

## **Agglomeration economies and other spatial impacts of infrastructure: do we know what we're looking for (or at)?**

*Dr. Cameron Gordon, Associate Professor of Economics at University of Canberra*

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### **Abstract**

Traditional benefit-cost analysis and other program evaluation techniques applied to public infrastructure investment tend to focus on relatively narrowly conceived measures of market benefit (e.g. a transport project's reductions in travel-times that will be generated for travellers); these are sometimes supplemented with market valuations of broader social impacts (e.g. lowered Greenhouse Gas Emissions). In many cases benefit measures such as these are more than sufficient, especially when considering increments to existing transport and other infrastructure networks. However, public infrastructure, especially transport, can have significant spatial effects such as expansion in effective access to markets for goods and services and an ability to achieve agglomeration and other spatial economies across those markets. Agglomeration economies in particular are inconsistently understood and often incompletely specified. This presentation discusses how these types of effects can be missed by traditional methods and how methods might be enhanced to account for them.

### **Biography**

Cameron Gordon is an Associate Professor of Economics at the University of Canberra's Faculty of Business and Government and currently a Visiting Professor at the Imperial College of London Centre for Transport Studies. Professor Gordon has previously been a Visiting Professor at the University of Sydney Institute for Transport and Logistics Studies (ITLS) and a Visiting Fellow in Public Policy at the City University of New York (CUNY) Research Foundation. He has had prior academic appointments in Finance with CUNY and in Public Policy and Administration with the University of Southern California. Prior to entering academia, Professor Gordon had a long public service career with appointments at the US Congress Joint Committee on Taxation, the US Advisory Commission on Intergovernmental Relations and the City of New York Municipal Water Finance Authority. His research interests include transport and economic development, urban passenger and freight transport and infrastructure privatisation and PPPs.

# AGGLOMERATION ECONOMIES AND OTHER SPATIAL IMPACTS OF INFRASTRUCTURE: DO WE KNOW WHAT WE'RE LOOKING FOR (OR AT)?

Cameron Gordon

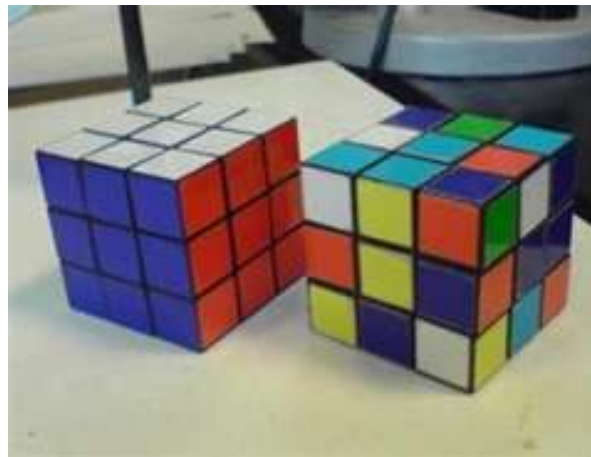
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# Agglomeration Economies: the research conundrum

- Transport investments have spatial effects.
- When positive, these spatial effects are often referred to as agglomeration economies.
- These are well studied but there still is an elusive quality about what they are, what causes them and the nature of their effects.



