Blue-sky Thinking:

Aviation Connectivity Impacts on Regional Economies and Innovation in the United States

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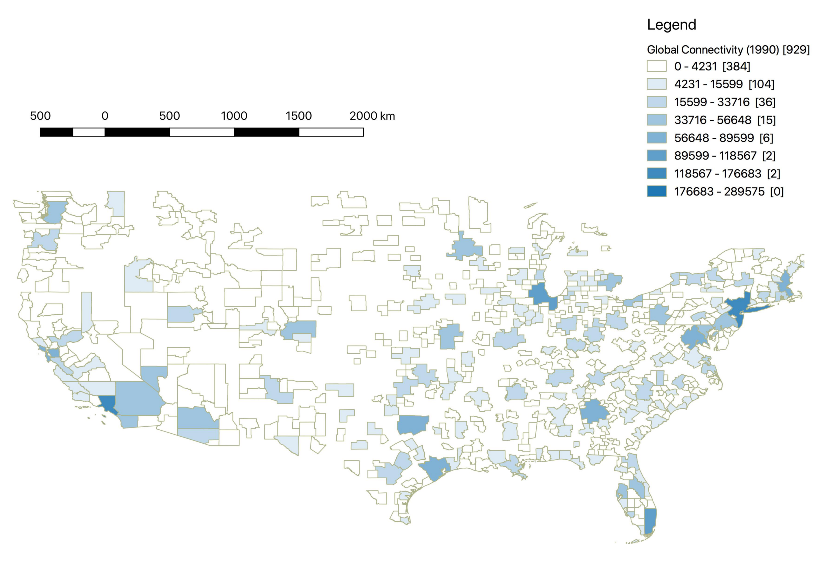
Aviation: An engine for globalization

- Aviation is an important sector of the economy
  - An effect of 3.4-5% of world GDP without accounting for the spillovers (Belobaba 2016/ATAG 2014)
  - In the U.S.: $1.6 trillion in total economic activity; nearly 11 million jobs; the nation's top net export (FAA 2016)
  - Air traffic growth of 5-6% per year; worldwide annual GDP growth at 2-3%
- Aviation impacts society
  - Through spillovers - facilitating interactions that lead to innovation and knowledge accumulation
  - Through negative externalities - aviation emissions impact local and global health, climate

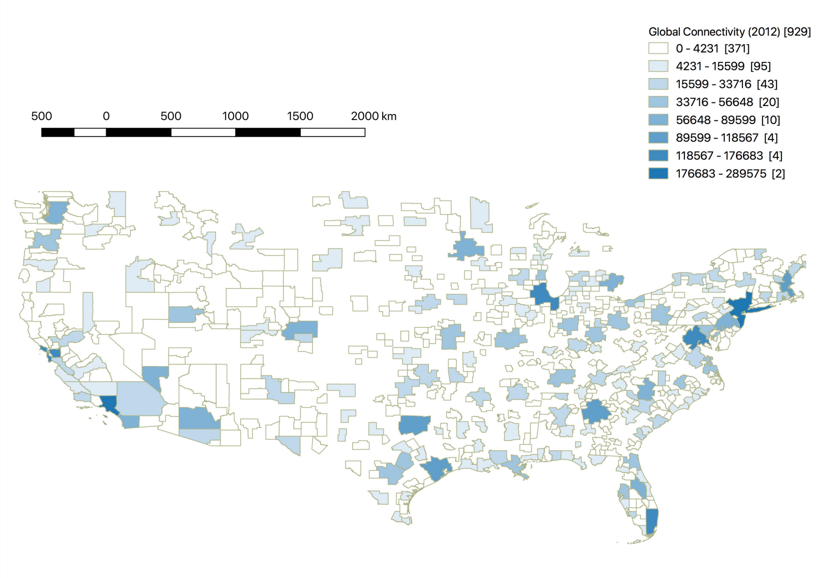
Key Research Question

How does aviation affect regional economies and foster innovation?

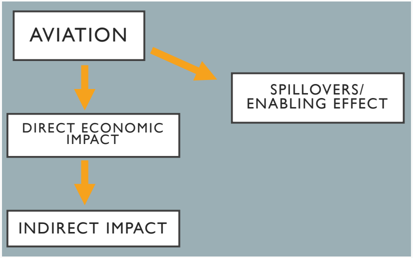
Aviation Connectivity in 1990



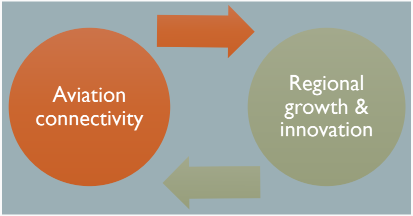
Aviation Connectivity in 2012



Methods



Aviation creates spillovers and enabling effects in the economy by enabling interactions that otherwise would not happen.



However, we face an endogeneity issue. One solution: Instrumental variables and 2SLS.

Data

- Outcomes of interest
  - Socioeconomics: U.S. Census and Bureau of Economic Analysis Data (e.g CA 30 Economic Profiles, sectoral income and employment), 1970-2012
  - **New!** Innovation: use of 2+ million granted patent data with inventor records (PTO, NBER, Lai et al 2015), 1975-2010
- Instrumental Variables
  - **Institutional/Incidental:** Air Traffic Control Airports in 1938, Military installments in the U.S.
  - **Physical Geography:** Average slope, Land use in 1970
  - **Economic Geography:** Tourism destination in 1904, Traffic Shadow Cities in 1952, Rail service loss/overnight zones from 1950-1970
- Measurement of Aviation Connectivity: Global Connectivity Index (GCI)

Results Preview

Connectivity, Income, and Innovation

After accounting for endogeneity, a 1% increase in GCI causes a long-term total income increase of 1.7% and a 2% increase in patent activity. Example: Myrtle Beach, SC - $218 million, about 6 more patents granted.

Example: Atlanta vs. San Diego

If San Diego increased its connectivity to Atlanta levels, the model would predict long-term income increases in the order of $73 billion.

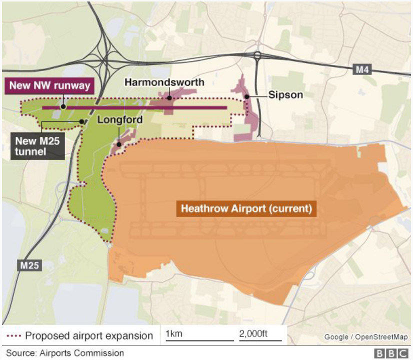
Threshold effects?

Only larger cities benefit from connectivity increases (top 100 in population).

Outline

Motivation and Theory

Motivation



Benefits of increasing aviation activity. Example: Heathrow Expansion (BBC)

Cost of infrastructure interruption. Example: Kansai Airport and Typhoon Jebi (Nikkei)

Motivation

- Are transportation investments worth it? Much work on roads, highways, railways etc.
- Sustainability of Aviation: Aviation accounts for some 2% of global greenhouse gas emissions
  - Resistance to regulation because of positive economic impact, lack of substitutes
  - Climate impacts to large-scale infrastructure
- Some evidence of sectoral impacts - but the induced interaction and opportunity through aviation has not been studied

- Air transport can enable population growth, income growth, new employment, and higher levels of interaction - higher quality ideas

People have investigated this on the ground

Estimate social rates of return on infrastructure investments
Examples: Canning and Fay 1993, Aschauer 1989, Wylie 1996, Winston 1991, Duranton & Turner 2012; on rail: Haines & Margo 2006, Donaldson & Hornbeck 2016, Dong et al 2018; Trade impacts: Donaldson 2018

... but in the air, this has been new

Examples: Brueckner 2003, Sheard 2014/2015, McGraw 2015/2016, LeFors 2014, Catalini et al 2016, Campante & Yanagizawa-Drott 2016

Urban Growth Theory

- Extending Glaeser et al. (1995)'s urban growth framework by introducing aviation (Blonigen and Cristea 2015)
- Idea: aviation enters model as a driver for growth in productivity and local amenity value
- Let the total output of an area be given by

$$Y_{it} = Z_{it} f(L_{it})$$

where Z_{it} denotes the level of productivity within CBSA i at time t, L_{it} denotes the level of population in MSA i at time t. $f(.)$ is a Cobb-Douglas production function and is common across cities, where

$$f(L_{it}) = L_{it}^{\alpha}$$

with α a national production parameter.

- Individuals who work earn the marginal product of labor as their wages, with normalized output prices:

$$W_{it} = \alpha Z_{it} L_{it}^{\alpha-1}$$

- And quality of life captures socio-economic factors specific to a location that is declining in the size of the city:

$$\Lambda_{it} = L_{it}^{-\delta} Q_{it}$$

  where $\delta > 0$ and Q_{it} a vector capturing the variety of local conditions.
- Individuals derive utility from their labor income and the enjoyed quality of life, entering as a product:

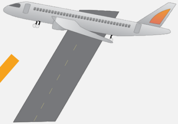
$$U_{it} = W_{it} \Lambda_{it}$$

Urban Growth Theory

METRO AREA

Production: (productivity, production function (population/labor supply))

Aviation: drives productivity + local amenity



Change in productivity = Change in Air Activity + other factors
Change in local amenity = Change in Air Activity + other factors

Utility: (Wages (productivity, population), quality of life)

Combining and substituting …

Change in Utility = Change in Wage + Change in Quality of life
= Change in Productivity + change in pop + change in amenity

Using Cobb-Douglas production and utility functions, we can derive the following models:

$$\dot{L}_i = \tilde{\beta}_1 \dot{A}_i + X'_{i,T_0} \tilde{\gamma}_1 + \varepsilon_{it}$$
$$\dot{W}_i = \tilde{\beta}_2 \dot{A}_i + X'_{i,T_0} \tilde{\gamma}_2 + \xi_{it}$$

L: labor supply/population, W: income, A: Air transport measure, X: other observables; i: region

Aviation in a spatial knowledge world (Adapting Davis and Dingel 2013)

- Individuals consuming three goods: tradables, non-tradable services, and non-tradable housing.
- The indirect utility function is given by

$$V(p, I) = I_c - p_{s,c}\bar{s} - p_{h,c}$$

- where consumers in city c have income I and expend on $\bar{s}$, housing h, and tradables (numeraire).
- Consumers are perfectly mobile across sectors.
- Choice of location and occupation maximizes V.
- "Low skill" people in this model will specialize in non-tradables by comparative advantage

Aviation in a spatial knowledge world (Adapting Davis and Dingel 2013)

- You can gain knowledge and increase productivity!
- Production of tradables is increasing in individual ability z and depends on learning opportunities available in the city, Z_c
- Tradable producers have one unit of time to divide between production (β units of time) and interaction ($1-\beta$ units of time)
- An agent with ability z produce tradables output

$$\tilde{z}(z, Z_c) = \max_{\beta \in [0,1]} \beta z(1 + (1-\beta) G Z_c z)$$

- G denotes a common productivity parameter of learning.
- Two classes of equilibria: all cities have the same population sizes or heterogeneous cities.

