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Essays on Transportation Innovations and Local Development

DISSERTATION

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in Economics

by

Michael Durward LeFors

Dissertation Committee:
Associate Professor Daniel Bogart, Chair
Professor Jan K. Brueckner
Assistant Professor Kevin Roth

2015

DEDICATION

To

my family, friends, and mentors

in recognition of their invaluable support

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ACKNOWLEDGMENTS

I would first like to express appreciation to my committee chair, Professor Daniel Bogart, who was instrumental in helping me find a place in the world of economic research and whose continual encouragement, patience, and example have made this dissertation possible. At many critical moments Professor Bogart's faith in my potential was the bedrock of my confidence, and his genuine passion for economic history has been an inspiration.

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FIELDS OF STUDY

Transportation Economics, Urban Economics, and Economic History

Abstract of the Dissertation

Essays on Transportation Innovations and Urban Growth

By

Michael Durward LeFors

Doctor of Philosophy in Economics

University of California, Irvine, 2015

Professor Daniel Bogart, Chair

Innovations in transportation create new economic opportunities, and modal innovations can yield additional innovations throughout the entire transportation sector. Given transportation's fundamental role in mediating trade, commerce, and human movement and migration, these innovations ultimately transform the intensity and distribution of economic activity.

Chapter 1 examines the impact of a new transportation mode (namely, canal travel) on the use of existing modes (mostly roads), as well its impact on the rate of innovations within existing modes. The specific lens is Canal Age Britain, and due to the nature of the historical data we rely chiefly on OLS regressions. Chapters 2 and 3 concern the economic value of the most important modal innovation in the 20th century: the development of aviation. These chapters analyze the role of aviation in facilitating local growth. Chapter 2 does so by defining a novel measure of a city's air-travel connectedness and analyzing Metropolitan Statistical Area growth from 2000-2007. Chapter 2 addresses endogeneity concerns through the use of instruments that build on the intuition of earlier scholarship. Chapter 3 exploits a unique air-subsidy provider, the Essential Air Service program, to further elucidate the economic

importance of air travel. In Chapter 3 we are able to take a longer-term perspective, and endogeniety concerns are addressed through a Propensity Score Matching procedure.

Chapter I: Intermodal Competition and Innovation in Britain’s Canal Age

Abstract

Intermodal competition is perceived to be a key driver of efficiency in the transportation industry. The canal age in Britain provides one of the earliest considerable occurrences of intermodal competition, namely between canals and roads. I use directory data to determine the availability of canal transport services and the frequency of road transport services from London to 66 major cities in Britain. I employ a panel-data framework, regressing counts of road-based services on the availability of canal-based services, in order to test the hypothesis that canals displaced roads. I find that canals did displace road traffic, but only insofar as a particular service, the fly-boat, was available. Coasting vessels and traditional barges, on the other hand, did not displace road traffic. Additionally, I find that fly-boats access altered the service-mix of road traffic by encouraging innovation. These results are consistent with a theory which emphasizes within-mode innovation and market segmentation as critical elements in the process of intermodal competition.

1 Introduction

Transportation is central to British economic history, and this paper provides insight into the role played by canals. It is commonly posited that if canals were critical to the process of industrialization in Britain, it was because they provided a superior substitute to road transport. Scholars espousing the merits of canal travel usually pinpoint the cheap movement of goods as the source of canals' superiority (Freeman, 1980, includes a survey of this view); low transportation costs allowed canals to displace road transport throughout Britain and enriched society through the resultant cost-savings. But were canals merely a thrifty alternative to roads, or is this too narrow a view of their economic importance? Might the canal network create new opportunities or permit economic activity which the road network could not have sustained, in which case we would find that canal traffic and road traffic were complementary? Moreover, canal transportation in this era suffered from a number of drawbacks (to be elucidated below) which limit the superiority of canals as a method of transportation, thus raising the question: was innovation in the canal industry a necessary prerequisite to overcoming these drawbacks and replacing road traffic? Finally, should we be convinced that the success of the canal network was limited to the underpricing of road-based services? Or did advancement of the canal industry also induce, as a competitive response, innovations in the road industry? The latter hypothesis is consistent with a process of market-segmentation, as opposed to uniform displacement, in the transport sector.

To answer these questions, I offer an empirical, quantitative test: if water-based transportation in the canal age presented a superior substitute to road-based services, then there should be evidence that road traffic was actually displaced by the expanding canal network. If, on the other hand, canals facilitated commerce which was unfeasible by road, we should find that the availability of canal services had a neutral or even positive impact on road traffic. And if innovation was necessary before canals could displace roads, we should find that some canal services displaced roads while others did not. Furthermore, if market-segmentation is the process which occurred during the canal age, we should find evidence of both modes adjusting their within-mode technology as they appropriate their respective niches. (Note that these hypotheses are differentiated by the nature of the impact wrought by canals, rather than the existence or magnitude of this impact.)

This paper required the construction of a data-set, derived from historical directories, which enumerates the number of weekly road-based services, by type, and the availability of water-based services, also by type, going from London to `other major cities in Britain in each of five years spread across the canal age. Thus, I have created a new data set which permits the first empirical test of the hypotheses described above. By providing a basis for analyzing the diffusion of various transportation services, this data set has potential benefits for future research related to Britain's canal age.

I analyze the data using a fixed effects panel framework. In the basic linear model, I regress traffic levels for various road transport services against indicator variables for various water transport services, controlling for population and city fixed-effects and including time-dummies for each directory year. Additionally, I test for robustness to two other models: (i) the basic linear model with city-specific time trends added and (ii) a fixed effects negative-binomial model. I also check whether my results are sensitive to the definition of the dependent variable. The analysis is performed separately for cargo services, passenger services, and several subsets of these categories.

The first major conclusion of this paper is that one canal service, the fly-boat[1], displaced road traffic for both cargo and passenger services. However, traditional barges, which also depended on the canal network, did not displace road traffic. I also find no displacement effect for coasting vessels. These conclusions are robust to model specification and to alternative definitions of the dependent variable.

The canal age is of historical interest in its own right, and that alone provides sufficient motivation for investigating the impact of canals on road traffic. However, this paper also pursues conclusions which are generalizable beyond the case of industrial Britain by. It seeks a general understanding of intermodal competition in the transportation sector; specifically, to what extent does intermodal competition encourage innovation in the transport industry? I have already alluded to evidence that canals displaced road services only after the development of the right vehicle technology, i.e. fly-boats. In addition, a second major conclusion of this paper is that the road-industry responded to the expanding canal network by innovating and specializing. For instance, the availability of fly-boats encouraged expedited road-cargo services (such as the fly-wagon) while displacing slower services. Thus, within-mode technological innovation may be crucial to the process of intermodal competition. Canals also altered the service-mix of road passenger traffic: fly-boats had little effect on passenger demand for private stagecoaches but did displace the quasi-public 'post-coach' service, further suggesting that canals were only competitive with subsets of the road-industry and that the canal age was characterized by a process of market-segmentation between road and canal services.

This paper will be organized as follows: Section 2 provides background. Section 3 presents the data. Section 4 presents regressions related to the displacement of roads by canals, while

[1] Fly-boats were a later innovation of the canal carrying industry. Like barges, they were canal-craft, but fly-boats were smaller, faster, and adhered to more regular schedules than barges did.

Section 5 discusses the technological shift among road vehicles in response to canals. Section 6 concludes.

2 Background

2.1 The Canal Age

The British 'canal age' was a period of rapid expansion of the inland water network between the mid-18th and mid-19th centuries. The canal age was preceded by a period in which the water network expanded primarily through river-navigation; rivers or streams were deepened, widened, and otherwise re-shaped so they could accommodate regular commerce. Incrementally, more and more complex modifications became feasible, including the use of short canals, or 'cuts', which completely bypass difficult sections of river. Eventually, we see the emergence of proper canals, i.e. completely artificial waterways.

The canal age began around 1761 with the completion of the Bridgewater canal. Bridgewater was built for transporting coal to Manchester from the Worsley mines (roughly 40 miles away) and is among the first 'proper' canals in Britain. While many canals, including the Bridgewater, were constructed without the goal of a national network in mind, the canal network did eventually span Britain. Major milestones include the completion of the Trent-Mersey canal in 1777, the Forth-Clyde canal in 1790, the Grand Junction canal in 1805, and the Leeds-Liverpool canal in 1816. Following half a century of intense development, the end of the canal age is roughly 1834, after which there was no significant new canal construction for decades.

Early canals were proposed and financed by individuals, often in part for the benefit of their own business; the Duke of Bridgewater commissioned his canal for the purpose of transporting coal from his mines, while Josiah Wedgewood, a major promoter of the Trent-Mersey canal, was interested in dependable transportation for the inputs and fragile outputs of his pottery business. The promoters and financiers of early canals also sought profits from the collection of canal tolls. The substantial profits of early canal projects[2] inspired a frenzy of canal building, and later canals were often financed by joint-stock companies. Investors in these later canal projects didn't necessarily have the same direct interest that characterized projects like Wedgewood's; indeed, rather than responding to a concrete need, many canal projects were built in anticipation of some demand which never materialized, and profit-losing canals were fairly common (Ville 2004).

It would be hard to overemphasize what an enormous undertaking the construction of a canal was. For one, canals required an Act of Parliament for their construction and operation. Moreover, canal projects could take many years to complete; the Forth-Clyde canal required more than twenty years to complete, and the Trent-Mersey required more than thirty (Ville, 2004).

The canal age is superseded by the rail age, which begins around 1830 with the opening of the Liverpool-Manchester line (Moyes 1978). The first major route from London, connecting it to Southampton, opened in 1840, and a period of intense railway construction began around 1845. Thus, railways initiated a second wave of intermodal competition, but the railway age is beyond my analysis (my data ranges from 1779-1827). Since I focus on the relationship between the road and canal industries, it is fortunate that my analysis is not complicated by the presence of a third modal alternative. Rail does have a role to play, though, in motivating the setting of my analysis. The arrival of rail precipitates the downfall of the canal industry, consequently transforming the relationship between road and canal; it is partly for this reason that we must

[2] For instance, the Sankey Brook canal, completed in 1762, paid dividends averaging 33.3% for eighty years (Hadfield 1968).

actually look back to the pre-rail age in order to understand the dynamics of road/canal competition.

Even in the pre-rail era, though, one would be mistaken to reduce the transport industry to a road/canal dichotomy. Canals and the services they accommodated should be seen as innovations in a broader water-transportation industry. Water-transport had always been competitive with road transport; shipping by river and coast was a cheap alternative to road transport long before canals (Bogart, 2013, presents evidence that in 1800 a carrier's cost for shipping coal by coast was roughly 1/20th the cost by road, exclusive of costs like taxes and insurance). In my data, there are three categories of water-based services: 'vessel,' 'barge,' and 'fly-boat.' Vessels are sailing-craft that travel primarily by coast and river; these services were competitive with road-services even before the canal age. Barge and fly-boat services, on the other hand, depended on the canal network.

Neither vessels, barges, nor fly-boats were steam-powered, so one might wonder if steamboats fit into my analysis. The short answer is that they do not. The first commercial steamboat service occurred in 1812 (Armstrong), and by 1818, steam tugboats were in regular use on the Tyne, providing coasting vessels access to the sea without the need to wait for wind and thereby reducing delays (Ville 1986). Clearly, then, steamboats are present in Britain by the end of my sample period, but they nevertheless do not appear in my dataset. This is not the result of steamboats' omission from the directories; in fact, the directories do list steamship service, but there are simply no steamship services between London and the major cities which comprise my sample. Steamships were initially limited to a few routes; for instance, the first steamship services in London carried passengers to Margate (and the directory for 1827 does in fact list steamship services for Margate). Steamships were present on routes that didn't cross

London (e.g. between Liverpool and Glasgow) and in international shipping. However, steam power was not yet ubiquitous in water-transport[3], so it is not surprising that my data suggests no steamboats were in regular use along the routes I analyze. Unfortunately, then, we cannot use my methodology to study steamships (since we are constrained to study a subset of cities), but we also need not worry about steamships complicating my analysis.

The classic opinion of roads in the canal age is that they were inferior to the system of inland waterways consisting of canals and rivers. The low cost of water transport is seen as a definitive advantage; expensive road services were displaced and the majority of goods were eventually transported by water, with the ascent of canal transport only halted by the arrival of rail. Economists like Freeman (1980) challenged this classic view. While Freeman agrees that only "a fool" could neglect the dominance of canals in the transport of "heavy, bulky, low-value goods, coal especially," he also points out that there is "little evidence in the canal traffic record" to suggest canals were dominant in the wider transport industry. Even though the cost advantage of canals is clear, it would "be mistaken to infer from this that canals formed the country's primary transport arteries." Focusing on canals' cost advantage neglects the fact that demand for transport services are not lexicographic; the relative merits of canal and road travel must be considered with respect to other modal characteristics, such as speed, not only price.

Economic historians have since rectified the lack of evidence on canal-age traffic. Chartres and Turnbull (1983) are the first to estimate traffic growth on Britain's road network using directory data, and their analysis shows that both passenger and cargo traffic were

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[3] Indeed, use of steam is rare on canals before the mid-1800's (Ville 2004). Steamboats were not even used for tugging canal-craft until around 1830, and Ville (1986) tells us that specialist steam tugs aren't developed until around 1844. Hadfield (1968) confirms a dearth of steam-power on canals. Furthermore, Hadfield claims this scarcity was a matter of practicality; steam was experimented with on canals, but steam engines came at the cost of lost cargo space, while the benefit of steam power (increased speed) was weak due to the fundamental speed constraints dictated by the depth and width of existing canals.

increasing on roads well into the canal age, strongly suggesting something is wrong with the simple story of cheap canals displacing expensive roads. Other authors, such as Gerhold (1988), confirm the growth of the road industry throughout the canal age and the continuing dependence of many businesses on road-carriages, and they additionally hypothesize that mode choice might depend on a user's preferences for speed and reliability, on the value and fragility of the goods being shipped, and on distance.

Interest in Britain's canal age and in the concurrent growth of the road network has not waned; recent work deepens our understanding of the dynamics in the road network at the time: for instance, Bogart (2005) explores the role of turnpike trusts in facilitating investments in roads and the resulting effect on the extent and quality of the road network. Gerhold (1996) explores the growth of productivity in the road industry, and calls attention to improvements in organization, vehicle-technology, horse-breeding, and road-technology.

In spite of our increasingly sophisticated understand of industrial Britain's road and canal networks, a basic question nevertheless lacks an empirical answer: did canals displace road traffic? The fact that road transport thrived during the canal age only superficially answers this question: the fundamental concern is whether technological progress in the road industry might have increased road-traffic levels *even more* in the absence of canals. The panel regressions I employ suggest that road traffic would have grown more in the absence of fly-boats, but not in the absence of canal services more generally. In addition, when I look at road traffic in finer detail, I find differential effects; only some types of road traffic were displaced by canals, while others were unaffected or would have grown *less* in the absence of canals.

2.3 Characteristics of Road and Water Transportation

This section discusses the characteristics of road-based and water-based travel and, in the process, establishes the relative advantages of each mode during my sample period. This discussion is organized around six criteria: efficiency/user-cost, speed, reliability, cost of infrastructure, extent of network, and quality of infrastructure. Additionally, this section concludes with some notes on the regulation and market structure of the transport sector.

2.3.1 Efficiency

Efficiency, in terms of the user-cost of transporting goods, is the criterion by which canals clearly dominated roads. The superiority of canals in this respect is beyond dispute. For the reader un-acquainted with this consensus, consider the following: "the cost of canal conveyance by water was on average between 1/4 and 1/2 the cost of carriage by road" (Freeman 1980). Similarly, Moyes (1978) reports that canals "at least halved the cost of freight movement compared with road transport, and at most cut it by three quarters." The source of canals' efficiency is simple: it takes much less power to pull a vehicle over water than it does over road. A horse can pull roughly 20x as much weight when pulling a barge versus pulling a cart (Bagwell & Lyth 2003).

Of course, these averages mask the fact that the advantage of canals varied from route to route (Ville 2004); for instance, transshipment costs arise because canals, unlike roads, do not usually permit door-to-door shipment; so shipment by canal often involved shipment by road for some part of the journey. Nevertheless, comparing modal costs along common routes reveals that canals are almost always superior from a nominal cost-of-shipping perspective (Bagwell & Lyth 2003, Table 1).

2.3.2 Speed

In terms of speed, the advantage belongs to roads. Road-based modes of transportation held a slight advantage in maximum vehicle speed, and this advantage is only magnified when we regard actual journey times. Canal travel was significantly slowed by the need to pass through locks. By nature, uninterrupted stretches of canal must lie in a horizontal plane. Changes in elevation require boats to move through a lock, or – in many cases – a series of locks[4]. Passing through locks took a significant amount of time; up to 30 minutes were required to move a single boat through a lock. Actual delays at a lock could be even greater than this when congestion is taken into account. Moreover, in Britain especially, the number of locks on a route could be substantial. The Leeds –Liverpool canal had 91 locks in a span of 127 miles, while the Rochdale canal had 92 in a span of just 33 miles (Freeman 1980). Roads, on the other hand, contain no impediments akin to a lock. Moreover, locks were generally closed at night (i.e. from one hour after sunset until one hour before sunrise), as a rule, although there were no objections to a lock-keeper letting boats pass during the night in exchange for a tip (Hadfield 1968)[5]; meanwhile, road-services freely operated at night. Accounting for all these factors, journey times tended to be roughly twice as long via canal as they were via road (Freeman 1980).

2.3.3 Reliability

Roads were also superior to canals in terms of reliability. While both modes were subject to delays caused by extremes of weather, canals were affected even more so than roads; the Achilles' heel of canal travel is water itself.

[4] A single lock could accommodate between 0 and 16 feet of elevation change; typically they accommodated 6-10 feet (Hadfield 1968).

[5]Fly-boats typically operated throughout the night insofar as possible; barges, on the other hand, typically rested at night.

In the summer, drought was an issue because locks required a ton of water for their operation. For instance, moving a boat from a lower elevation to a higher elevation requires water from the higher plane be used to fill the lock in which the boat is sitting, so that the boat rises with the water level. Each such passage through a lock required upwards of 10,000 gallons of water (e.g. some locks on the Leeds-Liverpool and Rochdale canals displaced 50,000-60,000 gallons each time they were used, Hadfield 1968). Since canals, unlike rivers, are standing bodies of water, the loss that much water is substantial and the possibility of water-shortage is not surprising. Methods for mitigating water shortages were derived, including the construction of reservoirs to collect water, the use of pumps to replenish water to the higher planes, and the design of more efficient locks. However, water-saving methods were insufficient to overcome severe drought; Freeman (1980) claims that lockage itself would not have been an insurmountable problem in isolation, but a single drought "often produced havoc."

Conversely, during winter, ice could make canals inoperable. More than the freezing of the canals themselves, the freezing of locks was a major issue; locks had many moving parts which easily became frozen, resulting in delays while the ice was removed or, in many cases, resulting in extended closure of the lock. How significant were these delays from weather? Freeman (1980) shows that canals could be closed for weeks due to weather. Furthermore, when he estimates the total number of lost working-days per winter for canals in the Lancashire Plain, his estimates exceed twenty lost days for half of the years between 1771 and 1831 and exceed thirty lost days for ten of those years. Given Britain's present-day climate, one may suspect these figures are excessive, but it is important to recall that there was a 'Little Ice Age' in Britain, marked by harsh winters, until around 1850.

2.3.4 Capital Cost

With respect to capital cost, roads again have the advantage. The 127-mile Leeds-Liverpool canal cost 1.25 million pounds to build. The 33 mile Rochdale canal cost 600,000 pounds. These translate to figures of roughly 10,000-20,000 pounds per mile of canal. On the other hand, one turnpike in Hampshire allocated 10,000 pounds for 7.25 miles of road (about 1,200 pounds per mile), while another turnpike in Lancashire authorized the construction of one mile of road and permitted 1,800 pounds for the purpose (Freeman 1980). These anecdotes indicate that the per-mile infrastructure cost of canals far exceeded that of roads.

2.3.5 Extent of Infrastructure

The road-transport network was in place by 1780, in the sense that there was a relatively direct and passable route from London to the major cities I observe in my sample, and most of the major roads in Britain were already under the supervision of turnpike trusts (see Figure 1,

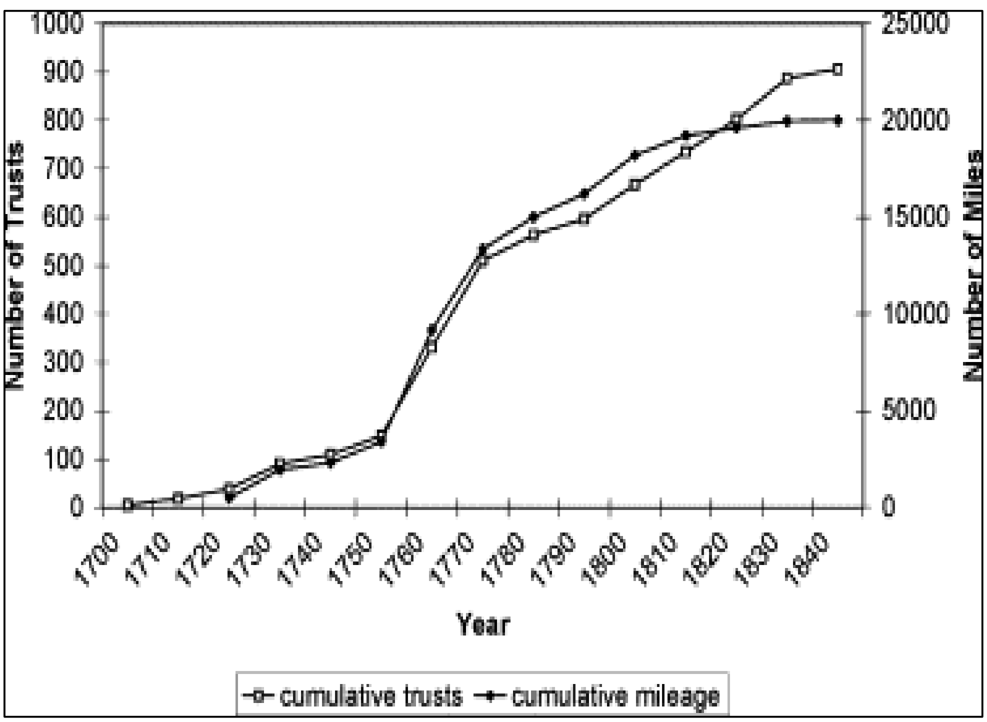

Figure 1: Turnpike Trust Evolution

courtesy of Bogart, 2005, which plots the total mileage of the turnpike network. Also, see the Appendix for a map, courtesy of Pawson (1977), which illustrates the turnpike network in 1770). The canal network, by contrast, was in the process of being completed during my sample period (1779-1827). For instance, the old Grand Union canal was not completed until 1814, and the Leeds-Liverpool canal was not completed until 1816, more than halfway into my sample period. Total mileage of inland waterways grew from about 1,400 in 1760 to about 3,900 in 1830 (Ville 2004).

It is precisely the relatively static extent of the road network combined with the rapid growth of the canal network which makes this paper's analysis possible. The growth of the canal network provides the necessary variation in the availability of water-based services, while the inertness of the road network suggests that road traffic is flexible enough to actually respond to changes in the canal network. To put it more formally, we want to analyze how demand for road services responds to the supply of canal services, so we want variation in canal infrastructure (a shock to supply) but we do not want variation in road infrastructure (we assume that the road-service industry is in equilibrium and attribute changes in traffic levels to shifts in demand).

I should note that road haulage technology (i.e. the carrying capacity of roads) does improve over my sample period; additionally, stronger horses requiring less food were obtained through breeding (Ville 2004). However, I do not expect this to cause major problems for my regressions; the road network is basically stable, so haulage technology only increases the capacity of the existing network. Increased capacity does not present the same problems as the addition of new road-mileage would, plus the use of time dummies controls for any universal increase in capacity, leaving differential adoption of haulage-technology as a small source of error.[6]

2.3.6 Quality of Infrastructure

What can we say about the quality of the road network? During my sample period, major roads are generally under the authority of a turnpike trust. The poor state of roads around the middle of the 17th century led parliament to transfer the responsibility for road maintenance to turnpike trusts (Ville 2004). Road maintenance was generally good under these trusts, at least along routes to London (precisely the routes relevant to my analysis); in addition to incentives provided by the ability to toll, shareholders in turnpike trusts typically had a personal interest in the roads they oversaw (e.g, the shareholders were landowners, merchants, and coal-masters) (Hopkinson).

The quality of the water-network is more complicated. A route may be connected to London by canal, but we do not know how circuitous this route is[7], how many locks must be bypassed, how susceptible that route is to weather-related delays, or even which watercraft that route could accommodate (for instance, some barges are too wide to fit on 'narrow' canals). We would like to control for canal quality, and a conceptually straightforward extension to this paper would do so, but I do not attempt this here. Instead, this paper implicitly assumes that a positive dummy for water-based services indicates a route of 'sufficient' quality, and inversely that all routes of sufficient quality will have at least one water-based service.

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[6] In particular, we worry that in some locations canals may have been a prerequisite to the provision of cheap road materials (Moyes), in which case canal infrastructure contributed to a lower cost of road carriage, thereby positively biasing the regression coefficient on the indicators for canal services.

[7] Circuitousness could be significant, and it also varied widely. We know that in 1715 (prior to the canal age) distance from London to Portsmouth by water was 3 times as long as by land, while distance from London to Severn was 6.5 times as long (Moyes).

2.3.7 Regulation and Market Structure

Road and waterway networks both required Acts of Parliament for expansion of their infrastructure; in addition, Parliament set a schedule of maximum tolls. While permission for road projects was typically granted to turnpike trusts, which were non-profit entities, canal projects were typically for-profit enterprises; indeed, later canal projects were often financed by joint-stock companies. Until 1845, Parliament typically required separation of canal-ownership and operation of canal services, though there were major exceptions to this rule, especially among early canals. Integration of operator and user was not similarly discouraged (i.e. it was not uncommon for producers or merchants to operate their own barge), but the largest operators were specialists. Moreover, many large non-integrated carriers operated both water and road services; the Pickford family is a notable example (Ville 2004).

Though members of turnpike trusts often had economic interests in the roads they maintained, road "ownership" and operatorship were strictly separate. The road-carrier industry generally seems competitive, in that there were a large number of small firms. However, it should be noted that many of those firms were local, while large networks were the purview of a smaller number of large firms, such as the Pickfords (Ville 2004).

The Pickford family warrants some additional discussion. In addition to being a leading specialist carrier, their business is notable for its longevity. The Pickfords were involved in transport at least as early as 1756, operating a route between Manchester and London. By 1779, the first year of my analysis, they owned about 8 wagons and 72 horses; by 1803, they owned 50 wagons, 400 horses, and 28 barges (Turnbull 1980); and by 1838 they owned 116 canal-craft (Ville 2004). The Pickford family gradually became the Pickford Company and remained involved in transportation into the 20th century. Perhaps commensurate with their longevity and the geographic scope of their operations, the Pickfords were important in the innovation process; they were among the early providers of fly-wagon and fly-boat services[8].

2.4 A Simple Model of Intermodal Competition

This section lays out a simple framework for thinking about the relationship between canal-services and road-based services. Let's assume that transport services are distinguished along two dimensions only, say cost and speed[9]. Furthermore, assume that technology forces a trade-off between these two dimensions, so that faster speeds always imply higher costs. Then, the set of all possible transportation service bundles can be thought of as a line, with the cheapest/slowest services at one end and fastest/dearest services at the other. Imagine that prior to the canal age the transport market was in equilibrium, with road carriers providing relatively fast/dear services and coasting vessels providing relatively slow/cheap services. Furthermore, assume that in equilibrium there was a gap between road and coasting services, so that neither mode provided medium-speed/medium-cost services. Now, let there be a shock to the distribution of transport demands (for instance, the shock derives from a newfound need to transport coal), so that there is now high demand for those medium-speed services which are not currently profitable for either mode. Two things could happen: the coasting industry or the road industry could innovate, thus expanding the borders of their product space enough to include this new demand. Or, a new mode could arise to accommodate this demand. I do not predict which outcome should happen, but let's assume it is the latter case. Then, the new mode's initial product space will exist in the gap between existing modes and not compete with them. However, once the new mode is in place, it too can innovate and may eventually expand the

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[8] Fly-boats are innovative because they are faster and smaller than traditional barges. Additionally, fly-boats, unlike barges, often adhered to regular schedules and did not cease travelling at nightfall.

