumer demand with firms' pricing decisions in a coherent equilibrium framework.

From today's perspective, the success of these models is remarkable. More than thirty years after their introduction, they remain the benchmark for empirical work on differentiated products. Nevertheless, they are not without limitations. Estimation relies on the availability of valid instruments for endogenous prices, numerical integration can become computationally demanding (although many modern estimation softwares propose nowadays ready-to-run commands that facilitate the implementation of these models), and identification often depends on functional-form assumptions about the distribution of consumer preferences. As emphasized by Berry and Haile (2021), recent research has focused less on replacing the BLP framework than on strengthening its identification, improving its computational properties and exploiting increasingly rich sources of micro-level data.

The availability of such data has, in turn, transformed the nature of empirical demand estimation. Rather than inferring consumer heterogeneity indirectly from aggregate market shares, researchers can now observe individual travel behaviour through ticketing databases, smart cards, mobile-phone records and online booking platforms. This new generation of data has opened the door to even richer structural models of transportation demand, discussed in the next subsection.

19.2.4 Big Data and the New Generation of Demand Models

The most recent transformation in transportation demand estimation has been driven less by the development of new econometric models than by the emergence of entirely new sources of data. Until the early 2000s, empirical analyses relied primarily on aggregate market shares, household travel surveys or stated-preference experiments. Although these datasets played a fundamental role in the development of discrete-choice models, they were often expensive to collect, limited in size, and observed travellers only at a few points in time. Since the 2010s, the widespread use of digital technologies has profoundly changed this landscape. Electronic ticketing systems, smart cards, GPS devices, mobile phones, connected vehicles and online booking platforms now generate massive amounts of information on individual travel behaviour, allowing researchers to observe travel decisions with an unprecedented level of spatial and temporal detail.[2]

[2] For a more detailed discussion, see the Big Data chapter of this book.

The transportation sector has been at the forefront of this data revolution. Huang et al. (2018) provide a comprehensive review of the new data sources available to transportation researchers and their applications to demand analysis, traffic management and infrastructure planning. Unlike traditional travel surveys, which typically observe a limited number of trips for a representative sample of individuals, these new datasets record millions of actual travel decisions on a continuous basis. As a result, they provide much richer information on travellers' preferences, daily activity patterns and responses to changes in prices, service quality and network conditions.

Among these new data sources, smart-card systems have had a particularly important impact on the analysis of public transportation. Pelletier, Trépanier and Morency (2011) review the extensive literature based on automated fare collection systems, showing how these data make it possible to reconstruct complete travel trajectories, identify transfer behaviour and analyse network usage at a highly disaggregated level. Such information has considerably improved the estimation of demand models for urban transit systems and has provided operators with valuable tools for planning services and evaluating policy interventions.

The increasing availability of location data has also transformed the study of travel behaviour. Using anonymized mobile-phone records, González, Hidalgo and Barabási (2008) demonstrate that individual mobility patterns exhibit a remarkable degree of regularity despite their apparent complexity. Building on these developments, Toole et al. (2015) show how mobile-phone data can be used to estimate origin–destination matrices and travel demand at a scale that was previously unattainable using conventional surveys. More generally, Chen, Ma, Susilo, Liu and Wang (2016) argue that large-scale passive data complement rather than replace traditional data collection methods. While Big Data provide exceptional spatial and temporal coverage, conventional surveys remain indispensable for collecting socioeconomic characteristics and attitudinal variables that are generally absent from administrative databases.

From the perspective of structural econometrics, the main contribution of Big Data has not been to replace random utility models, but rather to estimate them more accurately and at a much finer level of detail. Rich individual-level data allow researchers to identify heterogeneous preferences directly rather than inferring them indirectly from aggregate market shares. They also facilitate the estimation of dynamic travel behaviour, repeated choices and responses to unexpected network disruptions. At the same time, the increasing size and complexity of modern transportation datasets have stimulated the development of new computational methods, including simulation-based estimation, machine learning algorithms and high-dimensional optimization techniques.

Despite these remarkable advances, Big Data have not solved every empirical problem. Many administrative datasets contain detailed information on travel behaviour but relatively little information on travellers' socioeconomic characteristics or the motivations underlying their decisions. Privacy concerns often limit data accessibility, while the observational nature of these data raises familiar issues of selection bias and causal identification. Consequently, contemporary transportation demand analysis increasingly combines the behavioural foundations of structural discrete-choice models with the richness of Big Data, rather than viewing the two approaches as substitutes. The current frontier of research lies precisely at this intersection, where economic theory, structural econometrics and data science complement one another to improve our understanding of travel demand.

The evolution of demand estimation reviewed in this section also marks the point at which empirical transportation economics became genuinely structural. Modern demand models are rarely estimated in isolation. Instead, they constitute one side of a broader equilibrium framework in which consumer demand interacts with firms' pricing decisions and production technologies. Once demand elasticities have been recovered, researchers can combine them with firms' first-order conditions to infer markups and estimate marginal costs, thereby linking the demand and supply sides of transportation markets. This integration considerably expands the scope for policy analysis, allowing economists to evaluate mergers, pricing policies, entry decisions and regulatory reforms within a unified framework. The next section therefore turns to the estimation of operating costs and the role of regulation, completing the supply side of structural models in transportation economics.

19.3 Cost Estimation and the Economics of Regulation

The estimation of production costs has long occupied a central place in transportation economics. Unlike many manufacturing industries, transportation is characterized by large fixed costs, network technologies, public service obligations and extensive government intervention. As a result, cost estimation has never been a purely descriptive exercise. Rather, it has served as the foundation for evaluating economies of scale, designing regulatory mechanisms, setting subsidies and assessing the performance of transport operators.

The econometric methods used to estimate cost functions have evolved alongside the changing role of regulation. During the 1980s, most empirical studies sought to measure technological characteristics such as economies of scale and economies of density using flexible cost functions estimated from accounting data. As deregulation and privatization spread across transport industries, attention shifted towards evaluating the impact of alternative regulatory regimes on firms' efficiency. Early empirical work often relied on reduced-form comparisons between regulated and unregulated firms. While these studies provided valuable evidence, they typically treated regulation as exogenous, overlooking the fact that regulatory institutions are themselves shaped by political, economic and informational constraints.

The development of structural models based on the economics of asymmetric information during the 1990s represented a major conceptual advance. Rather than estimating the effects of regulation alone, these models explicitly described the strategic interaction between regulators and firms, recognizing that regulators face imperfect information about firms' production costs and managerial effort. Structural estimation consequently allowed researchers to recover technological parameters while simultaneously evaluating the incentive properties of alternative regulatory mechanisms.

This historical evolution also illustrates an important lesson. Improvements in empirical methods have not simply reflected advances in econometric techniques, but a progressively richer understanding of regulatory institutions. Reduced-form evaluations ignored the endogenous nature of regulation, while some early structural models relied on the strong assumption that regulators implemented optimal incentive schemes. More recent work has increasingly recognized that actual regulatory policies are themselves the outcome of political, institutional and informational constraints, suggesting that positive models of regulation remain an important frontier for empirical research.

19.3.1 Cost Functions and Transportation Technologies

The estimation of production costs has long been one of the central empirical questions in transportation economics. During the 1970s and 1980s, governments throughout Europe and North America faced difficult policy choices concerning the regulation and organization of transportation industries. Should railways, airlines and urban transit systems be operated by a single firm or by competing operators? Were these industries natural monopolies requiring public regulation, or could competition improve efficiency without sacrificing productive performance? Answering these questions required a detailed understanding of transportation cost technologies.