# Outline of the research project

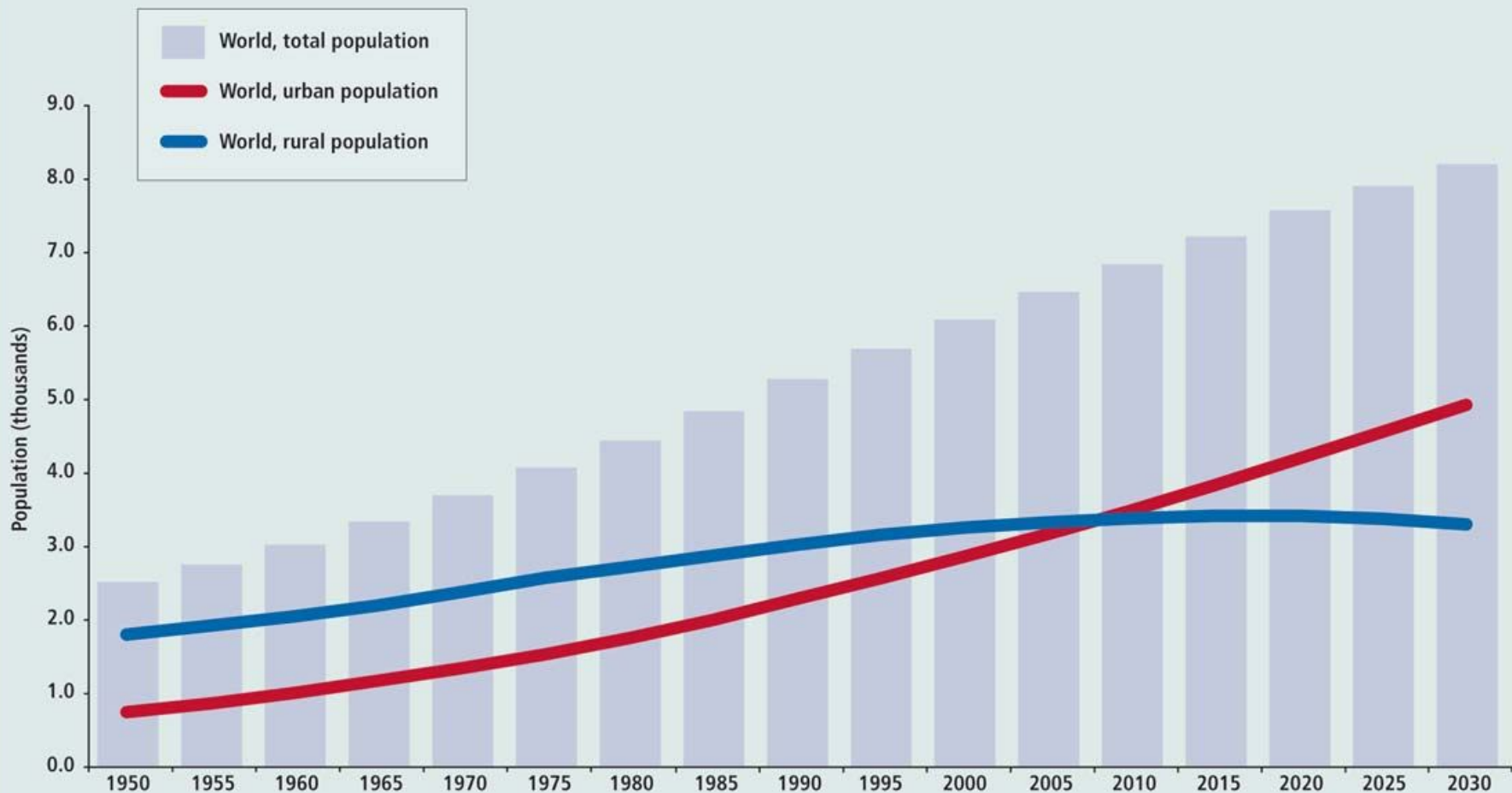
- Stating the 'obvious': evidence that agglomerations and agglomeration economies exist.
- But what are agglomeration effects really? The 'social savings debate' from economic history
- Three issues from that debate: embodied effects, topography and market access/network effects
- The nine basic assumptions of spatial economics and how their violations lead to agglomeration effects
- For the future: contemplating some possible ways of augmenting analysis to account more fully for agglomeration effects.