[9] The reduction to two characteristics is for simplicity only. It seems that convenience and reliability are also important characteristics with respect to canal-road competition.

borders of its product space to the point that it overlaps with, say, the lower-speed end of the road industry's product space. Finally, the road industry, facing competitive pressure in the slow/cheap end of its market, now finds it optimal to invest in innovation aimed at expanding its coverage of the fast/dear market.

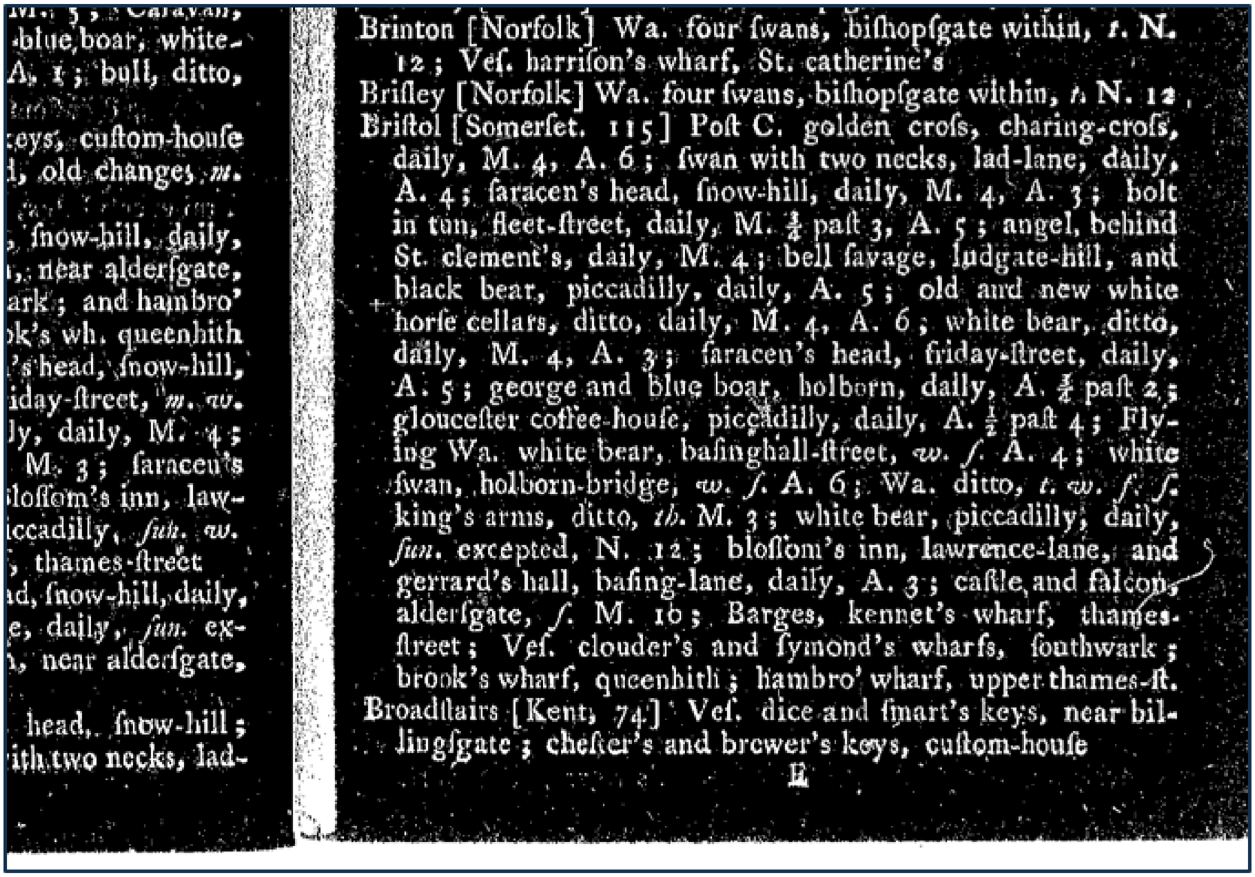
3 Data

The primary data source for this paper is a series of directories titled "The Shopkeeper's and Tradesman's Assistant." I have five such directories, for the years 1779, 1790, 1800, 1816, and 1827[10]. They contain, among other things, listings of all road and water transport services going from London to other cities in Britain. These directories are comprehensive, with entries for all of Britain's cities, but I only construct a dataset for a sample of 66 major cities.[11] The reason for restricting the dataset in this manner will be discussed below. Since I have complete directories for five separate years, I have a total of 330 observations in my sample. I will now discuss the directory entries in detail and explain how I derive the data-set used in this paper.

3.1 Road-Based Services

The directories would have been consulted by people wishing to travel or ship goods from London. For any given city in Britain, a directory provides several pieces of information about every road transportation service from London to that city, including the vehicle type, departure times, and pick-up locations of each service. I divide services according to vehicle-type and, for each vehicle, I use the directory information to derive a 'count' of the number of weekly services departing from London to that city.

[10] These directories all published by the same firm. They are available online. Also, note that the five years for which I have directories span the majority of the canal age (which can be roughly dated 1761-1834).
[11] In particularly, I select the 66 largest cities, according to population in 1750.



Brinton [Norfolk] Wa. four ſwans, biſhopſgate within, t. N. 12; Veſ. harriſon's wharf, St. catherine's
Briſley [Norfolk] Wa. four ſwans, biſhopſgate within, t. N. 12
Briſtol [Somerſet. 115] Poſt C. golden croſs, charing-croſs, daily, M. 4, A. 6; ſwan with two necks, lad-lane, daily, A. 4; ſaracen's head, ſnow-hill, daily, M. 4, A. 3; bolt in tun, fleet-ſtreet, daily, M. ¾ paſt 3, A. 5; angel, behind St. clement's, daily, M. 4; bell ſavage, ludgate-hill, and black bear, piccadilly, daily, A. 5; old and new white horſe cellars, ditto, daily, M. 4, A. 6; white bear, ditto, daily, M. 4, A. 3; ſaracen's head, friday-ſtreet, daily, A. 5; george and blue boar, holborn, daily, A. ¾ paſt 2; glouceſter coffee-houſe, piccadilly, daily, A. ½ paſt 4; Flying Wa. white bear, baſinghall-ſtreet, w. ſ. A. 4; white ſwan, holborn-bridge, w. ſ. A. 6; Wa. ditto, t. w. ſ. ſ. king's arms, ditto, th. M. 3; white bear, piccadilly, daily, ſun. excepted, N. 12; bloſſom's inn, lawrence-lane, and gerrard's hall, baſing-lane, daily, A. 3; caſtle and falcon, alderſgate, ſ. M. 10; Barges, kennet's wharf, thames-ſtreet; Veſ. clouder's and ſymond's wharfs, ſouthwark; brook's wharf, queenhith; hambro' wharf, upper thames-ſt.
Broadſtairs [Kent, 74] Veſ. dice and ſmart's keys, near billingſgate; cheſter's and brewer's keys, cuſtom-houſe

Figure 2: Directory Entry for Bristol, 1800

Figure 2 is a directory entry for Bristol in the year 1800. The first lines read: "Post C. golden cross, charing-cross, daily, M. 4, A. 6;" This meant there was a 'post-coach' (a type of passenger service which also carried mail) which departed at 4 in the morning and one which departed at 6 in the afternoon from Golden Cross, Charing-Cross. Thus, this line contributes 14 post-coach services per week (i.e. two per day) from London to Bristol. The next line of this directory entry reads "swan with two necks, lad-lane, daily, A. 4.," contributing 7 more services to the count of weekly post-coach services from London to Bristol (bringing the total to 21). We continue to count the number of post-coach services in this manner until, about halfway through the entry, we see "Flying Wa." 'Flying wagon' is an expedited cargo service, so at this point we stop adding services to the 'post-coach' count and instead add them to the count of weekly 'flying-wagon' services from London to Bristol. Note that the first service under Flying Wa. reads: "w, s, A. 4". This meant there was a service which departed at 4 in the afternoon, but only on Wednesday and Saturday rather than daily, so this line adds 2 weekly services to the flying wagon count. The final type of road service in this entry is wagon (signified by Wa. in Figure 2).

In total, the entry in Figure 2 tells us that in 1800 there were 119 weekly 'Post-Coach' services, 4 weekly 'Flying-Wagon' services, and 25 weekly 'Wagon' services between London and Bristol. I derived counts in this manner for each of the 66 sample cities in each of the 5 sample years. These counts are used to construct the dependent variables in my regressions below.

Figure 2 only listed three distinct types of road service, but the directories list over two dozen road types in total. Table 1 displays the total number of services, summed over all cities and all time periods, for each type of road vehicle. These services can be broadly divided between cargo and passenger services: I will separately estimate models with these two categories as the dependent variables.

Table 1

Cargo Services		*Passenger Services*	
Wagon	3421	Post Coach	8747
Fly Boat & Wagon	1041	Coach	5939
Flying Wagon	590	Diligence	604
Van & Wagon	200	Machine	552
Fly Van	174	Fly-Machine	34
Van	165	Expedition	45
Van, Fly Boat & Wagon	161	Balloon Coach	41
Canal Wagon	135	Telegraph Coach	22
Post Wagon	98	Long Coach	21
Fly Van & Wagon	48	Post Chair	14
Fly Caravan	42	Fly Coach	6
Fly Van, Boat & Wagon	29	Royal Patient Coach	6
Fly Boat & Van	7	Sweepstakes	3
Cart	4		

In the case of cargo services, the biggest categories are 'Wagon,' 'Fly-Wagon,' 'Van,' and 'Fly-Van.' Other categories ('Cart,' 'Fly-caravan', 'Canal Wagon', and 'Post-Wagon') occur less frequently. In addition, there are ‘hybrid listings,’ which will be discussed in greater detail in Section 3.2.

For passenger services, the biggest categories are ‘Post-Coach’ and ‘Coach.’ ‘Diligence,’ and ‘Machine’ occur less frequently, while the many other categories of passenger service occur very rarely. All these vehicles are horse-drawn carriages. Post-coaches and regular coaches were typically drawn by four horses and had room for about four passengers inside (though more could sit outside, and reports of coaches loaded with an almost comical excess of passengers are common). ‘Machines’ typically were smaller and required less horsepower, while ‘diligences’ were larger than the standard ‘coach’ (diligence capacities ranged up to 16 internal passengers). Post-coaches carried mail in addition to passengers, and these services operated under contract with the post office (or, in some cases, were operated by the post office itself); ‘coaches’ and other road-passenger services were purely private enterprises.

Figure 3.1 plots the diffusion of road-passenger services over time, while Figure 3.2 charts the diffusion of road-cargo services over time. Note that, in Figure 3.2, the arrival of fly-boats in 1816 coincides with a period of increasing use of fly-wagons and, eventually, decreased use of traditional wagons. This suggests that fly-boat availability might have altered the service-mix of the road-cargo industry; we will verify this intuition below.

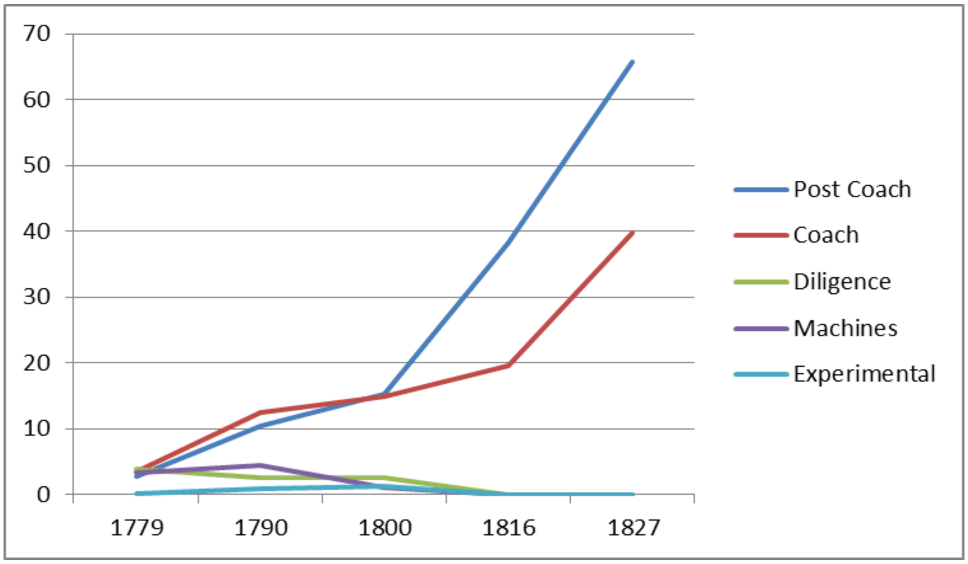


Figure 3.1: Total Passenger Services for All Sample Cities

3.2 Water-Based Services

The directories contain listings for three broad categories of water-based service: 'Vessel,' 'Barge,' and 'Fly-Boat'.

For vessels and barges, a directory entry for a particular city lists the locations within London (e.g. wharfs) where these services could be accessed, but frequencies and departure times are not included as they were with road-based services. For fly-boats, departure times and frequencies may or may not be included. The lack of frequency and departure time data is not a concern, since the variable of interest for water-services is just an indicator. In Figure 2 above, we see that there was one wharf in London from which a barge departed for Bristol and three

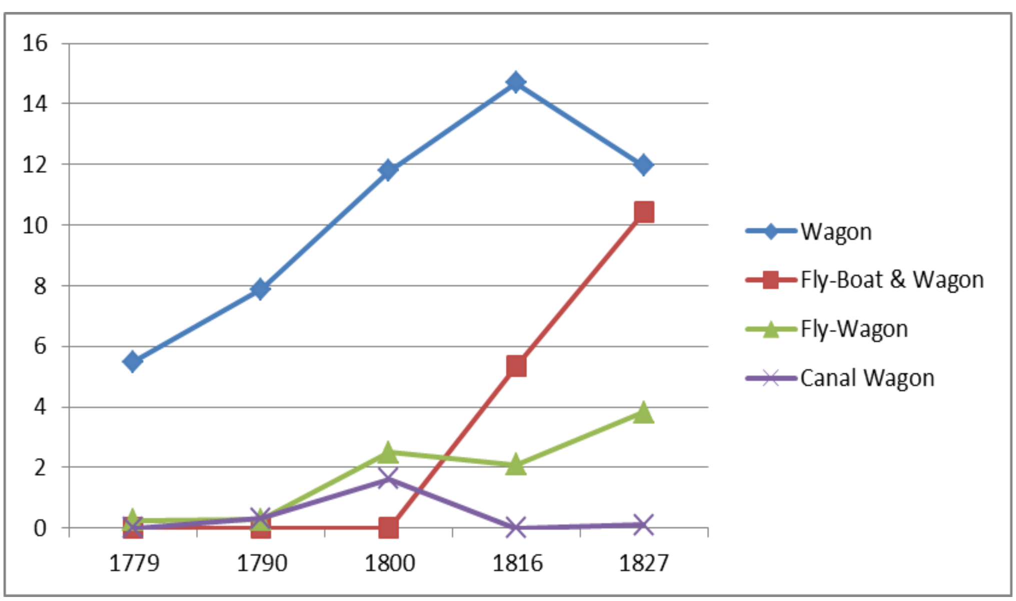


Figure 3.2: Total Cargo Services for All Sample Cities

wharfs from which a vessel departed. I do in fact make a count of these locations, but interpreting these counts is difficult and I do not use them as a measure of distinct services. Rather, I code indicator variables for whether a city had access to London via *any* water service

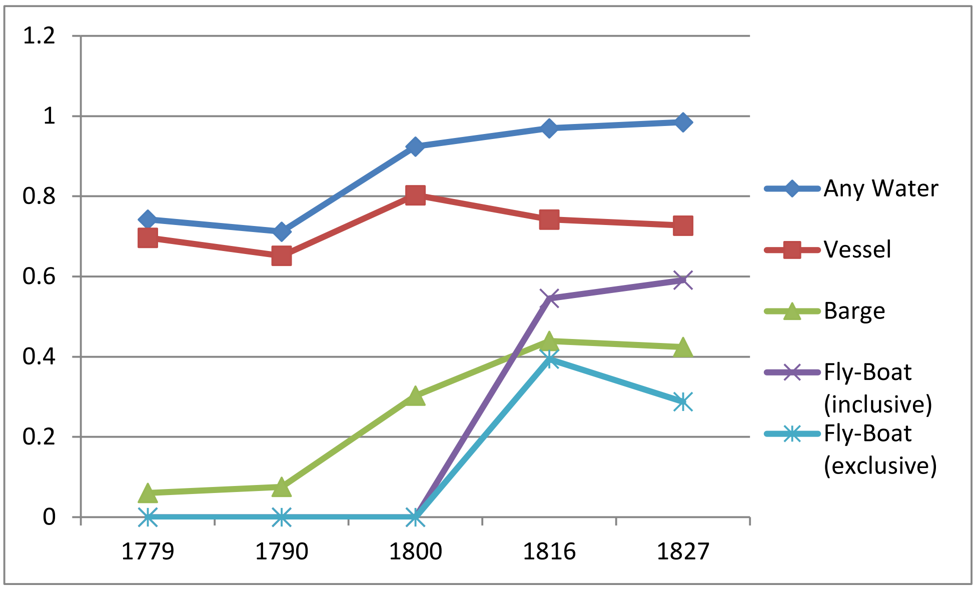


Figure 3.3: Fraction of Sample Cities with Water-Transport Service

and, additionally, for whether a city had each *particular* water service.

We can confidently match the categories 'Vessel', 'Barge' and 'Fly-Boat' with particular vehicle classes. 'Vessel' refers to coasting vessels, sailing-craft designed for ocean travel and also used on river navigations. We do not see much growth in the use of this craft during our period, partly because vessels were an established technology and were already in widespread use before the canal age. (Figure 3.3 shows the diffusion of different types of watercraft over time. The vertical axis is the proportion of major cities for which the directories list each type of service). 'Barge' refers to a standard barge, used for shipping on canals and navigable rivers. As we can see in Figure 3.3, this type of service diffused rapidly as the canal age progressed. Finally, there is the category of 'Fly-Boat'. Like barges, these were canal craft pulled by horses, but fly-boats were smaller and faster[12]. Fly-boats, unlike barges, often worked all night and they adhered to regular timetables[13] (Ville, 2004). Fly-boats carried merchandise and light goods, whereas barges specialized in bulky cargo. Finally, Hadfield (1968) reports that fly-boats were in theory granted right-of-way on the canals and precedence at locks, though he also reports that barges did not always adhere to these conventions. Fly-boat service is absent from my data until 1816, the 4th of the 5 directory years[14], but it diffused rapidly once it was introduced. The fly-boat represents an innovation in canal-worthy craft; it is essentially a faster, more versatile version of the barge.

In addition to the three broad categories above, there are a few categories of watercraft in which fly-boats[15] are paired with wagons or vans. The 'hybrid' categories with the greatest number of observations are: 'Fly-Boat & Wagon' and 'Fly-Boat, Van, & Wagon'. These 'hybrid listings' (as I will refer to them from now on) complicate my regressions, since there are too many instances of them to simply ignore yet I cannot simply include 'Fly-Boat & Wagon' in both my independent and my dependent variables. I will address these problems further below.

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[12] Flyboats were a type of narrowboat. Narrowboats have a maximum width of 7 feet, which is important because it means that they can be used on any canal (whether broad or narrow) in Britain. The use of *fly* in any service-title is meant to indicate an expedited service. Faster speeds were obtained, in part, by switching out teams of horses along the way, so that the journey could be made more or less 'non-stop'. Fly-boats carried double crews (two crews of two) so that they could potentially work all day and night (Hadfield 1968).

[13] Barges did not typically have a regularly-scheduled departure time for leaving London, and they rested at night. However, keep in mind that fly-boats' adherence to a schedule did not make them immune to the many delay factors associated with canal travel (e.g. frost, drought, time required to pass through locks), as discussed above. Hadfield (1968) reports that in 1825, barges took three to four day to go from Birmingham to Liverpool (~93 miles), while fly-boats made the journey in just under two days.

[14] The first fly-boats services occurred around 1803, shortly after my 3rd directory year.

[15] In hybrid listings, we will sometimes see the name 'boat' instead of 'fly-boat', as in the category 'Fly-Van, Boat & Wagon' in figure "". 'Boat' and 'Fly-Boat' are interpreted to refer to the same type of craft; with 'fly' referring, as it does elsewhere, to an expedited service. However, it seems that this expedited service is the norm. The simple term 'boat' is rarely used in the directory; this term is only employed in those hybrid listings that include a non-expedited, road-based service. In all other cases, the directory employs the term 'fly-boat'. In light of this fact, I use the term 'fly-boat' rather than 'boat' to refer to this particular type of watercraft and, furthermore, I do not distinguish between the two services.

For now, observe that these hybrid listings only involve the pairing of fly-boats with cargo services. Vessels and barges are never paired with a road service, nor are passenger road services ever paired with any type of water service[16].

3.3 Indicator Variables vs. Counts

I emphasize that using an indicator variable for water transport services would be desirable even if we did have richer water-service data. We are not actually interested in the correlation between levels of road-traffic and canal-traffic; rather, we are interested in understanding how the introduction of canals impacted demand for road services. An indicator variable for having any water-based service of a particular type is basically a proxy for whether a city is usefully connected to London via a water-network or not, and changes in this indicator are meant to capture the growth of the canal network. Similarly, an indicator variable for having any water-based service of a particular *type* is a proxy for whether a city is connected to London via a water network which can accommodate that vehicle-type. Thus, my indicators for water-based services serve as indicators for the feasibility of using a water-based mode of transportation.

For road transport, we want a measure of services levels, not just an indicator (in any case, such an indicator would almost always be positive for this dataset). We want to see the effect of the canal network on road traffic. Did canals divert traffic away from roads, thus acting as their substitute, or were canals being used for purposes which were independent of road-based commerce, so that road traffic would be unaffected when a city gains access to the water

[16] Two issues remain. (i) There is exactly one occurrence of something called a "packet boat" in one year: 1779. This is simply a small boat used for regularly-scheduled mail, passenger, and cargo services. I have tried various ways of categorizing this service (e.g. as a fly-boat or as a barge or as a separate service), and it doesn't significantly affect the results of my analysis. For this paper, I simply ignore the one "packet boat" observation. (ii) There are some water-based services (I have identified two: Steamboat and Yacht) which appear in the directories but not for any of the 66 major cities I sample; thus, we do not analyze these services.

network? The difficulty of inferring road traffic levels from directory counts will be discussed below.

3.4 Problems with the Data

3.4.1 General Problems with Directory Data

The purpose of the "Shopkeeper's and Tradesman's Assistant" directory was to let people know how to travel and ship goods between London and rest of the country. It was not intended to be a record of traffic levels, which begs the question: are the 'counts' I've derived sufficient as a measure road-traffic levels? Gerhold (1988) is an excellent review of the problems associated with using directory data to infer traffic levels. Gerhold's concerns can be summarized in two categorical questions: (1) to what extent were the contents of the directories "accurate, up-to-date, and comprehensive" and (2) "What did the entries really represent in terms of horses and wagons on the road?" The first question is arguably not pertinent to my data. My sample period begins in 1779, and Gerhold admits that the accuracy and contemporaneity of directories had improved by this time; his harshest criticisms are of directories from the mid-1700's and prior. By the time my sample period begins, accuracy is guaranteed by greater competition among publishers, while being up-to-date is guaranteed by the combination of greater competition and greater frequency of publication.

The more pressing issue for my analysis is Gerhold's second concern: what do these directory entries tell us about the level of traffic on the roads? Unfortunately, there is a lack of corroborating evidence which could prove or disprove the reliability of my dataset as a measure of road traffic. Nevertheless, we can have confidence in my analysis because it avoids many of the usual pitfalls associated with directory data. First and foremost, it is fortunate that all five of my directories are from the same publisher. Since I am using a panel-data framework, my analysis only requires that differences in directory counts accurately capture differences in traffic levels. Even if we do not know the exact function mapping directory counts to traffic levels, when the directories are all from the same publisher, it is relatively safe to assume that the same function applies in all periods and cities (especially since we have restricted our analysis to major cities). Keeping in mind that standards of accuracy and contemporaneity were in place, we can proceed to assume that differences in counts are a meaningful reflection of differences in traffic levels.

Still, two concerns remain, which I will refer to as the ‘double-listings problem’ for cities along the same route from London and the ‘multiple originations problem.’ Both of these issues are a potential source of measurement error and deserve further elucidation.

3.4.2 Double-listings

It is possible that if two cities lie along the same route, a service destined for City A may also be listed as a service for the intermediate City B. This is a problem if City B only has that service due to City A and not on account of its own economic activity; we would have measurement error in City B’s demand for that service. If this error is correlated with our independent variables, our results could be biased. To deal with this issue, we restrict our analysis to major cities, whose routes to London are most likely to command transportation services on their own account rather than as a by-product of the other cities on that route. It is precisely for this reason that my analysis has been limited to the 66 most populous cities of the period. Of course, services along routes to big cities may still suffer from this double-listings issue, but it is hard to see how the resultant measurement error would be correlated with canal-service availability; thus, in context of my analysis, the double-listings problems most likely makes the data noisy, thereby attenuating any coefficients, so that the bias is towards finding no effect of canals on road-traffic.

There is an additional reason to discount the 'double-listings' issue. Sometimes, the directory entry for City X will consist of a single line "see City Y." In less extreme cases, the directory entry for City X may list some types of services but then say "see City Y" for others. For the most extreme cases, then, the double-listings problem is identified in the data whenever it occurs. This identification does not solve the double-listings problem, but fortunately entries of the form "see City Y" only occur for 13 cities of our 66[17] and, if these cities are left out of the regressions, none of this paper's conclusions are fundamentally changed.

3.4.3 Multiple-Originations

The previous paragraph dealt with the idea that a new service in City A may actually represent a new service to City B. Our final concern is that a new service for City A may actually represent an existing service for City A adding more pick-up points, more 'originations', within London. To see the problem, imagine that five services, each consisting of a single wagon with a single pick-up point in London, are cancelled. At the same time a single new service, again consisting of a single wagon but now making five stops in London, is added. My data would read that as a neutral change, even though it in fact represents a decrease in City A's demand for road transport. This issue remains a concern for me, since I do not know of any way to systematically identify routes with multiple originations. Therefore, I proceed by assuming the 'multiple originations problem' is merely a source of white-noise and therefore the direction of bias is towards finding no effect of canals on road-traffic.

3.4.4 Problems with deriving counts from directory data

[17] Consistent with our stated reasons for restricting our analysis to 66 cities in the first place, entries of this form seem to occur much more frequently for cities outside our sample.

The previous section addressed general problems related to the mapping of directory-based ‘counts’ to actual traffic levels. There are also issues with the first step of converting directory data into ‘counts’. First and foremost is the problem of ‘hybrid services.’ By this, I refer to the fact that there are not only services named ‘Wagon’, ‘Fly-Wagon’, ‘Van’, or ‘Fly-Boat’, but also services named ‘Fly-Boat & Wagon’ or ‘Van, Fly-Wagon & Fly-Boat’ (see Table 1). This is problematic if we want to determine, for instance, the effect of fly-boat access on the level of wagon traffic. Simply adding ‘Fly-Boat & Wagon’ to the count of both fly-boats and wagons would obviously induce a positive correlation between them, but to completely ignore these aggregated services would be equally problematic. I will wait to fully address these issues in the context of presenting my regressions.