Early empirical studies therefore focused on estimating flexible cost functions capable of measuring the technological characteristics of transport firms. Rather than simply estimating average or marginal costs, researchers sought to determine whether production exhibited economies of scale, economies of scope or other technological features that could justify market concentration or public intervention. Flexible functional forms, such as the translog cost function, became the standard econometric tool because they imposed relatively few restrictions on the underlying production technology while allowing researchers to estimate cost elasticities from accounting data.

One of the most influential contributions in this literature is the study by Caves, Christensen and Tretheway (1984), which introduced the important distinction between *economies of scale* and *economies of density* in the airline industry. Economies of scale arise when average costs decline as the entire network expands proportionally, whereas economies of density refer to cost reductions obtained by increasing traffic on an existing network while holding the network itself fixed. This distinction proved particularly important for transportation industries, where firms operate complex networks whose size and intensity of use can evolve independently.

The authors show that much of the apparent cost advantage enjoyed by large airlines reflected economies of density rather than economies of scale. Increasing passenger traffic on an existing network substantially reduced average operating costs, while expanding the network itself generated much smaller efficiency gains. This result had important policy implications. It suggested that the presence of large firms did not necessarily imply that the industry was a natural monopoly. Instead, high traffic density and network utilization could explain a significant share of observed cost differences across airlines. The distinction between scale and density consequently played an important role in the policy debates surrounding airline deregulation and competition.

From a methodological perspective, these studies represented an important step forward because they provided a rigorous empirical framework for recovering technological characteristics from observed cost data. However, they remained essentially descriptive. Flexible cost functions explained how production costs varied with output, input prices and network characteristics, but they said little about why firms achieved different levels of efficiency or how regulatory institutions affected managerial behaviour. Cost differences were largely attributed to technological factors, while incentives created by regulation received comparatively little attention.

As transportation industries became progressively deregulated and governments experimented with privatization, competitive tendering and incentive regulation, the focus of empirical research shifted accordingly. The relevant policy question was no longer simply whether transportation technologies exhibited economies of scale, but whether different regulatory institutions encouraged firms to reduce costs and improve efficiency. This change in perspective marked the transition from technological cost estimation to structural models of regulation, in which firms' observed costs are interpreted as the outcome of strategic interactions between regulated firms and public authorities under asymmetric information.

19.3.2 Regulation and Efficiency: Reduced Forms versus Structural Costs with Asymmetric Information

During the late 1980s, the empirical focus of transportation economics shifted from describing production technologies to evaluating the impact of alternative regulatory institutions on firms' performance. Many governments experimented with deregulation, competitive tendering and incentive contracts, raising a natural empirical question: do different regulatory regimes improve productive efficiency?

The first generation of empirical studies addressed this question using reduced-form econometric models. Firms operating under different regulatory regimes were compared after controlling for observable characteristics such as size, input prices and network configuration. A typical specification considers that the operating cost can be expressed as a function of the regulatory regime and a set of firm characteristics. The coefficient associated with the regime dummy measures the average association between regulation and production costs.

Studies such as Mathios and Rogers (1989) adopted this approach to evaluate the effects of alternative regulatory schemes. Similar methodologies were subsequently applied in transportation economics to compare publicly and privately operated firms or to assess the impact of competitive tendering. At approximately the same time, stochastic frontier models became increasingly popular for separating productive inefficiency from statistical noise, allowing researchers to construct efficiency scores for regulated firms, see Bauer (1990).

Although these approaches represented an important empirical advance, they suffered from an important conceptual limitation. Regulatory institutions are rarely assigned randomly. Governments typically choose regulatory mechanisms according to market characteristics, political constraints or firms' expected performance. Consequently, regulation is endogenous, and simple comparisons between regulatory regimes cannot generally be interpreted as causal. Moreover, frontier models measure inefficiency but do not explain its origin. They remain essentially descriptive, treating firms' performance as independent of the incentives created by regulation.[3]

These limitations motivated the development of structural models based on the economics of asymmetric information. The seminal contributions of Baron and Myerson (1982) and Laffont and Tirole (1986) model regulation as a principal-agent problem in which the regulator seeks to minimize production costs while lacking complete information about the firm's efficiency and managerial effort. A simple representation of this framework assumes that realized production costs depend on the firm's intrinsic efficiency and the managerial effort. While realized costs are observable, neither efficiency or effort can be directly observed by the regulator. The regulator must therefore design an incentive contract that simultaneously limits informational rents and encourages cost-reducing effort.

This framework fundamentally changed the interpretation of observed costs. Differences in production costs no longer reflected technological characteristics alone but also the incentive properties of regulatory contracts. Structural estimation therefore aimed to recover not only production technologies but also the underlying informational asymmetries governing the relationship between regulators and firms.

Gagnepain and Ivaldi (2002) provide one of the first structural applications of this approach to urban public transportation. Estimating the principal-agent model developed by Laffont and Tirole using data on French transit operators, they jointly recover firms' technological characteristics, managerial effort and informational rents. Their analysis illustrates how structural econometrics makes it possible to evaluate counterfactual regulatory mechanisms, something that reduced-form approaches cannot accomplish because they do not explicitly model firms' behavioural responses to alternative incentive schemes.

From today's perspective, these structural models represented a major advance over reduced-form evaluations by embedding regulation within an explicit economic model of incentives and asymmetric information. Nevertheless, they also relied on a strong assumption: regulators were generally modelled as implementing optimal incentive schemes. In practice, regulatory institutions are themselves shaped by political objectives, administrative constraints and imperfect commitment. More recent research has therefore increasingly shifted towards positive models of regulation that seek to explain not only firms' behaviour but also the design of regulatory policies themselves.

[3] For a more detailed discussion, see the Treatment Effects and the Qualitative Variables chapters of this book.

19.3.3 Positive versus Normative Views

The structural models discussed in the previous section represented a major advance because they explicitly incorporated asymmetric information into the analysis of regulation. Nevertheless, they also raised a fundamental methodological question. Do these models describe how regulators actually behave, or do they describe how regulators should behave if they were implementing the optimal contracts prescribed by economic theory? This distinction between positive and normative modelling has played an important role in the development of empirical industrial organization and is particularly relevant in transportation economics, where regulatory institutions are often shaped by political, legal and administrative constraints that differ substantially from the assumptions of normative models.

The seminal contributions of Baron and Myerson (1982) and Laffont and Tirole (1986) are primarily normative. They characterize the optimal regulatory contract under asymmetric information and identify the trade-offs between productive efficiency, informational rents and incentives. These models provide powerful theoretical benchmarks against which observed regulatory institutions can be compared. However, there is no guarantee that regulators actually implement the optimal mechanisms predicted by the theory. Political constraints, budgetary limitations, lobbying, imperfect commitment and administrative complexity may all lead to regulatory outcomes that depart significantly from the theoretical optimum.

Recognizing this distinction, several authors have attempted to estimate alternative structural models of regulation and confront them with the data. Wolak (1994), for example, estimates a structural model of the interaction between regulators and utilities in the electricity sector, allowing the observed behaviour of regulators to differ from the prescriptions of the normative benchmark. Similarly, Dalen and Gomez-Lobo (1997) develop an empirical framework for regulated industries characterized by asymmetric information in which the structure of the regulatory mechanism itself becomes an object of empirical investigation rather than an assumption imposed a priori.