Aviation in a spatial knowledge world (Adapting Davis and Dingel 2013)

- Include aviation connectivity as a factor increasing probability of encounter m, with M_c time spent interacting by all

$$Z_c \equiv m(M_c, A_c)\bar{z}_c$$

- Introduce aviation as a factor that reduces the opportunity cost interacting, i.e.

$$M_c = f(L, \beta, \mu(z, c), A_c)$$

- Add aviation as a new sector: the *enabling* sector that is the "helper" for improving tradables productivity; has value itself, consumed by individuals - endogenizing aviation in the model

Empirical Model

Combining both the urban growth model and the spatial knowledge model we can write down an empirical model to be estimated, where outcomes of interest are changes in socioeconomics (e.g. income, labor) and innovation activity (e.g. patenting that increases as a result of higher encounter probability induced by aviation).

Estimate: Effect of Transport Network on Outcomes of Interest

$$y_i = \alpha + \rho c_i + \boldsymbol{X}\beta + \varepsilon_i$$

y: change in population growth, GDP, employment, patents etc; c: transport activity or connectivity; i: region

Data and Instrument

Data Sources for Economic Outcomes

Census and BEA Data

CA 30 - Economic Profiles - income and employment, BEA income and employment by industry/service sectors

U.S. Patent and Trademark Office

- Data available at the Patent and Trademark Office (raw registration data from 1975-present) as well as the National Bureau of Economic Research's Patent Data Project but only by inventor city based on address.
- The data is at the **inventor-patent** level with addresses and zip-codes with the granted year of the patent. Lai et al. (2011) created a inventor-patent instance that allows us to use both the granted unique patent and the authorship.

Parametrizing air transport facilitation

- Transport networks enable *accessibility*
- **Accessibility** includes the set of cumulative opportunities, transport costs, gravity, and utility (Allroggen 2013)

$$AC_i = \sum_{j=1}^{N} g(W_j) \cdot I_{ij}(\tau_{ij})$$

- where $g(W_j)$ is a function of the attractivity of j partners; I_{ij} the interaction weight of the partner, which is a function of τ_{ij} - resistance or costs between partners
- **Connectivity** through aviation can be applied to these measures to see how it affects regional growth.

Measuring aviation activity: some issues

- Measures of aviation through passenger volume, airport size, number of flights can be biased
- Alternative: the ***Global Connectivity Index***

$$GCI_{a,t} = \sum_{r \in R_{a,t}} \alpha_{a,t} f_{r,t} w_{d_r,t}$$

- a: airport, d: destination airport, R: set of routings, α: directness, f: frequency, w: destination quality, t: time
- Opportunity costs of transfer and layover are taken into account.
- In the one-stop index, transfer and layover are taken into account. NYC only has 10 more million pax, but 2.5x the connectivity than ATL.

GCI Construction (Allroggen 2018)

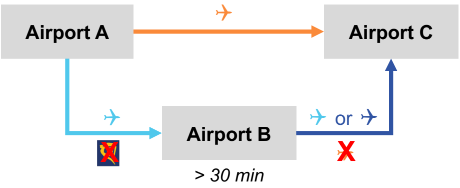
Route builder

From full-year OAG files, we analyze all permutations of nonstop and one-stop connections

+

Identify valid connections

- ***Nonstop routings***
- **Onestop routings if**
  1. the minimum connecting time is met *AND*
  2. the airline sells connecting tickets *AND*
  3. both flights are operated by the same airline OR under a codeshare agreement



World GCI, 2012

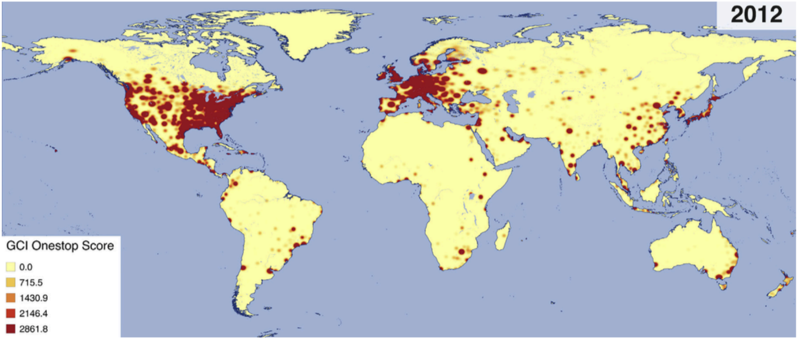
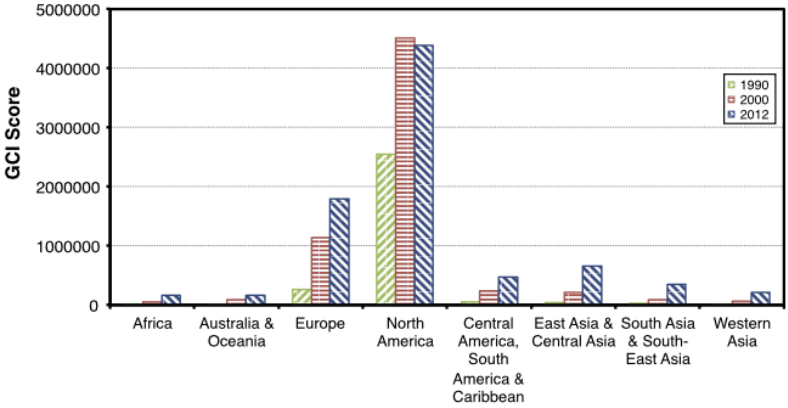


Fig. 7b. World map of onestop GCI – year 2012.

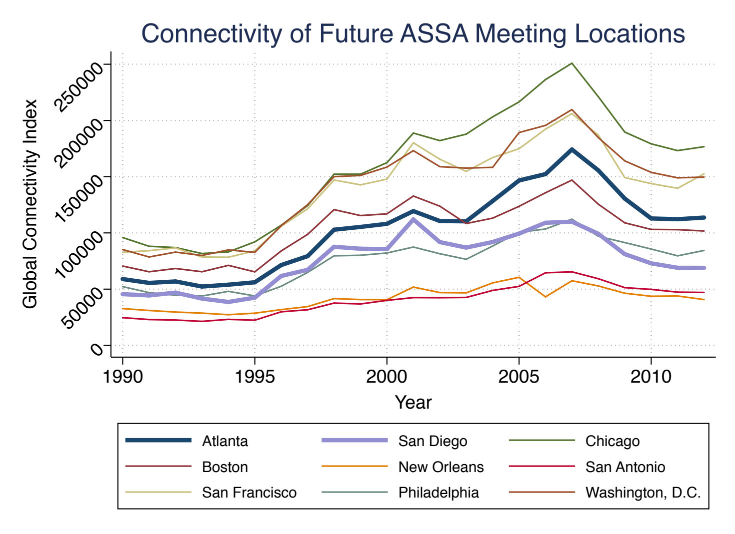
US by far has the largest connectivity via aviation



Note: The definition of world regions is presented in Appendix B.

Fig. 9a. Onestop connectivity distribution by world region – onestop GCI.

Is there enough variation in GCI data?



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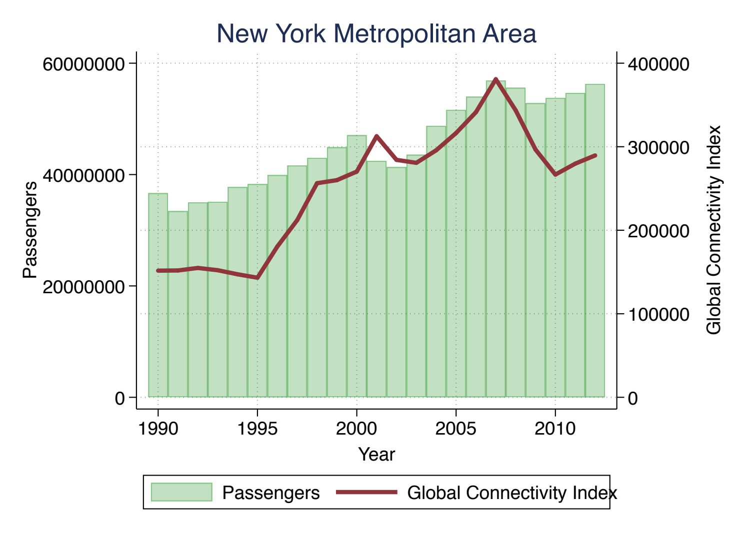