3.4.5 Problems with the Water-Service Data

‘Hybrid services’ also complicate the construction of an indicator variable for water-based services. The question is: should a city with listings for ‘Fly-Boat & Wagon’ but no listings for ‘Fly-Boat’ be coded as having fly-boat access to London? There is no satisfactory answer because it is not clear what the hybrid listing ‘Fly-Boat & Wagon’ really represents. If ‘Fly-Boat & Wagon’ refers to a service that will travel by canal where possible and otherwise travel by wagon, what can we infer about a city which has ‘Fly-Boat & Wagon’ service but no ‘Fly-Boat’ service? The most efficient route between this city and London could be anywhere from 99% road to 99% canal. In the former case, it is mistaken to say that city had access to London by fly-boat, while in the latter case it is mistaken to say otherwise.

I solve this problem by employing two sets of indicators for fly-boat access. One indicator will be positive whenever any service including the word ‘fly-boat’ is available (that is, it will take account of both unique ‘Fly-Boat’ listings and hybrid services). The other indicator will be positive only when a city has a unique 'Fly-Boat' listing, regardless of whether or not it has hybrid listings. Fortunately, as we will see below, regressions based off either indicator typically support the same broad conclusions[18].

Constructing indicator variables for other canal services is straightforward. 'Vessel' and 'Barge' are always unique listings; these services never appear as part of a hybrid listing. A priori, one might think that an indicator for having access to London via *any* water service would be subject to the same issues as the indicators for fly-boat access. However, there are exactly 30 observations for which a city has hybrid service access but no unique 'Fly-Boat' listings, and in 29 of these cases, the city has access to 'Vessel' or 'Barge' services, meaning that two sets of indicators for whether a city has *any* water-services to London differ for exactly one observation. Therefore, I only employ one such indicator in my regressions (i.e. hybrid services always count as a water-based services), but as one would expect, all my results are robust to using the other indicator.

3.4.6 Quantity Data vs. Price Data

Finally, one might question the wisdom of attempting to measure road traffic volumes when price-responsiveness is a natural way of investigating substitutability. Competitive pressure from canals would have eliminated the most inefficient road-carriers first, leading to a fall in prices as the road-industry achieved a lower marginal cost. The problem is that records of fares tell us almost nothing about actual fairs. Freeman (1977) points out that assessed rates, which we do have records of, are merely upper limits on advertised rates. Further complicating the issue, advertised rates have very little to do with rates actually charged. Thus, unfortunately, reliable fare data is simply not available for this analysis.

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[18] I report all my regressions for both sets of indicators, excepting those cases where my choice of dependent variable renders the inclusive indicator inappropriate

3.5 Model

This paper employs a fixed-effects panel framework. To control for unobserved, city-specific factors influencing road-traffic levels, I include city-level fixed effects. To control for trends, I include time dummies for four of the directory years. Omitted variable bias is a concern (especially high levels of economic activity may, for instance, contribute to both a higher probability of obtaining canal service to London and a higher demand for road services). Therefore, my regressions utilize population estimates to control for a city's level of economic activity. The population data for my sample years was constructed by interpolating population data from McCulloch (2011) and Law (1972).

The complete model is thus a simple fixed-effects panel regression:

$$(1)\ \ r_{it} = \alpha_i + \delta_t + \beta \cdot w_{it} + \gamma \cdot X_{it} + e_{it}$$

where *i* and *t* are city and time indices, respectively, r is a measure of road-traffic, α is a city-fixed effect, delta is the coefficient on a time dummy, X is population, and w is an indicator for water-based services. The coefficient of interest is β, and ultimately we are interested in a hypothesis test on this coefficient.

I do not include city-specific time trends in my preferred regression (1) because of the large cost, in terms of degrees of freedom, to doing so. But it is reasonable to expect that unobserved city-specific trends may be a source of endogeneity bias; for instance, the fastest growing cities, in terms of road service, may get treated earlier. Thus, as a robustness check, I run regressions on a model identical to model (1) except for the addition of city-specific time trends. This regression is:

$$(2)\ \ r_{it} = \alpha_i + \delta_t + \theta_i * year + \beta \cdot w_{it} + \gamma \cdot X_{it} + e_{it}$$

Where θ_i is a city-specific time trend and 'year' is simply the nominal year of observation.

Finally, since my road-service measures are, in fact, counts, I consider an econometric model suitable for such data. I employ a negative binomial framework as a robustness check to the simple OLS framework in model (1)[19].

$$(3)\ Pr(\,r_{it} = k) = NB(\alpha_i + \delta_t + \theta_i * year + \beta \cdot w_{it} + \gamma \cdot X_{it} + e_{it}\,, k)$$

Though the negative binomial model is theoretically the appropriate model for count data, I prefer regression (1) for simplicity and transparency; the lingering potential for measurement error and endogeneity bias is more readily discussed in the context of regression (1) than in a non-linear model.

4 Analysis

4.1 Cargo Regressions

Table 4.1 presents the results of my preferred panel regression (1), where the dependent variable is the count of all road-cargo services. The columns differ only by the indicator variables of interest. In column 1, the indicator is positive whenever a city has access to any water-based service to London. In columns 2-5, the indicator is for one particular vehicle type only (as discussed above, there are two ways to construct the fly-boat indicator and I report regressions for both). Finally, in columns 6-7, I include indicators for all three types of watercraft. The coefficients in columns 6-7 tell us the impact of a particular water-service *conditional* on the presence of other vehicle types, while the coefficients in columns 2-5 are unconditional in this respect. A 10% significance level is appropriate for this analysis, and I bold/italicize significant results.

[19] A priori, we could also considered a Poisson model, but in every negative binomial regression I run, a test for over-dispersion suggests that a Poisson model is not appropriate.

Table 4.1: Cargo – Basic Regression

	1	2	3	4	5	6	7
Any Water	***-3.414***						
	1.719						
	0.047						
Vessel		0.569				0.051	0.164
		2.363				2.551	2.486
		0.810				0.984	0.947
Barge			0.633			1.923	1.367
			2.242			2.043	2.152
			0.778			0.347	0.525
Fly Boat (Inclusive)				***-12.029***		***-12.260***	
				2.334		***2.286***	
				0.000		***0.000***	
Fly Boat (Exclusive)					***-4.656***		***-4.882***
					2.372		***2.522***
					0.050		***0.053***
Population	-3.68E-05	-2.96E-05	-3.23E-05	3.29E-05	-3.48E-05	2.69E-05	-4.01E-05
	1.24E-04	1.13E-04	1.18E-04	1.10E-04	1.31E-04	1.13E-04	1.27E-04
	0.766	0.793	0.785	0.765	0.791	0.813	0.753
N	330	330	330	330	330	330	330
R^2 (Adjusted)	0.234	0.227	0.227	0.322	0.241	0.320	0.236
Legend:	**Coefficient** **Std. Error** **P-Value**	Coefficients significant at the10% level have been ***bolded and italicized*** . Coefficients near but above 10% significance have been *italicized*. Standard Errors are based on 1000 block-bootstrap iterations.					

These regressions suggest that canal services are displacing roads, but that the effect is dependent on the availability of fly-boats. The coefficient on the indicator for having any water-based services (column 1) is negative and significant, but when we differentiate specific vehicle types, only the coefficients on fly-boat access are significant.

The significant and negative impact of fly-boat access does not depend on the specification of the fly-boat indicator or whether I condition on the presence of other water-services. Therefore, it seems that canals did displace roads, but only after the appearance of fly-boat technology. Since this technology appears late in the canal age, our results confirm that canals were ultimately a superior substitute to roads (at least for some types of traffic) while also suggesting that value of the canal network was not limited to the underpricing of roads. During the long period before fly-boat technology, the canal network diffused rapidly without displacing road traffic. Since many early canal projects were profitable (Ville 2004), this suggests that canals originally exploited economic opportunities which were not practical by road. Only later in the canal age, after the introduction of a specialized vehicle-service, did canals become competitive with roads. We can think of initial canal development as an effort to provide services which were prohibitively expensive by road, so that canals and roads served segregated markets. Once some canal infrastructure was in place, though, entrepreneurs developed new vehicles/services; these services, having addressed some of canals' weaknesses, were substitutes for traditional road services and therefore displaced them. We will see, in Section 5, that the competitive pressure of this latter stage incentivized a technological shift in the road-transport industry.

Returning to Table 4.1, note that the coefficients on the time dummies conform to what we would expect: they are positive and increasing over time, and always significant. This is basically always the case, so for simplicity I will not report these coefficients for any other regressions.

I also perform regressions for two re-specifications of the model. In Table 4.2, the first three columns present the results for the panel regression with city-specific trends included

Table 4.2: Cargo – Robust Regression

	Regression with City-Trends			*Negative Binomial Regression*			*Weighted Dependent Variable*		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Any Water	*4.642*			-0.099			***-11.379***		
	2.985			0.188			***6.805***		
	0.120			0.598			***0.095***		
Vessel		2.030	2.459		-0.027	-0.003		-0.898	-0.780
		2.739	3.010		0.187	0.180		9.193	8.928
		0.459	0.414		0.884	0.987		0.922	0.930
Barge		3.577	4.464		0.029	0.070		5.988	4.771
		3.370	3.509		0.124	0.133		9.154	9.403
		0.288	0.203		0.812	0.598		0.513	0.612
Fly Boat (Inclusive)		***-13.021***			**-0.600**			***-35.358***	
		3.227			**0.163**			***9.214***	
		0.000			**0.000**			***0.000***	
Fly Boat (Exclusive)			-2.569			-0.215			***-16.637***
			3.490			0.153			***9.366***
			0.462			0.159			***0.076***
Population	-2.60E-04	-3.21E-04	-3.09E-04	***-6.06E-06***	-3.71E-06	***-6.89E-06***	-2.22E-04	-3.77E-05	-2.35E-04
	3.15E-04	3.01E-04	3.22E-04	***3.67E-06***	4.12E-06	***3.79E-06***	3.18E-04	3.46E-04	3.58E-04
	0.409	0.287	0.339	***0.098***	0.368	***0.069***	0.486	0.913	0.511
N	330	330	330	330	330	330	330	330	330
R^2 (Adjusted)	0.307	0.360	0.308				0.144	0.190	0.144
Log-Likehihood				-813.0867	-799.2211	-811.47197			

Legend: **Coefficient** / **Std. Error** / **P-Value** — Coefficients significant at the10% level have been ***bolded and italicized***. Coefficients near but above 10% significance have been *italicized*. Standard Errors are based on 1000 block-bootstrap iterations.

(model 2).[20] Including city-specific trends reverses some of our results; access to water-based services now seems to *increase* the number of wagons on the road (column 1). However, it seems this complementarity is being driven by access to barges and vessels, and we see in columns 2-3 that the effect of fly-boat access is still negative, with point estimates similar to those in model (1) but with larger standard errors, so that the coefficient in column 3 is

[20] For simplicity, I have only included the regressions where the effect of one-water service is conditional on the effects of the others (corresponding to columns 6-7 in tables 4.1). For all the regressions I will present, the 'unconditional' versions (i.e. columns 2-5 in Table 4.1) support the same conclusions, with similar point estimates and significance results. The only major difference is that the effect of fly-boats is more likely to be significant in the 'unconditional' version; this is always because of smaller standard errors rather than smaller point estimates.

insignificant now. The negative binomial regressions (model 3), presented in columns 4-6 of Table 4.2, reinforce the conclusions that fly-boat service displaced road-based cargo traffic but other types of canal service did not.

Table 4.3: Inclusive Road-Cargo Variable

	1	2	3	4	5
Any Water	*-3.553*				
	2.341				
	0.129				
Vessel		-0.200			-1.445
		2.822			2.537
		0.943			0.569
Barge			1.058		3.342
			2.606		2.657
			0.685		0.209
Fly Boat (Exclusive)				***-14.435***	***-15.111***
				3.218	***3.159***
				0.000	***0.000***
Population	***4.766E-04***	***4.824E-04***	***4.785E-04***	***4.673E-04***	***4.530E-04***
	0.000	***0.000***	***0.000***	***0.000***	***0.000***
	0.000	***0.000***	***0.000***	***0.000***	***0.000***
N	330	330	330	330	330
R^2 (Adjusted)	0.506	0.502	0.503	0.568	0.570
Legend:	**Coefficient** **Std. Error** **P-Value**	Coefficients significant at the10% level have been bolded and italicized. Coefficients near but above 10% significance have been italicized. Standard Errors are based on 1000 block-bootstrap iterations.			

In addition to testing the robustness of my results to model specification, we also want to consider alternative measures of the dependent variable. In all the previous regressions, the dependent variable is simply the combined counts of all road-based cargo services. However, not all cargo vehicles had the same capacity; we have implicitly assumed a monotonic relationship between traffic levels and tonnage hauled, but insofar as this relationship does not hold, we'd prefer to have the tonnage measure. Fortunately, Gerhold (88) provides a guide to the capacities of different types of cargo vehicles. I use this information to construct an alternate measure of cargo traffic, with each vehicle type weighted by its assumed capacity[21]. I run regressions using my preferred model (1) with this alternative measure of cargo traffic. The results, presented in the last three columns of Table 4.2, are consistent with the results in Table 4.1: the same coefficients are significant and those coefficients have the same sign (we would not expect the same point estimates, due to the weighting).

In all the regressions presented so far, the count of cargo services does not include hybrid-services. Table 4.3 presents regressions in which the cargo variable does include these services. When we use this inclusive cargo measure, it no longer makes sense to consider an 'inclusive' fly-boat indicator; therefore Table 4.3 only employs the 'exclusive' fly-boat indicator. Once again, the results are consistent with our previous regressions: fly-boats displace road-cargo traffic but other canal services do not. As with the original cargo measure, I test the sensitivity of my results to model specification; I do not display the regressions here, but the results in Table 4.3 are robust to including city-specific time trends or employing a negative binomial framework.

Two other regressions, which I do not present here, are worth noting. If I do not include city-fixed effects in a model which is otherwise identical to equation (1), the regression results are mostly consistent with those in Table 4.1 (i.e. similar point estimates and significance levels): the major difference is that barges have a positive, significant effect on road-cargo traffic.

Motivated by the idea that the advantage of canals could depend on distance, I also run a regression for a model identical to equation (1) except for the addition of an interaction between 'distance' and the water-service indicators (distance is crudely measured as straight-line mileage to London). However, the coefficient on the interaction term is always small and insignificant,

[21] The weighting scheme is: Vans, Caravans, and Carts have a weight of "1" for distances under 45 miles and a weight of "1.5" for all greater distances. Wagons have a weight of "2" for distances under 45 miles, "3" for distances between 45-80 miles, and "4" for distances over 80 miles.

while the coefficients on the indicators are similar to those we have already found. This could mean that distance is not driving preferences with respect to road vs. canal transportation, but perhaps my distance measure is too crude to pick up the effect.

4.2 Passenger Regressions

Table 4.4: Passengers – Basic Regressions

	1	2	3	4	5	6	7
Any Water	-7.978						
	7.919						
	0.314						
Vessel		-10.275				-6.471	-7.386
		8.965				5.803	5.631
		0.253				0.265	0.190
Barge			-8.243			-6.697	-5.412
			6.324			6.229	6.127
			0.192			0.282	0.377
Fly Boat (Inclusive)				*-14.902*		*-14.308*	
				9.460		*9.059*	
				0.115		*0.114*	
Fly Boat (Exclusive)					***-18.954***		***-18.501***
					10.041		***9.256***
					0.059		***0.046***
Population	***7.13E-04***	***6.40E-04***	***7.61E-04***	***8.07E-04***	***7.09E-04***	***8.25E-04***	***7.26E-04***
	3.33E-04	***3.79E-04***	***3.11E-04***	***3.27E-04***	***3.51E-04***	***3.02E-04***	***3.08E-04***
	0.032	***0.093***	***0.014***	***0.014***	***0.043***	***0.006***	***0.019***
N	330	330	330	330	330	330	330
R^2 (Adjusted)	0.416	0.368	0.416	0.422	0.428	0.421	0.426

Legend: **Coefficient** / **Std .Error** / **P-Value** — Coefficients significant at the10% level have been ***bolded and italicized***. Coefficients near but above 10% significance have been *italicized.* Standard Errors are based on 1000 block-bootstrap iterations.

This section will analyze the impact of canals on road-passenger services. Returning to regression (1), the dependent variable in Table 4.4 is a sum of all passenger services (see Table 1). We see that the results are similar to those for cargo services, with significant negative coefficients on indicators for fly-boat service but not for other water-based services. However, the point estimates for the coefficient on ‘Vessel’ and ‘Barge’ indicators are consistently negative, unlike the case of the cargo regressions.

I also perform regressions with several re-specifications of the dependent variable. Rather than include all passenger services, I alternatively include (i) only ‘Coach’ and ‘Post-Coach’, (ii) those two services plus ‘Diligence,’ or (iii) only those three services plus ‘Machine’ and ‘Fly-Machine’. I do not report any of these regressions; the point estimates and significance levels are almost identical to those in Table 4.4; the only significant change is that in every other specification, the ‘Fly-Boat’ coefficient in column 6 is significant rather than marginally insignificant.

Table 4.5: Passenger – Robust Regressions

	Regressions with City-Specific Trends			**Negative Binomial Regressions**		
	1	**2**	**3**	**4**	**5**	**6**
Any Water	-9.207			0.127		
	6.396			0.257		
	0.150			0.619		
Vessel		***-15.877***	***-15.958***		0.150	0.151
		6.423	***6.401***		0.192	0.180
		0.013	***0.013***		0.434	0.400
Barge		***-8.446***	***-9.144***		-0.007	-0.009
		5.113	***5.344***		0.119	0.112
		0.099	***0.087***		0.950	0.934
Fly Boat (Inclusive)		***-13.663***			***-0.219***	
		8.201			***0.131***	
		0.096			***0.096***	
Fly Boat (Exclusive)			*-19.436*			***-0.353***
			12.530			***0.154***
			0.121			***0.022***
Population	***1.05E-03***	***9.84E-04***	7.83E-04	***7.92E-06***	***8.90E-06***	***6.82E-06***
	6.26E-04	***5.61E-04***	5.98E-04	***2.27E-06***	***2.46E-06***	***2.31E-06***
	0.094	***0.079***	0.191	***0.001***	***0.000***	***0.003***
N	330	330	330	330	330	330
R^2 (Adjusted)	0.691	0.698	0.704			
Log-Likelihood				-1042.837	-1040.607	-1037.268
Legend:	**Coefficient** **Std. Error** **P-Value**	Coefficients significant at the10% level have been ***bolded and italicized.*** Coefficients near but above 10% significance have been *italicized*. Standard Errors are based on 1000 block bootstrap iterations.				

As I did with cargo traffic, I perform passenger-traffic regressions for two alternative specifications of the model. The first three columns of Table 4.5 report the regression results when city-specific time trends are included, while the rest of the table reports the results of negative binomial panel regressions. The results are broadly consistent with the conclusions I have drawn so far; however, the regressions including city-trends suggest that all forms of water-transport, not just fly-boats, displaced road-passenger traffic. The coefficients on the fly-boat indicators have similar point estimates with or without city-specific trends, while the point estimate for barges and, especially, vessels are larger and are now significant[22].

5 Innovation

The previous section is consistent with a theory in which canals are ultimately a superior substitute to roads, but there is a technological hurdle that has to be overcome before canals can realize their full potential and actually displace road traffic. This technological hurdle was apparently significant, in that it was only overcome well into the canal age (recall that fly-boats' first use occurred around 1803). Clearly, vehicle technology cannot be taken for granted when thinking about modal competition; technological progress is integral to this process. There is reason to expect technological innovation would have occurred in the road-industry, as well. If canals displaced road-traffic, then road carriers would have had to innovate or specialize in order to survive. This section asks whether the road-service industry responded to canals in this manner. We only expect technological shifts to occur when road and canals are actually competitive so, given the results of the previous section, we should only expect fly-boat access to induce innovation/specialization in the road industry.

[22] It is not surprising that including city-trends is particularly important for estimating the 'vessel' coefficient. The assumption of endogeneity is a priori more tenuous for vessels than for barges and fly-boats. It is the expanding canal network – and to some extent the introduction of novel services – which this paper implicitly takes as exogenous. Coasting vessels, however, were in use long before the canal age, do not experience much diffusion in this period, and do not rely on the expanding canal network for whatever diffusion they experience.

As further motivation for this section, consider Figure 5. I've constructed a measure of 'Fast Cargo' services, which consists of all those cargo services which include the prefix 'Fly'. I use this to construct a ratio of 'Fast-Cargo' as a fraction of all 'Cargo' services. Similarly, I construct a ratio of 'Post-Coach' services as a fraction of all 'Passenger' services. Figure 6 plots the evolution of these ratios and we see that both ratios are initially increasing but seem to stabilize near the end of my sample period; thus, the mix of services offered by road carriers may have been influenced by canals.

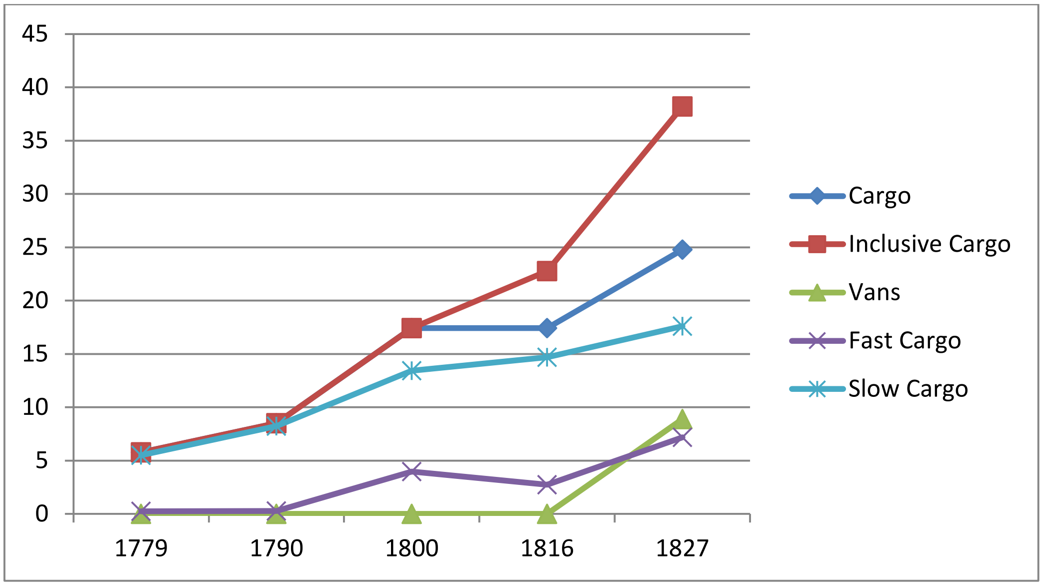

Figure 5: Diffusion of Cargo-Service Categories

Continuing to use the framework of equation (1), I run regressions with these service-mix ratios as the dependent variables. Table 5.1 presents the results for the ratio of 'Fast-Cargo' services to all 'Cargo' services, while Table 5.3 presents the results for the ratio of 'Post-Coach' services to all 'Passenger' services.

Given the speed advantage of roads, we expect fly-boats to displace slow road services at a more substantial rate than fast road services; thus we look for a positive coefficient on the 'Fly-Boat' indicators. Table 5.1 confirms our expectations for road-cargo traffic. The non-competitive 'Vessel' and 'Barge' services do not alter the mix of road-cargo traffic, but fly-boat access does encourage the road industry to specialize in expedited cargo services.

Table 5.1 leaves open the question of whether fast-cargo traffic was simply surviving

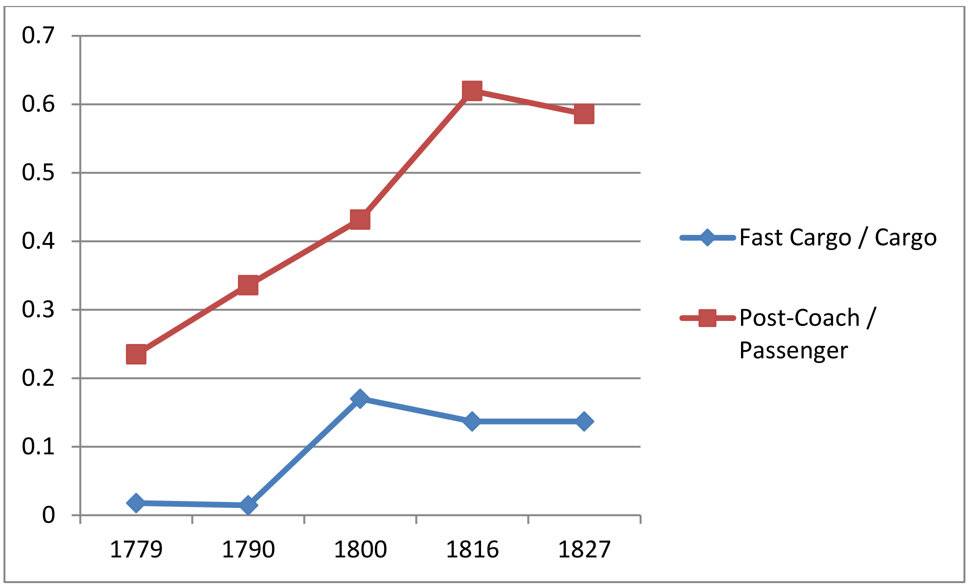

Figure 6: Evolution of Service-Type Mix for Cargo and Passenger Services

while slow-cargo traffic was displaced or whether fast-cargo traffic was actually thriving. The former explanation merely points to a differential impact of canals on distinct service-types, while the latter explanation is more consistent with a theory, like that presented in Section 2.4, of canals inducing specialization in the road-cargo industry. Table 5.2 presents the results of regressions (still following model (1)) where a count of 'Fly-Wagon' services is the dependent variable. We see that these services are in fact complementary with fly-boat access, consistent with specialization by road carriers.

Somewhat surprisingly, Table 5.2 also suggests that 'Barges' had a negative impact on 'Fly-Wagon' service levels, suggesting competition between these two specific vehicles even though we found little evidence of more general competition between barges and road-cargo services in Section 4. It could be the case that barges and fly-wagons both specialize in

Table 5.1: Ratio of Fast-Cargo Traffic vs. All Cargo Traffic

	1	2	3	4	5	6	7
Any Water	-0.038 0.047 0.425						
Vessel		-0.022 0.059 0.714				-0.013 0.062 0.834	-0.015 0.062 0.804
Barge			-0.049 0.052 0.347			-0.065 0.058 0.266	-0.058 0.057 0.310
Fly Boat (Inclusive)				***0.154*** ***0.056*** ***0.006***		***0.161*** ***0.057*** ***0.005***	
Fly Boat (Exclusive)					0.053 0.064 0.411		0.061 0.067 0.359
Population	***6.76E-06*** ***2.30E-06*** ***0.003***	***6.82E-06*** ***2.37E-06*** ***0.004***	***7.02E-06*** ***2.30E-06*** ***0.002***	***6.05E-06*** ***2.27E-06*** ***0.008***	***6.89E-06*** ***2.35E-06*** ***0.003***	***6.25E-06*** ***2.16E-06*** ***0.004***	***7.11E-06*** ***2.32E-06*** ***0.002***
N *R^2 (Adjusted)*	*326* *0.085*	*326* *0.083*	*326* *0.087*	*326* *0.120*	*326* *0.087*	*326* *0.120*	*326* *0.086*
Legend:	**Coefficient** **Std. Error** **P-Value**	Coefficients significant at the 10% level have been ***bolded and italicized***. Coefficients near but above 10% significance have been *italicized*. Standard errors are based on 1000 block-bootstrap iterations.					

transporting some of the same goods, but these goods represent too little traffic for the effect to have been picked up in Section 5's regression (consider Table 1.1; fly-wagon traffic is only small fraction of all cargo traffic).