This perspective naturally leads to viewing structural econometrics as a tool for testing economic theories rather than merely implementing them. Gasmi, Laffont and Sharkey (1999) provide an influential illustration by comparing competing models of telecommunications regulation using observed data. Rather than asking whether one theoretical model is internally consistent, the objective becomes determining which model provides the most convincing empirical description of the regulatory process.

The econometrician therefore faces a problem of model selection. When competing structural models imply different behavioural mechanisms, they can be compared statistically using non-nested specification tests such as the likelihood ratio test developed by Vuong (1989). These procedures make it possible to discriminate between alternative theoretical representations of the same economic environment, providing an objective criterion for evaluating competing regulatory models. Structural econometrics thus becomes a dialogue between theory and data: economic theory proposes alternative mechanisms, while econometric evidence determines which mechanisms are most consistent with observed behaviour.

This distinction between positive and normative modelling remains highly relevant today. Normative models continue to provide indispensable benchmarks for designing efficient regulatory institutions, while positive models recognize that actual regulators operate under political, institutional and informational constraints that may prevent them from implementing theoretically optimal policies. One of the principal contributions of structural econometrics is precisely its ability to quantify these discrepancies and to identify the behavioural mechanisms that best explain observed regulatory outcomes. In this sense, the role of the econometrician is not simply to estimate structural parameters, but to confront competing theories with data and assess their empirical validity.

The evolution of cost estimation in transportation economics illustrates a broader trend in applied econometrics. Early empirical studies were primarily concerned with describing production technologies and identifying the presence of economies of scale or density. As regulatory reforms spread across transportation industries, the focus shifted towards measuring the impact of alternative regulatory regimes on firms' efficiency. Structural models based on asymmetric information subsequently provided a richer framework by recognizing that firms' costs are shaped not only by technology but also by the incentives created by regulation.

Perhaps the most important lesson from this literature is methodological. The objective of structural econometrics is not simply to estimate increasingly sophisticated cost functions, but to explain the economic mechanisms generating the observed data. In the context of regulation, this means explicitly modelling the strategic interaction between regulators and firms while confronting competing theories with empirical evidence. The distinction between positive and normative models highlights that structural models should not be viewed as faithful representations of reality, but as competing hypotheses whose empirical relevance must ultimately be assessed using data.

The same methodological issues arise in the analysis of competition. Just as regulatory institutions cannot be treated as exogenous, market concentration and firms' pricing behaviour are jointly determined by firms' strategic decisions. This observation naturally motivates the next part of the chapter, which examines how structural models have been used to measure competition and identify market power in transportation industries.

19.4 Competition and Prices

The relationship between market structure and prices has been one of the oldest questions in industrial economics and has naturally occupied a central place in transportation economics. Following the deregulation of airlines, trucking and several public transport services, economists sought to determine whether increased competition translated into lower prices, improved service quality and greater productive efficiency. The empirical challenge was to measure the intensity of competition using observed market outcomes.

The first generation of empirical studies was largely inspired by the Structure-Conduct-Performance (SCP) paradigm, which postulated that more concentrated industries should exhibit higher prices and profitability, as suggested by Schmalensee (1989). These studies played an important role in assessing the consequences of deregulation but generally treated market structure as exogenous. Industries characterized by higher concentration ratios or larger market shares were expected to exhibit higher prices, reflecting greater market power. These studies provided some of the earliest empirical evidence on competition in transportation markets and played an important role in evaluating the consequences of deregulation.

Over time, however, an important conceptual limitation became increasingly apparent. Market concentration is itself an equilibrium outcome resulting from firms' pricing, entry and investment decisions. Regressing prices on observed concentration therefore raises a familiar endogeneity problem: high concentration may increase prices, but high prices may also attract entry, while both variables may be jointly determined by underlying market characteristics. As emphasized by Bresnahan (1989), identifying market power requires models that explicitly describe firms' strategic behaviour rather than relying solely on correlations between prices and market structure.

The development of structural models of oligopoly during the late 1980s and early 1990s transformed the empirical analysis of competition in transportation industries. Researchers progressively moved from reduced-form price equations towards models that jointly determine prices, quantities, market structure and firms' strategic interactions. This evolution also illustrates a recurring theme of this chapter: empirical models became increasingly structural as economists recognized that the institutions they sought to evaluate—consumer demand, regulation or market concentration—could not be treated as exogenous.

19.4.1 The impact of Market Concentration on Price

The deregulation of the U.S. airline industry in 1978 fundamentally changed the nature of competition in air transportation and generated a vast empirical literature on the determinants of airline fares. One of the central policy questions was whether increased competition translated into lower prices for consumers. During the late 1980s and throughout the 1990s, empirical studies therefore sought to quantify the relationship between market concentration and prices using relatively simple reduced-form econometric models. These studies were closely related to the Structure–Conduct–Performance (SCP) paradigm, according to which firms operating in more concentrated markets are expected to enjoy greater market power and charge higher prices.

A typical empirical specification relates average fares to a measure of market concentration, together with a set of observable market characteristics, see for instance Ng and Seabright (2001). These characteristics entail typically route distance, passenger density and airport characteristics. Among the most influential contributions, Borenstein and Rose (1994) examine the relationship between competition and price dispersion in the U.S. airline industry. Using a large sample of airline markets, they show that increased competition does not simply reduce average fares but also affects the entire distribution of ticket prices. Price dispersion is found to be substantially larger on more competitive routes, reflecting the widespread use of yield management and price discrimination. Their results illustrate that competition influences not only the level of prices but also firms' pricing strategies.

Stavins (2001) extends this analysis by investigating how market concentration affects price discrimination across different categories of travellers. Using detailed airline fare data, she shows that concentration influences the ability of airlines to discriminate between business and leisure passengers. More concentrated markets tend to exhibit larger fare differentials, suggesting that market power allows firms to exploit differences in consumers' willingness to pay more effectively.

These studies made an important contribution by documenting robust empirical relationships between market structure and pricing behaviour. They also demonstrated the richness of airline pricing strategies following deregulation and highlighted the importance of market concentration as a determinant of fares. More generally, they provided some of the earliest quantitative evidence used by competition authorities to assess airline mergers and monitor the competitive effects of deregulation.

From today's perspective, however, the principal limitation of this literature is its treatment of market concentration as an exogenous explanatory variable. The degree of concentration observed on a route is itself the outcome of firms' strategic decisions regarding entry, capacity and pricing. Routes with persistently high demand may simultaneously attract more entrants and sustain higher fares, while barriers to entry may affect both market structure and prices. Consequently, the estimated relationship between concentration and fares cannot generally be interpreted as causal. As emphasized by the New Empirical Industrial Organization literature, identifying market power requires models in which prices and market structure are determined jointly as equilibrium outcomes. This insight motivated the development of structural models of competition, to which we now turn.

19.4.2 The Conduct Parameter

The reduced-form studies discussed in the previous section provided valuable evidence on the relationship between market concentration and prices, but they left an important question unanswered: how much market power do firms actually exercise? Market concentration is at best an indirect proxy for competition. Two markets with identical concentration levels may exhibit very different pricing behaviour if firms compete aggressively in one market but coordinate implicitly in the other. During the late 1980s, the emergence of the New Empirical Industrial Organization (NEIO) shifted attention away from market structure itself towards the direct estimation of firms' conduct.