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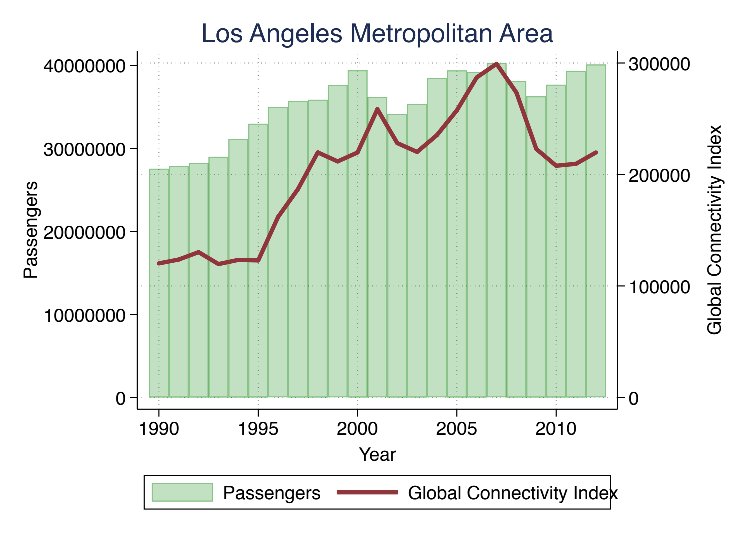
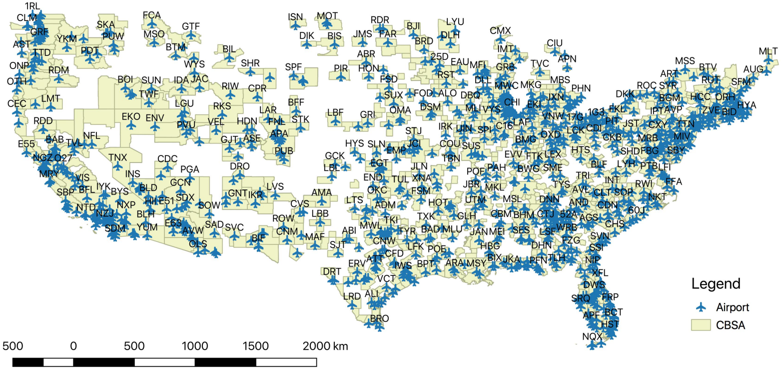
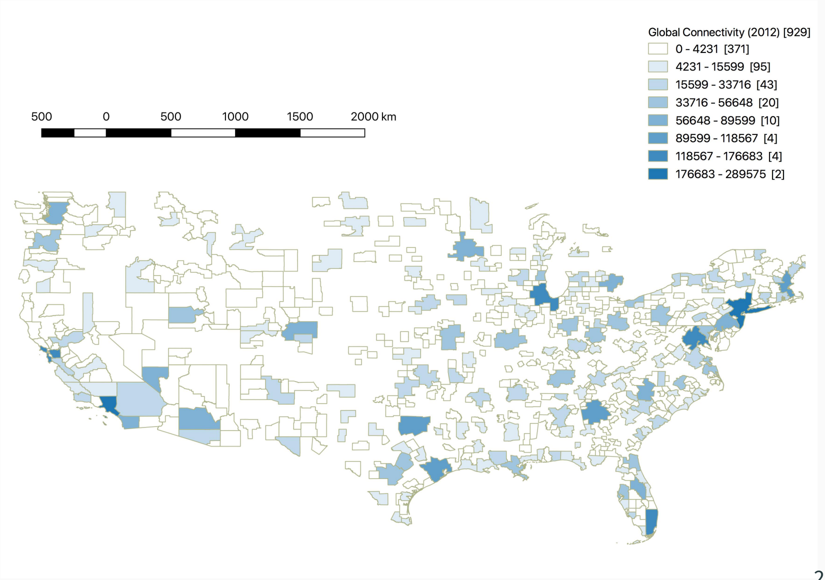


Airport-CBSA Correspondence



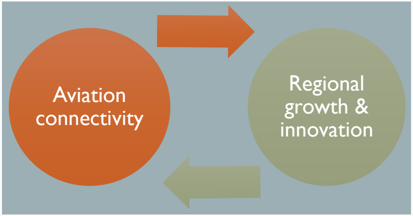
Aviation Connectivity in 2012



Data Preparation and Construction

- Spatial correspondence of airports and GCI to CBSAs
- Socioeconomic data collection at the CBSA level
- Pairing of connectivity data to socioeconomic time series
- Adding Bureau of Transportation aviation statistics for robustness
- Innovation data: Patent database at zipcode level - time-series geospatial sorting and city matching
- Construction of IVs

Empirical Problem



Endogeneity Problem

1. Presence of aviation sector brings jobs, creates new interaction opportunities, allows for business expansions, connects populations - thus drive changes in our outcomes
2. But it is also observed that increased economic activity in turn raises travel demand, driving increases in air links - based on demand analysis

Approach to Endogeneity Problem

Instrumental Variables (Redding and Turner 2015)

1. Planning: variation in the observed infrastructure
2. Historical route: old transportation routes as quasi-random variation
3. Inconsequential place: "accidental" infrastructure

Applications of IV to aviation thus far

Hubs/De-hubbing (Brueckner 2003, McGraw 2016)
Airport Plans, Historic air-mail routes (Sheard 2014/2015, McGraw 2015)
Herfindahl index and through-traffic share; network change
Bartik Instrument (LeFors 2014, Sheard 2017)
City pairs & 6000-mile discontinuity (Campante & Yanagizawa-Drott 2016)

Construction of IVs

What are the ingredients to expand on air activity?

- **Institutions** that lead to the birth of airports/construction of new runways/mixed civil and military use by navy, air force, local transport authorities
- **Railroad access:** historic transport routes and transportation of construction materials; or loss of railroad access (need for a replacement)
- **Old Money:** Businesses that began airlines; tourist destinations and attractions in the past
- **Land:** flat, cleared, open, or near coast; longer runway potential; not too close to settlements (noise) but not too far for access. E.g. Ag land that can be cleared or shrunk; slope - can't build on a hill!

Instrumental Variables: Primary

Two Key Conditions

- Relevance: The instrument has to be a **determinant** of the endogenous variable in question.
- Exogeneity: The instrument has to be conditionally **uncorrelated** with the error term u.

Institutions

- Presence of military installations?
- Was there a designated air traffic control airport (ATC) for navigational purposes?

Instrumental Variables: Secondary

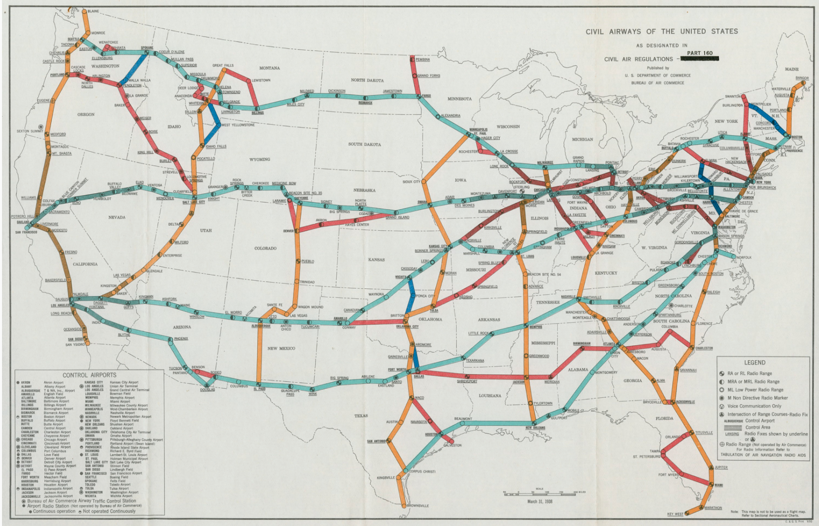
Economic Geography

- Was there historic presence of tourism/attractions?
- Does the city already sit in a “traffic shadow” of a major city given the highways and connections then?
- Was there overnight rail service? Did the dawn of Amtrak remove rail connections?

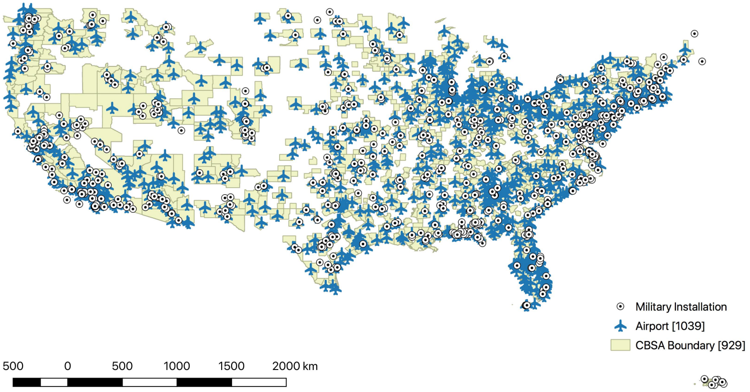
Land Use and Phyiscal Geography:

- What were the land use ratios before deregulation of aviation?
- How steep is the CBSA on average?

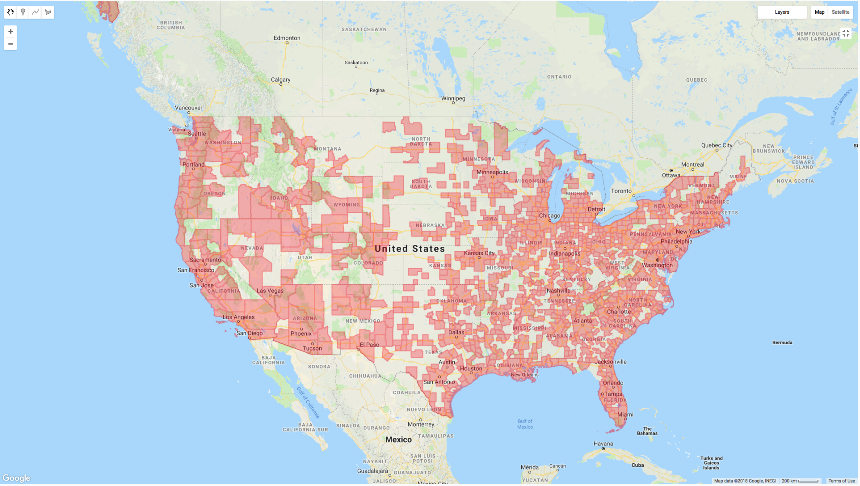
Air Traffic Control in 1938: Radio Stations and Landmarks needed for navigation



Military Installations

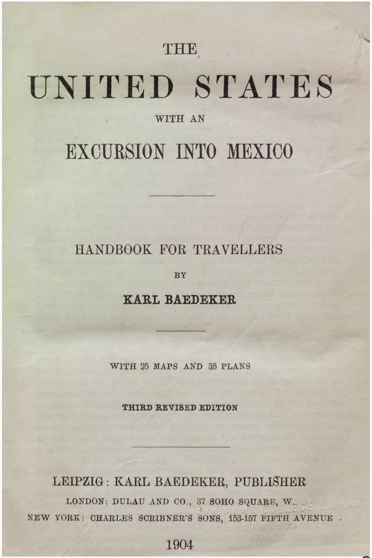


Land use in 1970 (USGS D240)



Historic Tourism/Attraction: 1904 Baedecker Travel Guide

- Relevance: Historic tourism likely to create air service supply (first) in the future
- Exogeneity: Old attractions do not necessarily create innovation
- Examples: Baedecker, Blue guides, Frommer's, Fodors, Michelin
- Use page span, chapter names, presence of maps to generate variation