Table 5.2 Flying Wagon

	1	2	3	4	5	6	7
Any Water	-0.085 0.777 0.913						
Vessel		1.766 1.213 0.145				1.908 1.251 0.127	1.867 1.254 0.136
Barge			-1.520 1.231 0.217			-1.856 1.272 0.145	-1.695 1.399 0.226
Fly Boat (Inclusive)				***2.781*** ***1.171*** ***0.018***		***3.069*** ***1.205*** ***0.011***	
Fly Boat (Exclusive)					0.661 1.746 0.705		1.079 1.778 0.544
Population	0.000124 9.45E-05 0.1884	0.000126 9.42E-05 0.1823	0.00013 8.84E-05 0.1406	0.00011 9.42E-05 0.2428	0.000125 9.52E-05 0.1886	0.000117 9.35E-05 0.2116	0.000133 9.14E-05 0.1447
N	330	330	330	330	330	330	330
R^2 (Adjusted)	-0.090	-0.080	-0.080	-0.061	-0.088	-0.043	-0.074
Legend: Coefficier **Std. Error** **P-Value**	Coefficients significant at the 10% level have been ***bolded and italicized***. Coefficients near but above 10% significance have been *italicized*. Standard errors are based on 1000 block-bootstrap iterations.						

Finally, Table 5.3 presents the regressions for the Post-Coach vs. Passenger service ratio. Fly-boats apparently displaced post-coaches at a greater rate than regular coach services. It is unclear which features of post-coaches are driving this result. We know that post-coaches were more expensive but also more comfortable, and we know that post-coaches were more prone to travel at night. These qualities leave post-coaches in a worse position than regular coaches with respect to differentiation from fly-boats, since fly-boats also travel at night and are relatively comfortable[23]. The most relevant feature may be that post-coaches, which carry mail in addition to passengers, seem to have operated like a public monopoly. Perhaps the lack of flexibility in this quasi-public sector amplified the displacement effect of fly-boat access, while purely private

Table 5.3: Ratio of Post-Coach Traffic vs. All Passenger Traffic

	1	2	3	4	5	6	7
Any Water	0.001937						
	0.129465						
	0.9881						
Vessel		-0.03278				-0.04293	-0.05639
		0.106567				0.103582	0.104406
		0.7584				0.6786	0.5891
Barge			0.057578			0.082099	0.100457
			0.091218			0.089072	0.088426
			0.5279			0.3567	0.2559
Fly Boat (Inclusive)				***-0.21906***		***-0.23043***	
				0.099631		***0.104721***	
				0.0279		***0.0278***	
Fly Boat (Exclusive)					***-0.26132***		***-0.2825***
					0.099848		***0.099157***
					0.0089		***0.0044***
Population	-1.28E-06	-1.31E-06	-1.50E-06	-1.40E-07	-1.56E-06	-4.20E-07	-2.00E-06
	3.33E-06	3.42E-06	3.19E-06	3.46E-06	3.11E-06	3.34E-06	3.16E-06
	0.7006	0.7025	0.6381	0.9677	0.6157	0.8999	0.5272
N	330	330	330	330	330	330	330
R^2 (Adjusted)	0.023321	0.023651	0.024754	0.041373	0.04892	0.037327	0.046678
Legend:	**Coefficier** **Std. Error** **P-Value**	Coefficients significant at the10% level have been ***bolded and italicized*** . Coefficients near but above 10% significance have been *italicized* . Standard errors are based on 1000 block-bootstrap iterations.					

coaches were able to adjust to the presence of fly-boats and, hence, survive. I do not report the regressions here, but if we run our basic panel regressions with a count of 'Post-Coach' services as the dependent variable, the results are quite similar to Table 4.1, except that the point-estimates on the fly-boat coefficients are a little larger in magnitude. However, if we take the

[23] Hadfield (1968) quotes Thomas Grahame as saying, of swift boats (not quite the same thing as a fly-boat): "They are more airy, light, and comfortable than any coach." He also quotes Sir Archibald Geikie: "For mere luxury of transportation, such canal travel stands quite unrivalled."

counts of ‘Coach’ services as the dependent variable, none of the water-indicator coefficients are significant, and the point estimates for the fly-boat indicators are positive. Taken together with Table 5.3, these results suggest that fly-boats only displaced a particular type of road-traffic; namely, post-coaches.

6 Conclusion

We now know that the availability of the seminal canal-craft, the barge, is not associated with lower levels of road carriage. However, technological innovation within the canal industry led to the development of the fly-boat, whose availability does seem to have displaced road carriage. Future research can verify a causal effect by addressing lingering concerns about endogeneity. In addition, it’s worth noting that this analysis is relatively high-level, in that cargo traffic has not been differentiated by characteristics of the goods being carried. Research that could differentiate by good-type (likely not possible with my dataset) would enrich the story presented here. Additionally, better measures of the distance to London by each mode could be combined with my data-set to further pin down the precise market-segmentation between water and road transport.

Beyond academic understanding of the canal age, we have drawn conclusions about the process of intermodal completion. If we don’t make any non-trivial assumptions, it is theoretically ambiguous whether competition is bad for innovation (because it stifles post-entry rents) or good for innovation (because it incentivizes incumbents to innovate in order to discourage entry) (Aghion and Griffith 2008). In the context of Britain’s canal age, at least, it seems that increased competition encouraged innovation. One interesting avenue for further empirical and theoretical research would seek to determine whether intermodal competition in the transportation industry generally encourages innovation, or whether the conclusions of this paper are due to idiosyncrasies of the canal/road dichotomy. For now, claims that intermodal competition discourage innovation in transport should be compelled to explain why canal-age Britain is an exception.

Even lasses-faire governments usually plant a stake in the transport sector, especially when novel modes of transport are involved, and therefore they desire estimates of the social impact their investment and regulation decisions will have. This paper suggests that the social savings from a new mode of transport can understate the total benefits *even when* that mode is dropped into a sophisticated economy already in possession of an extensive transport infrastructure. Social-savings estimates neglect the benefit of increased innovation within the older mode and ignore the possibility that the newer mode might facilitate more intense economic activity than the old mode could have sustained (e.g. the modes may have different returns to scale). My research suggests that future analysis ought to give more consideration to those benefits of transport which lie beyond the scope of social savings estimates.

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8 Appendix

Figure 8: Britain's Turnpike Network in 1770 (courtesy of Pawson 1977)

Chapter II: The Role of Air Accessibility in Urban Development

Abstract

Several authors have explored the role of airports in urban development, but this paper is the first to employ a market-access approach to explain growth in a cross-section of cities. Using a disaggregated 10% sample of all U.S. airline tickets in 2000, we create a novel variable – an air accessibility measure – to capture the contribution of airports to MSAs' market access. The primary finding is that air accessibility greatly increases the growth rate of employment within tradable services industries, and this result is highly robust. However, we find the impact of air accessibility on total employment and productivity growth to be weak and statistically insignificant, suggesting that growth in tradable services crowds out growth in other sectors.

1 Introduction

The advancement of aviation technology ranks among the major economic developments of the 20th century. By dramatically reducing travel time between far-flung locations, air travel permits an unprecedented degree of human mobility. Insofar as the temporal and monetary costs of long-distance travel are a barrier to production, relaxing these costs affects both the distribution and intensity of economic activity.

Airports facilitate a city's growth through several channels. Foremost among these are the potential inter-city agglomeration economies permitted by air-travel. There has been a good deal of research demonstrating that firms have lower production costs when located physically near one another (see, for example, Glaeser & Gottlieb (2009)). Possible explanations for this relationship include employment "spillovers", where firms requiring similarly-skilled workers take advantage of a common labor pool, and information spillovers, where proximity accelerates both the flow of information and, consequently, the accumulation of human capital. Just as these "spillover effects" increase with geographic proximity, firms may obtain similar benefits when they become 'closer' to one another by air. For instance, firms can take advantage of a wider labor market when they are more accessible by air, since search frictions for workers in other cities will often be a function of air-travel costs. Industries whose costs depend on the price and convenience of air travel[24] can become more geographically concentrated when air travel costs fall, allowing them to realize greater economies of scale. And within any industry, airports facilitate the flow of new ideas by facilitating in-person interaction. For example, workers are

[24] For instance, passenger airfares may be a substantial cost for certain services industries in which the client lives in a different city than the business (e.g. consulting), or in which some part of production must take place remotely (e.g. journalism).

able to attend more professional conferences when they enjoy relatively low fares and relatively short, convenient flights.

Another employment channel arises from the amenity values of destinations reachable by air, which raise the utility of workers in a city, making new workers easier to attract. Additionally, there are the direct employment effects of the airport itself. Moreover, if some industries (e.g. tradable services) enjoy economies of scale in cities well-connected by air, welfare in all well-connected cities increases due to lower prices, making them a more attractive place for workers to live.

Conversely, airports may be fundamentally irrelevant to urban growth.[25] In fact, airports may even dampen city growth by putting government spending and valuable land to inefficient use. Even if there is no doubt that airports are a positive amenity for local residents, airports may still suppress growth if the resources[26] they consume could be more efficiently allocated to other ends. Moreover, an airport's value might depend on city characteristics, in which case some cities' growth could be dampened by greater air accessibility. For instance, if greater access causes tradable services firms to concentrate in fewer cities, then airports would increase growth in the largest cities at the expense of smaller cites.

Empirically, the precise contribution of air transportation to the current economic landscape remains inadequately understood. Several economists have taken steps towards quantifying the benefits of access to the air-transport network, but the need for further research persists. In particular, since the value of an airport lies in the air-travel network to which that facility provides access, a precise estimation of the impact of airports must employ some

[25] For example, agglomeration economies may be exhausted at smaller distances than those relevant to air travel.
[26] Airports investments are measured in the billions, and the power eminent domain is often exercised to make way for expansions. A case in point is the Chicago O'Hare Modernization Program: it is currently expected to cost ~$15 billion and around 500 houses were obtained through power of eminent domain.

measure of *accessibility* as the independent variable of interest. To date, other authors have analyzed airports using traffic variables (e.g. number of departing passengers, number of departing flights, etc.) as their variable of interest, but while these variables are correlated with measures of air-network access, they may not be sufficiently sensitive to every dimension of variation in that measure.

This paper focuses on quantifying the impact of air accessibility on Metropolitan Statistical Area (MSA) outcomes, primarily growth in tradable-services employment. Growth is measured between 2000 and 2007, which permits exploitation of data from the 2000 Census and the 2007 Economic Census. The end date of 2007 is preferable to the census year 2010 since we wish to exclude the Great Recession. Our analysis departs from the existing economic literature by introducing a new theoretical and empirical approach for analyzing the local benefits of airports: we create a market-access variable for passenger air travel, which we name *air accessibility*, and employ this measure as our independent variable of interest. Since air accessibility is endogenous, the analysis employs an instrumental variable framework. We find that a one standard deviation increase in air accessibility yields upwards of 26 extra percentage points in tradable-services growth between 2000 and 2007. Though we also hypothesize that airports could impact the growth of tourism or leisure sectors, our analysis discerns no such impact.

Additionally, we consider the impact of air accessibility on population, total employment, and Gross Metropolitan Product (GMP) growth, as well as MSA in-migration rates. We find a positive, but small and statistically insignificant, impact of air accessibility on all of these outcomes.

The analysis builds upon several strands of economic literature, including those concerned with aviation-specific economics, general transportation infrastructure (especially those studies employing a market access approach), urban growth, and new economic geography. Section 2 will discuss each of these in literatures in turn. Section 3 motivates an accessibility approach, while Section 4 presents the estimation model. Section 5 describes data sources and the computation of air accessibility. Section 6 discusses the estimation results, and Section 7 concludes.

2 Previous work on the economic impact of transportation infrastructure

2.1 Airports

Estimating the impact of access to the air transportation network is complicated by an endogeneity problem: locations experiencing exceptional economic growth will tend to have higher demand for air services relative to similar locations. Since growth spurs access while access stimulates growth, identifying causality requires some exogenous source of variation in access.

Brueckner (2003) is one of the first significant papers studying airports' role in urban growth; it estimates the impact of air traffic, measured as the number of passengers boarding planes, on contemporaneous levels of employment. Brueckner analyzes a cross section of 91 metro areas in 1996, and addresses endogeneity using these instrumental variables: hub-status of airports, a parameter capturing geographic centrality, proximity to other cities, and dummies for leisure destinations and slot-controlled airports. Brueckner finds that a 10% increase in enplanements (i.e. originating and connecting passengers) generates a 1% increase in employment in the surrounding city, with the effect explained entirely by growth in service-related employment.

Green's (2007) study is similar to Brueckner's, except it estimates the effect of airport activity in 1990 (measured alternatively as total passenger traffic, departing passenger traffic, hub status, and cargo traffic) on *subsequent growth* in the decade 1990-2000. Green's instruments include 'distance to the coast' and 'distance to Kansas City,' and he concludes that all measures of "airport activity", except for cargo traffic, generate growth in population and employment.

Button (1999) takes hub status as the airport variable of interest and analyzes 321 MSAs in 1994. Button employs the 1978 Airline Deregulation Act to create an instrument for the hub status of airports and finds that hub status raises high-tech employment in the surrounding city by an average of 12,000 jobs. As in Brueckner (2003), this work demonstrates that the employment impact of airports varies by sector.

More recently, Sheard (2014) uses the National Airport Plan of 1944 to create an instrument for the distribution of current airport sizes. He finds that total employment in the surrounding metro area is unaffected by flight departures, but that a greater departure volume yields a greater employment *share* for tradable services.

The papers discussed so far are cross-sectional analyses, and we may worry that cities have fixed characteristics that determine city growth but are also correlated with airport activity.[27] Therefore, a panel regression can provide additional insights. Blonigen & Cristea (2013) are notable for taking this approach, comparing long-run growth rates before and after the Airline Deregulation Act of 1978. Since the Civil Aeronautics Board subsidized short routes, the CAB's abolition in 1978 affected cities differently according to their size and level of airport activity. Blonigen & Cristea exploits this differential impact to create an instrument for changes

[27] For instance, an attractive place to travel may also be an attractive place to work. Such a city could attract skilled labor while also attracting airplanes full of tourists, and researchers would wrongly conclude that airport activity causes growth.

in airport activity. The analysis concludes that air traffic has a large, positive impact on the annual growth rates of employment, population, and income.

2.2 Roads and Highways

Other authors have investigated the economic role of transportation infrastructure in the form of roads. Baum-Snow (2007) demonstrates that the highway system is responsible for a substantial fraction of suburbanization, illustrating in a local context the role of transportation infrastructure in determining population distribution. Duranton and Turner (2007) demonstrate the value of intercity road connections, concluding that a 10% increase in highway infrastructure yields a 1.5% increase in employment over a 20-year period.

The literature on roads often finds that the impact of connectivity depends on the initial characteristics of the city, especially location and size. Michaels (2008) finds that the US Highway System redistributed demand for skilled labor among rural counties, increasing the skill-premium where skilled labor was already abundant and decreasing the premium where skilled labor was scarce; however, the magnitude of this effect is small. Faber's (2012) analysis of China's National Trunk Highway system and the peripheral cities that it incidentally connected concludes that highways reinforced the concentration of economic activity, increasing production in initially remote periphery cities and depressing it in other peripheral cities.

Both Michaels and Faber rely on "incidental connections" for identification. Roads meant to connect one particular set of locations will incidentally connect other, in-between locations to that same road network; these latter connections are a source of exogenous variation in road access. One may think air travel is distinct from land travel in that it lacks such "incidental connections." However, several of the airport instruments mentioned above essentially extend this intuition to the case of air travel: because not all flights are direct, cities which are chosen as hubs (or cities likely to be chosen as hubs based on their *centrality* or *distance to coast*) enjoy inflated airport infrastructure and air accessibility relative to similar, but less fortuitously positioned, cities. This paper employs instruments that build on the logic of incidental connectedness, namely, the share of through-traffic at each airport and a carrier Herfindahl index for passenger travel originating at each airport.

2.3 Railroads

The oldest literature concerning the relevance of transportation infrastructure to growth started with the classic work of Fogel (1964), who evaluated the impact of railways using a "social savings" framework. According to Fogel, GNP would have been no more than 3% lower in 1890 if America had relied solely on road and water transportation in the absence of railways. Fishlow (1965) retains Fogel's social savings framework but aims to improve on his estimation, concluding that railways were responsible for at least 15% of GNP. Like Fishlow, more recent research often finds that the contribution of railways to economic outcomes is substantial. Donaldson (2010) analyzes railway expansion in colonial India and concludes that connected cities experienced a 16% increase in real income; moreover, he provides evidence that this increase is entirely accounted for by newly exploited gains from trade. Jedwab and Moradi (2011) illustrate the potential long-run effects of infrastructure on the distribution of economic activity, finding that regions of Ghana exposed to railroad access during the cocoa boom continued to experience high levels of urbanization even after decades of railway obsolescence. Bogart and Chaudary (2011) provide an overview of evidence that the Indian railway system accelerated market integration, price convergence, and income growth. Finally, Donaldson and Hornbeck (2012) bring a market-access approach to the Fogel-Fishlow debate and estimate that the U.S. stock of railroads was worth 73% of the value of agricultural land in 1890, or 6.3% of GNP.

2.4 New-Economic-Geography Perspective and the Market Access Framework

Two papers are notable for extending New Economic Geography models and introducing the concept of market access to the empirical urban growth literature. Redding & Sturm (2007) exploits the division of post-WWII Germany and demonstrates that the population decline of East German cities near the east-west boarder, relative to their West German counterparts, is best explained by a market-access model. Ploeckl (2012), a historical case study of 1834 Saxony, finds that locational characteristics predict relative city size and relative growth rates, but that second-order effects through market access explain a much greater portion of variation than locational characteristics alone.

In their respective analyses of railways, Donaldson and Hornbeck (2012) and Donaldson (2010) employ a market-access framework, each basing their approach on the theory that the total economic impact of a transportation improvement is captured, in equilibrium, by changes in market access. Similarly, Gutberlet (2013) demonstrates the essential role of access – via railways – in the regional development of German industry during the 19th century.

The market-access framework is applicable across modes, since any transportation improvement that lowers travel costs will foster growth through common channels. Considering the vastly different speed, cost, and convenience characteristics of different modes of travel, it is worth applying a market-access approach directly to an air transportation network. Though the requisite datasets are familiar to aviation economists, we are the first to apply an accessibility approach in analyzing the economic impact of air travel.

3 Air Accessibility vs. Airport Traffic

In the literature regarding airports' role in urban growth, the most ubiquitous variable of interest is airport traffic, typically flight or passenger volumes. We argue that these measures fail to fully incorporate the network characteristics of transportation infrastructure. Essentially, these variables are afflicted with measurement error because the proper measure of network access depends not only on the level of activity at a particular node but on the size and structure of the entire network. An airport's usefulness to a potential user depends on the number of locations reachable from that airport, the characteristics of each such location, the price of travel to each location, and the convenience of using the airport, among other factors. Improvements in these factors will result in more traffic, making traffic a useful approximation of underlying air accessibility. Since passenger-level fare and routing data are available for U.S. air travel, it is possible to construct several market access variables at the MSA level, which we more precisely name *air accessibility* variables, for use in our analysis. In light of the above considerations, it is worthwhile to see what insights this approach can provide.

Sheard (2014) relies on flight volumes as a variable of interest, arguing these are a better measure of airport activity than passenger volumes, because the former measure reflects capacity *as well as* the variety of destinations. While Sheard's insight is valuable, we are motivated by the verity that no aggregate traffic measure can account for every dimension of variation in air accessibility. Since the value of access to a transportation network depends on the value of reaching other nodes in the network, we must take into account the economic characteristics of potential destinations. For instance, if a low-cost air carrier initiates a new service from Los Angeles to New York and a similar carrier initiates service from Los Angeles to San Antonio, Texas, these developments will have different consequences for Los Angeles' economic development. Thus, the proper predictor of interest should not, as aggregate traffic variables do, treat all destinations the same; rather, some measure of each destination's value ought to be incorporated. Failure to do so will result in less precise estimation, at best, and if the difference between traffic and access variables is correlated with determinants of growth, estimates of airports' impact will be biased.

Furthermore, traffic variables do not incorporate the costs of air travel and, ultimately, the value of a transportation network depends on the generalized cost of using it. For instance, if air travel is valuable for its time savings relative to other modes, a new circuitous route is not as valuable as a new direct route. Though airport traffic will be correlated with these costs, this paper presumes that the best approach incorporates them directly.

In light of these considerations, our "air accessibility" measure seems appropriate. It is essentially a gravity variable that quantifies a transportation node's access to a network as a weighted sum of the sizes of all the markets that network provides access to, with the weights depending on transportation costs and an elasticity parameter. Such a variable answers the criticisms discussed above by incorporating a valuation of each destination as well as the costs of using the network. At this point, it's important to note that we do not rest our approach on its intuitive appeal alone. Gravity variables are ubiquitous in geography and spatial economics since they are a straightforward way to reduce complex network relationships into a single measure. Within empirical economics, a market potential variable was notably employed as early as Harris (1956) to explain industrial location. Harris provides intuitive justification for his ad hoc measure, but the works of Redding & Venables (2004), Fujita et. al (1999), and Hanson (2004), to name a few, provide the approach with solid theoretical underpinnings. In particular, Redding & Venables (2004) demonstrate that the total impact of changes in a transportation network are wholly captured, in equilibrium, by changes in market access. The details of the aforementioned theoretical models are not worth repeating here, since our air accessibility measure is only a first order approximation to the measures derived from them. We note, however, that such approximations are normal and to some degree necessary in empirical work. As noted above, Donaldson (2010) and Donaldson & Hornbeck (2010) apply a market access approach in their analyses of railways and our measure bears resemblance to theirs, though ours is less complex since we treat "passengers" as a homogenous category while they consider heterogeneous goods traffic. The calculation of "air access" will be explicitly detailed in Section 4, but the formula is:

$$AirAccessibility_i = \sum_{j \neq i} \frac{MarketSize_j}{C_{ij}^{\gamma}} \quad (1)$$

where the subscript (i) indexes MSAs, "Market Size" is measured by MSA population, C_{ij} is the generalized cost of air travel between MSA_i and MSA_j, and γ is an elasticity parameter.

Having enumerated the several benefits of employing a market access approach in our analysis, the costs of this approach also demand consideration. One drawback is computational complexity: the costs of air travel must be derived for every city *pair* before the air accessibility of each city can be calculated. A second drawback is that "air travel costs" enter our regressions indirectly through market access, meaning we lack the flexibility to use a generalized cost measure while simultaneously estimating the relative contributions of each individual component of that generalized cost. To be more concrete, imagine that the true generalized cost of travel takes the following form:

$$Cost = \alpha * Fare + \beta * Time + \omega * SchedulingInconvenience \quad (2)$$

First of all, our measures ignore the third term on the right-hand side, since we do not know the distribution of departure times for a route.[28] Besides this restriction, we are additionally constrained to (1) use only time costs, effectively setting $a = 0$, (2) use only fares, effectively setting $\beta = 0$, or (3) fixing the ratio $\frac{\alpha}{\beta}$ without estimating it. Note that options (1) and (2) both result in measurement error if time and money costs are not perfectly correlated. To address these drawbacks, we employ several air accessibility variables that span these options, and we discuss our conclusions in light of all alternatives. It turns out, however, that our various measures of air accessibility are highly correlated, suggesting that average fare is a good proxy for average generalized travel cost.

The final drawback of our approach is that an ideal "market access" approach would properly include *all* transportation alternatives, not just air travel. A perfect measure of a city's market access would, for instance, consider the passenger-transportation alternative with the lowest average generalized cost between any two cities rather than only the average airfare. Omitting other transportation alternatives may especially misstate the market access of a highly populated urban corridor like the northeast United States. Two cities that are very near each other may not enjoy any advantage in airfare costs relative to two similar cities situated much farther away (and, if they are too close together, they may also suffer a disadvantage in direct-flight availability), but the availability of road and rail suggests that the two proximate cities ought to contribute more to each other's market access than two far-flung cities. It is tempting to try and explicitly incorporate other transportation alternatives into a general, multi-modal accessibility measure. However, it is not actually clear that this approach is tractable: different

[28] That is, we set $\omega = 0$. Although the volume of departing flights on a route is the inverse of flight frequency, and flight frequency is therefore a crude proxy for convenience, we think this proxy is too crude to warrant inclusion, keeping in mind that our other measures of cost already reflect convenience (see below).

transportation modes are characterized by unique trade-offs among temporal, monetary, and scheduling costs. Thus, the aforementioned problems related to computing generalized travel costs would only be exacerbated by such an approach. Consequently, we do not take this approach; instead we use a “market potential” variable to control for accessibility via other transportation alternatives. This variable is similar to a “market access” variable, but rather than weighting each city’s size by the cost of traveling to it, market potential weights other cities by the raw distance to them. Thus, this measure controls for road and rail travel insofar as the costs of these modes can be assumed directly proportional to distance. Moreover, additional reasons for employing a market potential variable will be discussed in Section 4.[29]

While all our specifications incorporate a market potential variable, some specifications will also include a variable, “Hwy Density Fringe,” measuring the density of major roads at the borders of an MSA; this measure provides additional control for accessibility by road. Finally, we also test our hypothesis without including MSAs from the dense northeast corridor (i.e. BEA Region 2), since this is the region where controlling for other alternatives is of greatest concern; our qualitative conclusions are unaffected by this omission.

3.2 Adjustment to Equilibrium

It should be noted that our approach is consistent with a world in disequilibrium, where adjustments in city sizes facilitate equilibration.[30] We can model this approach using a simple partial adjustment framework. Let $M_i^*(Access_i, X_i)$ be the equilibrium employment level as a function of air accessibility and additional city characteristics X_i, and let M_i be the initial

[29] To be clear, we choose the term “air accessibility” to describe our predictor of interest, reserving the term “market access” for a hypothetical variable incorporating costs across all transportation modes and “market potential” for the similar variable based on raw distances.

[30] While we assume workers freely move among cities, we do not believe they move instantaneously. The decision to migrate, even within a region, is a long-run decision. While spatial equilibrium could also be mediated by more responsive factors (e.g. capital flows), it seems that migration always plays a role. Hornbeck (2008), for instance, demonstrates that agricultural shocks associated with the dust bowl resulted in economic adjustments *primarily* through migration over a long period.

employment level. Employment growth in city *i* closes a fixed fraction of the gap between the initial and equilibrium levels of employment. That is,

(3) $$\Delta M_i = \zeta * (M_i^*(Access_i, X_i) - M_i)$$

where $0 < \zeta < 1$, and ΔM_i is employment growth in city i. Thus, this model implies that ΔM_i depends on air accessibility, initial employment, and other city characteristics. If a city has exceptionally high air accessibility access relative to its initial employment level and other characteristics, the absolute value of $(M_i^*(Access_i, X_i) - M_i)$ will also be exceptionally large, and we would therefore expect exceptional values of ΔM_I.

This model abstracts from general equilibrium considerations since we do not explicitly model the fact that one city's growth comes partly at other cities' expense, nor do we incorporate the fact that general equilibrium requires living standards and firm profits to be equalized across cities. Equilibrium can be mediated by increases in the local cost of living as population and employment increase, though it can also be mediated by increases in airfares (hence, decreases in air accessibility) as demand for air travel grows, or similarly through the congestion of other local amenities as demand for them grows. Additionally, since an MSA's air access is the result of past decisions (by city planners, airlines, air passengers, etc.) that may anticipate growth, air access is treated as endogenous in the analysis below.

4 Model and Data

Most of our regressions take the following form:

(4) $$PercentChangeInOutcome_{2000-2007} = \beta_0 + \beta_1 Access_{i,2000} + \beta_2 OutcomeLevel_{i,2000} + \lambda_1 E_{i,2000} + \lambda_2 X_{i,2000} + \epsilon_i$$

where "Outcome" is alternatively sectoral employment, total employment, population, income, or GMP; "Access" is air accessibility; "E" is a vector of initial economic conditions; and "X" is a vector of additional controls. The subscript "i" indexes MSAs. While (1) is our preferred regression, we will also modify the equation by including "E" but not including "X" (or including only some subset of "X"), and we will also consider two outcomes variables that are not growth rates: MSA in-migration per capita and changes in the employment share of tradable services. Note that we always condition on the initial level of the outcome whose growth rate is on the left-hand side.