The central idea is to model firms as maximizing profits subject to a demand system and to recover their competitive behaviour from the first-order conditions of profit maximization. Rather than inferring market power from concentration measures, researchers estimate a parameter that summarizes the extent to which firms internalize the effects of their pricing decisions on competitors. This *conduct parameter* provides a direct measure of the degree of competition prevailing in the market.

Consider a market in which firms compete by setting prices. The first-order condition of profit maximization typically includes the price, the marginal cost, market demand, and the conduct parameter. The conduct parameter summarizes firms' competitive behaviour: a value equal to 0 corresponds to perfect competition, in which case price equals marginal cost, while a value equal to 1 is consistent with joint profit maximization. Intermediate values describe various forms of imperfect competition, including Cournot and differentiated Bertrand competition depending on the market environment.

As emphasized by Bresnahan (1989), the conduct parameter approach represented a major methodological advance because it shifted the focus from market structure to market behaviour. Instead of asking whether concentrated markets exhibit higher prices, the econometrician asks whether firms price as competitive firms, Cournot competitors or collusive oligopolists. The estimated conduct parameter therefore provides a direct test of alternative theories of competition.

The implementation of these models nevertheless requires considerably more structure than reduced-form price regressions. Identifying conduct relies on estimates of demand elasticities and marginal costs, implying that the demand and supply sides of the market must be estimated jointly. In practice, the researcher must specify both consumers' demand behaviour and firms' pricing decisions, making the estimated degree of competition conditional on the maintained structural assumptions. This observation also explains why advances in demand estimation, such as the discrete-choice models discussed earlier in this chapter, became an essential component of modern empirical studies of market power.

Although the conduct parameter framework remains one of the cornerstones of empirical industrial organization, it also has important limitations. A single conduct parameter summarizes firms' behaviour at the industry level and therefore abstracts from many dimensions of strategic interaction, including entry, exit, product differentiation and dynamic competition. These limitations motivated the development of richer structural models in which firms' strategic decisions are derived explicitly from dynamic games. In transportation economics, these models have proved particularly valuable for analysing airline entry, network formation and merger policies.

19.4.3 Alliances and Mergers in the Airline Industry

The deregulation of air transport markets in the United States and, subsequently, in Europe and Asia Pacific fundamentally changed the competitive landscape of the airline industry. As carriers gained freedom to set fares, enter and exit routes, and organise their networks, two phenomena became central to the empirical analysis of competition: horizontal mergers between domestic carriers and the formation of international code-sharing alliances. Both raised the same fundamental question—do consolidation and cooperation among airlines reduce fares for consumers, or do they facilitate the exercise of market power?

The Airline Origin and Destination Survey (DB1B). A distinctive feature of this literature is its heavy reliance on a single data source: the Airline Origin and Destination Survey, commonly referred to as DB1B. Collected quarterly by the United States Department of Transportation's Bureau of Transportation Statistics, DB1B is a ten percent random sample of domestic airline tickets purchased in the United States. Each observation records the origin airport, the destination airport, the sequence of intermediate airports, the operating and ticketing carriers, the fare paid, and the number of passengers travelling on that itinerary. The richness of this dataset—covering virtually the entire U.S. domestic market continuously since 1993—made it the natural empirical platform for studying airline pricing, market structure, and competitive conduct.

DB1B possesses several features that proved particularly valuable for the empirical analysis of mergers and alliances. The itinerary-level structure allows researchers to reconstruct route-level market shares and average fares, to distinguish between nonstop and connecting services, and to track how competitive conditions change following entry, exit, or consolidation events. Its panel dimension makes it possible to exploit within-market variation before and after a merger or alliance, addressing some of the concerns about unobserved market heterogeneity that arise in cross-sectional comparisons. The large sample size, covering thousands of origin-destination markets over multiple quarters, also provides sufficient statistical power to detect even modest competitive effects.

Nevertheless, DB1B has important limitations that the subsequent literature progressively recognised. The dataset records fares actually paid by passengers, which may differ substantially from posted fares depending on advance purchase requirements, fare class restrictions, and yield management practices. It contains no direct information on capacity, flight frequencies, or service quality attributes beyond the sequence of connecting airports (this information is however available nowadays in other data sources published by the Bureau of Transportation Statistics). Most importantly for the analysis of alliances and mergers, DB1B records transactions rather than firm strategies: it observes the outcome of carriers' pricing decisions but does not directly reveal the informational or contractual arrangements underlying cooperative agreements. These limitations meant that DB1B was well suited to measuring the price effects of mergers and alliances after the fact, but ill-equipped to explain the endogenous formation of these agreements or to recover the structural parameters of the underlying competitive interaction.

Mergers and Market Power. Among the early contributions to exploit DB1B, Kim and Singal (1993) provide an influential analysis of horizontal mergers in the U.S. airline industry during the wave of consolidation that followed deregulation. Their study examines a sample of mergers completed between 1985 and 1988 and documents the evolution of fares on routes served by the merging carriers relative to routes unaffected by the merger. The identifying variation comes from the differential exposure of routes to the merger: routes on which both merging carriers were active prior to the transaction serve as the treatment group, while routes served by only one or neither carrier serve as comparison groups.

The empirical evidence points in two directions. On routes directly affected by the merger—where horizontal overlap was greatest—fares rose significantly following consolidation, consistent with the exercise of market power. On routes served by only one of the merging carriers, however, fares tended to decline, suggesting that efficiency gains, network integration, or the threat of competitive entry may partially offset the anticompetitive effects of reduced market concentration. This heterogeneity in competitive effects across route types is an early illustration of a broader lesson that the empirical literature would repeatedly confirm: the welfare consequences of airline mergers depend critically on local market structure, the degree of route overlap, and the presence of potential entrants.

From a methodological perspective, the framework of Kim and Singal (1993) reflects both the strengths and limitations of the reduced-form approach. The identification strategy exploits plausibly exogenous variation in merger exposure across routes, and the results provide credible evidence of average treatment effects. However, the analysis treats the merger itself as exogenous, setting aside the possibility that carriers strategically select acquisition targets partly on the basis of expected post-merger pricing power. Mergers are more likely to be proposed and approved on routes where the competitive constraint imposed by the target is greatest, which may bias simple before-after comparisons in either direction depending on the direction of strategic selection. Subsequent research addressed this concern through instrumental variable strategies and structural models of merger simulation, but the endogenous formation of mergers remains one of the central identification challenges in this literature.

International Alliances and Code-Sharing. The analysis of international airline alliances raises a structurally distinct set of empirical questions. Unlike domestic mergers, transatlantic and transpacific alliances typically involve code-sharing arrangements and coordinated pricing on connecting itineraries rather than the outright elimination of an independent competitor. The relevant competitive question is therefore not whether a rival has been removed from the market, but whether interline cooperation between carriers serving complementary route segments raises or lowers fares for passengers travelling multi-segment itineraries.

Brueckner and Whalen (2000) examine this question using DB1B data on international itineraries involving transatlantic alliances formed during the 1990s. Their central argument is that alliance partners serving complementary route segments face a classical double-marginalisation problem in the absence of coordination: each carrier independently sets its fare for its own segment without internalising the effect of higher fares on demand for the partner's segment. When two carriers operating connecting services coordinate their pricing—as alliance agreements typically require—they jointly maximise profit over the full itinerary, eliminating the double-marginalisation distortion and thereby reducing the combined interline fare. This pro-competitive mechanism predicts that alliance formation should lower fares on interline routes connecting the hub networks of the two partners.