THE

UNITED STATES

WITH AN

EXCURSION INTO MEXICO

HANDBOOK FOR TRAVELLERS

BY

KARL BAEDEKER

WITH 25 MAPS AND 35 PLANS

THIRD REVISED EDITION

LEIPZIG: KARL BAEDEKER, PUBLISHER

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NEW YORK: CHARLES SCRIBNER'S SONS, 153-157 FIFTH AVENUE

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Historic Tourism/Attraction: 1904 Baedecker Travel Guide

Historic Traffic Shadow: Access to a bigger CBSA for aviation - Taaffe 1956

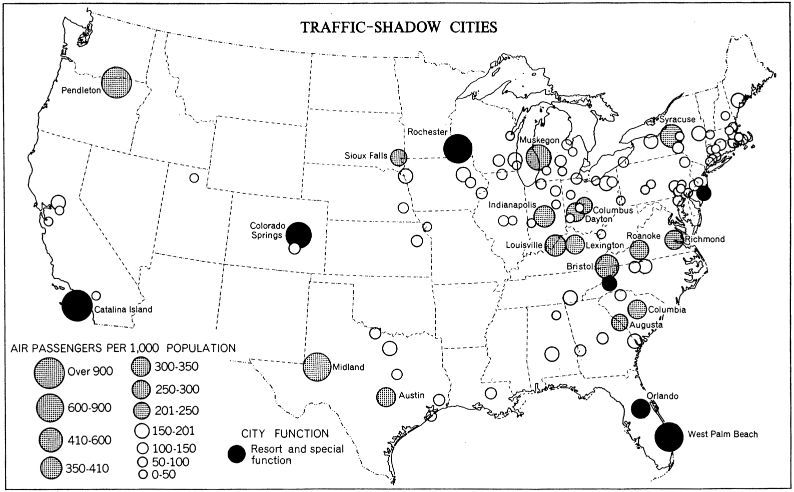

FIG. 5—Passenger indexes of those cities within 120 highway miles of a larger city or metropolitan area. Named and shaded cities are those with high indexes (more than 201). Resort and special-function cities are black; the five named are high-index, the unnamed (Atlantic City and Asheville) low-index cities.

Historic Traffic Shadow: Access to a bigger CBSA for aviation - Taaffe 1956

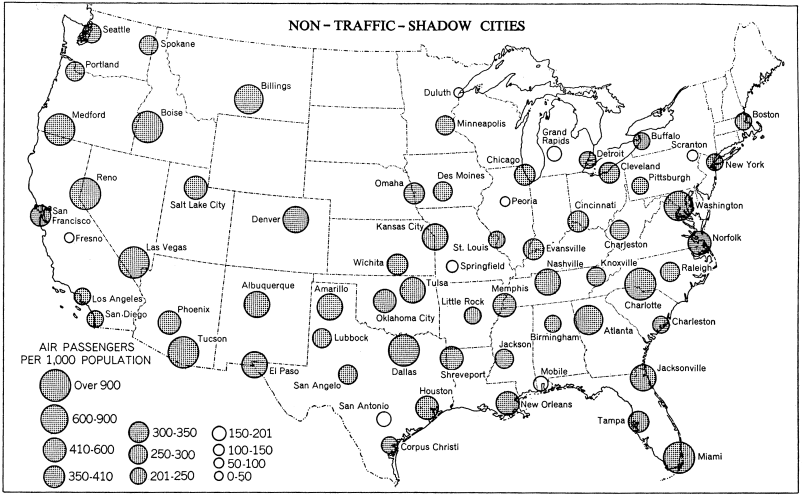

FIG. 6—Passenger indexes of those cities which do not have a larger city or metropolitan area within a radius of 120 highway miles. All cities are named, but only high-index cities are shaded.

Results

Estimate: Effect of Transport Network on Outcomes of Interest

$$\Delta y_{i,1990-2012} = \alpha + \beta c_{i,2012} + \boldsymbol{x}'_{2,i}\gamma + \varepsilon_i \tag{1}$$

y: outcome: GDP, employment, patents; c: transport activity or connectivity; i: region

Method: Using IVs. 2SLS

	(1)	(2)	(3)	(4)
	1.Stage 2012 GCI	*2.Stage* Δ Income	*1.Stage* 2012 GCI	*2.Stage* Δ Income
ATC Control Airport	22012.2***			
	(3819.8)			
Δ Emp	0.0969***	64.01†	0.110***	76.66
	(0.0109)	(34.75)	(0.0120)	(48.09)
2012 GCI Sum		1254.7***		1149.9***
		(154.2)		(282.2)
Military Installment			1383.3***	
			(342.7)	
SW F statistic	33.21		16.29	
SW p-value	1.38e-08		0.0000622	
J stat p-value				
N	549	549	549	549
Partial R^2	0.305		0.0886	
R^2		0.893		0.891

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1: 2SLS: Change in total personal income (1990-2012) - Preferred Instruments

	(1)	(2)	(3)	(4)
	1.Stage 2012 GCI	*2.Stage* Δ Income	*1.Stage* 2012 GCI	*2.Stage* Δ Income
Attraction	1069.0***		1292.4***	
	(178.8)		(263.0)	
Military Installment	770.7***		996.3***	
	(224.4)		(215.6)	
ATC Control Airport	15172.5***			
	(3275.4)			
Δ Emp	0.0800***	-4.092	0.0886***	-47.66
	(0.00812)	(32.24)	(0.00847)	(52.69)
2012 GCI Sum		1818.4***		2179.4***
		(344.4)		(514.7)
% of Transport Landuse 1970			434339.3**	
			(146873.9)	
SW F statistic	22.25		18.71	
SW p-value	1.33e-13		1.48e-11	
J stat p-value		0.238		0.282
N	549	549	546	546
Partial R^2	0.495		0.388	
R^2		0.874		0.841

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

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Table 2: 2SLS: Change in total personal income (1990-2012)

	(1) Δ Income	(2) Δ Income (GMM)	(3) Δ Emp	(4) Δ Emp	(5) Δ All Patent	(6) Δ Unqiue Patent
2012 GCI Sum	1818.4***	1336.8***	2.335***	1.839***		
	(344.4)	(190.5)	(0.550)	(0.405)		
Δ Emp	-4.092	23.52			-0.00204	-0.000332
	(32.24)	(27.29)			(0.00189)	(0.000625)
Δ Population			0.443***	0.478***		
			(0.0392)	(0.0332)		
2010 GCI Sum					0.0612***	0.0181**
					(0.0167)	(0.00552)
J stat p-value	0.238	0.238	0.0947	0.0552	0.104	0.172
N	549	549	549	549	496	482
R^2	0.874	0.876	0.969	0.972	0.377	0.365

Standard errors in parentheses

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Table 3: 2SLS: Second Stage Results

	(1) Δ Service Y	(2) Δ Service M	(3) Δ Service Y-Share	(4) Δ Service M-Share
2012 GCI Sum	-16.50	1.920**	-0.000000876†	-3.50e-08
	(72.80)	(0.595)	(0.000000511)	(0.000000164)
Δ Income	0.300***		4.14e-10	
	(0.0364)		(2.69e-10)	
Δ Emp		0.238***		1.79e-08
		(0.0618)		(2.04e-08)
J stat p-value	0.262	0.227	0.249	0.0749
N	157	549	157	549
R^2	0.964	0.911	-0.103	-0.00166

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: 2SLS: Change in Service Sector Outcomes between 1990 and 2012. Tourism/Attraction IV for Service Income replaced by Traffic Shadow

	(1) Δ Income	(2) Δ Income	(3) Δ Emp	(4) Δ Emp	(5) Δ All Inventors	(6) Δ All Inventors
2012 GCI Sum	2039.1***	274.9*	2.550***	1.948*		
	(383.7)	(131.0)	(0.577)	(0.859)		
Δ Emp	-9.819	62.41***			-0.00210	0.00177***
	(33.16)	(12.35)			(0.00206)	(0.000536)
Δ Population			0.444***	0.473***		
			(0.0371)	(0.0326)		
2010 GCI Sum					0.0622**	-0.00749†
					(0.0209)	(0.00449)
N	100	268	100	268	100	217
R^2	0.847	0.470	0.957	0.646	0.264	-0.0846

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: 2SLS Results: Large vs Small Cities - mulitple equilibria?

Results Summary

Connectivity, Income, and Innovation

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Example: Atlanta vs. San Diego

If San Diego increased its connectivity to Atlanta levels, the model would predict long-term income increases in the order of $73 billion.

Threshold effects?

Only larger cities benefit from connectivity increases (top 100 in population).

Takeaways

Instruments

ATC Control Airports and Military Installments are preferred instruments

Coefficients around 10% lower than using lagged socioeconomic variables as IVs

Connectivity Effects

Long-term significant improvements in total personal income, employment, and granted patent activity

Unclear: service sector incomes, employment, shares, per capita income (employment rate and nature may have changed)

Takeaways

Innovation

Significant effects for granted patents (all activity) and unique patenting activity

100-pt increase in GCI => around 6 more patents

Threshold effects?