# 'Obvious' point #1: Human beings do agglomerate

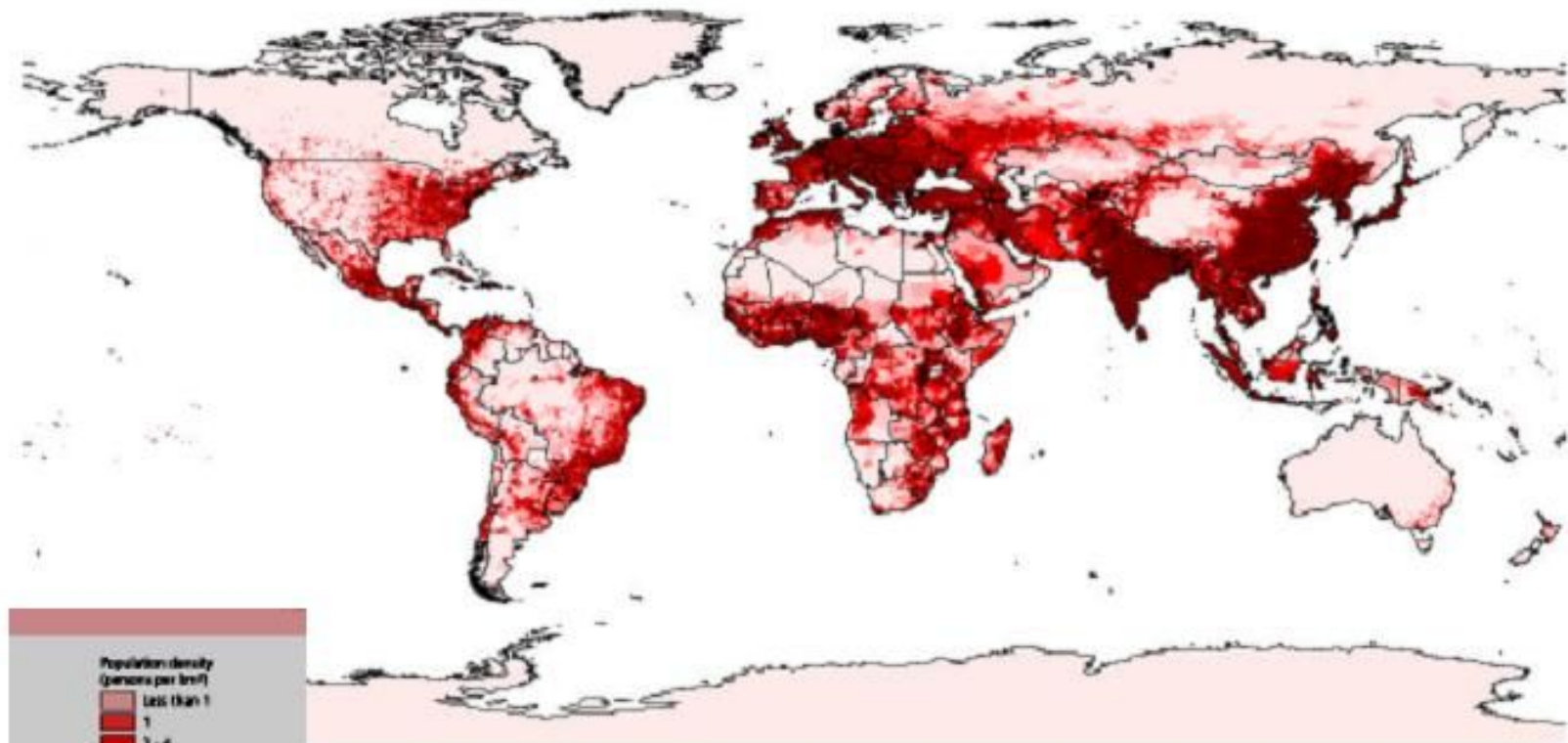
- One thing we do know is that, for whatever reason, human beings do agglomerate.
- There is widespread evidence of this, for example:
- existence of cities and increasing urbanisation;
- existence of marketplaces throughout history;
- phenomena of industrial, social and professional spatial clusters.

["World Urbanization Prospects: The 2005 Revision, Pop. Division, Department of Economic and Social Affairs, UN  
[<http://www.un.org/esa/population/publications/WUP2005/2005wup.htm>]

### The urban and rural population of the world, 1950-2030



## Global Population Density



Population density  
(persons per km<sup>2</sup>)

Less than 1
1
2 - 4
4 - 7
7 - 12
12 - 25
25 - 50
50 - 125
Greater than 125
No Data