Our primary outcome of interest is tradable-services employment.[31] Of all employment sectors, tradable-services are most likely to be affected by air accessibility. First of all, tradable-services may require inter-city passenger travel for the production or delivery of their products. For instance, consultants, photographers, or lawyers in one city may need to travel to another city to deliver their services to their client. Similarly, managers may to need to travel to and from corporate headquarters and nationally dispersed offices, and journalists and academics may need to travel to complete their research. Secondly, inter-city agglomeration economies, which we described above and posited as a channel through which airports impact growth, will most benefit sectors whose production processes benefit from face-to-face interaction among agents in multiple cities; this includes professions characterized by regional or national conferences, e.g. scientific services.

4.1 Basic Set of Controls

Our goal is to discern whether cities with high air access *relative to their other initial economic conditions* experience greater growth in some outcome. Besides the "Outcome Level" in

[31] Specifically, this outcome includes employment in NAICS sectors 51-56. These sectors are Information; Finance and Insurance; Real Estate; Professional, Scientific, and Technical Services; Management of Companies and Enterprises; and Administration and Support and Waste Management and Remediation Services, respectively.

equation (1), these "initial economic conditions" are captured by the vector "E", which includes an MSA's unemployment rate and per-capita income in 2000, as well as our "Market Potential" variable. Since Redding & Sturm (2007) and Ploeckl (2012) conclude that the impact of market access varies with city size, "E" also includes the interaction of market potential with MSA population. We could likewise interact our air accessibility measure with own MSA population, but the estimated coefficient is generally insignificant and adds little to our discussion, so we do not include this interaction in our primary regression equation.

In Section 3 we discussed the possibility that our air access measure might be biased due to its failure to incorporate other transportation alternatives. This is one reason for including the market potential control. Insofar as we can approximate land transportation with a constant per-mile cost, market potential captures accessibility by land. We are also concerned about geographic remoteness: cities that are generally remote from other cities will tend to have lower access when using mileage as measure of cost and, since fares are correlated with distance, they will also have lower access when cost is measured by fare (additionally, such cities may have low levels of direct flight service). But remoteness may be a determinant of growth in itself (Ploeckl (2012), Redding & Sturm (2007)). One particular concern is that remote locations may attract more migrants from a relatively larger shed of rural areas. Fortunately, our market potential variable controls for *remoteness* in addition to controlling for accessibility by road and rail.

4.2 Extended set of controls

The vector "X" in equation (4) contains additional controls. This set of controls is inspired by Glaeser (1995) and similar research that identifies initial economic conditions, age distribution, race, educational attainment, size of government, and manufacturing share of employment as key drivers of city growth (see also Helpman (1998) and Overman and Yannis (2001), while Simon (1998) emphasizes the importance of human capital to MSA growth). Each of these is potentially a determinant of air accessibility as well. Demographics may affect air accessibility if, say, preferences for air travel vary by age or race, so we control for the percentage of the population over 65 and over 18, and the percent black as well. Similarly, we control for the percentage of high school and college graduates, because educational attainment may also be correlated with travel preferences. Manufacturers may value good road and rail access, which could be a substitute for air access, so we control for the initial manufacturing share of employment (NAICS 31-33). As mentioned above, we include the density of major roads (essentially highways) at an MSA's fringe to further control for accessibility by road. In addition to manufacturing, we also control for the initial tourism employment share (NAICS 72) and the initial tradable-services employment share (NAICS 51-56), since we believe these sectors benefit most from greater air access. In particular, higher values of Tourism Employment Share correspond to greater shares of "leisure travel" in air transport, so this variable controls for the mix of leisure/business travel in and out of a city.

Since cities that provide good air accessibility also provide other unobserved amenities that drive growth, we proxy for city spending on amenities by including the government share of employment. Finally, since migration trends favor temperate climates and climate may be correlated with travel behavior, we control for annual rainfall (this is a state level average) and its square. Additionally, we control for mean heating-degree and cooling-degree days (at the MSA level).

4.3 Instrumental Variables

By conditioning on a broad set of growth determinants, we hope to mitigate concerns about endogeneity. Nevertheless, cities may still have additional, unobserved characteristics that contribute to both air access and population growth, so we also employ two instrumental variables: (1) the percent of air through-traffic for each MSA (essentially, connecting passengers as a fraction of all air passengers) and (2) a Herfindahl index for the carrier concentration of passengers departing from an MSA (both originating and through- passengers). Our instrumental variable regressions depend on the assumption that, conditional on our controls, airport concentration and aerial through-traffic within an MSA impact urban development only via relative air accessibility and are not correlated with other sources of growth. Rather, conditional variation in our through-traffic instrument reflects a city's incidental location along important air routes, while conditional variation in the Herfindahl index reflects a city's degree of subjection to particular carriers' spheres of influence. We in turn assume that a city's subjection to these spheres of influence is the result of a strategic game among national carriers, a game that, conditional on our control variables, is only remotely related to the characteristics of any particular city.

5 Data & Calculation of Air Accessibility

Population levels, total and industry employment levels, average incomes and unemployment rates, as well as age, race, and educational attainment measures for MSAs are from 2000 and 2010 Census, intercensal estimates, and the 2002 and 2007 economic census. Annual gross metropolitan product data are from the Bureau of Economic Analysis. MSA in-migration data are from the 2005 and 2006 American Community Surveys. Average rainfall, at the state level, comes from the National Oceanic and Atmospheric Administration (NOAA). Several additional variables, namely 'heating degree days', 'cooling degree days', and 'density of highways at the urban fringe', are courtesy of Burchfield et. al (2006).

5.1 Aviation Data

Our aviation data comes primarily from the Bureau of Transportation Statistics (BTS). We use two databases: (1) the DB1B database of airline tickets and (2) the T-100 database of air carrier statistics. Additionally, a list of airports with hub-status is taken, with appropriate modification, from Brueckner (2003).

The DB1B database is a disaggregated 10% sample of all airline tickets with at least one endpoint in the U.S.; the data are collected quarterly and are available from 1993 through the present, though a related database extends back to the 1960s. An entry in this dataset corresponds to an individual itinerary and lists the origin and destination airports, fare paid, routing information,[32] and carrier information for that itinerary. Using all available itineraries for a given city pair in a given year, we derive the average fare, average number of connections, average route mileage, and average direct-flight fare for that city pair. In calculating these averages, each itinerary entry is weighted by number of passengers. We also use the DB1B data to determine the percent of through traffic at an airport by dividing the total number of connecting passengers by the total number of departing passengers.

The T-100 database is a monthly time-series. It aggregates aviation data up to the carrier-route level and provides total passenger, cargo, and mail flows per month for each carrier-route. We use this dataset to determine the number of flights, number of passengers, and straight-line distance between each origin and destination. Additionally, for each airport, these data are used to calculate the Herfindahl index for outgoing passenger traffic.

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[32] Routing information includes total routing mileage, total non-stop mileage (used to determine whether a flights was direct), and # of ticket *coupons* in the itinerary (reflective of the number of connections).

5.2 *Calculating Air Access*

Our unit of analysis is the MSA (Metropolitan Statistical Area). To determine air accessibility, one must first calculate the average "price" of travel between every pair of cities. If two cities are not accessible to one another by air, their mutual contribution to one another's market access is zero; this outcome is akin to assuming an infinite fare between these cities. The ideal "price" is a generalized cost of travel: a single measure incorporating the value of a passenger's time, the scheduling convenience of his departure and arrival times, as well as the monetary fare. We undertake one attempt to construct such a generalized cost, but since the computation of that cost requires stringent assumptions, we also employ simpler measures of cost, namely fare and route distance (since we lack data on individual flight times, we rely on average routing miles as a proxy for travel time).[33] When an itinerary's "routing distance" is equal to" non-stop miles", we know that that the flight is a direct flight; therefore, restricting our attention to direct flights only, we can derive a third measure of the price of air travel equal to the average *direct-flight* fare. This measure has the advantage of guaranteeing that lower average fares are not simply a reflection of greater average circuity. The disadvantage of this measure is, for instance, that we risk undervaluing the air accessibility of a city that faces low connecting-flight fares but typical direct-flight fares. Since the metropolitan statistical area (MSA) is our unit of observation, we combine all airports within an MSA into a single unit before computing passenger-weighted averages.

After calculating the average price of air travel within each MSA-pair, we can finally compute each MSA's air accessibility. The air accessibility measure for a given MSA is simply a weighted average of the populations of every other city, where the weights are a function of the

[33] It is worth noting that distance and fare are highly correlated, so average fare and average routing miles are both good approximations of the ideal "generalized cost of air travel".

inverse cost of travelling to each city by air. Thus, as in equation (1), air accessibility takes the following form:

$$AirAccessibility_i = \sum_{j \neq i} \frac{Population_j}{Cost_{ij}^{\gamma}}$$

where "$Cost_{ij}$" is on of the four measures described above (average fare, average direct-flight fare, average route mileage, and average generalized cost), and γ is a parameter assumed to be 1 but which may theoretically take on other positive value. Letting γ instead be equal to 1/2 hardly changes the qualitative conclusions of this paper. See Section A1 in the appendix for further discussion of the choice of γ. Also, note that the summand on the right-hand side of equation (1) is taken over all MSAs for which we have aviation and population data (~300), though due to the limited availability of covariate data only somewhat more than half of these MSAs actually remain our regressions.

All air accessibility and market potential variables have been normalized to each have a maximum of 1. Thus, the coefficients on air accessibility correspond to the consequence of increasing accessibility by 100% of the air access of the highest-access city. For our fare-based air accessibility measure, the highest access city is Denver, CO. The air access of Jacksonville, FL is roughly equal to 90% of Denver's. Thus, the effect of Jacksonville suddenly attaining Denver's air access is equal to 1/10th of the air access coefficients in our regression. Summary statistics for all variables and a correlation matrix for aviation and accessibility variables can be found in Table 1. As we would expect, air access is positively correlated with departing flights, market potential, and through-traffic share, and it is negatively correlated with the passenger traffic Herfindahl index. Note that, when $\gamma = 1$, our access variables are strongly correlated with each other; in particular, the measure based on generalized cost is highly correlated with each of the other measures. Also note the weak correlation coefficient on access using $\gamma = 1.5$ relative to access using $\gamma = 0.5$ when each is compared to our preferred measures using $\gamma = 1$.

Tables 2-5 below present the results of regressions based on equation (4), where the outcome is growth in tradable services employment (NAICS codes 51-56). In Table 2, the air access measure is calculated using average fares. For Tables 3 and 4, the air access measure is calculated using, respectively, average fare for direct flights only and average routing mileage. Since the ideal "price" for calculating air access is a generalized cost, the measure employed in Table 5 values time at $35/hr and assumes (1) that 500 miles of flight mileage corresponds to one hour, (2) that all layovers last 1.5 hours, and (3) that time at the origination and destination airports sums to 1.5 hours[34]. Thus, Table 5 reports regression results for an air access variable that measures the generalized cost of travel as:

$$Cost = Fare + 35 * \left(\frac{RoutingMileage}{500} + NumberOfCoupons * 1.5\right) \quad (5)$$

6 Analysis

6.1 OLS Results

In tables 2-5, the first column always reports the basic OLS regression where the right-hand side consists only of air accessibility, population, market potential, and basic initial economic conditions. Column 2 adds additional economic/demographic controls, while Column 3 also adds controls for age distribution, climate, and fringe road density (Column 3 is the preferred specification). The fourth column replaces the air access variable based on $\gamma = 1$ with a measure based on $\gamma = 0.5$.

[34] The number of layovers is assumed to equal 1 – (# of flight coupons), but this is not an entirely accurate assumption. Many on-line flights with stopovers do not change flight number, and hence have only 1 coupon, violating the assumption above. Nevertheless, the number of coupons is not a critical source of variation in equation (5).

In tables 2-5, we always obtain a positive air access coefficient. Additionally, the access coefficient is always highly significant for the most basic regression (Column 1) and the regression with an intermediate set of controls (Column 2). With the full set of controls (Columns 3 and 4), we retain significance when using a measure based on all fares or generalized cost, but the coefficient on access using direct flight fares is insignificant. When air travel costs are measured by routing mileage, the air access coefficient is barely insignificant in Column 3 and significant in Column 4. In magnitude, the air access coefficients in column three range from 0.7-1.26, suggesting that if Jacksonville had been endowed with Denver's access in 2000, it's tradable services sector would have grown an additional 7 to 13 percentage points.

The covariates with significant coefficients are generally unsurprising. MSAs with less manufacturing, more adults, fewer retirees, more cooling-degree days, and fewer poor experience greater growth. Moreover, the coefficient on market potential is negative (and often significant), but the coefficient on the interaction with population is positive (if insignificant): the total impact of market potential is negative for the vast majority (or, in some cases, all) population values. As expected given the framework captured by equation (3), the coefficient on initial tradable-services share is negative and significant.

6.2 IV Results

Though the impact of air access is robust to moderate levels of conditioning, the fact that adding controls tends to shrink the coefficient of interest is consistent with an unresolved endogeneity problem. So we now turn to an instrumental variable specification. Table 6 reports the first-stage results of a two-stage IV regression, with the Herfindahl index for air passenger traffic and the through-traffic share instrumenting for air accessibility. The signs on "Herfindahl Index" and "% through-traffic" are as expected (through-traffic increases access while carrier concentration reduces it) and the former is always significant while the latter is significant only when the outcome is air access using routing mileage. In each column, the p-values for the under-identification test are small enough, and first stage F-stats for the instrumental variables are all large enough, that we deem the instruments to be valid.

Table 7 reports the second-stage results for growth in the share of tradable services employment. The air access coefficients are substantially larger; the point estimates now range from 1.64 to 3.14. The coefficient in Column 2 suggests that if Jacksonville had been endowed with Denver's access in 2000, it would have experienced an additional 21 percentage points in tradable services employment growth between 2000 and 2007. If we multiply each coefficient by the standard deviation of that measure, we find that a 1 standard deviation increase in air accessibility yields between 26 and 62 additional percentage points of growth in this sector over a seven-year period. Note that a Hansen J-test indicates the instruments are valid in each column. Larger coefficients in the IV regression are consistent with a negative correlation between endogenous air access and tradable services growth; this makes sense if expected future growth accelerates current growth, which in turn increases current demand for air-services, driving up fares and thereby reducing air accessibility.

We also analyze employment growth for most 2-digit NAICS sectors individually (not shown here). We do not find a statistically significant impact of air access on any such sector, nor do we find any impact when we combine NAICS codes 71 and 72 into a single "Leisure" variable.

6.3 Alternative Outcomes: Total Employment, Population, Gross Metropolitan Product, and MSA In-Migration

Table 8 presents OLS and IV results for several alternative outcomes. We restrict our attention to the air access measure that uses generalized cost (these results are reflective of the results for the other air access measures in terms of sign and significance, though its worth noting that the estimated coefficient on air access is generally larger when using routing miles as the measure of air travel costs).

In columns 1-2 the coefficient for the effect of air access on total employment growth is positive but insignificant. We also consider the growth rate of GMP, since air access may have a greater effect on GMP than total employment if airports impact high-income jobs especially. In columns 3-4, we see that the coefficient on air access is also insignificant (and, for IV, negative). Finally, we consider whether air access impacts population growth rates; since airports are a consumption amenity, they may cause population growth even in the absence of an employment effect. In columns 5-6, the coefficient on access is again negative. Note, however, that the Hansen J-test often rejects the validity of our instruments when the growth rate of total employment or population is the outcome, though not when the outcome is GMP growth.

Though not shown here, it is worth mentioning that if we perform the instrumental variable regressions in Table 8 with the basic set of controls "E" but not "X", the coefficient on access is positive and highly significant when population or total employment growth is the outcome but not when GMP growth is the outcome.

Since the most plausible channel of differences in population growth is differences in migration rates, we also ask whether air accessibility in the year 2000 affects an MSAs per-capita in-migration rate (in-migration from ANY other location) in 2005. We find a statistically significant association between air access and in-migration in our most basic specification including "E" but not "X" (whether OLS or IV), but the results are not robust to including the full set of controls.

In most of the cases where our results are insignificant, at least the sign of the point estimate is "unsurprising", suggesting that greater precision may reveal a total employment, population, migration, or GMP effect. To this end, the air accessibility measures could be further refined to take into account the relative access of each destination (theoretically, a new connection to a well-connected city is not as valuable as a new connection to a less-connected city). Furthermore, the air access measures could be refined in terms of the "market size" component in equation (1); we use "MSA population" as a proxy for "market size" but some other measure, for instance "tradable-service employment levels," may be worth considering in the future.

6.4 Employment Shares

Sheard (2014) demonstrates that airports matter more for employment shares than total employment in an MSA. As in Sheard (2014), we are particularly interested in the employment share for tradable services (NAICS=51-56).[35] Given air access' strong impact on tradable services growth and insignificant impact on total employment growth, the results in Table 9, which shows the effect of air access on the growth of tradable services' employment share, are no surprise. Exceptional air access increases the growth of this employment share between 2000 and 2007.

In column 3, the preferred specification, the air access coefficient is 0.19. Thus, a 1 standard deviation difference in air access yields an extra 2.5 percentage point increase in

[35] Sheard uses NAICS codes 51-55 only. My results are highly robust to this re-specification, though the results I present here are somewhat stronger.

tradable services' employment share over this seven-year period. Or, 10% of Denver's access is worth an extra 2 percentage points of growth. This is a large impact, given that the mean MSA had a tradable-services employment share of 19% in 2000. But, take note of the negative coefficient on the initial share of tradable services. If air access increases tradable services' share but tradable services resist concentration, then in the long-run air accessibility will be most beneficial to cities with initially low tradable service employment shares.

Finally, replacing "air accessibility" with a traffic variable, given by total number of "departing flights", yields an insignificant coefficient for the latter. This is consistent with our observation in Section 3 that an air accessibility approach is especially fruitful when the outcome is a growth rate.[36]

6.5 Additional Robustness

We have shown that the large, positive impact of air access on tradable-services employment growth is robust to several specifications of the air access variable and also to several specifications of the estimation equation. Additionally these results are generally robust to a number of other transformations; a selection of IV results for tradable services growth are presented in Table 10a, and the relevant first stage results are in Table 10b. To instrument for the interaction terms in Table 10a, we add interactions of our instruments with population or land area respectively. According to Bun & Harrison (2014), these instruments are valid under fairly weak conditions, which we assert apply to our simple linear cross-sectional analysis.

In Column 1, air accessibility is interacted with population, since the literature discussed above often finds that impact of access depends on city size. Compared to Table 7, Column 2, the coefficient on access is virtually unchanged and the interaction term is insignificant. In

[36] Note that the instruments we use are not ideal for Departing Flights. Other instruments (such as those from Sheard (2014) or Brueckner (2003)) are better predictors of Departing Flights but do not change the significance of the Departing Flights coefficient in column 6.

Column 2 of Table 10a, air accessibility is interacted with the land area of the MSA. Since we have not accounted for variations in travel time *to* airports from, say, one's home, air access may have a smaller impact in expansive MSAs than in those confined to narrower boundaries. However, once again the coefficient on access is virtually unchanged and the interaction term is insignificant. In Column 3, we drop all cities with at least one hub airport, and the coefficient is slightly smaller but still significant. This indicates that our instruments are not useful merely as proxies for hub status; rather, consistent with the motivations of "incidental location along air routes" and "subjection to carriers spheres of influence", carrier concentration and through traffic also affect urban development via variation in the air access of *non-hub* cities. Column 4 drops all MSAs located in BEA Region 2; this region contains the dense northeast corridor, which is the region where our controls for access by alternative travel modes may still be insufficient. While this is the one column in Table 10a where the coefficient on air access is unexpectedly insignificant, note the loss of precision compared to the first three columns. In the last three columns, we consider alternate measures of tradable services growth. In Column 5, the outcome is growth in tradable services *payroll* rather than employment, and the point estimate on access is actually larger in this case. In Column 6, the outcome is growth in tradable services *establishments;* the coefficient on access is negative but insignificant, suggesting that air access impacts growth via existing establishments rather than new ones. Finally, in Column 7 the outcome is the *log change* in tradable services employment rather than percent growth. The coefficient on access remains significant.

7 Conclusion

This is the first paper studying the economic impact of air transportation that computes an accessibility measure as its airport variable of interest. The analysis confirms that air accessibility matters for the growth rate of tradable-services employment in an MSA; the huge coefficients on air access in the IV regressions of Table 7 imply that a one standard deviation increase in air accessibility yields at least 26 (or as much as 62) additional percentage points of growth in tradable services employment between 2000 and 2007.

Besides tradable services, the tourism (NAICS code 72) sector should also benefit from passenger air travel, but we do not find that tourism employment grows faster in cities with exceptional air accessibility. Additionally, we do not find a significant air access coefficient when our outcome is the growth rate of other industries, and in our preferred regression we find no statistically significant relationship between air accessibility and either population growth rates or GMP growth rates. Neither do we find any significant impact on total employment growth.

Broadly speaking, we have demonstrated that air accessibility, like access by other modes of transport, is an important determinant of the *distribution* of economic activity across sectors. Growth in tradable services is accelerated in cities with exceptional air accessibility and the impact is very large. But what can we say about the *intensity* of economic activity? First of all, we do not have strong enough evidence to conclude that air access affects aggregate employment or productivity, and what evidence we do have suggests a weak impact. Even if growth in tradable services crowds out other employment, it is temping to think there may be some long-run aggregate benefit to cities from strengthening a particular sector. However, higher initial employment shares for the tradable services sector actually dampen its subsequent growth rate. This is consistent with our partial adjustment framework, which suggests that a sector's growth rate slows as employment in that sector approaches its equilibrium value. Any impact of air accessibility on aggregate growth via tradable services is therefore subject to decreasing returns.

Finally, we have not necessarily captured the total impact of air accessibility on economic activity. We have captured a marginal effect: *among cities with airports*, we have estimated the benefit of having high air accessibility relative to similar cities. But, it may be the case that the extensive margin, whether one has access to the air network at all, is equal in importance to the intensive margin of air access levels.

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9 Appendix: Determining the value of γ

The choice of γ is a key element of our market access calculation. A value of 1 has intuitive appeal, since it incorporates market size and air travel costs in a straightforward way. Moreover, this allows us to interpret air access as simple gravity variable, which needs little theoretical justification beyond that already provided above. Finally, a value of 1 retains congruence between our market potential and air accessibility measures, lack of which would complicate our interpretation of market potential as a control variable.

Nevertheless, we claim continuity with the market access literature, in which case we must interpret γ as the elasticity of some flow variable with respect to total cost. In the case of goods traffic, this would be the elasticity of the total value of goods shipped on a route with respect to freighting costs. In our case, the relevant flow includes the delivery of tradable services, tourist travel, and any other air travel that is contingent on the location of employment. Or, to be more precise, the relevant flow is the *total value* of all these trips taken on a route. However, we do not know the value of all trips taken; we only know the number of trips taken. Taking passenger travel as our relevant flow variable assumes that the number of trips is an adequate proxy for the total value of these trips.

If $\gamma = 1$, a 1% decline in the cost of air travel on a particular route yields a 1% increase in services being traded along that route. Setting $\gamma < 1$ could be interpreted as assuming that there are some unobserved fixed costs, so that true average cost falls faster than measured average cost. Alternatively, even with perfectly measured cots, γ could be less than or greater than one, depending on the distribution of potential trip values. If this distribution is negatively (positively) skewed, we would expect $\gamma < 1$ ($\gamma > 1$).

Short of relying on intuition for our choice of γ, we have two options for choosing this value. First, we could consult the related literature, wherein Donaldson (2010) finds a value of 3.8 for agricultural railway freight. The shortcoming of this approach is that it relies on two potentially false analogies, between goods traffic and passenger traffic and between train travel and air travel.

The second method for choosing γ involves a regression of log-passenger traffic on log-air-travel costs; this method makes the strong assumption, discussed above, that passenger volumes reflect the total value of transactions mediated by air travel. We present these results in Table A1 below. Column (1) suggests that $\gamma = \frac{1}{3}$, while Column (2) suggest a value of ½ and columns 3-6[37] suggest a value near 1 (for columns 4-5 we base this assertion on the sum of the coefficients). Therefore it seems safe to assume γ=1, and our analysis proceeds with this assumption. While we do present some results for $\gamma = 0.5$, we have also run every regression referenced in this paper with γ=0.5 instead, and *all* the qualitative results are robust to this substitution. However, the results are not very robust to the substitution $\gamma = 1.5$.

[37] In column 6, we combine fare and time costs by adding 0.7 times the Mean Routing Mileage to the Mean Fare. 0.7=35/500, where $35/hour is a passenger's value of time, and 500 mph is a typical speed for a passenger airplane.