Effects diminish with smaller CBSAs; connectivity impacts are larger for larger cities

Conclusion

Conclusion

- This paper used an improved measure of aviation connectivity by taking into account one-stop and non-stop connections to study the effect of aviation on regional economies
- For the first time showed potential effects on innovation
- Constructed and used three new sets of instruments based on the prerequisites to future airport development, air activity increases, and industrial requirements
- Showed an improvement over using lagged socioeconomic variables
- Found mixed results with service sector - further specifications needed

Conclusion

- In the mean-connectivity city: a 100-point increase in GCI in 2012 = 1.03% increase, with an increases in income at 1.87% and a 30% increase in patent activity.
- If San Diego increased its connectivity to Atlanta levels (an increase in GCI of 44,721), the model would predict long-term income increases in the order of $73 billion.
- Aviation connectivity could have significant spillovers into the economy through total income and innovation - value, productivity, labor force participation could be at play, as well as sectoral shifts
- Economic complexity, relatedness, and other measures of innovation and inventiveness would be of interest (Hidalgo et al)

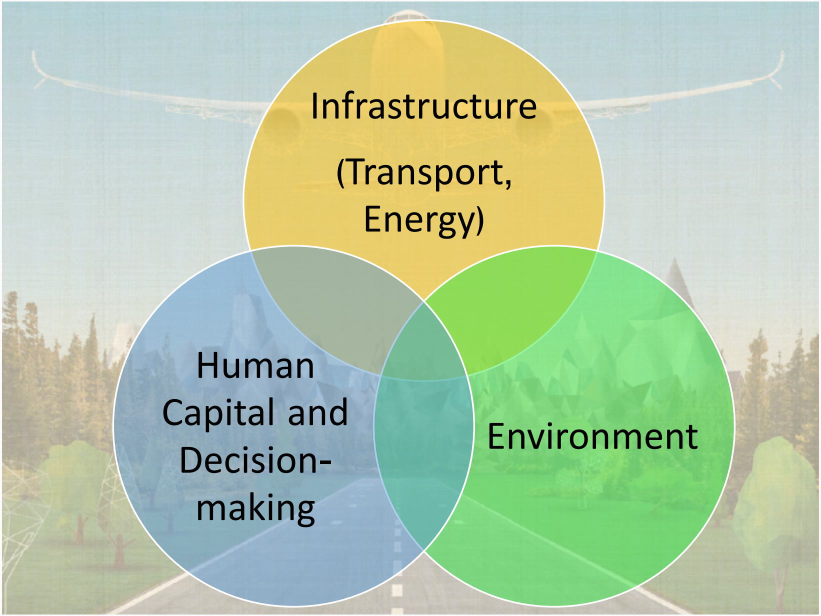
Further Work

- Winners, Losers, or win-win?
    - Do gains in one area offset losses in another? Inter-jurisdictional competition
    - Competition versus induced demand effects
- Patents do not measure innovation perfectly
    - Patent inventor movement, citation networks - somewhat possible with current data
    - Conferences, collaborators on articles (Catalini et al 2016)
- Who benefits from aviation? How do LCCs change the game?
- Contemporaneous health (e.g., Schlenker and Walker 2016)
- Conflict and crime (intercultural understanding)
- Stress and mental health (congestion externality, over-bookings, security times; aviation staff stress)
- Disamenity-amenity tradeoff

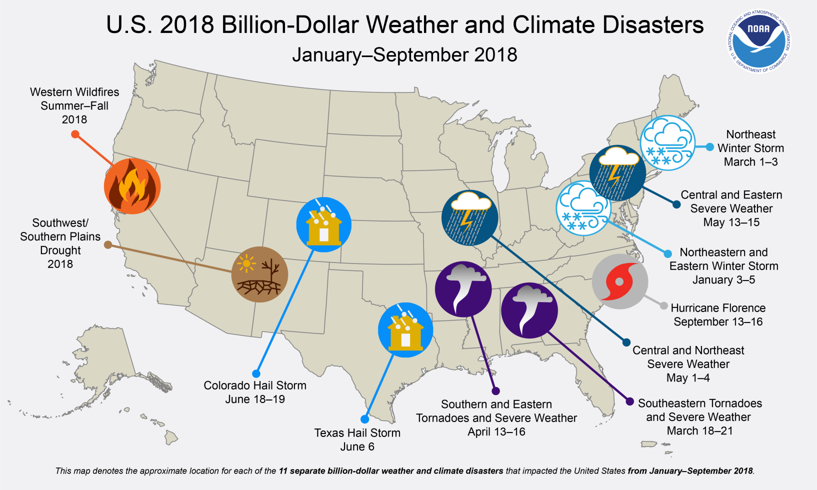
Thank you for your attention and feedback!

My website: https://jasoncwong.com

My Research

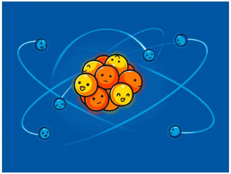

Infrastructure
(Transport, Energy)
Human Capital and Decision-making
Environment

Climate Change Impacts on Aviation Infrastructure



Carbon Offsetting and Reduction Scheme for International Aviation - Would CORSIA work?

Charismatic Carbon: Bundling Private and Public Goods versus Offsetting Externalities



- Carbon offset is **heterogeneously** provided - bundled with different characteristics for the very same ton, sold by different sellers (e.g. ETS, offset companies, CDM credits)
- Joint production of a private and an environmental good
- **Does behavior differ when one faces a choice between a public good and the option to offset the externalities associated with their consumption?**

Other research topics

- Ongoing projects: Energy access and sustainability in India
    - Willingness to pay for electricity improvements
    - Social acceptability of theft
    - Incentives for solar lantern adoption
- Measurements of innovation, social connectedness and their relationship with transport
- Climate change, infrastructure, and mobility

Appendix

- Instrumental Variables
- Literature
- Theory
- Simple Stats
- Additional Results/Robustness Checks

Appendix - GCI

GCI Construction

1. Nonstop routings: A nonstop routing r consists of a single scheduled flight which links departure airport a_r to destination airport d_r without a (non-technical) stop. Derived from flight schedules as published in the Official Airline Guide (OAG). It is obtained by listing all scheduled passenger flights, which depart airport a during year t.
2. Onestop routings: A onestop routing r links its departure airport a_r to its destination airport d_r through two scheduled flights and a transfer at layover airport l_r. For each nonstop flight, we list all connecting flights in airport l_r's flight schedule to build all potential onestop routings. 30 min minimum and codesharing required.

ATL vs SAN

- GCI 2012: ATL 113671.6, SAN 68950.34. $\Delta = 44721.26$.
- But: ATL sees 46 million pax vs 9 million pax in SAN!
- Compare to NYC: 56 million pax, GCI is better than ATL: 289574.5
- Predict with diff. in Emp changes: Δ Income = 73,368,904,000.

Appendix - IVs

Overnight Rail and Rail Replacement - Taaffe 1956

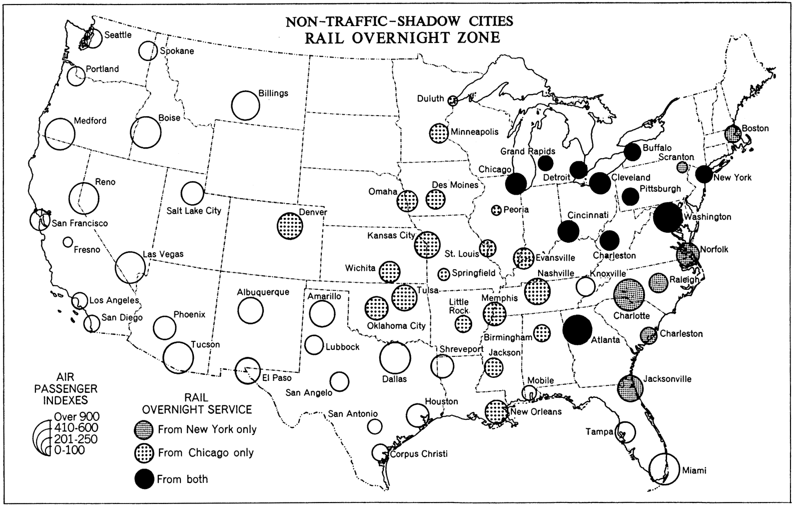
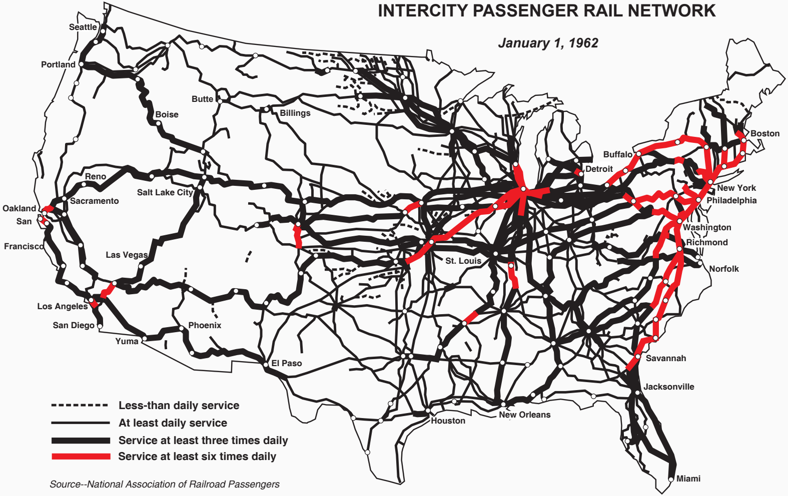
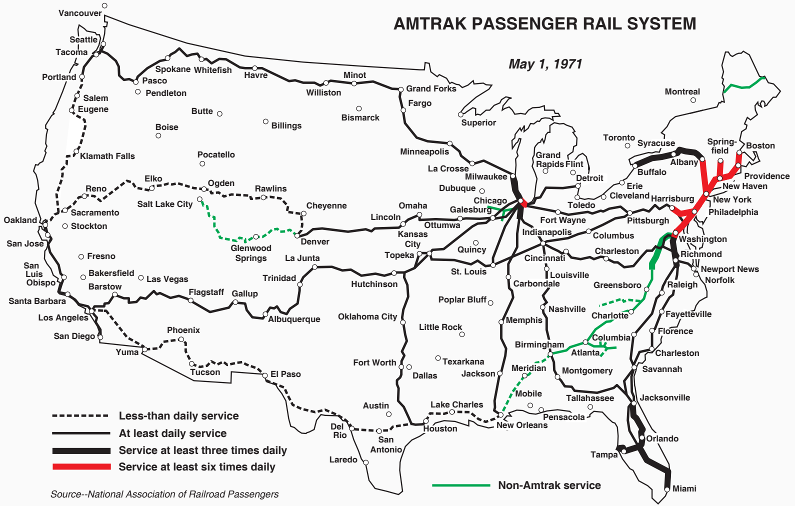


FIG. 8—Rail overnight service from New York or Chicago, here defined as that service which comes within at least one hour of a 4:00 p.m. departure and a 9:30 a.m. arrival, local standard time. (Source: "Official Guide of the Railway and Steam Navigation Lines of the United States . . .", National Railway Publishing Co., New York, 1951.)