**POPULATION DENSITY 2003**  
**(Populated Places)**

World Resources Institute 2006

# “Obvious” Point #2: Agglomerations do have economic benefits

- (1) Rosenthal and Sachs (2002) found that 57 per cent of the income in the US was generated within 80 km from the coast and only 13 per cent of the landmass;
- (2) Rosenthal and Strange (2004) survey the literature on agglomeration economies and very roughly find that doubling of city size increases productivity by an amount that ranges from 2 to 8 per cent. This has been confirmed in later studies;



- (3) Glaeser and Mare (2001) find that workers in cities over a million earn a wage premium over those living in cities under 100,000, even after adjusting for the selection bias of more productive workers locating in larger cities.
- This is consistent with more general findings of core-periphery 'gradients' in rents, wages, and land prices, all of which suggest that there must be returns to locating close to centres since people are willing to pay a premium for being there.

- (4) Graham (2006, 2008) uses measures based on 'effective density' or employment potential and aggregate up the employment counts in a circular region centred on each individual firm, with higher weights. Others look at the effects of employment within several preset distance or travel time bands.
- Using this latter approach, Rosenthal and Strange (2003) find for the US that new firms within a given industry are most attracted to zones within 1 miles of existing employment centres within that industry with effects diminishing rapidly with distance. Rice et al (2006) use travel-time bands and find that most of the productivity benefits of agglomeration are related to population within 80 minutes travel time.

- (5) Swinburn et. Al. (2008) estimate forecast productivity changes to worker density in London as a way of estimating the productivity returns of high buildings and find that by 2026 the resulting “agglomeration benefit” is equal to 17% of the rent paid in those buildings.
- This builds on work by Graham (2005, 2006) which estimates that a 10 per cent increase in effective density, controlled for other changes, yields a 1.25 per cent increase in productivity for firms in that area.
- Ciccone and Hall (1996, 1999) estimate that doubling of employment density, all other things constant, increased average labour productivity in the US by 6% and in Europe by 5%.

# But agglomeration's costs do not always outweigh its benefits

- Agglomerations have costs (e.g. congestion) as well as benefits and so there are limits to agglomeration economies;
- There is also evidence of decentralisation (e.g. suburbanisation) and agglomeration is clearly a dynamic ebb-and-flow phenomenon over time;
- Finally just because an agglomeration exists does NOT mean it is necessarily economically optimal.



# Still..what ARE these effects – beneficial or otherwise – of agglomeration?



We know well  
– and trumpet  
the value of –  
the time  
savings due  
to transport  
investments

Author picture taken on Lordship  
road near Finsbury Park,  
October 12 2011

# But do we account for or understand THIS properly or completely?

Author pics, Lordship Road October 12 2011



# A motivating thought: Fogel and the 'Social Savings' controversy

- Perhaps a change of perspective is needed. Looking at a different but related field of inquiry is one way to begin.
- So let's start with the economist Robert Fogel and his book *Railroads and American Economic Growth* in 1964 (work that he would later win a Nobel Prize for).



# The concept of 'Social Saving'

- Fogel challenged the then prominent notion that modern industrial growth was a result of 'take-off' technological innovations.
- Fogel specifically examined the “indispensability” of railroads to US economic growth, creating a measure called the “social saving” due to the technology.