Table 1: Elasticity of Passenger Volumes with Respect to Air Travel Costs

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Passengers	Log Passengers	Log Passengers	Log Passengers	Log Passengers	Log Passengers
Log(Non-Stop Distance)	-0.33			-0.11	1.98	
	(0.011)			(0.011)	(0.060)	
Log(Mean Routing Miles)		-0.48			-2.31	
		(0.012)			(0.065)	
Ln(Mean Fare)			-0.91	-0.84	-0.70	
			(0.019)	(0.019)	(0.019)	
Ln(Mean Fare + .07*Mean Routing Miles)						-1.09
						(0.019)
Constant	2.56	3.63	5.73	6.04	6.99	6.94
	(0.16)	(0.16)	(0.20)	(0.23)	(0.23)	(0.20)
Origin CBSA Fixed Effects	X	X	X	X	X	X
Observations	63,162	63,162	63,162	63,162	63,162	63,162
R-squared	0.228	0.240	0.255	0.256	0.286	0.267

Robust standard errors in parentheses

Table 1a: Correlation Matrix for Accessibility and Aviation Variables (N=203)

	Air Access (All Fares)	Air Access (Direct Fares)	Air Access (Routing Miles)	Air Access Generalized Cost	Air Access γ =0.5 Fares	Air Access γ =1.5 Fares	Market Potential	Departing Flights	Herfindahl Index	% Through-Traffic
Air Access (All Fares)	1.000									
Air Access (Direct Fares)	0.635	1.000								
Air Access (Routing Miles)	0.578	0.617	1.000							
Air Access (Generalized Cost)	0.839	0.800	0.818	1.000						
Air Access (γ =0.5, Fares)	0.897	0.738	0.695	0.967	1.000					
Air Access (γ =1.5, Fares)	0.677	0.119	0.135	0.227	0.305	1.000				
Market Potential	0.383	0.381	0.766	0.569	0.488	0.084	1.000			
Departing Flights	0.413	0.664	0.445	0.560	0.494	0.068	0.223	1.000		
Herfindahl Index	-0.584	-0.498	-0.438	-0.656	-0.681	-0.164	-0.372	-0.227	1.000	
% Through-Traffic	0.311	0.411	0.199	0.321	0.300	0.117	-0.004	0.499	-0.036	1.000

Table 1b: Summary Statistics for Accessibility and Aviation Variables (N=203)

	Mean	Std. Dev.	Min	Max
Air Access (All Fares)	0.311	0.125	0	1
Air Access (Direct Fares)	0.201	0.241	0	1
Air Access (Routing Miles)	0.418	0.199	0	1
Air Access(Generalized Cost)	0.557	0.214	0	1
Air Access (Gamma=0.5, Fares)	0.644	0.228	0	1
Air Access (Gamma=1.5, Fares)	0.064	0.076	0	1
Market Potential	0.453	0.179	0	1
Departing Flights	32126.2	69330.7	0	443720
Herfindahl Index	0.449	0.282	0	1
% Through-Traffic	0.473	0.117	0	0.852

Table 1c: Summary Statistics for Non-aviation Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Market Potential	203	0.453	0.179	0.000	1.000
MktPotential*Pop	203	0.420	1.002	0.000	10.762
Population 2000 (millions)	203	0.772	1.550	0.051	16.846
% Pop Change 2000-2100	203	0.240	0.232	-0.185	1.477
Employment 2000	201	0.408	0.782	0.024	7.704
Employment 2007	203	0.401	0.773	0.021	7.671
% Total Employment Growth 00-07	201	0.057	0.178	-0.745	0.525
Gross Metropolitan Product 2001	200	36251	8877	15533	63909
% GMP Growth 2001-07	200	0.081	0.071	-0.143	0.303
Unemployment Rate 2000	203	5.882	1.834	2.600	13.100
Per Capita Income 2000 (x$10,000)	203	2.016	0.315	0.990	3.120
% Change Emp. Tradable Services	199	0.252	0.833	-0.744	9.128
Share of Tradable Services, 2000	201	0.200	0.062	0.000	0.374
Change in Share of Tradable Services	356	0.006	0.060	-0.226	0.292
% In Poverty 2000	203	12.770	4.607	5.200	35.900
% High School Graduates 2000	203	81.801	6.345	50.500	92.300
% College Graduate 2000	203	23.591	6.393	11.000	41.700
Percent Black 2000	203	11.338	11.138	0.200	51.000
Government Share of Employment 2000	203	15.566	4.981	6.600	36.100
Manufacture Employment Share 2000	203	0.152	0.082	0.000	0.518
Tourism Employment Share 2000	201	0.104	0.040	0.000	0.333
% Age 18, 2000	203	74.446	2.673	63.800	80.400
% Age 65, 2000	203	12.445	3.034	5.500	25.400
Heating Degree Days (1000s), 2000	177	4.518	2.295	0.350	9.892
Cooling Degree Days (1000s), 2000	177	1.400	0.917	0.132	3.884
Hwy Density at MSA Fringe	177	0.845	0.370	0.051	1.640
Rainfall (State Average)	203	38.0	13.6	0.0	60.1
Rainfall Squared	203	1630	987	0	3611

Table 2: Growth in Tradable Services Employment (Air Access measured using Average Fares)

Y=% Growth in Tradable Services Employment (NAICS 51-56)	(1) Basic Regression	(2) Additional Controls	(3) Full Controls	(4) Full Controls / γ =0.5
Air Access ~All Fares	1.37**	0.93*	0.86*	0.68**
	(0.42)	(0.41)	(0.41)	(0.24)
Tradable Services Emp. Share	-8.50*	-10.2**	-7.06**	-7.02**
	(3.37)	(3.33)	(2.37)	(2.31)
Pop. 2000 (millions)	0.092	0.19	0.057	0.048
	(0.12)	(0.10)	(0.10)	(0.12)
Market Potential	-0.52	-0.28	-0.54	-0.72*
	(0.31)	(0.42)	(0.31)	(0.31)
MktPotential*Pop	-0.043	-0.23	0.14	0.11
	(0.16)	(0.16)	(0.17)	(0.20)
Unemployment Rate	0.011	-0.0099	0.030	0.028
	(0.031)	(0.028)	(0.023)	(0.023)
Income ($10,000)	0.62	0.24	-0.18	-0.22
	(0.40)	(0.37)	(0.19)	(0.19)
% < Poverty Line		-0.017	-0.055*	-0.058*
		(0.021)	(0.023)	(0.025)
% High-School Grad		-0.011	-0.012	-0.017
		(0.0091)	(0.0079)	(0.0088)
% w/ College Degree		0.023	0.015	0.016
		(0.012)	(0.0097)	(0.0095)
% of Pop = Black		-0.0019	-0.0030	-0.0016
		(0.0042)	(0.0061)	(0.0054)
Govt. Employ. Share		0.0023	0.011	0.014
		(0.019)	(0.010)	(0.010)
Manufacturing Emp. Share		-4.51	-1.88*	-1.78
		(2.24)	(0.93)	(0.93)
Tourism Emp. Share		-5.22	-3.50	-3.37
		(3.28)	(3.37)	(3.30)
% of Pop(Age>=18)			0.050*	0.053*
			(0.024)	(0.024)
% of Pop (Age>=65)			-0.041*	-0.037*
			(0.019)	(0.018)
Annual Rainfall (in)			-0.0030	-0.00019
			(0.028)	(0.027)
Rainfall^2			-0.000062	-0.000099
			(0.00034)	(0.00032)
Heating Degree Days (1000s)			-0.021	-0.017
			(0.035)	(0.035)
Cooling Degree Days (1000s)			0.16**	0.15**
			(0.053)	(0.051)
Hwy Density Fringe			-0.032	-0.030
			(0.12)	(0.13)

Constant	0.42	3.40*	0.48	0.48
	(0.77)	(1.54)	(1.07)	(1.02)
Observations	199	199	175	175
Adjusted R-squared	0.233	0.378	0.346	0.363

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05

Table 3: Growth in Tradable Services Employment (Air Access measured using Average Direct-Flight Fares)

Y=% Growth in Tradable Services Employment (NAICS 51-56)	(1) Basic Regression	(2) Additional Controls	(3) Full Controls	(4) Full Controls / γ =0.5
Air Access ~Direct Flight Fares	0.95**	0.82**	0.75	0.65
	(0.32)	(0.25)	(0.41)	(0.37)
Tradable Services Emp. Share	-8.64*	-10.5**	-7.12**	-7.15**
	(3.40)	(3.33)	(2.33)	(2.35)
Pop. 2000 (millions)	0.056	0.15	0.0021	0.047
	(0.097)	(0.095)	(0.076)	(0.088)
Market Potential	-0.53	-0.32	-0.37	-0.36
	(0.30)	(0.38)	(0.28)	(0.27)
MktPotential*Pop	-0.044	-0.22	-0.023	-0.066
	(0.13)	(0.15)	(0.23)	(0.25)
Unemployment Rate	-0.0047	-0.032	0.025	0.030
	(0.029)	(0.030)	(0.023)	(0.026)
Income ($10,000)	0.50	0.24	-0.19	-0.17
	(0.37)	(0.31)	(0.21)	(0.23)
% < Poverty Line		-0.0066	-0.052*	-0.049*
		(0.020)	(0.023)	(0.021)
% High-School Grad		-0.0069	-0.0096	-0.0090
		(0.0093)	(0.0077)	(0.0080)
% w/ College Degree		0.018	0.017	0.015
		(0.011)	(0.010)	(0.011)
% of Pop = Black		-0.0024	-0.0027	-0.0018
		(0.0043)	(0.0057)	(0.0054)
Govt. Employ. Share		0.0066	0.011	0.010
		(0.019)	(0.011)	(0.010)
Manufacturing Emp. Share		-4.43*	-1.85*	-2.02*
		(2.13)	(0.88)	(0.96)
Tourism Emp. Share		-5.19	-3.45	-3.58
		(3.19)	(3.31)	(3.38)
% of Pop(Age>=18)			0.042	0.050
			(0.023)	(0.026)
% of Pop (Age>=65)			-0.032	-0.036*
			(0.016)	(0.018)
Annual Rainfall (in)			0.0022	0.0043
			(0.025)	(0.023)
Rainfall^2			-0.00011	-0.00013
			(0.00030)	(0.00028)
Heating Degree Days (1000s)			-0.0091	-0.0071
			(0.033)	(0.031)
Cooling Degree Days (1000s)			0.20**	0.19**
			(0.052)	(0.048)
Hwy Density Fringe			-0.098	-0.16
			(0.10)	(0.098)
Constant	1.04	3.36*	0.65	0.063
	(0.80)	(1.35)	(1.00)	(0.97)
Observations	199	199	175	175
Adjusted R-squared	0.246	0.396	0.362	0.364

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05

Table 4: Growth in Tradable Services Employment (Air Access measured using Average Routing Mileage)

Y=% Growth in Tradable Services Employment (NAICS 51-56)	(1) Basic Regression	(2) Additional Controls	(3) Full Controls	(4) Full Controls / γ =0.5
Air Access ~Route Miles	1.42*	1.38**	1.26	1.12*
	(0.65)	(0.48)	(0.65)	(0.44)
Tradable Services Emp. Share	-8.66*	-10.6**	-7.31**	-7.10**
	(3.50)	(3.43)	(2.46)	(2.28)
Pop. 2000 (millions)	0.13	0.21*	0.13	0.071
	(0.12)	(0.100)	(0.13)	(0.12)
Market Potential	-1.24*	-1.02*	-1.04*	-1.12*
	(0.48)	(0.40)	(0.50)	(0.45)
MktPotential*Pop	-0.12	-0.28	-0.11	0.015
	(0.16)	(0.16)	(0.28)	(0.23)
Unemployment Rate	0.030	-0.0084	0.039	0.035
	(0.033)	(0.028)	(0.026)	(0.024)
Income ($10,000)	0.69	0.42	-0.19	-0.18
	(0.39)	(0.36)	(0.19)	(0.18)
% < Poverty Line		-0.014	-0.060*	-0.059*
		(0.019)	(0.023)	(0.024)
% High-School Grad		-0.014	-0.017	-0.020
		(0.0093)	(0.0096)	(0.0097)
% w/ College Degree		0.015	0.016	0.014
		(0.011)	(0.011)	(0.0098)
% of Pop = Black		-0.0028	-0.0035	-0.0029
		(0.0042)	(0.0060)	(0.0056)
Govt. Employ. Share		0.012	0.014	0.016
		(0.017)	(0.012)	(0.011)
Manufacturing Emp. Share		-4.68*	-2.08*	-1.85*
		(2.09)	(0.95)	(0.91)
Tourism Emp. Share		-4.73	-3.07	-3.05
		(3.16)	(3.16)	(3.13)
% of Pop(Age>=18)			0.053	0.057*
			(0.027)	(0.026)
% of Pop (Age>=65)			-0.031	-0.033
			(0.018)	(0.017)
Annual Rainfall (in)			-0.0053	-0.0013
			(0.028)	(0.026)
Rainfall^2			-0.000017	-0.000079
			(0.00034)	(0.00031)
Heating Degree Days (1000s)			-0.034	-0.028
			(0.042)	(0.038)
Cooling Degree Days (1000s)			0.14**	0.12*
			(0.049)	(0.051)
Hwy Density Fringe			-0.070	-0.025
			(0.12)	(0.13)
Constant	0.36	3.42*	0.62	0.34
	(0.73)	(1.44)	(1.06)	(0.96)
Observations	199	199	175	175
Adjusted R-squared	0.246	0.405	0.369	0.384

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05

Table 5: Growth in Tradable Services Employment (Air Access measured using Average Generalized Cost)

Y=% Growth in Tradable Services Employment (NAICS 51-56)	(1) Basic Regression	(2) Additional Controls	(3) Full Controls	(4) Full Controls / γ =0.5
Air Access ~Generalized Cost	1.23**	0.96**	0.91*	0.83**
	(0.35)	(0.26)	(0.35)	(0.30)
Tradable Services Emp. Share	-8.80*	-10.5**	-7.01**	-7.01**
	(3.40)	(3.31)	(2.27)	(2.27)
Pop. 2000 (millions)	0.044	0.15	0.032	0.038
	(0.12)	(0.11)	(0.11)	(0.12)
Market Potential	-0.90**	-0.62	-0.83*	-0.85*
	(0.30)	(0.39)	(0.36)	(0.35)
MktPotential*Pop	0.0079	-0.19	0.071	0.098
	(0.16)	(0.16)	(0.21)	(0.21)
Unemployment Rate	0.016	-0.011	0.029	0.027
	(0.032)	(0.029)	(0.023)	(0.023)
Income ($10,000)	0.59	0.27	-0.23	-0.21
	(0.37)	(0.32)	(0.20)	(0.19)
% < Poverty Line		-0.018	-0.059*	-0.058*
		(0.021)	(0.025)	(0.024)
% High-School Grad		-0.012	-0.018	-0.018
		(0.0090)	(0.0094)	(0.0092)
% w/ College Degree		0.019	0.016	0.015
		(0.011)	(0.0097)	(0.0096)
% of Pop = Black		-0.0019	-0.0017	-0.0017
		(0.0041)	(0.0053)	(0.0053)
Govt. Employ. Share		0.0096	0.016	0.015
		(0.019)	(0.011)	(0.011)
Manufacturing Emp. Share		-4.29	-1.77	-1.78
		(2.17)	(0.92)	(0.93)
Tourism Emp. Share		-5.08	-3.32	-3.25
		(3.22)	(3.25)	(3.23)
% of Pop(Age>=18)			0.053*	0.055*
			(0.025)	(0.025)
% of Pop (Age>=65)			-0.032	-0.036*
			(0.017)	(0.017)
Annual Rainfall (in)			0.00099	0.00097
			(0.025)	(0.026)
Rainfall^2			-0.00011	-0.00011
			(0.00030)	(0.00031)
Heating Degree Days (1000s)			-0.024	-0.019
			(0.035)	(0.035)
Cooling Degree Days (1000s)			0.13*	0.14**
			(0.049)	(0.050)
Hwy Density Fringe			-0.045	-0.029
			(0.13)	(0.13)
Constant	0.43	3.35*	0.46	0.37
	(0.73)	(1.45)	(1.00)	(0.98)
Observations	199	199	175	175
Adjusted R-squared	0.258	0.396	0.372	0.374

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05

Table 6: First Stage IV

Y=Air Accessibility in 2000	(1) Access using Fares	(2) Access using Direct Fares	(3) Access using Routing Mileage	(4) Access using Generalized Cost
Tradable Services Emp. Share	-0.0415	-0.0350	0.201	-0.152
	(0.201)	(0.313)	(0.204)	(0.223)
Pop. 2000 (millions)	-0.0458	0.0165	-0.0764	-0.0506
	(0.0499)	(0.0935)	(0.0446)	(0.0829)
Market Potential	0.124	-0.0547	0.494**	0.337*
	(0.0823)	(0.142)	(0.141)	(0.146)
MktPotential*Pop	0.147	0.374*	0.258**	0.250
	(0.0930)	(0.170)	(0.0925)	(0.156)
Unemployment Rate	-0.00118	0.00933	-0.00859	0.0129
	(0.00676)	(0.0142)	(0.00720)	(0.00728)
Income ($10,000)	0.0611	0.0920	0.0327	0.106
	(0.0693)	(0.0726)	(0.0669)	(0.0727)
% < Poverty Line	0.000489	-0.00319	0.00178	0.00126
	(0.00456)	(0.00875)	(0.00310)	(0.00431)
% High-School Grad	0.000453	-0.00136	0.00330	0.00515
	(0.00335)	(0.00534)	(0.00224)	(0.00375)
% w/ College Degree	-0.000752	-0.00258	-0.00204	-0.00285
	(0.00301)	(0.00404)	(0.00334)	(0.00385)
% of Pop = Black	0.000286	-0.000225	5.63e-05	-0.00161
	(0.00165)	(0.00128)	(0.000902)	(0.00123)
Govt. Employ. Share	4.91e-05	-0.00164	-0.000910	-0.00407
	(0.00291)	(0.00538)	(0.00235)	(0.00285)
Manufacturing Emp. Share	0.0410	-0.134	0.391	0.00620
	(0.147)	(0.266)	(0.193)	(0.148)
Tourism Emp. Share	-0.0378	-0.220	-0.457	-0.556**
	(0.178)	(0.314)	(0.278)	(0.198)
% of Pop(Age>=18)	0.00140	0.00882	-0.000911	0.00491
	(0.00540)	(0.00858)	(0.00616)	(0.00690)
% of Pop (Age>=65)	5.81e-05	-0.0129	-0.00896	-0.0123*
	(0.00617)	(0.00832)	(0.00579)	(0.00621)
Annual Rainfall (in)	-0.00198	-0.00910	0.000805	-0.00564
	(0.00442)	(0.00681)	(0.00380)	(0.00587)
Rainfall^2	4.47e-05	0.000112	-7.44e-06	8.53e-05
	(5.43e-05)	(9.11e-05)	(4.46e-05)	(7.07e-05)
Heating DDs (1000s)	0.0118	-0.00431	0.0185	0.0110
	(0.00959)	(0.0146)	(0.00990)	(0.0105)
Cooling DDs (1000s)	0.0397*	-0.00778	0.0369	0.0601**
	(0.0173)	(0.0250)	(0.0193)	(0.0176)
Hwy Density Fringe	-0.115**	-0.0336	-0.0383	-0.104**
	(0.0366)	(0.0466)	(0.0283)	(0.0333)
Air Travel Herfindahl Index	-0.192**	-0.245**	-0.113**	-0.300**
	(0.0226)	(0.0394)	(0.0231)	(0.0361)
% Airport Through-Traffic	0.122	0.189	0.251**	0.244
	(0.103)	(0.143)	(0.0807)	(0.142)
Observations	153	153	153	153
p-value(KP LM Stat)	0.0001	0.0002	0.002	0.0001
Wald F-Stat for Instruments	37.6	19.3	17.2	35.1

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05, Constant not Shown

Table 7: Second Stage IV Results for Tradable Services Employment Growth

Y=% Growth in Tradable Services Employment (NAICS 51-56)	(1) Access using Fares - Basic	(2) Access using Fares - Full	(3) Access using Direct Fares	(4) Access using Routing Mileage	(5) Access using Generalized Cost
Air Accessibility	2.91*	2.06*	1.64*	3.14*	1.35*
	(1.26)	(0.93)	(0.75)	(1.43)	(0.60)
Tradable Services Share	-9.84**	-7.30**	-7.32**	-7.95**	-7.17**
	(3.71)	(2.15)	(2.01)	(2.34)	(2.07)
Pop. 2000 (millions)	0.020	-0.028	-0.15	0.14	-0.057
	(0.14)	(0.087)	(0.11)	(0.14)	(0.091)
Market Potential	-1.01**	-1.17*	-0.83	-2.35*	-1.38*
	(0.35)	(0.54)	(0.43)	(1.06)	(0.59)
MarketPotential*Pop	0.064	0.23	-0.086	-0.40	0.19
	(0.19)	(0.18)	(0.32)	(0.42)	(0.19)
Unemployment Rate	-0.0052	0.031	0.014	0.058	0.012
	(0.039)	(0.032)	(0.034)	(0.039)	(0.029)
Income ($10,000)	0.58	-0.19	-0.22	-0.20	-0.21
	(0.42)	(0.21)	(0.26)	(0.22)	(0.19)
% < Poverty Line		-0.062*	-0.056*	-0.067**	-0.063*
		(0.027)	(0.028)	(0.023)	(0.027)
% High-School Grad		-0.020	-0.017	-0.026	-0.026
		(0.013)	(0.013)	(0.016)	(0.015)
% w/ College Degree		0.013	0.016	0.018	0.015
		(0.010)	(0.011)	(0.014)	(0.011)
% of Pop = Black		-0.0025	-0.0015	-0.0030	0.00023
		(0.0068)	(0.0058)	(0.0056)	(0.0052)
Govt. Employ. Share		0.018	0.021	0.022	0.023
		(0.012)	(0.014)	(0.015)	(0.013)
Manufacture Emp. Share		-1.45	-1.12	-2.47*	-1.35
		(0.84)	(0.87)	(1.14)	(0.84)
Tourism Emp. Share		-3.75	-3.53	-2.81	-3.16
		(3.32)	(3.06)	(2.92)	(3.07)
% of Pop(Age>=18)		0.065*	0.053*	0.067*	0.061*
		(0.028)	(0.026)	(0.033)	(0.027)
% of Pop (Age>=65)		-0.052*	-0.031	-0.024	-0.035*
		(0.022)	(0.017)	(0.021)	(0.017)
Annual Rainfall (in)		-0.00021	0.011	-0.0039	0.0039
		(0.026)	(0.023)	(0.027)	(0.024)
Rainfall^2		-0.00012	-0.00022	-0.000045	-0.00015
		(0.00033)	(0.00028)	(0.00033)	(0.00029)
Heating DD (1000s)		-0.032	-0.00037	-0.069	-0.022
		(0.040)	(0.037)	(0.055)	(0.033)
Cooling DD (1000s)		0.12	0.21**	0.075	0.12*
		(0.064)	(0.067)	(0.088)	(0.055)
Hwy Density Fringe		0.12	-0.064	0.0100	0.020
		(0.18)	(0.13)	(0.17)	(0.16)
Observations	174	153	153	153	153
p-value(Hansen J-test)	0.2189	0.2120	0.2080	0.6322	02504

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05, Constant Not Shown

Table 8: Growth in Alternative Outcomes: Employment, Gross Metropolitan Product, & Population

	(1) Employment Growth 2000-2007: OLS	(2) Employment Growth 2000-2007: IV	(3) GMP Growth 2001-2007: OLS	(4) GMP Growth 2001-2007: IV	(5) Population Growth 2000-2007: OLS	(6) Population Growth 2000-2007: IV
Air Access ~Generalized Cost	0.0007	0.024	0.044	-0.075	0.050	0.13
	(0.072)	(0.241)	(0.040)	(0.064)	(0.067)	(0.14)
Initial Employment (millions)	-0.447**	-0.420**				
	(0.075)	(0.069)				
Initial GMP			5.17e-07	6.46e-07		
			(1.57e-06)	(1.38e-06)		
Pop. 2000 (millions)					-0.18*	-0.20*
					(0.087)	(0.081)
First Stage Coefficients						
Air Travel Herfindahl Index		-0.191**		-0.281**		-0.298**
		(0.023)		(0.037)		(0.037)
% Airport Through-Traffic		0.127		0.245		0.253
		(0.101)		(0.134)		(0.136)
Full Set of Controls	X	X	X	X	X	X
p-value (KP LM Stat)		0.0001		0.0001		0.0001
Wald F-Stat for Instruments		25.31		18.83		32.37
Observations	177	155	174	155	177	155
Adjusted R-squared	0.392		0.152		0.593	
p-value (Hansen J-Stat)		0.075		0.199		0.002

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05, Constant Not Shown

Table 9: Change in the Share of Tradable Services 2000-2007 (Access measured using Average Fares)

Y=Change in Tradable-Services Employment Share	(1) Access - Basic	(2) Access - Full	(3) Access - IV	(4) Flights - Basic	(5) Flights - Full	(6) Flights - IV
DepartingFlights2000				1.28e-07	-3.48e-08	-7.76e-08
				(7.55e-08)	(9.94e-08)	(1.94e-07)
Air Accessibility ~Fares	0.099**	0.057	0.19**			
	(0.032)	(0.033)	(0.056)			
Tradable Services Emp. Share	-0.65**	-0.75**	-0.78**	-0.62**	-0.74**	-0.77**
	(0.069)	(0.066)	(0.073)	(0.071)	(0.066)	(0.069)
Pop (Initial Population)	1.71e-08	4.12e-08*	3.61e-08*	1.60e-08	4.32e-08*	4.58e-08**
	(1.09e-08)	(1.66e-08)	(1.66e-08)	(1.16e-08)	(1.66e-08)	(1.53e-08)
Market Potential	0.048	0.062*	0.013	0.072**	0.078**	0.077*
	(0.025)	(0.028)	(0.037)	(0.023)	(0.023)	(0.030)
MarketPotential*Pop	-0.017	-0.039	-0.039	-0.021	-0.033	-0.030
	(0.016)	(0.034)	(0.034)	(0.016)	(0.030)	(0.032)
Unemployment Rate	0.0024	0.0020	0.0013	0.0016	0.0017	0.00070
	(0.0021)	(0.0026)	(0.0034)	(0.0022)	(0.0027)	(0.0029)
Income ($10,000)	0.059*	-0.0033	-0.00010	0.057*	-0.00017	-0.0013
	(0.026)	(0.030)	(0.027)	(0.026)	(0.033)	(0.031)
% < Poverty Line		-0.0031	-0.0029		-0.0031	-0.0034
		(0.0022)	(0.0020)		(0.0023)	(0.0023)
% High-School Grad		-0.00098	-0.0010		-0.00083	-0.00074
		(0.0010)	(0.00099)		(0.0010)	(0.0010)
% w/ College Degree		0.0018	0.0015		0.0018	0.0016
		(0.0011)	(0.0011)		(0.0012)	(0.0012)
% of Pop = Black		0.00011	0.00013		0.000099	-0.000018
		(0.00026)	(0.00041)		(0.00025)	(0.00026)
Govt. Employ. Share		-0.0011	-0.00042		-0.0013	-0.00086
		(0.0011)	(0.0012)		(0.0011)	(0.0012)
Manufacture Emp. Share		-0.21**	-0.19**		-0.22**	-0.20**
		(0.050)	(0.056)		(0.054)	(0.064)
Tourism Emp. Share		-0.23**	-0.24**		-0.21**	-0.17**
		(0.049)	(0.061)		(0.055)	(0.058)
% of Pop(Age>=18)		0.0029	0.0028		0.0026	0.0021
		(0.0019)	(0.0023)		(0.0019)	(0.0026)
% of Pop (Age>=65)		-0.0045**	-0.0050**		-0.0046**	-0.0052*
		(0.0013)	(0.0016)		(0.0015)	(0.0021)
Hwy Density Fringe		-0.0068	0.0078		-0.012	-0.013
		(0.010)	(0.014)		(0.011)	(0.013)
Control for Climate Variables		X	X		X	X
Observations	201	177	155	201	177	155
R-squared	0.544	0.696		0.516	0.686	
BIC	-603.4	-650.2		-711.51	-644.23	
p-value(Hansen J-Stat)			.7093			.0111
p-value(rk LM Stat)			.0001			.0027
Wald F-Stat for Instruments			36.60			14.05

Robust standard errors in parentheses, Clustered by State, ** p<0.01, * p<0.05, Constant Not Shown

Table 10a: Robustness of Instrument Variable Regression for Tradable Services Growth.

	Outcome is Growth Rate of Tradable Services Employment				*Alternative Tradable-Services Outcomes*		
	(1) Interaction of Air Access w/ Population	(2) Interaction of Air Access w/ MSA Area	(3) Drop Hub Cities	(4) Drop BEA Region 2 (New England)	(5) Growth in Tradable Services *Payroll*	(6) Growth in Number of Tradable Services *Establishments*	(7) *Log Change* in Tradable Services Employment
Air Accessibility ~Fares	2.06*	2.08*	1.86*	1.87	2.37*	-0.067	1.18*
	(0.91)	(0.95)	(0.95)	(1.22)	(1.06)	(0.34)	(0.48)
AirAccess*Pop	-0.37						
	(0.68)						
AirAccess*Area (x10^6)		1.27					
		(3.51)					
Tradable Services Emp. Share	-7.35**	-7.30**	-7.78**	-7.20**	-6.90**	-0.051	-3.84**
	(2.14)	(2.16)	(2.19)	(2.53)	(1.95)	(0.51)	(0.68)
Full Set of Controls	X	X	X	X	X	X	X
Observations	153	153	144	142	153	155	153
p-value (Hansen J-Stat)	0.300	0.211	0.237	0.174	0.201	0.052	0.083

Robust standard errors in parentheses, Clustered by State
** p<0.01, * p<0.05

Table 10b: First Stage for Table 10a

(Column numbers corresponds to respective column in 10a. First stage for Columns 5-7 are same as Table 6 above)

Column Names Indicate Outcome Variable	(1a) Air Accessibility ~Fares	(1b) AirAccess *Pop	(2a) Air Accessibility ~Fares	(2b) AirAccess *Area	(3) Air Accessibility ~Fares	(4) Air Accessibility ~Fares
Air Travel Herfindahl Index	-0.18**	0.048	-0.20**	-237	-0.19**	-0.18**
	(0.034)	(0.027)	(0.033)	(184)	(0.024)	(0.025)
% Airport Through-Traffic	0.14	-0.073	0.096	-2,244**	0.130	0.115
	(0.14)	(0.083)	(0.11)	(517)	(0.11)	(0.10)
Herfindahl*Pop	-0.022	-0.33*				
	(0.097)	(0.13)				
% Airport Through-Traffic *Pop	0.0058	0.44*				
	(0.16)	(0.20)				
Herfindahl*Area			3.36e-06	-0.10		
			(9.94e-06)	(0.077)		
% Airport Through-Traffic *Area			5.36e-06	0.79**		
			(0.000010)	(0.071)		
Tradable Services Emp. Share	0.077	0.020	0.060	-355	0.091	0.100
	(0.17)	(0.099)	(0.18)	(651)	(0.20)	(0.19)
Full Set of Controls	X	X	X	X	X	X
p-value (KP rk LM Stat)	.038	----	.0002	----	.0001	.0002
1st Stage Wald F-Stat for Instruments	2.90	----	20.70	----	34.99	26.36
Observations	155	155	155	155	146	144
R-squared	0.564	0.970	0.566	0.903	0.551	0.571

Robust standard errors in parentheses, Clustered by State
** p<0.01, * p<0.05

Chapter III: Essential Air Service Subsidies and the Local Impact of Air Travel

Abstract

The Essential Air Service (EAS) program provides generous subsidies to maintain scheduled air service to eligible communities. We exploit the program's inflexible eligibility requirements to estimate the economic impact of air service over two periods: 1979-1987 and 1990-2000. In our OLS regressions, we find that EAS communities experience greater employment growth in some sectors, including service industries and retail, in each period. Additionally, EAS eligibility increases total employment growth in the second period (by ~2%) but not in the first, and we find some evidence that average compensation falls. To address the endogeneity of EAS eligibility, we repeat our analysis employing propensity score matching. Many of the aforementioned results are confirmed, often with larger coefficients (e.g. 3-7% for employment growth), but, most notably, the list of impacted *sectors* varies a bit. Finally, we also comment on the success, and lack thereof, of the EAS program itself.