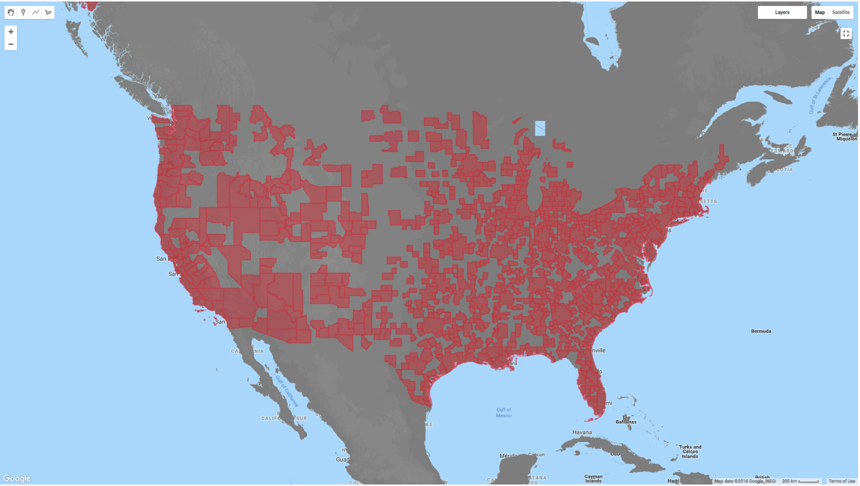
Overnight Rail and Rail Replacement - National Assoc. of Rail-way Passengers



Overnight Rail and Rail Replacement - National Assoc. of Railway Passengers



SRTM Digital Elevation Data V4 - GE Engine



Appendix - Literature

Authors	Geo	Time	Aviation Measure	IV/Identification	Dependent Var.	Result
Brueckner (2003)	91 U.S. Metro areas	1996	Enplanement	Hubs	Service Employment	1% + with 10% increase in enplanement, 185,000 ORD 50% expansion effect on jobs
Sheard (2014)	290 U.S. CBSA	1999 - 2011	Log Departures	1944 National Airport Plan	Service Employment	1650 jobs with 10% growth in air traffic
LeFors (2014)	153 U.S. MSA	2000, 2007	Air access metric, DB1B	Herfindahl index and through-traffic share	Service Employment	26% + with 1 SD change in air access
Sheard (2015)	183 U.S. CBSA	1991 - 2013	Air traffic segment (T-100)	Airlines, the aircraft types, and the approximate distances of the flight growth rates (Bartik Instrument)	Economic growth, employment	4.4 jobs outside airport for 1 airport job
Blonigen & Cristea (2015)	263 U.S. MSA	1969 - 1991	Passenger Growth – FAA Airport Activity Stat. of Carriers	1978 Deregulation (quasi-natural policy experiment)	Growth in Pop, income, employment	7.4 % GDP generated from 50% growth in air traffic

Authors	Geo	Time	Aviation Measure	IV/Identification	Dependent Var.	Result
McGraw (2015)	U.S. CBSA (small-med)	1950 - 2010	Airport presence	Air Mail system of 1938, 1922 Air Defense System, Emergency Air Fields	Population, income, employment	3.2 percent employment growth per decade in non-tradable services; mixed results for other variables
Campante & Yanagizawa-Drott (2016)	Global city pairs (819)	1992 - 2010	ICAO - Traffic by flight stage	6000-mile discontinuity in connectedness	Night light for economic growth, population, FDI	+, connections lead to connections?, capital flow from high to middle income
Catalini, Fons-Rosen, Gaule (2016)	Scientists	1991 - 2012	DB1B Origin-Destination	DiD, LCC Entry	Papers published, collaborations	Southwest entry increased collaboration by 50%, stronger effect on young scientists

Appendix - Theory

Urban Growth Theory

- Extending Glaeser et al. (1995)'s urban growth framework by introducing aviation (Blonigen and Cristea 2015)
- Idea: aviation enters model as a driver for growth in productivity and local amenity value
- Let the total output of an area be given by

$$Y_{it} = Z_{it} f(L_{it})$$

where Z_{it} denotes the level of productivity within CBSA i at time t, L_{it} denotes the level of population in MSA i at time t. $f(.)$ is a Cobb-Douglas production function and is common across cities, where

$$f(L_{it}) = L_{it}^{\alpha}$$

with α a national production parameter.

Urban Growth Theory

- Individuals who work earn the marginal product of labor as their wages, with normalized output prices:

$$W_{it} = \alpha Z_{it} L_{it}^{\alpha-1}$$

- And quality of life captures socio-economic factors specific to a location that is declining in the size of the city:

$$\Lambda_{it} = L_{it}^{-\delta} Q_{it}$$

  where $\delta > 0$ and Q_{it} a vector capturing the variety of local conditions.

- Individuals derive utility from their labor income and the enjoyed quality of life, entering as a product:

$$U_{it} = W_{it} \Lambda_{it}$$

Urban Growth Theory (Glaeser et al. 1995; Blonigen and Cristea 2015)

- Assuming free migration - labor mobility across cities, each individual's utility equals the reservation utility levels at any city at any time in equilibrium, so $U_{it} = U_t, \forall i$. Therefore, for each city,

$$\log\left(\frac{U_{t+1}}{U_t}\right) = \log\left(\frac{W_{i,t+1}}{W_{it}}\right) + \log\left(\frac{\Lambda_{i,t+1}}{\Lambda_{it}}\right)$$
$$= \log\left(\frac{Z_{i,t+1}}{Z_{it}}\right) + (\alpha - \delta - 1)\log\left(\frac{L_{i,t+1}}{L_{it}}\right) + \log\left(\frac{Q_{i,t+1}}{Q_{it}}\right)$$

- Utility grows at a common rate across cities; pop. adjusts to reflect amenities
- Population growth rate can be expressed as:

$$\log\left(\frac{L_{i,t+1}}{L_{it}}\right) = \frac{1}{1-\alpha+\delta}\left[\log\left(\frac{Z_{i,t+1}}{Z_{it}}\right) + \log\left(\frac{Q_{i,t+1}}{Q_{it}}\right)\right] + \kappa_t$$

where $\kappa_t \equiv \log(U_{t+1}/U_t)/(\alpha - \delta - 1)$, a constant.

Urban Growth Theory (Glaeser et al. 1995; Blonigen and Cristea 2015)

- Taking annual growth rate of the wages equation and substituting the population growth rate above to yield:

$$\log\left(\frac{W_{i,t+1}}{W_{it}}\right) = \frac{1}{1-\alpha+\delta}\left[\delta\log\left(\frac{Z_{i,t+1}}{Z_{it}}\right) + \log\left(\frac{Q_{i,t+1}}{Q_{it}}\right)\right] + \omega_t$$

where $\omega_t \equiv (\alpha - 1)\kappa_t$, a constant.

- Taking annual growth rate of the wages equation and substituting the population growth rate above to yield:

$$\log\left(\frac{W_{i,t+1}}{W_{it}}\right) = \frac{1}{1-\alpha+\delta}\left[\delta\log\left(\frac{Z_{i,t+1}}{Z_{it}}\right) + \log\left(\frac{Q_{i,t+1}}{Q_{it}}\right)\right] + \omega_t$$

where $\omega_t \equiv (\alpha - 1)\kappa_t$, a constant.

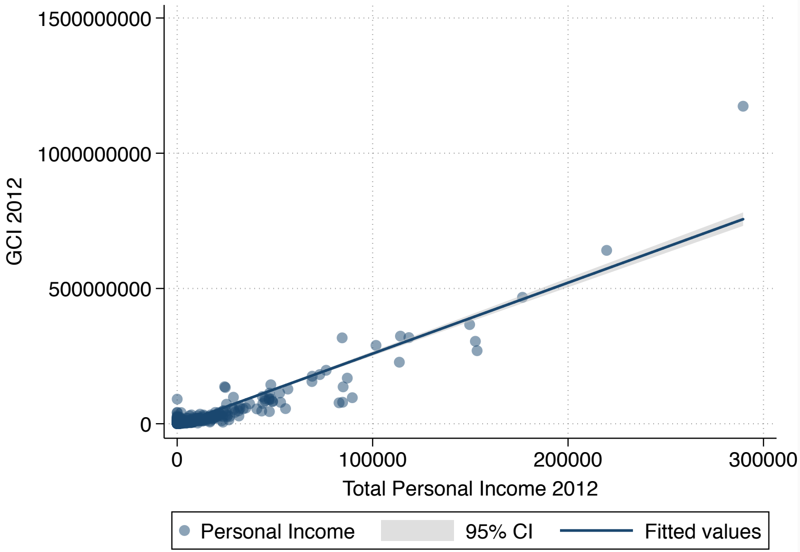
By substitution we may derive the reduced form for log growth rates as

$$
\begin{aligned}
\dot{L}_i &= \tilde{\beta}_1 \dot{A}_i + X'_{i,T_0} \tilde{\gamma}_1 + \varepsilon_{it} \\
\dot{W}_i &= \tilde{\beta}_2 \dot{A}_i + X'_{i,T_0} \tilde{\gamma}_2 + \xi_{it}
\end{aligned}
$$

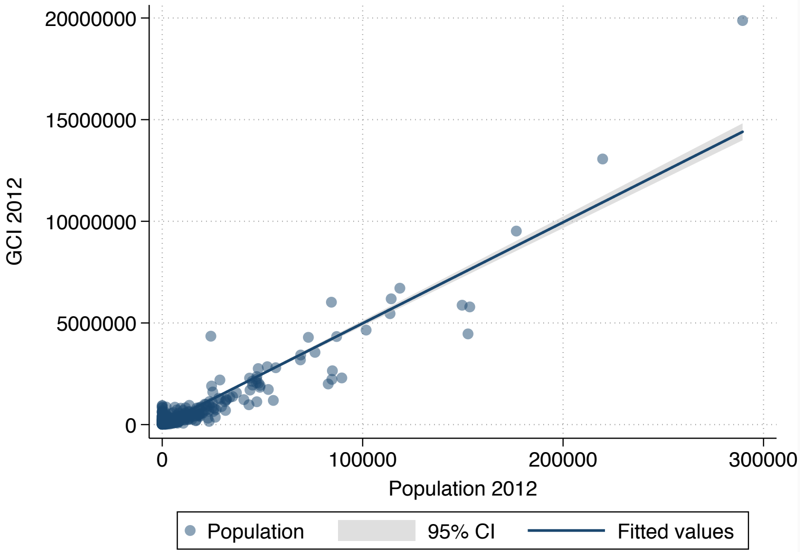
L: labor supply/population, W: income, A: Air transport measure, X: other observables; i: region