Empirically, Brueckner and Whalen (2000) find substantial fare reductions on alliance interline routes relative to comparable non-alliance itineraries. The estimated effects are large, with alliance membership associated with fare reductions of roughly twenty to thirty percent on interline journeys, while fares on the purely intraline segments of alliance partners show little systematic change. This asymmetry is consistent with the double-marginalisation mechanism: coordination generates efficiency gains primarily on routes requiring an interline connection, while leaving the competitive interaction on pure point-to-point routes largely unaffected.

The Brueckner and Whalen (2000) analysis also raises an important endogeneity concern that the authors acknowledge explicitly. Alliance formation is not random: carriers choose partners strategically, and the routes ultimately connected through alliance agreements are those for which cooperation is most commercially attractive. If alliances tend to form on routes where interline demand is strongest and double-marginalisation is therefore most distortionary, naive comparisons between alliance and non-alliance routes may overstate the fare reductions attributable to coordination. To address this concern, the authors instrument for alliance status using indicators of bilateral route characteristics that are unlikely to affect fares directly, though the validity of these instruments remained a subject of subsequent debate.

With the benefit of hindsight, several features of this early literature proved less durable. Most importantly, the reliance on DB1B as the primary data source imposed binding constraints on what questions could be credibly addressed. DB1B records observed transactions, not the strategic decisions underlying them. Empirical attempts to model the endogenous formation of alliances or the selection of merger partners using this dataset were necessarily indirect, relying on reduced-form proxies for the informational and contractual determinants of cooperative agreements. The data simply did not contain the variation required to identify why specific alliances form, which carriers are most likely to merge, or how the terms of cooperative contracts shape subsequent pricing conduct.

A second limitation concerns the treatment of competitive responses. Both Kim and Singal (1993) and Brueckner and Whalen (2000) focus primarily on the routes directly served by the merging or cooperating carriers, with relatively limited attention to the strategic responses of rivals. In practice, mergers and alliances reconfigure network competition, potentially affecting fares on routes where the parties do not overlap directly if rivals adjust capacity, entry decisions, or pricing in response to the changed competitive environment. Capturing these general equilibrium effects requires a structural model of network competition in which carriers' pricing and entry decisions are jointly determined—a modelling framework that the literature developed only gradually through the subsequent contributions of Berry (1992), Borenstein (1990), Aguirregabiria and Ho (2012), and more recently Bontemps, Gualdani and Remmy (2023).

Taken together, the empirical literature on airline mergers and alliances illustrates a recurring theme in structural transportation economics. Reduced-form analyses of observed price effects provided credible and policy-relevant evidence, but they left the underlying mechanisms—endogenous alliance formation, network competition, dynamic entry—largely unmodelled. The progressive shift towards structural models capable of addressing these mechanisms was driven precisely by the recognition that policy evaluation requires counterfactual analysis, which in turn demands explicit modelling of the strategic interactions that reduced-form approaches leave in the background.

19.4.4 Structural Models of Entry and Network Formation

By the early 1990s, empirical research on competition had largely moved beyond reduced-form analyses of prices and conduct parameters. While these approaches provided useful measures of market power, they remained ill-suited to answering many of the policy questions raised by airline deregulation. Competition authorities were increasingly interested in predicting the effects of mergers, airport dominance, entry barriers and changes in network configuration. Addressing such questions requires models in which market structure is itself an equilibrium outcome resulting from firms' strategic decisions.

Berry (1992) represents one of the first major contributions in this direction. Rather than treating the observed number of firms as exogenous, he develops a structural model in which airlines enter a market whenever expected profits are non-negative. Market profitability depends on observable characteristics such as population, income and route distance, together with the anticipated behaviour of competitors. Estimating the model allows the researcher to recover the determinants of entry costs and to predict how changes in market conditions affect the equilibrium number of firms. More importantly, it provides a framework for conducting counterfactual policy experiments, such as evaluating the competitive consequences of changes in entry conditions or airport access. In Berry's model, entry occurs until profits become non-positive. Unlike the conduct-parameter models discussed previously, competition is no longer summarized by a single parameter. Instead, market structure becomes an endogenous equilibrium outcome. The econometrician estimates the determinants of profitability and predicts how the number of firms changes following policy interventions, demand shocks, or changes in entry costs.

The importance of strategic interactions in airline markets had already been emphasized by Borenstein (1990), who showed that airport dominance could confer substantial market power independently of conventional measures of concentration. Airlines controlling a large share of airport facilities may deter entry by potential competitors, allowing them to sustain higher fares despite industry deregulation. This observation highlighted the need for empirical models capable of jointly explaining market structure, entry decisions and pricing behaviour rather than analysing each outcome separately.

A second generation of structural models extended the analysis from static entry decisions to dynamic competition. Aguirregabiria and Ho (2012) develop a dynamic oligopoly model in which airlines simultaneously choose prices, capacities and network configurations while anticipating the future consequences of their current decisions. Entry into a new market or the expansion of an existing network involves substantial sunk costs, implying that firms' decisions depend not only on current profitability but also on expected future market conditions. By explicitly modelling these dynamic incentives, the authors are able to conduct policy experiments evaluating the long-run effects of regulatory changes, airport expansion or merger policies. These models build on the structural demand framework of Berry et al. (1995), combining demand estimation with dynamic models of firms' strategic behaviour.

Recent research has pushed the structural approach one step further by recognizing that firms compete not only through prices and market entry but also through endogenous product design. In the airline industry, products correspond to routes, frequencies, schedules and network connections. Bontemps et al. (2023) develop a structural model in which airlines jointly determine their network structure and pricing decisions. The model captures the interaction between demand, pricing and product choice, allowing researchers to evaluate how firms reorganize their networks in response to changes in competition, demand or regulation. Such models illustrate the increasing realism of modern structural econometrics, where firms optimize simultaneously along several strategic dimensions.

The evolution of this literature reflects a profound change in the empirical analysis of competition. Early studies viewed market concentration as an explanatory variable, while the conduct-parameter approach sought to infer firms' behaviour from observed prices. Modern structural models instead derive market structure, prices and network configurations from explicit models of firms' dynamic optimization problems. These richer frameworks considerably expand the scope of policy analysis, making it possible to evaluate mergers, airport access policies, entry regulations and infrastructure investments within a unified structural model.

From today's perspective, structural models of entry and network formation constitute one of the most successful applications of empirical industrial organization to transportation economics. At the same time, they illustrate the growing trade-off between realism and computational complexity. As models incorporate dynamic decisions, differentiated products and network effects, estimation becomes substantially more demanding and increasingly dependent on detailed administrative data. Nevertheless, these models remain the benchmark for evaluating competition policy in network industries because they explicitly account for the strategic interactions that determine market outcomes.

19.5 Auction Models

The previous section examined competition in transportation markets where firms strategically choose prices, entry decisions and network configurations. However, many transportation services are not allocated through decentralized market competition. Urban bus services, railway concessions, airport operations and the construction of transport infrastructure are frequently awarded through procurement procedures organized by public authorities. In these industries, firms compete not *within* the market but *for* the market. Following the waves of deregulation, privatization and competitive tendering that spread across Europe and North America during the 1980s and 1990s, understanding how procurement mechanisms affect prices, efficiency and investment became a central question in transportation economics.