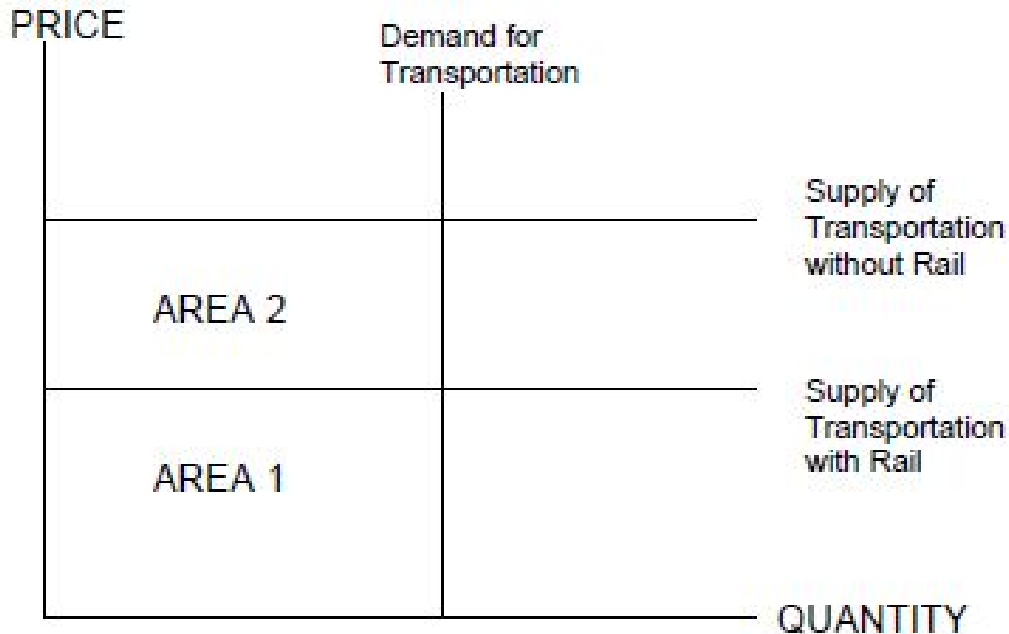


FIGURE 1 Demand for transportation.