Simple Stats

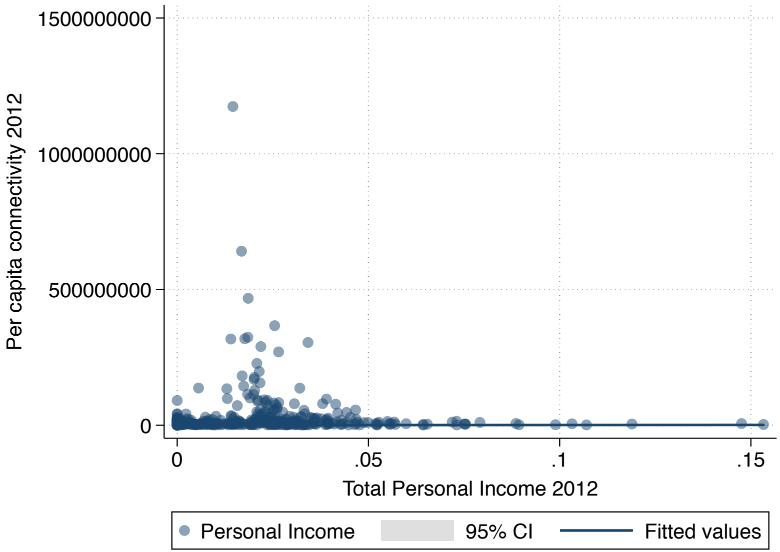
Income and GCI



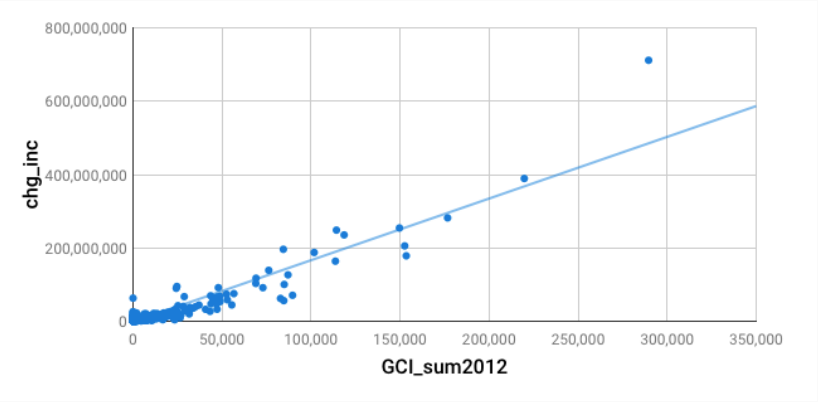
Population and GCI



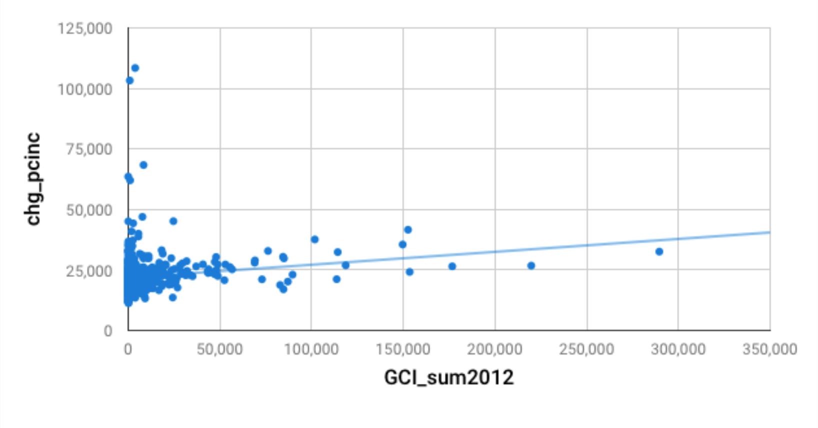
Population and per capita GCI



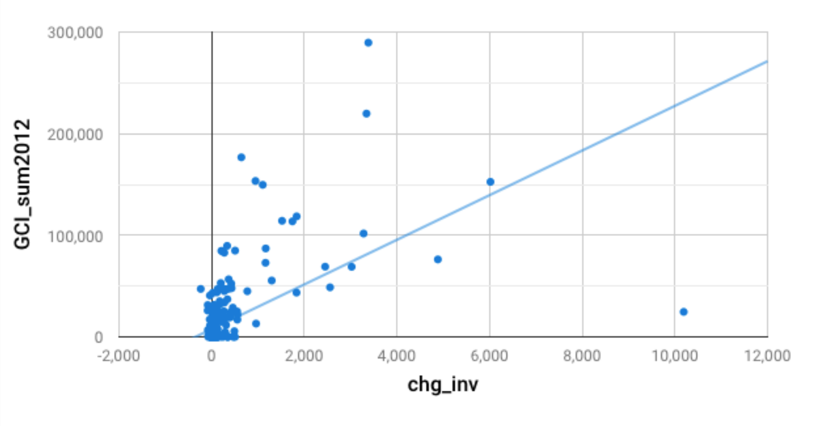
△ Income and GCI



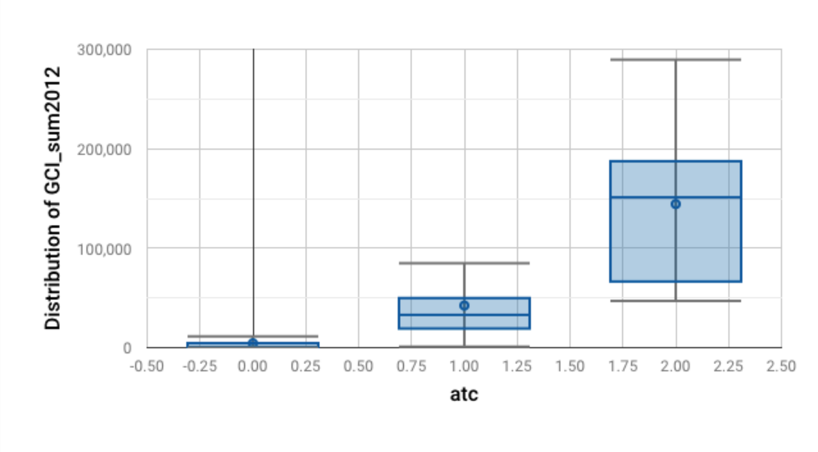
△ Per capita Incomeand GCI



△ Patent and GCI

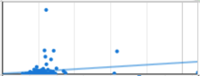
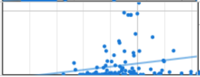
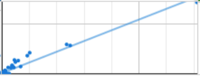


△ ATC and GCI

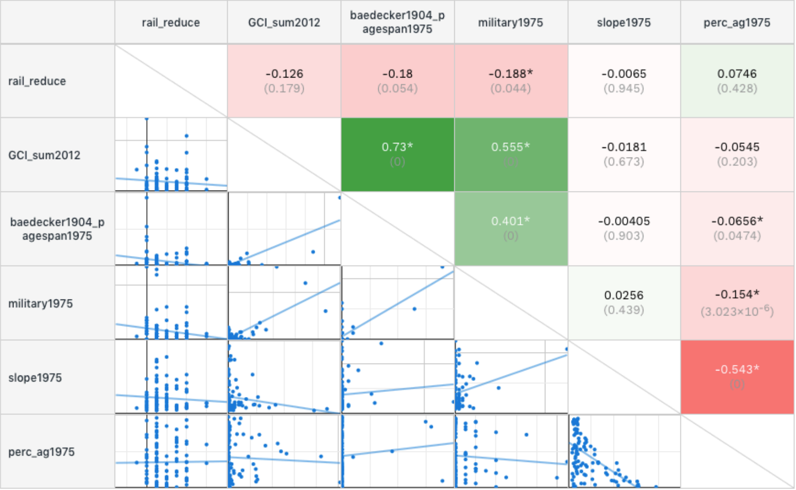


Distribution of GCI_sum2012
300,000
200,000
100,000
0
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
atc

Correlation Matrix 1

	chg_pcinc	chg_inc	GCI_sum2012
chg_pcinc		0.191* (5.500×10^{-9})	0.171* (0.0000545)
chg_inc			0.938* (0)
GCI_sum2012			

Correlation Matrix 2



	rail_reduce	GCI_sum2012	baedecker1904_pagespan1975	military1975	slope1975	perc_ag1975
rail_reduce		-0.126 (0.179)	-0.18 (0.054)	-0.188* (0.044)	-0.0065 (0.945)	0.0746 (0.428)
GCI_sum2012			0.73* (0)	0.555* (0)	-0.0181 (0.673)	-0.0545 (0.203)
baedecker1904_pagespan1975				0.401* (0)	-0.00405 (0.903)	-0.0656* (0.0474)
military1975					0.0256 (0.439)	-0.154* (3.023×10^{-6})
slope1975						-0.543* (0)
perc_ag1975						

Additional Tables

	(1) 2012 GCI Sum	(2) Δ Income	(3) 2012 GCI Sum	(4) Δ Income
Attraction	1069.0***		1292.4***	
	(178.8)		(263.0)	
Military Installment	770.7***		996.3***	
	(224.4)		(215.6)	
ATC Control Airport	15172.5***			
	(3275.4)			
Δ Emp	0.0800***	-4.092	0.0886***	-47.66
	(0.00812)	(32.24)	(0.00847)	(52.69)
2012 GCI Sum		1818.4***		2179.4***
		(344.4)		(514.7)
% of Transport Landuse 1970			434339.3**	
			(146873.9)	
AR F statistic		19.45		23.01
AR p-value		5.39e-12		4.93e-14
J stat p-value		0.238		0.282
N	549	549	546	546
Partial R^2	0.495		0.388	
R^2		0.874		0.841

Standard errors in parentheses

Odd columns show first-stage results with Anderson-Rubin first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Adding Anderson-Rubin (1949) Weak Instrument Test