The empirical analysis of procurement naturally borrowed from the rapidly expanding literature on auction theory and structural auction models. Early contributions sought to recover bidders' private costs from observed bids, measure the degree of competition, and detect collusive behaviour. As richer data became available, researchers extended these models to more complex procurement environments involving combinatorial auctions, multidimensional bids and incomplete contracts. These structural models considerably expanded the scope for policy analysis, allowing economists to compare alternative auction formats, evaluate procurement rules and quantify the costs of collusion or inefficient contract design.

As in the previous sections of this chapter, the methodological evolution reflects the progressive recognition that institutions themselves are endogenous. Early empirical work often treated the procurement mechanism as fixed and focused exclusively on bidder behaviour. More recent studies recognize that governments strategically choose between negotiations and auctions, determine the design of bidding rules, and specify the contractual environment in which firms compete. Identifying the determinants and consequences of these institutional choices remains challenging because procurement procedures are rarely assigned randomly and available data often contain limited information on the contracting process. Consequently, while structural auction models have become one of the most successful applications of empirical industrial organization, explaining the endogenous choice of procurement mechanisms remains an active area of research.

19.5.1 Auction versus Negotiation

The rapid expansion of competitive tendering during the 1980s and 1990s fundamentally changed the organization of transportation industries. Public authorities increasingly relied on private firms to provide urban bus services, railway concessions, road maintenance and transport infrastructure, replacing direct public provision with contractual relationships. This evolution raised a fundamental institutional question: under which circumstances should procurement rely on competitive auctions rather than bilateral negotiations? While standard auction theory generally predicts that competition among bidders reduces procurement costs, transportation projects are often characterized by considerable uncertainty regarding future demand, engineering conditions and technical specifications. Because contracts are necessarily incomplete, ex post renegotiation frequently becomes unavoidable.

The theoretical foundations of this debate originate in the transaction-cost economics literature developed by Williamson (1975, 1985), according to which governance structures should be adapted to the characteristics of the transaction. Bajari and Tadelis (2001) formalize this intuition in a procurement setting by showing that the optimal procurement mechanism depends on the expected importance of contractual adaptations. When projects can be specified accurately before bidding, competitive auctions generate strong price competition and efficiently allocate contracts. Conversely, when projects are complex and significant design changes are anticipated during execution, negotiations may outperform auctions by facilitating contractual adaptation and reducing renegotiation costs.

A simple representation of this trade-off expresses the expected procurement cost as the sum between the procurement price determined during the bidding stage and the expected cost of contractual adaptations occurring after the contract has been awarded. Competitive auctions tend to minimize the first component but may increase the second if the initial contract proves too rigid. Negotiated procurement generally leads to higher initial prices while reducing the costs associated with unforeseen modifications. The optimal procurement mechanism therefore depends on the expected balance between ex ante competition and ex post contractual flexibility.

Bajari, McMillan and Tadelis (2009) provide one of the first structural empirical evaluations of this trade-off using detailed data on procurement contracts awarded by the California Department of Transportation. Rather than assuming that procurement methods are assigned randomly, they explicitly recognize that public buyers choose between auctions and negotiations according to project characteristics. Their empirical results show that negotiated procurement is systematically selected for projects involving greater contractual complexity, higher uncertainty and larger expected adaptation costs. Conversely, standardized projects with well-defined specifications are more likely to be auctioned. The observed procurement mechanism therefore reflects an endogenous institutional choice rather than an exogenous policy variable.

Although their application concerns highway construction, the underlying economic mechanisms are highly relevant for transportation economics more generally. Urban transport concessions, railway franchises, public-private partnerships and infrastructure maintenance contracts all involve similar trade-offs between ex ante competition and ex post contractual flexibility. A growing empirical literature has documented how contract duration, risk allocation and incentive mechanisms are adapted to these institutional environments. In particular, Saussier (2000) and Yvrande-Billon (2006) examine concession contracts and public service delegation in the French transportation sector, showing that procurement design responds to transaction costs, information asymmetries and the need to accommodate contractual incompleteness. Their work illustrates how the insights of transaction-cost economics and incomplete contract theory can be brought to bear on transportation policy using detailed institutional data.

From today's perspective, the principal contribution of this literature lies less in comparing the performance of auctions and negotiations than in recognizing that the procurement mechanism is itself an endogenous decision. This insight parallels the evolution observed throughout this chapter. Just as demand models progressively recognized the endogeneity of prices, regulation models incorporated endogenous incentive schemes, and competition models treated market structure as an equilibrium outcome, modern procurement models explain not only firms' bidding behaviour but also the institutional environment within which competition takes place. At the same time, explaining the choice of procurement mechanism remains empirically challenging because detailed information on governments' objectives, contractual negotiations and ex post adaptations is rarely observed, limiting the identification of the underlying selection process.

19.5.2 Structural Auction Models

Once procurement has been organized through competitive bidding, the next challenge is to understand what information can be recovered from observed bids and how alternative auction designs affect economic outcomes. This question gave rise to a large literature on structural auction models, whose objective is to infer bidders' underlying costs, detect strategic behaviour, and evaluate alternative procurement mechanisms. As emphasized by Paarsch and Hong (2006), auction data provide a particularly attractive environment for structural econometrics because the institutional rules governing competition are often well defined, allowing researchers to estimate models closely linked to economic theory and to conduct explicit counterfactual analyses.

The starting point of most structural auction models is the observation that bids contain information about bidders' private costs. In its simplest form, a bid can be represented as the sum of the private cost of the firm and the markup implied by strategic bidding considerations. Structural auction models seek to recover the underlying cost distribution from observed bids by exploiting the equilibrium relationship between costs and bidding strategies. Once costs have been identified, researchers can evaluate alternative auction formats, estimate the cost of collusion, or assess the efficiency of procurement mechanisms.

One of the earliest and most influential applications is Porter and Zona (1993), who develop an econometric methodology to detect bid rigging in procurement auctions. Studying highway construction contracts, they show that collusive bidders exhibit bidding patterns that differ systematically from those predicted by competitive auction models. Rather than relying on direct evidence of cartel behaviour, their approach uses deviations from equilibrium bidding behaviour to infer the presence of collusion. This contribution illustrates one of the major strengths of structural auction models: economic theory provides a benchmark against which observed bidding behaviour can be evaluated. More generally, the paper demonstrated that auction data could be used not only to estimate costs but also to uncover hidden strategic interactions among firms.

As transportation procurement became more sophisticated, researchers increasingly confronted auction environments involving multiple contracts and network effects. The London bus system provides a particularly interesting example. Rather than viewing individual routes in isolation, operators may benefit from operating combinations of routes that share depots, maintenance facilities, personnel or administrative resources. Cantillon and Pesendorfer (2007) analyze this setting using a combinatorial auction framework in which firms submit bids reflecting these complementarities. Their study shows that ignoring network effects can lead to inefficient contract allocations and higher procurement costs. More broadly, it illustrates how transportation industries often require auction models that account explicitly for the network structure of production rather than treating contracts as independent objects.

The literature subsequently moved beyond the assumption that contracts are fully specified at the time of procurement. As discussed in the previous subsection, transportation projects frequently involve substantial uncertainty regarding future conditions, making contractual adaptations unavoidable. Bajari, Houghton and Tadelis (2014) develop a structural framework that explicitly accounts for these adaptation costs. Using detailed procurement data, they estimate the costs associated with contract modifications and show that these costs can represent a substantial component of total project expenditures. Their results provide empirical support for the incomplete-contract perspective developed by Bajari and Tadelis (2001), demonstrating that procurement outcomes depend not only on ex ante bidding competition but also on the contractual flexibility available once projects are underway.