1 Introduction

Articulating the economic impact of air travel is an important endeavor, and one that has received increased attention in recent years. Although scholars have consistently concluded that air travel has *some* impact on local economic outcomes, their more precise conclusions continue to differ. For instance, Brueckner (2003) and Blonigen & Cristea (2013) conclude that air travel increases overall local employment, while Sheard (2014) and LeFors (2015) find no impact on total employment, though they concur with Brueckner that service employment[38] increases in the presence of increased air travel.

Ultimately, our knowledge of air-travel's economic role is incomplete, and sufficient guidance is lacking for policymakers considering an airport expansion or, in the case at hand, air travel subsidies. While recent air-travel data is very rich, estimation must overcome an endogeneity problem: local employment, earnings, and population are all determinants of air travel demand. A review of recent literature on the topic is essentially a review of unique attempts to overcome this problem: Sheard (2014) employs the 1944 National Airport Plan to create an instrument variable, Blonigen & Cristea (2013) exploit the 1978 Airline Deregulation to create an instrument, and LeFors (2015), among other authors, relies on an instrument based on airline market structure, while also employing an air-travel variable of interest that mitigates endogeneity concerns.

However, at least one interesting source of variation in air-travel provision has yet to be analyzed in the economics literature. The Essential Air Service program was established in 1978, immediately after airline deregulation, as a way to prevent small communities from losing scheduled air service. The major eligibility requirement, possessing scheduled air service at the time of deregulation, remained unchanged until very recently. Among those communities who, a

[38] Note: the definition of 'service sector' varies among these papers.

priori, cannot acquire air service at market rates, the consequence of the Essential Air Service program is the creation of two classes: those who are eligible for subsidies and those who are not. Crucially, this latter point makes the Essential Air Service program a fruitful opportunity for analysis. Insofar as EAS communities are identical to other cities, conditional on local economic aggregates and other controls, we can infer the impact of air service by regressing local employment outcomes on an indicator for EAS eligibility.

Of course, EAS-eligible communities are obviously different from non-eligible communities precisely because the latter possessed scheduled air service by 1978. However, if we accept that the availability of air service in 1978 is largely a function of contemporaneous observables, particularly county size, income and geography, then a propensity score matching procedure can control for this difference and yield unbiased estimates.

Section 2 discusses the Essential Air Service program, Section 3 discusses data and modeling, Section 4 presents our results, and Section 5 concludes.

2 Essential Air Service

According to the U.S. Department of Transportation (DOT): “The Essential Air Service (EAS) program was put into place to guarantee that small communities that were served by certificated air carriers before deregulation maintain a minimal level of scheduled air service.” The critical phrase is “were served”: only those communities that actually possessed scheduled air service prior to deregulation are eligible for EAS subsidies.

2.1 History of the Program

One feature of the regulated period of air travel was an implicit cross subsidization of low-demand routes by high-demand routes. Airlines were required to serve each route on which they were certified with at least two round trips per day. Through such requirements, airlines were essential obliged to serve unprofitable routes in exchange for monopoly power on profitable ones.

We know empirically that, following deregulation, fares on high-demand routes fell (or, more precisely, grew more slowly than the general price level), while fares on low-demand routes rose (grew faster than the general price level)[39]. Pre-deregulation policymakers were also aware of, and generally in support of, the cross-subsidizing influence of regulation. Concerned that areas with relatively low traffic might lose air network access altogether in the absence of regulation, Congress added Section 419 to the Federal Aviation Act, which created the Essential Air Service program. Section 419 *mandates* that the DOT must ensure eligible communities access to the air transportation network and authorizes the DOT to do so by subsidizing routes when necessary. In practice, the EAS contracts with individual carriers to provide air service to communities determined to be in need of EAS assistance.

2.2 EAS Contracts and Subsidies

Contracts for EAS-eligible communities are awarded following a sealed-bidding process, in which airlines declare their required *per-flight* subsidy for serving a route, having already been informed of the appropriate flight frequency, aircraft, and endpoint (i.e. hub) for that route. The required subsidy is only one criterion considered by the DOT, and there are four other mandatory criteria the DOT must consider. Those criteria are the service reliability of the airline making the

[39] See, for example, (Borenstein 1992)

bid, the bidding airline's relationship with larger carriers at the relevant hub[40], and the views of the EAS-desginated community itself.

Contracts are generally awarded for two-year periods. The bidding periods are purposefully staggered, so that contract renegotiations occur relatively uniformly over time. Mid-contract negotiations among the airline, the community, and the EAS agency are permitted, but the per-flight subsidy cannot be raised mid-contract.

What happens when promised service is not delivered? If an airline deviates from the agreed upon service, say by willfully cancelling a flight or using a smaller-than-agreed-upon aircraft, the subsidy for that flight is withheld or adjusted, respectively. However, when flights are cancelled on account of weather, the airline typically still gets paid.

2.3 EAS Eligibility and Minimum Service Levels

As stated above, the critical requirement for eligibility is possessing scheduled air service at the time of deregulation (specifically, October 24th, 1978), although it is up to the DOT to determine the "minimum level of service" for each eligible community.

For each EAS community, the DOT defines "minimum service" by first designating a particular hub through which the community is linked to the national air transportation network, then specifying the minimum number of daily/weekly round trips and available seats that must be provided to that hub. Additionally, the DOT specifies mandatory characteristics of the aircraft used, as well as a maximum number of stops to be made en route to the designated hub. Only after making these specifications does the DOT take bids from air carriers.

[40] This "relationship" merely summarizes two sub-criteria: (1) contractual and marketing arrangements and (2) interline arrangements

For the first 12 years of the program (1978-1990), possessing service at the time of deregulation was the *sole* requirement for EAS eligibility[41]. Since then, two sets of revisions have been made to the EAS program. The first revision was in 1990. In that year, Congress implemented a maximum per-passenger average subsidy of $200 for communities in the contiguous 48 states[42] who are less than 210 miles from a medium or large hub. Keep in mind that subsidies are actually awarded by flight, not by passenger, so whether per-flight payments violate this cap depends not only on the agreed-upon flight subsidy but also on local demand for those subsidized flights. Affected communities will lose their subsidies if the average per-passenger subsidy exceeds $200 in any given year, although they can regain eligibility if they propose a plan to restore compliance with the subsidy limit. This reform appears relatively minor, in that it places a still-generous limit on the subsidy for very short flights. Nevertheless, cities have indeed lost (and, regained) subsidies upon violating (restoring) compliance with these limits.

A second set of revisions was made between 2011 and 2012. In August 2011, the "Airport and Airway Extension Act, Part IV" established a maximum per-passenger average subsidy of $1000 for *all* communities in the contiguous 48 states. This dollar limit is weaker than the 1990 limit, but it includes all communities rather than only those within 210 miles of a medium or large hub.

Three additional, significant reforms were also passed in 2012. The "Consolidated and Further Continuing Appropriations Act, 2012" waived the requirement that communities receive

[41] It is somewhat unclear, but there may have been another requirement that the community be at least 70 miles from a medium or large hub. However, given the rule that communities *must fly to the nearest such hub on any EAS flight*, the requirement to live 70 miles from that hub seems unimportant the context of the contiguous U.S.
[42] Alaska and Hawaii participate in the EAS program, but they have generally been exempted from reform. We do not include either state in our analysis, due to their unique geography as well as their special treatment under EAS rules.

EAS-subsidized service on 15-seat or larger aircraft. By loosening aircraft restrictions, this act *could* have expanded the scope of the EAS; however, one consequence of subsequent reforms was to head off any such expansion.

Secondly, the "Federal Aviation Administration (FAA) Modernization and Reform Act of 2012" decreased the number of eligible communities in the contagious 48 by capping the program at FY2011 enrollment. From now on, in order to be eligible for EAS subsidies, a city must have received subsidized access in FY2011. Thus, communities that had scheduled service in 1978 but, for whatever reasons, did not have subsidized access in 2011, lost their EAS eligibility.

Finally, that same act implemented a minimum number of average enplanements per flight. Beginning in 2013, communities in the contiguous 48 that are more than 175 miles from the nearest hub must have an average of 10 enplanements per flight. Communities whose average enplanements per flight fall below 10 in a given year will lose their subsidy. As with the per-passenger subsidy, communities that become ineligible on account of this criterion can regain eligibility with a credible plan for compliance.

2.4 Eligibility, Participation, and "Treatment"

For the purpose of our analysis, we need to define the exact set of "EAS communities." Until now, we have discussed eligibility requirement, but *eligibility* is a different matter than *participation.* There are about 567 communities in the contiguous U.S. that are *eligible* for EAS subsidies. However, many of these places never have, and never will, receive subsidies. *Participation*, or reception of EAS-subsidized service, is dynamic. Figure 1 plots both the number of communities served and annual spending over the program's history. As of 2015, the EAS program subsidizes 159 communities at a total cost of over $260 million.

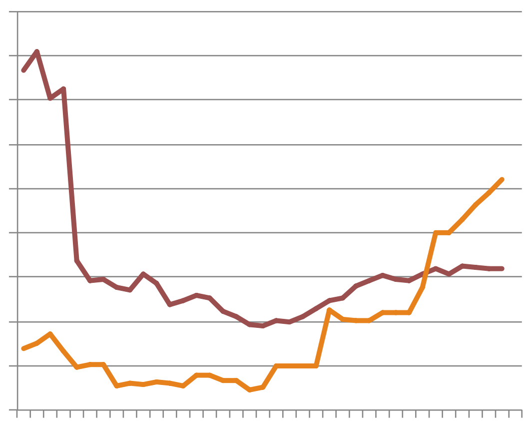

Figure 1: EAS Participation and Spending by Year

For the purpose of analysis, then, which cities should be considered treated? As mentioned above, the DOT must provide EAS-eligible communities with a minimum level of air service, but the EAS legislation leaves it up the program's administrators to determine what exactly constitutes "minimum service" for a given community. The DOT officially defines "minimum service" by issuing something known as a *determination.* An EAS community's *determination* defines (1) a medium or large hub that the subsidized flights must ultimately reach, (2) the maximum number of stops allowable on the way to that hub, (3) an appropriate flight frequency, and (4) aircraft requirements. The EAS office maintains a list of all *determinations* ever made by their agency.

If a city ever received EAS service, it must have received a *determination* as well. Conversely, it seems that nearly all cities that have a *determination* also received EAS service as some point. However, it is not possible to fully verify this expectation, since a complete list of participants is not available for the earliest years of the program (which, as Figure 1 shows, were high participation years). Nevertheless, official *determinations* were not issued haphazardly; a city would not have a *determination* issued unless it seemed plausible, at some point in time, that the community would soon lose unsubsidized service. So, even *if* the list of communities possessing *determinations* includes a few cities that never actually received subsides, the EAS program still benefited those cities by acting as guarantee of continued air service.

So, in the analysis to follow, we will use an indicator for whether an EAS-eligible community was ever issued a *determination* as our variable of interest. Likewise, we will consider cities with *determination* status as having been *treated* by the program. By this definition, our dataset contains 348 treated counties.

Clearly, our definition of treatment is better than *eligibility,* since the program does not treat, and was never intended to treat, many eligible communities. On the other hand, requiring participation in any given year leaves out many *treated* communities (besides, a complete list of points served is not available for every year). In a way, determination status merely captures whether a city has *ever* participated in the EAS. One might worry that such a measure does not take into account the "intensity" of treatment. However, the level of subsidy needed, and the frequency of subsidy reception, are endogenous in a much more problematic way than EAS-treatment as we have defined it. In any case, if *determination* status includes some communities who participate very little and others who participate very often, the coefficient on our variable of interest would tend to understate the impact of full-intensity treatment.

Table 1 lists some descriptive statistics for the current EAS program. In 2011, the mean number of flights/week for EAS-subsidized routes was 16.8. The mean number of seats/week was 357. In contrast, the mean number of enplanements per week was 201, so the seat-weighted mean percentage of seats filled was 56.2%, although the median across routes was substantially lower at 39.6%.

Table 1: Some EAS Statistics for 2011

Average Annual Subsidy	Average Per-Passenger Subsidy
$1,862,422	$234
Median Annual Subsidy	**Median Per-Passenger Subsidy**
$1,728,125	$140
Minimum Per-Passenger Subsidy	
$6.26	Joplin, MO
Maximum Per-Passenger Subsidy	
$1,904.79	Lewiston, MT

While subsidies are awarded on per-flight basis, a more useful metric for the program's cost is a computed per-passenger subsidy. In 2011, this subsidy ranged from a low of $6.26 per passenger (for Joplin, MO) to a high of $1904.79 per passenger (for Lewiston, MT [43]). The average per-passenger subsidy was $233.78, while the median was $139.61. Considering that the average round-trip airfare in 2011 was around $370, the EAS subsidies are clearly quite large. Given these generous subsidies, the low average and median load factors are puzzling. Their levels would seem to indicate that air travel is simply not valuable to these communities, and therefore we should not expect an airline subsidy to have much impact on the city.

[43] Note that the aforementioned "Airport and Airway Extension Act, Part IV" of 2011 renders Lewiston ineligible for future service.

Nevertheless, to skip ahead, our estimation produces strong evidence that air travel is impactful. How can we reconcile these two points? The solution, perhaps unsurprisingly, is that the EAS program is "poorly targeted." We will comment more on that issue in the conclusion.

3 Data and Modeling

The value of the EAS program might vary over time if, for instance, the air-travel amenity it provides is quickly congested, permitting some additional growth in early years but no benefits post-congestion. Additionally, the value of air travel itself might vary with history if evolving economic conditions make air travel more or less vital to local growth. It is plausible that air travel has become a more important part of life, and therefore more economically valuable, in more recent periods. We will consider two periods of economic growth at the U.S. county level: 1979-87, and 1990-2000. Our first period is so chosen because 1979 is the first full year following the establishment of the EAS (and deregulation), while the original EAS legislation established the agency through 1988 (subsequently the legislation was renewed a few times before becoming "permanent" in 2000). For the second period, we begin with 1990 as the next census year, and we end the period in 2000 to avoid transitioning from SIC to NAISC codes in our data. Additionally, 2000 is the first year of a competing initiative, the Small Community Air Development Program, which we will comment on in the conclusion.

All program details and participation data for the EAS are from the agency's office within the Department of Transportation. Annual economic data at the county level is available from the Bureau of Economic Analysis; they have constructed multi-source panel-datasets for local economic data starting from 1969. From this data we obtain total employment and sectoral employment by SIC code. Additionally, we can obtain population, income-per-capita, and earnings-per-job. Unfortunately, county-level unemployment rates are not available, so we settle for constructing a naive “employment rate” as Employment/Population.

We model employment growth for county *i* in state *s* as a function of initial employment, state-level amenities, income, the employment rate, and the benefit of EAS determination status:

$$(1) \quad E_{post,i} = e^{\alpha * \theta_s} \left(E_{pre,i}\right)^{1+\gamma_1} (IPC_i)^{\gamma_2} (JPC_i)^{\gamma_3} \Delta_i^{\eta}$$

where E is employment, θ_s captures state effects, IPC is income-per-capita, and JPC is the employment-to-population ratio. The variable Δ represents the boost in air-service access attributable to EAS treatment (thus it is equal to 1 for untreated cities), while η is an elasticity parameter capturing the employment impacts of air-service generally. Dividing through by E_{pre} and then taking the log of both sides, we get:

$$(2) \quad \ln\left(\frac{E_{post,i}}{E_{pre,i}}\right) = \alpha + \theta_s + \gamma_1 \ln\left(E_{pre,i}\right) + \gamma_2 \ln(IPC_i) + \gamma_3 (JPC_i) + \eta \ln(\Delta_i)$$

Setting $\eta \ln(\Delta_i) = \beta * D_i$, where $D_i = 1$ if city *i* has a determination and 0 otherwise, and adding in a pre-trend to control for local autocorrelations in growth, we obtain our estimation equation:

$$(3) \quad \ln\left(\frac{E_{i,1987}}{E_{i,1979}}\right)$$

$$= \alpha + \beta(D_i) + \gamma_1 \ln(E_{i,1977}) + \gamma_2 \ln(IPC_{i,1977}) + \gamma_3(JPC_{i,1977}) + \zeta \ln\left(\frac{E_{i,1977}}{E_{i,1970}}\right)$$

$$+ \sum_{k=1}^{46} \theta_k I_{i,k} + \epsilon_i$$

where there are 46 state-level indicators since we exclude Alaska (for remoteness, and for having a unique EAS program), Hawaii (for remoteness, and for having every county served by EAS), and Rhode Island (for having being the only state with no counties served by EAS). Note that equations (2) and (3) retain initial employment on the right hand side, but its associated coefficient is γ_1 as opposed to the (1+γ_1) in equation (1).

Summary statistics and correlation coefficients for our regression variables are included in Tables 2-4 at the end of the paper. Additionally, to summarize the distribution of EAS counties among states, Figure 2 depicts frequencies for the percentage of a state's counties characterized by D=1.

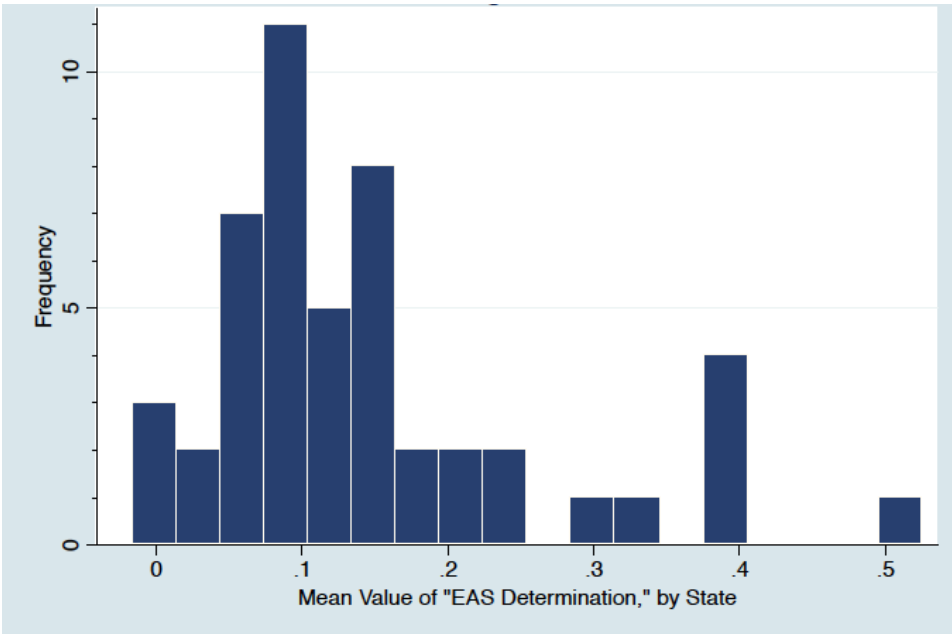

Figure 2: EAS Communities by State

4 Results

4.1 OLS

We begin by estimating Equation 3. The results of this OLS regression are available in column 1 of Table 5. We discern no impact of EAS treatment on county employment; IPC, JPC, and the pre-trend for employment all have the expected sign; and initial employment yields greater subsequent growth.

In the remaining columns of Table 5, we replace total-employment growth rates with sector-employment rates (on both the LHS and the RHS), and we add a variable to control for the sector's initial share of total employment. Thus, we have:

$$(4)\quad \ln\left(\frac{S_{i,1987}}{S_{i,1979}}\right) = \alpha + \beta(D_i) + \gamma_1 \ln\left(E_{i,1977}\right) + \gamma_2 \ln\left(IPC_{i,1977}\right) + \gamma_3\left(JPC_{i,1977}\right) + \zeta \ln\left(\frac{S_{i,1977}}{S_{i,1970}}\right) + \lambda\left(SectorShare_{i,1977}\right) + \sum_{k=1}^{46} \theta_k I_{i,k} + \epsilon_i$$

where "S" is sector employment, "E" is overall employment, as above, and "SectorShare" is the sector's job-share of overall employment (i.e. S/E). Unsurprisingly, given the existing literature, we find that EAS determination-status is associated with 2.3% greater service-employment growth over the first period. Additionally, we find greater retail employment growth (2.7%). More surprisingly, we find greater growth in government employment (1.6%). It is not immediately clear why this sector would grow, but one explanation would be that more service-intensive (and retail-intensive) economies also demand more government services. In each column, other coefficients seem to have the expected sign. Notably, prior growth generally predicts future growth, while the sectoral employment share generally depresses growth. The final column 8 of Table 5 analyzes all non-agricultural employment, since it may be a more robust measure of county employment, but it supports the same conclusions as column 1.

In Table 6, we extend our OLS analysis to the second time period, 1990-2000. The RHS of our estimation equations remain unchanged: only the growth rate on the LHS is adjusted for the new period dates. Interestingly, we *do* see that EAS treatment increases employment (and non-farm employment) by about 2% over the second period. We also see that the exact same sectors which responded to air service from 79-87 continue to do so, but with larger coefficients: ~3% growth for service and government employment and ~2% growth for retail. As hinted above, we may see employment effects in the second period but not the first if air travel is more essential in the ‘90s than in the ‘80s. Alternatively, it may be that the initial joint impact of deregulation and the EAS program was a redistribution of sector employment among cities. In transition, slow initial growth in retail and service industries was matched by slow decline in displaced industries, but after some period of adjustment EAS cities enjoyed sufficient growth in services and retail to outweigh the displacement of less advantageous sectors.

We may be interested in outcomes other than employment. For instance, when the employment mix changes, it could impact local earnings. In Table 7, we repeat our OLS analysis for three alternative outcomes. In place of employment growth, we analyze the growth rates of income-per-capita, earnings-per-job, and population. Estimation for these outcomes follows equations 5, 6, and 7, respectively.

$$(5)\ \ln\left(\frac{IPC_{i,1987}}{IPC_{i,1979}}\right) = \alpha + \beta(D_i) + \gamma_1 \ln\left(E_{i,1977}\right) + \gamma_2 \ln\left(IPC_{i,1977}\right) + \gamma_3\left(JPC_{i,1977}\right) + \zeta \ln\left(\frac{IPC_{i,1977}}{IPC_{i,1970}}\right) + \sum_{k=1}^{46} \theta_k I_{i,k} + \epsilon_i$$

$$(6)\ \ln\left(\frac{EPJ_{i,1987}}{EPJ_{i,1979}}\right) = \alpha + \beta(D_i) + \gamma_1 \ln\left(E_{i,1977}\right) + \gamma_2 \ln\left(EPJ_{i,1977}\right) + \gamma_3\left(JPC_{i,1977}\right) + \zeta \ln\left(\frac{EPJ_{i,1977}}{EPJ_{i,1970}}\right) + \sum_{k=1}^{46} \theta_k I_{i,k} + \epsilon_i$$

$$(7)\ \ln\left(\frac{POP_{i,1987}}{POP_{i,1979}}\right) = \alpha + \beta(D_i) + \gamma_1 \ln\left(POP_{i,1977}\right) + \gamma_2 \ln\left(IPC_{i,1977}\right) + \gamma_3\left(JPC_{i,1977}\right) + \zeta \ln\left(\frac{POP_{i,1977}}{POP_{i,1970}}\right) + \sum_{k=1}^{46} \theta_k I_{i,k} + \epsilon_i$$

Columns 1-3 of Table 7 concern growth rates for 1979-1987, while Columns 4-6 concern 1990-2000 growth rates. We conclude that both earnings-per-job and income-per-capita fall by ~1% in the first period for cities with an EAS determination. In the later period, we see that earnings-per-job continue to be depressed, but the counteracting force of greater employment seems to stabilize income-per-capita. Local population appears unaffected by EAS treatment.

4.2 Propensity Score Matching

Propensity Score Matching (PSM) is a procedure for estimating treatment effects by controlling for the probability of treatment. If our LHS variable is y_1 under treatment and y_0 without treatment, then the average treatment effect (ATE) is equal to average of [y_{i1}-y_{i0}] over *all* cities "i" in the sample, where one outcome (i.e. y_1 for the treated, or y_0 for the untreated) is observed, while the other outcome must be estimated. The estimate of the unobserved outcome depends on the exact implementation of the PSM protocol. We use a standard "nearest neighbor" matching procedure: for a given *untreated* city *i* the estimate of $\hat{y}_{i1}$ is equal to the observed value of y_{k1} for whichever *treated* city *k* has the closest propensity score (in terms of absolute difference) to city *i.* Likewise, for a given *treated* city, the estimate of $\hat{y}_{i0}$ is equal to observed value of y_{ko} for whichever *untreated* city *k* has the closest propensity score. Whereas the ATE averages over all cities in the sample, we can also define the average treatment effect on the treated (ATET) as the average of [y_{i1}-y_{i0}] over only those cities that were actually treated.

EAS determination status is not completely exogenous. After all, given two comparable communities, there must be some reason that one had air service in 1978 and the other did not. In order for propensity score matching to yield valid conclusions, we need to have data on all the determinants of treatment. We proceed by assuming that the critical determinants of air-service provision are economic size, geography, and expectations. Our data includes total employment and income, which account for size; growth pre-trends, which account for expectations; and state fixed effects, which account for geography. Thus, we have sufficient data to control for the probability of EAS treatment via propensity score matching (PSM).

The determinants of treatment in our PSM estimation are the same as the covariates in our OLS regressions. Under certain strict assumptions, then, we could expect the same results from both procedures. In general, however, PSM balances our covariates (a propensity score is a type of “balancing score”) in a way that OLS cannot. If, for instance, a given size city on the West coast was more likely to have air service in 1978 than the same size city in the South, estimates based on OLS will not be consistent, but those based on PSM will.[44]

If our data includes all the determinants of treatment, then a treated and untreated city with the same propensity score can properly be treated as if they had been randomly assigned to treatment, making PSM preferable to OLS. However, if we have *not* in fact captured the determinants of treatment, then by combining all our covariate data into a single coarse measure, PSM may provide less reliable estimates than OLS.   As stated above, we believe that our data sufficiently captures all the determinants of having scheduled air service in 1978.

In Table 8, we compare EAS-treated counties to non-treated counties and to all counties generally. On average, EAS counties are larger than other counties, and they are less engaged in manufacturing and agriculture but more engaged in every other sector. In preparation for our PSM estimation, Table 9 presents probit-regression estimates for the impact of our covariates on EAS determination status. (Each column corresponds to one of the 11 distinct OLS equations considered so far.) Table 9 shows that larger counties are more likely to have an EAS determination, but higher income actually make it less likely, while service, wholesale, retail, and manufacturing job shares also play a role.

Next, the top panel of Table 10 presents our PSM estimation results for 1979-1987. For convenience, we gather the coefficients on determination status, for all outcomes, into a single table, including both an estimate of the average treatment effect (ATE) and estimate of the average treatment effect on the treated (ATET).

[44] Assuming state dummies for OR, WA, and CA are sufficient to capture “west coast”

Examining the ATE results in Table 10, our conclusions from Table 2 are generally confirmed: there is no overall employment effect, but service and retail sectors grow. One major difference from Table 5 is that construction, rather than government, is the third impacted sector. Additionally, the service and retail ATE estimates are about twice as large as the coefficients in Table 5. That fact, combined with the lack of an impact in the ATET estimates, seems consistent with a “poorly targeted” treatment program. That is, those cities most likely to be treated are actually those with the least to gain from EAS (perhaps, for example, because their service sectors are already large, and therefore they experience small returns from this services-increasing amenity.)