	(1) 2012 GCI Sum	(2) Δ Income	(3) 2012 GCI Sum	(4) Δ Income	(5) 2012 GCI Sum	(6) Δ Income
Attraction	1316.4***		1230.5***			
	(317.6)		(252.3)			
Traffic Shadow	0		-12020.9***			
	(.)		(2728.4)			
Overnight Rail Reach	6504.5					
	(4587.1)					
Δ Emp	0.0862***	-50.51	0.0835***	-29.82	0.0817***	-13.39
	(0.00968)	(56.29)	(0.00923)	(44.48)	(0.0112)	(39.54)
2012 GCI Sum		2489.0***		2140.3***		1900.0***
		(579.4)		(484.2)		(385.1)
% of Transport Landuse 1970			1025134.0**			
			(389988.4)			
National Airport Plan					0.00154**	
					(0.000474)	
Military Installment					552.4	
					(370.7)	
SW F statistic	13.92		14.87		14.87	
SW p-value	0.0000105		1.55e-08		1.55e-08	
J stat p-value		0.0429		0.0105		0.203
N	65	65	157	157	517	517
Partial R^2	0.414		0.436		0.436	
R^2		0.869		0.854		0.855

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Robustness: Varying instrument sets, including ones in the literature

	(1) 2012 GCI Sum	(2) Δ Income	(3) 2012 GCI Sum	(4) Δ Income	(5) 2012 GCI Sum	(6) Δ Income
Traffic Shadow	-9108.7**					
	(3221.6)					
Military Installment	1299.2*		1532.8*		1291.1*	
	(584.7)		(619.9)		(608.9)	
Slope	93.70		44.93		1060.6	
	(588.7)		(593.3)		(1096.7)	
Δ Emp	0.0998***	109.2†	0.105***	30.14	0.102***	28.75
	(0.0140)	(59.97)	(0.0140)	(56.88)	(0.0130)	(36.06)
2012 GCI Sum		920.7**		1645.6***		1766.9***
		(344.9)		(405.0)		(384.8)
Reduction in Rail			1967.2			
			(2063.8)			
Overnight Rail Reach					14405.5**	
					(5319.2)	
SW F statistic	5.158		3.259		3.259	
SW p-value	0.00201		0.0243		0.0243	
J stat p-value		0.00561		0.0374		0.781
N	157	157	115	115	66	66
Partial R^2	0.102		0.0791		0.0791	
R^2		0.869		0.891		0.910

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Robustness: Varying instrument sets

	(1) Δ Service Y	(2) Δ Service M	(3) Δ Service Y-Share	(4) Δ Service M-Share
2012 GCI Sum	8.778	1.138**	-0.000000594	-0.000000231
	(72.91)	(0.424)	(0.000000601)	(0.000000230)
Δ Income	0.287***		3.49e-10	
	(0.0416)		(3.37e-10)	
Δ Emp		0.324***		4.09e-08
		(0.0568)		(2.77e-08)
J stat p-value	0.222	0.350	0.195	0.0135
N	517	517	517	517
R^2	0.964	0.914	-0.0152	-0.00861

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Sector Shares: Using 1944 National Airport Plan as part of the IV

	(1) Δ PC Income	(2) Δ PC Income	(3) Δ PC Income	(4) Δ Population	(5) Δ Population
2012 GCI Sum	0.120***	0.120**	0.107**	-3.965**	-3.005*
	(0.0316)	(0.0377)	(0.0400)	(1.305)	(1.294)
Δ Emp	-0.00847*	-0.00880†	-0.00758†	2.051***	1.915***
	(0.00401)	(0.00461)	(0.00456)	(0.145)	(0.160)
J stat p-value	0.709	0.859	0.771	0.0387	0.0599
N	549	66	157	549	157
R^2	0.0204	0.149	0.0373	0.952	0.953

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: PC Income and Population - GCI Levels

	(1) Δ PC Income	(2) Δ PC Income	(3) Δ PC Income	(4) Δ Population	(5) Δ Population
chg_gci	0.297**	0.294**	0.266*	-10.69**	-7.509*
	(0.102)	(0.105)	(0.114)	(3.689)	(3.609)
Δ Emp	-0.00997†	-0.0109†	-0.00962	2.147***	1.974***
	(0.00532)	(0.00590)	(0.00604)	(0.197)	(0.201)
J stat p-value	0.473	0.659	0.497	0.0644	0.0653
N	549	66	157	549	157
R^2	0.000249	-0.103	-0.0266	0.933	0.945

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: PC Income and Population - GCI Change

	(1) Δ PC Income	(2) Δ PC Income	(3) Δ PC Income	(4) Δ Population	(5) Δ Population
chg_pcgci	415091.4**	910398.1*	273719.3	-5568404.5*	-7961204.3*
	(141631.5)	(416833.4)	(181602.5)	(2737413.6)	(4042690.4)
Δ Emp	0.00476***	0.00475**	0.00343**	1.589***	1.607***
	(0.00112)	(0.00161)	(0.00116)	(0.0828)	(0.102)
J stat p-value	0.0357	0.503	0.0182	0.00466	0.0193
N	549	66	157	549	157
R^2	-0.596	-1.356	0.0333	0.878	0.937

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: PC Income and Population - PC GCI Change

Robustness: Lagged variables as IV

	(1) 2012 GCI Sum	(2) Δ Income	(3) 2012 GCI Sum	(4) Δ Income
Income in 1970	0.00220***			
	(0.000604)			
Δ Emp	0.0788***	-91.66	0.0751***	-75.51
	(0.00887)	(65.71)	(0.00872)	(57.02)
2012 GCI Sum		2543.5***		2409.8***
		(611.6)		(544.8)
Population in 1970			0.0113***	
			(0.00272)	
PC Income in 1970			2.356**	
			(0.847)	
SW F statistic	13.31		20.62	
SW p-value	0.000289		2.33e-09	
N	548	548	548	548
Partial R^2	0.472		0.472	
R^2		0.790		0.810

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: 2SLS: Change in total personal income between 2012 and 1990

	(1) 2012 GCI Sum	(2) Δ PC Income	(3) 2012 GCI Sum	(4) Δ PC Income
Income in 1970	0.00220***			
	(0.000604)			
Δ Emp	0.0788***	-0.00112	0.0751***	-0.00678
	(0.00887)	(0.00344)	(0.00872)	(0.00438)
2012 GCI Sum		0.0586*		0.106**
		(0.0275)		(0.0368)
Population in 1970			0.0113***	
			(0.00272)	
PC Income in 1970			2.356**	
			(0.847)	
SW F statistic	13.31		20.62	
SW p-value	0.000289		2.33e-09	
N	548	548	548	548
Partial R^2	0.472		0.472	
R^2		0.0260		0.0230

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 14: 2SLS: Change in per capita income between 2012 and 1990

	(1) 2012 GCI Sum	(2) Δ Emp	(3) 2012 GCI Sum	(4) Δ Emp
Income in 1970	0.00266***			
	(0.000498)			
Δ Population	0.0439***	0.442***	0.0418***	0.446***
	(0.00513)	(0.0532)	(0.00503)	(0.0496)
2012 GCI Sum		2.346**		2.290**
		(0.868)		(0.814)
Population in 1970			0.0136***	
			(0.00216)	
PC Income in 1970			2.180**	
			(0.776)	
SW F statistic	28.49		34.54	
SW p-value	0.000000138		7.55e-15	
N	548	548	548	548
Partial R^2	0.616		0.616	
R^2		0.969		0.969

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 15: 2SLS: Change in total employment between 2012 and 1990

	(1) 2012 GCI Sum	(2) Δ Emp	(3) 2012 GCI Sum	(4) Δ Emp
Income in 1970	0.00420***			
	(0.000677)			
Δ PC Income	0.167†	-0.00236	0.0710	-0.0211
	(0.0880)	(0.410)	(0.0692)	(0.407)
2012 GCI Sum		6.096***		6.130***
		(0.546)		(0.533)
Population in 1970			0.0210***	
			(0.00295)	
PC Income in 1970			3.746**	
			(1.261)	
SW F statistic	38.49		50.59	
SW p-value	1.09e-09		7.09e-21	
N	548	548	548	548
Partial R^2	0.713		0.713	
R^2		0.787		0.787

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 16: 2SLS: Change total employment between 2012 and 1990

	(1) 2012 GCI Sum	(2) Δ All Patent	(3) 2012 GCI Sum	(4) Δ All Patent
Income in 1970	0.00220***			
	(0.000601)			
Δ Emp	0.0785***	-0.00201	0.0748***	-0.00210
	(0.00884)	(0.00158)	(0.00865)	(0.00158)
2012 GCI Sum		0.0613***		0.0621***
		(0.0123)		(0.0126)
Population in 1970			0.0113***	
			(0.00270)	
PC Income in 1970			2.916**	
			(1.083)	
SW F statistic	13.42		19.72	
SW p-value	0.000277		5.81e-09	
N	491	491	491	491
Partial R^2	0.473		0.473	
R^2		0.370		0.369

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 17: 2SLS: Change in all inventors granted patents between 1990 and 2012

	(1) 2012 GCI Sum	(2) Δ Unique Patent	(3) 2012 GCI Sum	(4) Δ Unique Patent
Income in 1970	0.00220***			
	(0.000600)			
Δ Emp	0.0785***	0.000239	0.0747***	0.000156
	(0.00883)	(0.000543)	(0.00864)	(0.000540)
2012 GCI Sum		0.0124**		0.0130**
		(0.00480)		(0.00485)
Population in 1970			0.0112***	
			(0.00269)	
PC Income in 1970			3.004**	
			(1.116)	
SW F statistic	13.43		19.76	
SW p-value	0.000275		5.74e-09	
N	479	479	479	479
Partial R^2	0.473		0.473	
R^2		0.306		0.306

Standard errors in parentheses

Odd columns show first-stage results with Sanderson-Windmeijer (SW) first-stage F statistics

Even columns show second-stage

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 18: 2SLS Results: Change in unique granted patents between 1990 and 2012

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ Income	Δ Income	Δ Emp	Δ Emp	Δ All Patent	Δ All Patent
2012 GCI Sum	2459.6***	1147.6***	5.808***	-0.227	0.0695***	0.00484
	(462.0)	(250.8)	(0.763)	(1.603)	(0.0157)	(0.00826)
Δ Emp	-55.87	-4.721			-0.00305	0.00116
	(43.80)	(25.78)			(0.00194)	(0.000840)
Δ PC Income			-1.105	0.269**		
			(3.495)	(0.0873)		
N	100	267	100	267	100	211
R^2	0.797	-2.292	0.698	0.0678	0.241	0.0995

Standard errors in parentheses

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 19: 2SLS Results: Large vs Small Cities - mulitple equilibria?