Taken together, these studies illustrate the progressive enrichment of structural auction models. Early contributions focused primarily on recovering bidders' costs and detecting collusion from observed bids. Subsequent research incorporated increasingly realistic institutional features, including combinatorial bidding, network complementarities and contractual incompleteness. In transportation economics, these developments proved particularly valuable because many procurement environments involve large infrastructure investments, long-term contractual relationships and complex operational networks. Structural auction models therefore provide a powerful framework for evaluating procurement policies, designing auction rules and quantifying the welfare consequences of alternative institutional arrangements.

At the same time, these models face challenges similar to those encountered elsewhere in structural econometrics. Richer models generally require stronger assumptions regarding bidder behaviour, information structures and contractual environments, while identification often depends on detailed administrative data that are not always available. Nevertheless, structural auction models remain among the most successful applications of empirical industrial organization, offering a clear illustration of how economic theory and econometric methods can be combined to evaluate complex policy questions in transportation markets.

19.6 What aged well, and what did not

The historical perspective adopted throughout this chapter reveals that the evolution of structural econometrics in transportation economics has been remarkably cumulative. Few empirical approaches have disappeared entirely; rather, successive generations of models have incorporated the strengths of earlier methods while addressing their limitations. Looking back over the past five decades, several broad lessons emerge regarding which ideas have stood the test of time and which have proved less successful.

Perhaps the most enduring lesson is that economic theory provides an indispensable organizing framework for empirical work. While early reduced-form regressions often produced useful descriptive evidence, their policy implications were frequently limited because they ignored the equilibrium relationships linking prices, quantities, market structure and regulation. By contrast, structural models grounded in consumer and firm optimization have proved remarkably resilient. Whether estimating demand, costs, entry decisions or procurement auctions, modern empirical studies continue to rely on explicit economic models to interpret observed behaviour and perform counterfactual policy analysis.

A second idea that has aged particularly well is the recognition that endogeneity is not a technical nuisance but an intrinsic feature of transportation markets. Prices respond to demand conditions, market concentration reflects firms' entry and exit decisions, regulatory regimes are themselves chosen in response to political and informational constraints, and procurement mechanisms are selected according to project characteristics. Over time, the literature has progressively expanded the set of variables treated as endogenous. This evolution explains much of the increasing sophistication of empirical methods, from instrumental-variable demand estimation to dynamic games and structural auction models.

The importance of individual behaviour has also become increasingly apparent. Early transport demand studies relied almost exclusively on aggregate market data and average elasticities. Advances in discrete-choice modelling, followed by the widespread availability of individual-level administrative data, shifted the focus toward heterogeneous travellers making individual decisions under realistic constraints. This transition has considerably improved both the predictive performance of demand models and their ability to evaluate welfare and distributional effects of transportation policies.

At the same time, several empirical approaches have not aged as well. Linear demand systems, despite their simplicity and transparency, proved ill-suited to industries characterized by many differentiated products. Their dimensionality grows rapidly with the number of alternatives, while the resulting substitution patterns often lack clear behavioural foundations. Likewise, early empirical studies relating prices directly to measures of market concentration generally underestimated the simultaneity between market structure and firms' strategic decisions. Similar criticisms apply to reduced-form evaluations of regulation that ignored the endogenous determination of regulatory institutions.

Another lesson concerns the role of data. Throughout the chapter, improvements in econometric methodology have gone hand in hand with improvements in data availability. Nevertheless, richer datasets have rarely eliminated identification problems. The Airline Origin and Destination Survey (DB1B), for example, transformed empirical research on airline pricing while remaining poorly suited to explaining the endogenous formation of alliances or mergers. More recently, smart-card records, GPS traces and mobile-phone data have revolutionized the analysis of travel behaviour but have also introduced new challenges related to high-dimensional heterogeneity, computational complexity and privacy concerns. Better data therefore expand the questions researchers can address, but they do not substitute for careful economic modelling.

Finally, one of the most striking developments concerns the changing relationship between positive and normative analysis. Structural models are often viewed as tools for policy evaluation because they enable researchers to simulate hypothetical reforms. Yet the literature reviewed in this chapter also demonstrates the importance of confronting alternative structural models with the data rather than treating theory as unquestionable. The most influential contributions are those that combine strong economic foundations with rigorous empirical validation, allowing the data to discriminate between competing theories.

Taken together, these observations suggest that the future of structural econometrics in transportation economics is unlikely to consist of replacing economic models with increasingly flexible statistical algorithms. Instead, future progress will probably arise from combining richer behavioural models, more detailed data and modern computational methods while maintaining the economic discipline that gives structural analysis its policy relevance. In this respect, the central lessons developed over the past fifty years remain as relevant today as when the first structural models were introduced.

19.7 Conclusion

Structural econometrics has profoundly transformed transportation economics over the past five decades. What began as the estimation of demand elasticities and cost functions has gradually evolved into a unified framework for analyzing consumer behavior, firms' strategic interactions, regulation, and procurement. Today, structural models constitute one of the principal tools available to transportation economists for conducting policy evaluation and counterfactual analysis, allowing researchers not only to explain observed market outcomes but also to predict the consequences of policies that have never been implemented.

The development of these models has been driven by a continuous dialogue between economic theory, econometric methodology, and data availability. Advances in discrete-choice analysis, dynamic games, auction models, and incentive regulation were made possible not only by methodological innovations but also by the increasing availability of detailed data describing travelers, firms, and transportation networks.

Conversely, the growing richness of modern datasets has reinforced rather than diminished the need for structural economic models capable of distinguishing causal mechanisms from purely statistical correlations.

Looking ahead, several developments are likely to shape the next generation of structural research in transportation economics. The rapid expansion of digital mobility platforms, connected vehicles, smart infrastructure, and real-time data offers unprecedented opportunities to study travel behavior and market interactions at a much finer level of detail. At the same time, emerging policy challenges—including decarbonization, the electrification of transport systems, autonomous vehicles, congestion management, and multimodal mobility—raise questions that cannot be answered solely through descriptive or predictive methods. Their evaluation requires models capable of capturing behavioral responses, firms' strategic adaptation, and market equilibrium.

Artificial intelligence and machine learning will undoubtedly become increasingly important components of the empirical toolbox. Yet their greatest contribution is likely to come through complementing rather than replacing structural econometric models. Machine learning offers powerful methods for prediction, variable selection, and the analysis of high-dimensional datasets, while structural models provide the economic discipline required for identification, welfare analysis, and policy evaluation. The integration of these approaches represents one of the most promising directions for future research.

Transportation economics has historically served as an exceptional laboratory for methodological innovation because it combines differentiated products, network effects, regulation, strategic interaction, and abundant data within a single empirical setting. There is every reason to believe that it will continue to play this role. As transportation systems become increasingly digital, interconnected, and environmentally constrained, structural econometrics will remain essential for understanding how markets function and for designing effective public policies.

References

Aguirregabiria, V. & Ho, C.-Y. (2012). A dynamic oligopoly game of the us airline industry: Estimation and policy experiments. *Journal of Econometrics*, *168*(1), 156–173.

Bajari, P., Houghton, S. & Tadelis, S. (2014). Bidding for incomplete contracts: An empirical analysis of adaptation costs. *American Economic Review*, *104*(4), 1288–1319.

Bajari, P., McMillan, R. & Tadelis, S. (2009). Auctions versus negotiations in procurement: An empirical analysis. *Journal of Law, Economics, and Organization*, *25*(2), 372–399.