In the bottom panel of Table 10, our OLS results are not confirmed. The ATE estimates for income-per-capita and earnings-per job are positive and zero, respectively, in contrast with the negative OLS results. The ATET for both IPC and EPJ are, however, more in line with the OLS results. We interpret this latter fact as further evidence that EAS treatment is poorly targeted, in the sense that those with the most to gain from EAS treatment were unlikely to be treated.

Finally, PSM estimation results for 1990-2000 growth rates are summarized in Table 11. As with OLS, we find that total employment increases and earnings-per-job falls. However, compared to our OLS results, the impact on total employment (or non-farm employment) is larger, at 3.2% (or 7.7%!). Most surprising are the sectoral employment results; while Table 6 showed positive impacts for services, retail, and construction, we now see statistically significant impacts for manufacturing and government only, while services actually has a negative point estimate. Additionally, while the negative impact on earnings-per-job is in line with our OLS results, we find a positive impact on income-per-capita (instead of no impact); this makes sense given that we have also estimated a greater impact on total employment.

If our OLS regressions suffer from selection bias, the most likely explanation is that, in the absence of the EAS program, cities that failed to obtain scheduled air service by 1978 would have worse economic outcomes than cities that did obtain service by that time. Since cities that failed to obtain scheduled air service by 1978 are the ones "treated" by the EAS program, our OLS estimates would be biased downwards. If our PSM procedure eliminates the influence of selection, we would expect our ATE estimates to be higher (i.e. more positive) than our OLS coefficients, and in fact we saw that this is generally the case. The only exceptions are the sectoral employment results for government in Table 10 and for services, retail, and construction in Table 11; the ATE estimates are zero or negative whereas the corresponding OLS coefficients were positive. However, perhaps these results are not so troubling, since the direction of selection bias is actually much less clear for sectoral employment than for total employment and income. While it is true that the service-sector ATE results in Table 11 are at odds with the literature, we do find a positive impact on service-sector growth in Table 10, so it is possible that the impact of the EAS program on service-sector growth was fully exhausted in the first period 1979-1987, leaving no room for EAS-induced growth from 1990-2000.

5 Conclusion, Recommendations, and Suggestions for Future Research

The essential air service program has received some media and political attention in the last few years, most often as an example of bad policy. A likely culprit for this recent attention is evident in Figure 1 above (pg 4), which shows that after a long period of stability, program costs have exploded in the last decade, even though the number of points served has remained stable. Combined with low load factors on EAS flights, it is easy to see why it appears like the federal government is wasting, currently, a quarter-billion dollars annually on a program for communities who do not value air travel. But our regression results imply that air travel is in fact valuable at the county level, inflating employment and income-per-capita in the second period.

So, air travel impacts the size and employment mix of local economies, demonstrating to economists that air travel shapes our economic geography, even in a nation already well connected by road and rail. But was the EAS program successful? Is it worth the money spent on it? If we accept the ATE estimates of the impact of EAS treatment on income-per-capita, the answer is a modified yes.

In Table 10, the ATE is 3%, while the average county IPC in 1990 was $15,000, so the ATE corresponds to $370 per capita. Moreover, in 1990, around 50 million people lived in EAS-treated communities, and the cost of the entire program *from 1978 to 2000* was $966.2 million (see Figure 1), or less than $20 per capita. Thus, the *benefits of air service* are extremely high relative to *EAS program costs*. However, we should actually use ATET, not ATE, to judge the EAS program itself, and on those grounds we cannot reject that the return to EAS investments is zero. As pointed out above, the rules of the EAS render it a poorly targeted program. So while some cities (perhaps Joplin, cf. Table 1) are enjoying enormous returns from relatively small EAS investments, others are devouring program funds despite their hopeless air connections (perhaps Lewiston, cf. Table 1). Our conclusion must be, then, that the EAS is an overall failure as a policy, but it nevertheless demonstrates that better-targeted aviation subsidies are undoubtedly worthwhile.

We mentioned above that in the year 2000, the DOT initiated something named the Small Community Air Service Development Program (SCASDP). This program allows all small or rural communities to submit grant proposals for initiatives to improve local air service. The program's rules permit no more than 40 awards per year, including no more than four per state, but there is no limit on individual award amounts. In practice, grants have ranged from $20,000 to $1.6 million. Overall funding is still low, totaling $11.4 million in 2012, in contrast to the EAS program's $217.9 million in 2011.

While we do not evaluate the SCASDP at this time, it does appear to be a movement in the right direction relative to the EAS. The more judicious process of funding individual initiatives, rather than guaranteeing service for an inflexibly and somewhat arbitrarily defined class of locations, provides the opportunity to realize, according to our estimates, large local returns on relatively small federal investments in air service. Programs like the SCASDP could be expanded, or the EAS program could be reconfigured to have greater flexibility in allocating resources. To the latter point, flight itself may not be best way to help communities reach their nearest hub airport; subsidized shuttle services on existing roads may be a suitable substitute with much lower financial expense for both government and user. Of course, the time costs would be higher, but *how much* higher depends on the value of time in long-distance, daylong travel, which may be vastly different than the value of time on shorter daily commutes. Nearly all our value-of-time literature concerns the latter, so understanding the value of time in long-distance travel could be a useful topic for further study.

We found no evidence of population impacts for the EAS. This is consistent with no increase in the local quality of life, which would attract migration. And yet, we find evidence that employment mix is significantly impacted, and one feels that local quality of life, skill sets, and employment mix are tied together. So it begs the questions: are local residents staying put and changing industry? (This is plausible; after all, our time periods are on the scale of a generation). Or, for the same reasons that the employment mix changes, might some sorting of workers accompany that influence, without any discernable *net* effect on local population? Analyzing county-to-county migration data under the lens of EAS treatment would be one way to get at an answer.

Finally, recalling our modeling equations, the estimate $\hat{\beta}$ of the impact of the EAS was actually composed to two elements: η and Δ. The former corresponds to the economic value of air travel generally, while the latter is the EAS program's impact on access to air travel services. If the EAS program is inefficient, then η could actually be larger in magnitude than $\hat{\beta}$. If one had better historical flight data, the impact of EAS on air-services access (i.e. Δ) could be estimated, and the value of η thereby inferred.

6 Tables

Table 2: Descriptive Statistics: Initial Conditions

Variable	Obs	Mean	Std Dev	Min	Max	Median
Determination	3096	0.11	0.32	0.00	1.00	0.00
Total Employment 1977 (log)	3096	9.20	1.36	5.22	15.17	9.05
Service Emp_Share 1977	3013	0.16	0.05	0.04	0.50	0.16
Manufacturing Emp_Share 1977	2993	0.17	0.12	0.00	0.62	0.15
Wholesale Emp_Share 1977	2861	0.03	0.02	0.00	0.14	0.03
Retail Emp_Share 1977	3090	0.15	0.04	0.02	0.44	0.15
Construction Emp_Share 1977	3033	0.05	0.03	0.01	0.51	0.05
Government Emp_Share 1977	3096	0.17	0.08	0.05	0.78	0.15
Non-farm Emp_Share 1977	3096	0.85	0.12	0.28	1.00	0.88
Population 1977 (log)	3096	10.08	1.31	6.14	15.80	9.95
Income Per Capita 1977 (log)	3096	8.70	0.22	7.75	9.56	8.72
Earnings per Job 1977(log)	3095	9.15	0.25	8.09	10.55	9.16
Jobs Per Capita 1977	3096	0.43	0.10	0.14	1.00	0.43

Table 3: Correlation Matrix For Table-1 Variables

	Determination	Total Employment 1977 (log)	Service Emp_Share 1977	Manufacturing Emp_Share 1977	Wholesale Emp_Share 1977	Retail Emp_Share 1977	Construction Emp_Share 1977	Government Emp_Share 1977	Non-farm Emp_Share 1977	Population 1977 (log)	Income Per Capita 1977 (log)	Earnings per Job 1977(log)	Jobs Per Capita 1977
Determination	1.00												
Total Employment 1977 (log)	0.26	1.00											
Service Emp_Share 1977	0.20	0.41	1.00										
Manufacturing Emp_Share 1977	-0.03	0.28	-0.21	1.00									
Wholesale Emp_Share 1977	0.09	0.21	0.14	-0.20	1.00								
Retail Emp_Share 1977	0.22	0.27	0.49	-0.25	0.18	1.00							
Construction Emp_Share 1977	0.07	0.03	0.09	-0.15	-0.03	0.11	1.00						
Government Emp_Share 1977	0.08	0.07	-0.07	-0.32	-0.23	-0.05	-0.08	1.00					
Non-farm Emp_Share 1977	0.26	0.69	0.42	0.39	-0.07	0.35	0.16	0.20	1.00				
Population 1977 (log)	0.23	0.98	0.41	0.28	0.16	0.28	0.03	0.09	0.70	1.00			
Income Per Capita 1977 (log)	0.15	0.51	0.32	-0.09	0.26	0.27	0.19	-0.01	0.35	0.43	1.00		
Earnings per Job 1977(log)	0.20	0.62	0.18	0.16	0.10	0.17	0.16	0.13	0.65	0.60	0.68	1.00	
Jobs Per Capita 1977	0.20	0.33	0.14	0.01	0.32	0.03	0.03	-0.07	0.13	0.15	0.51	0.30	1.00

Table 4: Descriptive Statistics: Growth Rates

	Obs	Mean	Std Dev	Min	Max	Median
Log Growth 1970 to 1977						
Total Employment '70 to '77	3096	0.16	0.16	-0.69	1.62	0.14
Service Employment '70 to '77	3008	0.24	0.24	-1.27	2.13	0.24
Manufacturing Emp '70 to '77	2936	0.20	0.43	-2.27	3.90	0.15
Wholesale Emp '70 to '77	2778	0.54	0.50	-1.54	3.31	0.48
Retail Employment '70 to '77	3087	0.16	0.23	-1.85	2.22	0.16
Construction Emp '70 to '77	3018	0.33	0.48	-3.49	4.71	0.31
Government Emp '70 to '77	3096	0.11	0.19	-1.10	1.77	0.11
Non-Farm Employment '70 to '77	3096	0.19	0.17	-0.85	1.65	0.17
Population'70 to '77	3096	0.10	0.12	-0.31	0.96	0.08
Income-Per-Capita '70 to '77	3096	0.62	0.12	-0.48	1.24	0.62
Earnings-Per-Job '70 to '77	3095	0.62	0.15	-0.20	1.49	0.61
Log Growth 1979 to 1987						
Total Employment '79 to '87	3078	0.07	0.17	-0.92	1.09	0.05
Service Employment '79 to '87	2953	0.29	0.23	-0.47	1.50	0.26
Manufacturing Emp '79 to '87	2910	-0.04	0.40	-2.54	2.54	-0.04
Wholesale Emp '79 to '87	2789	0.02	0.38	-1.75	1.77	0.00
Retail Employment '79 to '87	3070	0.11	0.24	-1.26	1.41	0.11
Construction Emp '79 to '87	2960	0.00	0.45	-2.76	2.16	0.02
Government Emp '79 to '87	3078	0.08	0.14	-1.44	1.11	0.07
Non-Farm Employment '79 to '87	3078	0.10	0.18	-0.92	1.10	0.08
Population '79 to '87	3078	0.03	0.12	-0.39	0.90	0.02
Income-Per-Capita '79 to '87	3078	0.52	0.12	-0.22	1.77	0.53
Earnings-Per-Job '79 to '87	3078	0.39	0.16	-1.06	2.28	0.40
Log Growth 1990 to 2000						
Total Employment '90 to '00	3077	0.17	0.17	-0.50	2.16	0.15
Service Employment '90 to '00	2942	0.29	0.24	-0.68	3.41	0.28
Manufacturing Emp '90 to '00	2764	0.05	0.39	-2.63	2.16	0.04
Wholesale Emp '90 to '00	2678	0.16	0.37	-1.66	2.44	0.14
Retail Employment '90 to '00	3057	0.19	0.21	-0.86	1.69	0.18
Construction Emp '90 to '00	2756	0.35	0.34	-2.05	1.95	0.34
Government Emp '90 to '00	3077	0.14	0.17	-1.14	1.05	0.13
Non-Farm Employment '90 to '00	3077	0.19	0.18	-0.64	2.16	0.18
Population '90 to '00	3077	0.10	0.13	-0.32	1.07	0.08
Income-Per-Capita '90 to '00	3077	0.44	0.10	-0.36	1.08	0.44
Earnings-Per-Job '90 to '00	3077	0.36	0.09	-0.17	1.06	0.36

Table 5: OLS: log Employment Growth 1979-1987
Total Employment & by Sector

VARIABLES	(1) Total	(2) Service	(3) Wholes.	(4) Retail	(5) Manuf.	(6) Govt.	(7) Constrct.	(8) Non-Farm
EAS Determination	-0.0032	0.023*	-0.024	0.027**	-0.025	0.016*	-0.013	0.0062
	(0.0077)	(0.010)	(0.015)	(0.0092)	(0.021)	(0.0068)	(0.018)	(0.0083)
1977: Total Emp. (log)	0.011**	0.012*	0.072**	0.034**	-0.0016	0.0019	0.020*	0.020**
	(0.0029)	(0.0049)	(0.0078)	(0.0045)	(0.0087)	(0.0026)	(0.0081)	(0.0040)
1977: Income/Capita (log)	0.17**	0.36**	0.44**	0.25**	0.083	0.12**	0.49**	0.19**
	(0.020)	(0.033)	(0.057)	(0.033)	(0.062)	(0.023)	(0.059)	(0.023)
1977: Jobs Per Capita	-0.56**	-0.87**	-0.80**	-0.76**	-0.39**	-0.27**	-1.54**	-0.66**
	(0.045)	(0.060)	(0.10)	(0.053)	(0.10)	(0.037)	(0.11)	(0.047)
70-77: Total Emp. Growth	0.35**							
	(0.024)							
70-77: Service Job Growth		0.19**						
		(0.024)						
1977: Service Job-Share		-1.23**						
		(0.11)						
70-77: Wholes. Job Growth			-0.012					
			(0.017)					
1977: Wholesale Job-Share			-5.75**					
			(0.45)					
70-77: Retail Job Growth				0.32**				
				(0.030)				
1977: Retail Job-Share				-1.19**				
				(0.16)				
70-77: Manuf. Job Growth					-0.070*			
					(0.031)			
1977: Manuf. Job-Share					-0.71**			
					(0.078)			
70-77: Govt. Job Growth						0.046*		
						(0.020)		
1977: Govt. Job-Share						-0.18**		
						(0.038)		
70-77: Constr. Job Growth							-0.029	
							(0.024)	
1977: Constr. Job-Share							-2.81**	
							(0.57)	
70-77: Non-Farm Job								0.30**

Growth								
								(0.026)
1977: Non-Farm Job-Share								-0.28**
								(0.045)
Constant	-1.32**	-2.45**	-3.95**	-1.93**	-0.29	-0.87**	-3.57**	-1.25**
	(0.16)	(0.26)	(0.45)	(0.25)	(0.48)	(0.18)	(0.46)	(0.18)
Observations	3,078	2,950	2,715	3,068	2,889	3,078	2,945	3,078
Adjusted R-squared	0.389	0.277	0.207	0.386	0.091	0.179	0.358	0.336
State FE	X	X	X	X	X	X	X	X

All "Growth" Rates indicate log-differences

Robust standard errors in parentheses, ** p<0.01, * p<0.05

Table 6: OLS: log Employment Growth 1990-2000
Total Employment & by Sector

VARIABLES	(1) Total	(2) Service	(3) Wholes.	(4) Retail	(5) Manuf.	(6) Govt.	(7) Constrct.	(8) Non-Farm
EAS Determination	0.020**	0.031**	0.0045	0.022*	-0.010	0.029**	0.0029	0.023**
	(0.0067)	(0.0092)	(0.016)	(0.0090)	(0.017)	(0.0084)	(0.017)	(0.0071)
1977: Total Emp. (log)	0.0047	0.024**	0.029**	0.0048	-0.0055	-0.010**	-0.014*	0.0086
	(0.0029)	(0.0051)	(0.0084)	(0.0042)	(0.0077)	(0.0030)	(0.0072)	(0.0044)
1977: Income/Capita (log)	0.15**	0.099**	0.26**	0.15**	0.29**	0.040	0.15**	0.14**
	(0.023)	(0.036)	(0.057)	(0.030)	(0.062)	(0.021)	(0.057)	(0.024)
1977: Jobs Per Capita	-0.63**	-0.70**	-0.75**	-0.67**	-0.46**	-0.42**	-0.77**	-0.70**
	(0.043)	(0.060)	(0.10)	(0.057)	(0.089)	(0.038)	(0.089)	(0.044)
70-77: Total Emp. Growth	0.35**							
	(0.023)							
70-77: Service Job Growth		0.19**						
		(0.028)						
1977: Service Job-Share		-0.17						
		(0.098)						
70-77: Wholes. Job Growth			0.032					
			(0.018)					
1977: Wholesale Job-Share			-4.81**					
			(0.44)					
70-77: Retail Job Growth				0.29**				
				(0.025)				
1977: Retail Job-Share				-0.93**				
				(0.15)				
70-77: Manuf. Job Growth					0.039			
					(0.023)			
1977: Manuf. Job-Share					-0.58**			
					(0.077)			
70-77: Govt. Job Growth						0.19**		
						(0.028)		
1977: Govt. Job-Share						-0.44**		
						(0.055)		
70-77: Constr. Job Growth							0.044	
							(0.023)	
1977: Constr. Job-Share							-1.37**	
							(0.46)	
70-77: Non-Farm Job Growth								0.31**
								(0.024)
1977: Non-Farm Job-Share								-0.13*
								(0.051)
Constant	-0.97**	-0.50	-1.94**	-0.80**	-2.18**	0.026	-0.45	-0.81**
	(0.17)	(0.27)	(0.45)	(0.23)	(0.49)	(0.17)	(0.44)	(0.19)
Observations	3,077	2,884	2,531	3,052	2,731	3,077	2,692	3,077
Adjusted R-squared	0.334	0.228	0.131	0.220	0.143	0.226	0.217	0.287
State FE	X	X	X	X	X	X	X	X

All "Growth" rates indicate log-differences

Robust standard errors in parentheses, ** p<0.01, * p<0.05

Table 7: OLS: log 'Alternative Outcome' Growth
Income-per-Capita, Earnings-per-Job, & Population

VARIABLES	(1) IPC 79-87	(2) EPJ 79-87	(3) Pop 79-87	(4) IPC 90-00	(5) EPJ 90-00	(6) Pop 90-00
EAS Determination	-0.011*	-0.011*	-0.0025	0.00028	-0.020**	-0.0048
	(0.0045)	(0.0054)	(0.0041)	(0.0045)	(0.0040)	(0.0050)
1977: Jobs Per Capita	-0.11**	0.11**	-0.077**	-0.21**	-0.0039	-0.18**
	(0.028)	(0.039)	(0.023)	(0.025)	(0.021)	(0.027)
1977: Total Emp. (log)	0.012**	0.038**		0.014**	0.024**	
	(0.0026)	(0.0041)		(0.0023)	(0.0022)	
1977: Income/Capita (log)	-0.037		0.11**	-0.033*		0.072**
	(0.020)		(0.015)	(0.015)		(0.014)
1977: EPJ (log)		-0.17**			-0.20**	
		(0.024)			(0.013)	
1977: Population (log)			0.0090**			0.0072**
			(0.0019)			(0.0021)
70-77: IPC Growth	-0.25**			0.073**		
	(0.030)			(0.023)		
70-77: EPJ Growth		0.037			0.11**	
		(0.038)			(0.017)	
70-77: Population Growth Rate			0.51**			0.58**
			(0.024)			(0.025)
Constant	0.97**	1.55**	-1.05**	0.61**	1.85**	-0.58**
	(0.15)	(0.19)	(0.11)	(0.11)	(0.10)	(0.10)
Observations	3,078	3,077	3,078	3,077	3,076	3,077
Adjusted R-squared	0.305	0.228	0.584	0.191	0.239	0.533
State FE	X	X	X	X	X	X

Robust standard errors in parentheses
** $p<0.01$, * $p<0.05$

Table 8: Variable Comparison by Determination Status

	Total Employment (LEVEL)	Population (LEVEL)	Income Per Capita (LEVEL)	Earnings per Job (LEVEL)
D=0	29,836	63,998	6096	9591
D=1	58,574	121,073	6680	10888
Total	33,067	70,413	6162	9736

	Jobs Per Capita	Service Emp Share	Manufacturing Emp Share	Wholesale Emp Share
D=0	0.421	0.158	0.169	0.034
D=1	0.480	0.192	0.160	0.040
Total	0.427	0.162	0.168	0.035

	Government Emp Share	Non-farm Emp Share	Retail Emp Share	Construction Emp Share
D=0	0.169	0.842	0.143	0.052
D=1	0.183	0.938	0.168	0.058
Total	0.171	0.853	0.145	0.053

(all variables measured in 1977)

D=0 Signifies no determination isssued by EAS

D=1 Signifies Determination Issued by EAS

Table 9: Probit Regressions

Probit Outcome is Determination Status

Column Headings refer to Dependent Variable in Corresponding PSM Regression

VARIABLES	(1) Total Emp	(2) Service Emp	(3) Wholesale Emp	(4) Retail Emp	(5) Manufact. Emp	(6) Govt. Emp	(7) Constuct. Emp	(8) Non-Farm Emp	(9) Income per Capita	(10) Earnings per Job	(11) Population
1977: Total Emp. (log)	0.40**	0.35**	0.36**	0.35**	0.40**	0.40**	0.42**	0.22**	0.41**	0.37**	
	(0.034)	(0.036)	(0.039)	(0.036)	(0.036)	(0.034)	(0.036)	(0.039)	(0.034)	(0.038)	
1977: Income/Capita (log)	-1.11**	-1.00**	-0.97**	-1.21**	-0.99**	-0.91**	-1.12**	-1.59**	-1.03**		-1.04**
	(0.24)	(0.29)	(0.29)	(0.29)	(0.28)	(0.27)	(0.29)	(0.30)	(0.28)		(0.28)
1977: Jobs Per Capita	2.80**	2.73**	2.65**	3.52**	2.84**	2.68**	2.67**	2.98**	2.76**	1.91**	3.88**
	(0.47)	(0.47)	(0.49)	(0.48)	(0.47)	(0.46)	(0.46)	(0.48)	(0.47)	(0.42)	(0.47)
70-77: Service Job Growth		-0.092									
		(0.19)									
1977: Service Job-Share		3.78**									
		(0.78)									
70-77: Total Emp. Growth	0.82**										
	(0.23)										
70-77: Wholes. Job Growth			-0.18*								
			(0.089)								
1977: Wholesale Job-Share			0.48								
			(2.19)								
70-77: Retail Job Growth				0.43*							
				(0.22)							
1977: Retail Job-Share				9.77**							
				(1.24)							
70-77: Manuf. Job Growth					0.040						
					(0.093)						
1977: Manuf. Job-Share					-1.06**						
					(0.40)						
70-77: Govt. Job Growth						0.36					
						(0.22)					
1977: Govt. Job-Share						0.65					
						(0.40)					
70-77: Constr. Job Growth							0.13				
							(0.10)				
1977: Constr. Job-Share							2.55				
							(1.35)				
70-77: Non-Farm Job Growth								0.18			
								(0.24)			
1977: Non-Farm Job-Share								5.73**			
								(0.65)			
70-77: IPC Growth									0.67		
									(0.38)		

70-77: EPJ Growth										0.66	
										(0.39)	
1977: EPJ (log)										-0.070	
										(0.28)	
70-77: Population Growth Rate											0.96**
											(0.33)
1977: Population (log)											0.40**
											(0.034)
Constant	2.95	2.07	2.45	2.72	2.32	1.27	2.85	3.65	1.96	-5.54**	1.57
	(1.81)	(2.25)	(2.29)	(2.31)	(2.21)	(2.14)	(2.23)	(2.26)	(2.18)	(2.15)	(2.13)
Observations	3,087	2,999	2,769	3,078	2,927	3,087	3,009	3,087	3,087	3,086	3,087
State FE	X	X	X	X	X	X	X	X	X	X	X
log-lklhd	-864	-847	-845	-826	-861	-867	-858	-821	-868	-873	-867

Robust standard errors in parentheses
** p<0.01, * p<0.05

Table 10: Propensity Score Matching - log growth 1979 to 1987

		Coefficient	Std Error	p-value	log-lklhd	N
Total Employment	***ATE***	0.006	0.031	0.855	-0.054	3069
	ATET	-0.022	0.011	0.053	-0.043	3069
Service Employment	***ATE***	0.141	0.054	0.009	0.035	2941
	ATET	0.009	0.013	0.498	-0.017	2941
Wholesale Employment	***ATE***	-0.035	0.051	0.492	-0.134	2706
	ATET	-0.011	0.017	0.534	-0.045	2706
Retail Employment	***ATE***	0.156	0.025	0.000	0.106	3057
	ATET	0.012	0.015	0.425	-0.018	3057
Manufacturing Employment	***ATE***	-0.098	0.057	0.082	-0.209	2880
	ATET	-0.016	0.025	0.525	-0.066	2880
Government Employment	***ATE***	0.032	0.017	0.057	-0.001	3069
	ATET	-0.008	0.008	0.324	-0.024	3069
Construction Employment	***ATE***	0.134	0.023	0.000	0.088	2936
	ATET	-0.016	0.037	0.662	-0.090	2936
Non-Farm Employment	***ATE***	0.029	0.047	0.545	-0.064	3051
	ATET	-0.014	0.013	0.269	-0.040	3051
Income/Capita	***ATE***	0.012	0.005	0.023	0.002	3069
	ATET	-0.018	0.006	0.006	-0.031	3069
Earnings Per Job	***ATE***	-0.023	0.013	0.067	-0.048	3068
	ATET	-0.008	0.008	0.305	-0.024	3068
Total Population	***ATE***	0.006	0.011	0.583	-0.016	3069
	ATET	-0.015	0.008	0.046	-0.030	3069

ATE=Average Treatment Effect
ATET = Average Treatment Effect on the Treated
Shading indicates 5% significance for the coefficient
Propensity Scores Estimate via Probit Model
Robust Standard Errors

Table 11: Propensity Score Matching - log growth 1990 to 2000

		Coefficient	Std Error	p-value	log-lklhd	N
Total Employment	***ATE***	0.032	0.010	0.001	0.013	3068
	ATET	-0.004	0.008	0.575	-0.020	3068
Service Employment	***ATE***	-0.011	0.024	0.642	-0.057	2875
	ATET	0.014	0.010	0.176	-0.006	2875
Wholesale Employment	***ATE***	0.012	0.042	0.773	-0.070	2524
	ATET	0.005	0.022	0.829	-0.038	2524
Retail Employment	***ATE***	0.070	0.066	0.288	-0.059	3040
	ATET	-0.009	0.015	0.556	-0.037	3040
Manufacturing Employment	***ATE***	0.049	0.025	0.048	0.000	2724
	ATET	0.002	0.025	0.947	-0.047	2724
Government Employment	***ATE***	0.036	0.019	0.050	0.000	3068
	ATET	0.014	0.012	0.250	-0.010	3068
Construction Employment	***ATE***	-0.032	0.030	0.282	-0.090	2685
	ATET	-0.034	0.023	0.138	-0.078	2685
Non-Farm Employment	***ATE***	0.077	0.017	0.000	0.043	3050
	ATET	0.011	0.011	0.320	-0.010	3050
Income/Capita	***ATE***	0.021	0.008	0.006	0.006	3068
	ATET	-0.007	0.006	0.301	-0.019	3068
Earnings Per Job	***ATE***	-0.010	0.005	0.043	-0.019	3067
	ATET	-0.017	0.006	0.005	-0.029	3067
Total Population	***ATE***	0.010	0.009	0.283	-0.008	3068
	ATET	-0.016	0.006	0.010	-0.028	3068

ATE=Average Treatment Effect
ATET = Average Treatment Effect on the Treated
Shading indicates 5% significance for the coefficient
Propensity Scores Estimate via Probit
Robust Standard Errors

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