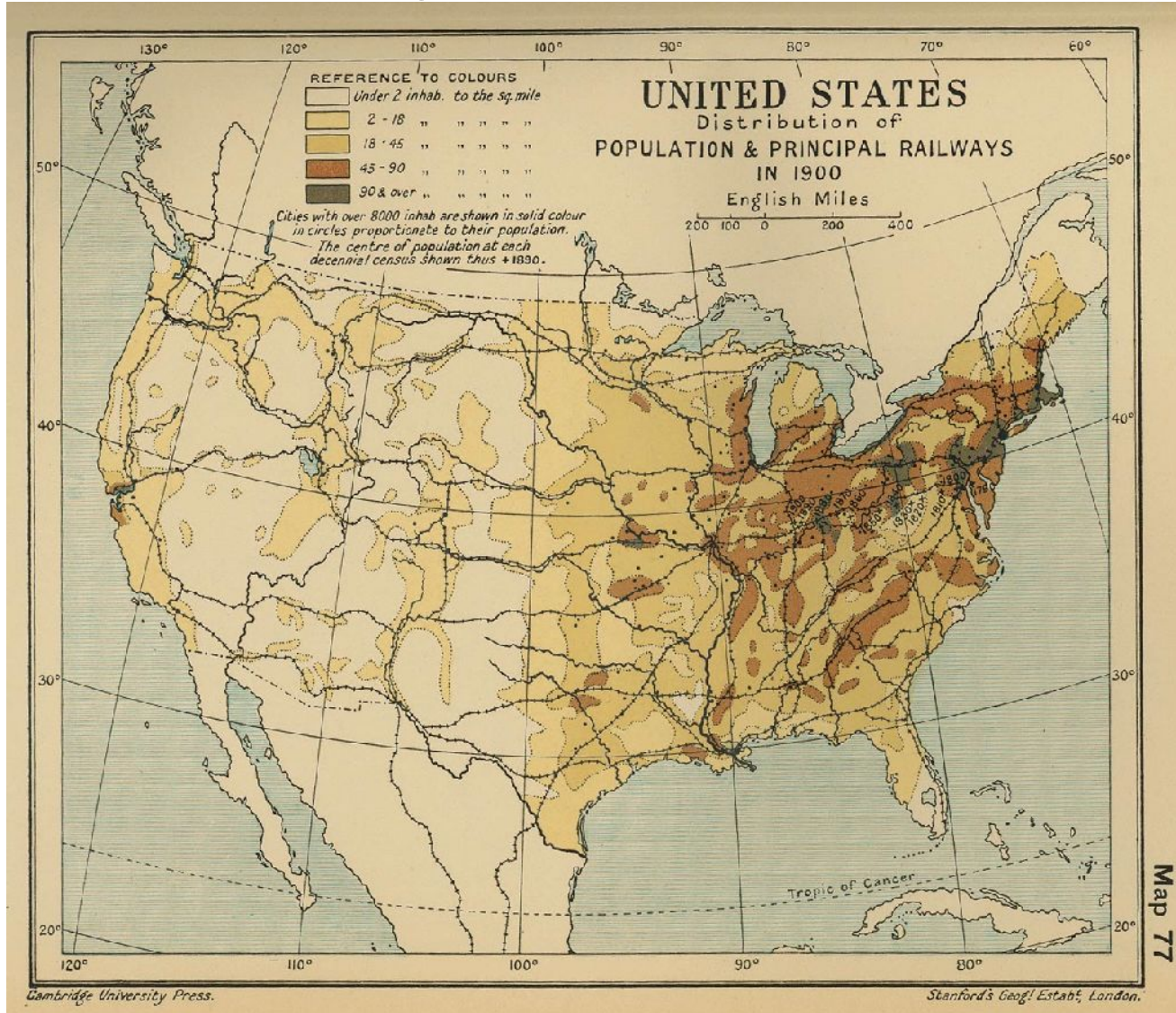
Source: Gordon, 2006

- There are two supply curves: the supply of transport available in the presence of railroads and the supply of transportation when railroads are unavailable and when only alternatives, such as canals, can be used. The amount spent on transport is equal to the appropriate price times the quantity. With railroads available, the amount spent on transport equals Area 1. Without railroads, the amount spent on transport equals Area 1 plus Area 2. The social saving refers to the resources that railroads free up for social uses other than transportation, i.e. the resources that would have been spent on transport without railroads minus the resources that are spent on transport with railroads.
- It should be clear that this difference is Area 2.

# The counterfactual

- Fogel looked at the US economy up until 1890 with railroads available and then in 1890 suddenly eliminated them from the economy, with alternative, and more expensive, transport methods such as canals then required.
- He measured the effect on US GNP in that year under several simplifying assumptions (i.e. the social saving).
- Fogel found that the social saving due to the railroads amounted to under 3% of GNP, a significant but not overwhelming figure.
- He argued that by choosing a peak year of agricultural production, when railways would be most utilised, and also by assuming perfectly inelastic demand for transport that he would 'stack the deck' in favour of railways so that any estimate he came up with would arguably be on the high side and hence an overestimate of social saving.

# This only 'saved' 3%?



# Fogel's backlash...and implications for agglomeration economies

- This finding created a torrent of objections to his method and estimate (and the literature is very worth reviewing because of its empirical, conceptual and theoretical richness and care. Fogel's 1979 review and retort is a good place to start).
- Three objections are particularly relevant for thinking about the complete nature of agglomeration economies:
  - (1) “Embodied” v “Disembodied” effects
  - (2) the role of topography and geography
  - (3) Market access and network effects

# 1. Embodied effects

- Fogel referred to the social saving as a disembodied effect, because any true transport innovation lowers costs and hence results in savings to society.
- However, railroads delivered these savings in a particular form, and the form which savings due to railroads, as opposed to a different transport innovation that might have occurred, are the embodied effects.
- Thus a relatively insignificant social saving might result in otherwise dramatic changes in a society.
- In other words, while total output might have remained fairly similar in the absence of railroads (assuming Fogel's estimate is correct), the economy would nonetheless have looked dramatically different without the specific form of effects that railroads delivered.

- Alfred Chandler and Oliver Williamson both argued that railroads produced not only transportation efficiencies, but organizational and institutional innovations that, when combined with the delivery of speedier and more regular goods and passenger carriage, made a system of mass distribution possible, promoted the growth of mass manufacturing, led to the development of the large, vertically integrated corporation and even established standardised time zones



- Effects such as these are hard, if not impossible, to capture in models that rest on consumption, production, and relative prices alone.
- Yet these may be as important as average net gains or net losses (and will have specific flow-on effects, negative and positive).
- (Chandler 1977; Williamson, 1985)

## 2. The role of topography and physical space

- Social saving was greatest in countries that relied most on roads—productivity in this sector remained low until the development of the internal combustion engine—and lowest where there were many navigable rivers, terrain well-suited to building canals, and good facilities for coastal trade.
- In general, railways alleviated poor natural endowments. Where these endowments were rich, rails had relatively little effect. Where these endowments were poor, railroads saved society more in terms of transport costs