Bajari, P. & Tadelis, S. (2001). Incentives versus transaction costs: A theory of procurement contracts. *RAND Journal of Economics*, *32*(3), 387–407.

Baron, D. P. & Myerson, R. B. (1982). Regulating a monopolist with unknown costs. *Econometrica*, *50*(4), 911–930.

Bauer, P. W. (1990). Recent developments in the econometric estimation of frontiers. *Journal of econometrics*, *46*(1-2), 39–56.

Behrens, C. & Pels, E. (2012). Intermodal competition in the london–paris passenger market: High-speed rail and air transport. *Journal of Urban Economics*, *71*(3), 278–288.

Ben-Akiva, M. & Lerman, S. R. (1985). *Discrete choice analysis: Theory and application to travel demand*. Cambridge, MA: MIT Press.

Berry, S. T. (1992). Estimation of a model of entry in the airline industry. *Econometrica*, *60*(4), 889–917.

Berry, S. T. (1994). Estimating discrete-choice models of product differentiation. *The RAND Journal of Economics*, *25*(2), 242–262.

Berry, S. T. & Haile, P. A. (2021). Foundations of demand estimation. In *Handbook of industrial organization* (Vol. 4, pp. 1–62). Elsevier.

Berry, S. T. & Jia, P. (2010). Tracing the woes: An empirical analysis of the airline industry. *American Economic Journal: Microeconomics*, *2*(3), 1–43.

Berry, S. T., Levinsohn, J. & Pakes, A. (1995). Automobile prices in market equilibrium. *Econometrica*, *63*(4), 841–890.

Bontemps, C., Gualdani, C. & Remmy, K. (2023). Price competition and endogenous product choice in networks: Evidence from the us airline industry. *Working Paper*.

Borenstein, S. (1990). Airline mergers, airport dominance, and market power. *American Economic Review*, *80*(2), 400–404.

Borenstein, S. & Rose, N. L. (1994). Competition and price dispersion in the us airline industry. *Journal of Political Economy*, *102*(4), 653–683.

Bresnahan, T. F. (1989). Empirical studies of industries with market power. *Handbook of industrial organization*, *2*, 1011–1057.

Brueckner, J. K. & Whalen, W. T. (2000). The price effects of international airline alliances. *Journal of Law and Economics*, *43*(2), 503–546.

Cantillon, E. & Pesendorfer, M. (2007). Combination bidding in multi-unit auctions.

Caves, D. W., Christensen, L. R. & Tretheway, M. W. (1984). Economies of density versus economies of scale: why trunk and local service airline costs differ. *The RAND Journal of Economics*, 471–489.

Chen, C., Ma, J., Susilo, Y., Liu, Y. & Wang, M. (2016). The promises of big data and small data for travel behavior (aka human mobility) analysis. *Transportation research part C: emerging technologies*, *68*, 285–299.

Dalen, D. M. & Gomez-Lobo, A. (1997). Estimating cost functions in regulated industries characterized by asymmetric information. *European Economic Review*, *41*, 935–942.

Deaton, A. & Muellbauer, J. (1980). *Economics and consumer behavior*. Cambridge University Press.

Gagnepain, P. & Ivaldi, M. (2002). Incentive regulatory policies: The case of public transit systems in france. *RAND Journal of Economics*, *33*(4), 605–629.

Gasmi, F., Laffont, J.-J. & Sharkey, W. W. (1999). Empirical evaluation of regulatory regimes in local telecommunications markets. *Journal of Economics and Management Strategy*, *8*(1), 61–93.

González, M. C., Hidalgo, C. A. & Barabási, A.-L. (2008). Understanding individual human mobility patterns. *Nature*, *453*(7196), 779–782.

Hensher, D. A., Rose, J. M. & Greene, W. H. (2015). *Applied choice analysis*. Cambridge university press.

Huang, Z., Ling, X., Wang, P., Zhang, F., Mao, Y., Lin, T. & Wang, F.-Y. (2018). Modeling real-time human mobility based on mobile phone and transportation data fusion. *Transportation research part C: emerging technologies*, *96*, 251–269.

Kim, E. H. & Singal, V. (1993). Mergers and market power: Evidence from the airline industry. *American Economic Review*, *83*, 549–569.

Laffont, J.-J. & Tirole, J. (1986). Using cost observation to regulate firms. *Journal of Political Economy*, *94*(3), 614–641.

Mathios, A. D. & Rogers, R. P. (1989). The impact of alternative forms of state regulation of at&t on direct-dial, long-distance telephone rates. *RAND Journal of Economics*, *20*(3), 437–453.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (Ed.), *Frontiers in econometrics* (pp. 105–142). New York: Academic Press.

Ng, C. K. & Seabright, P. (2001). Competition, privatisation and productive efficiency: Evidence from the airline industry. *The Economic Journal*, *111*(473), 591–619.

Oum, T. H., Waters, W. G. & Yong, J. S. (1992). Concepts of price elasticities of transport demand and recent empirical estimates: An interpretative survey. *Journal of Transport Economics and Policy*, *26*(2), 139–154.

Paarsch, H. J. & Hong, H. (2006). *An introduction to the structural econometrics of auction data*. MIT Press.

Pelletier, M.-P., Trépanier, M. & Morency, C. (2011). Smart card data use in public transit: A literature review. *Transportation Research Part C: Emerging Technologies*, *19*(4), 557–568.

Peters, C. (2006). Evaluating the performance of merger simulation: Evidence from the us airline industry. *The Journal of law and economics*, *49*(2), 627–649.

Porter, R. H. & Zona, J. D. (1993). Detection of bid rigging in procurement auctions. *Journal of Political Economy*, *101*(3), 518–538.

Saussier, S. (2000). Transaction costs and contractual incompleteness: The case of électricité de france. *Journal of Economic Behavior & Organization*, *42*(2), 189–206.

Schmalensee, R. (1989). Inter-industry studies of structure and performance. *Handbook of industrial organization*, *2*, 951–1009.

Small, K. A., Verhoef, E. T. & Lindsey, R. (2024). *The economics of urban transportation*. Routledge.

Stavins, J. (2001). Price discrimination in the airline market: The effect of market concentration. *Review of Economics and Statistics*, *83*(1), 200–202.

Toole, J. L., Colak, S., Sturt, B., Alexander, L. P., Evsukoff, A. & González, M. C. (2015). The path most traveled: Travel demand estimation using big data resources. *Transportation Research Part C: Emerging Technologies*, *58*, 162–177.

Train, K. (1986). *Qualitative choice analysis: Theory, econometrics, and an application to automobile demand*. Cambridge, MA: MIT Press.

Train, K. (2009). *Discrete choice methods with simulation* (2nd ed.). Cambridge: Cambridge University Press.

Vuong, Q. H. (1989). Likelihood ratio tests for model selection and non-nested hypotheses. *Econometrica*, *57*(2), 307–333.

Williamson, O. E. (1975). *Markets and hierarchies*. Free Press.

Williamson, O. E. (1985). *The economic institutions of capitalism*. Free Press.

Wolak, F. A. (1994). An econometric analysis of the asymmetric information, regulator–utility interaction. *Annales d'Économie et de Statistique*(34), 13–69.

Yvrande-Billon, A. (2006). The attribution process of delegation contracts in the french urban public transport sector: why competitive tendering is a myth. *Annals of public and cooperative economics*, *77*(4), 453–478.

Index