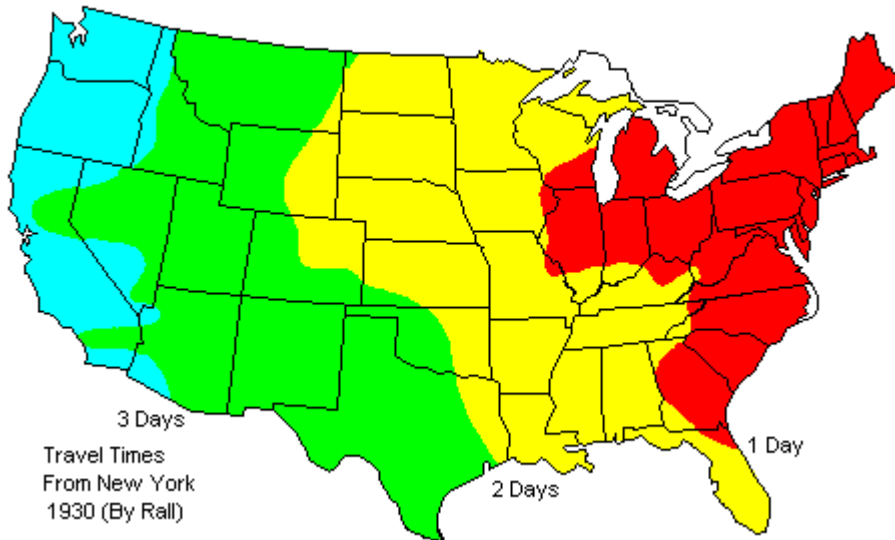
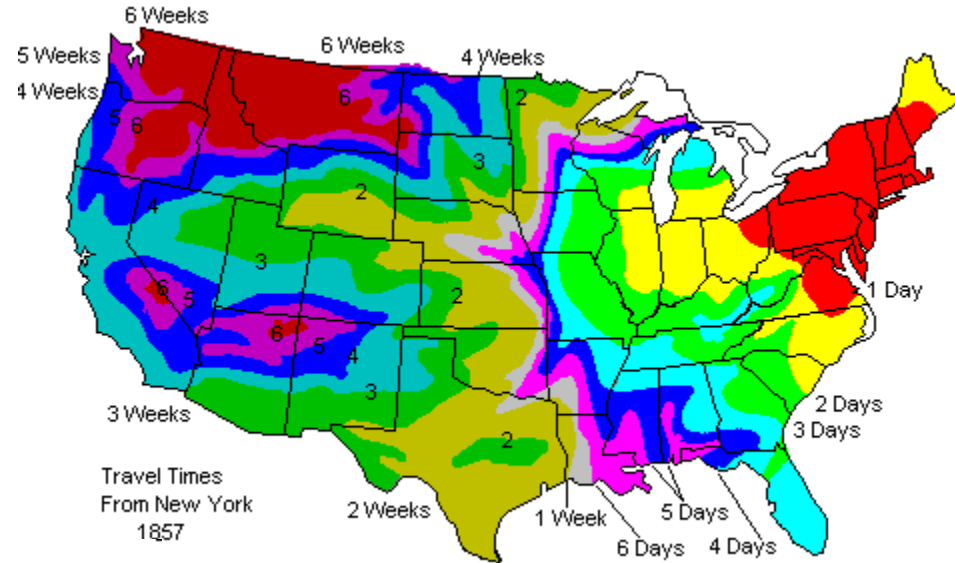
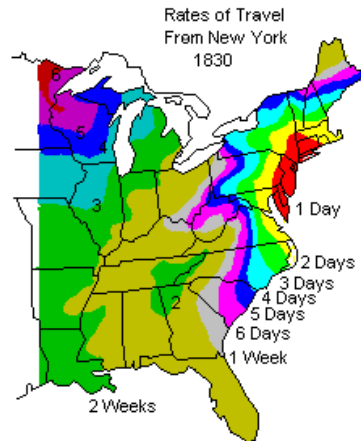
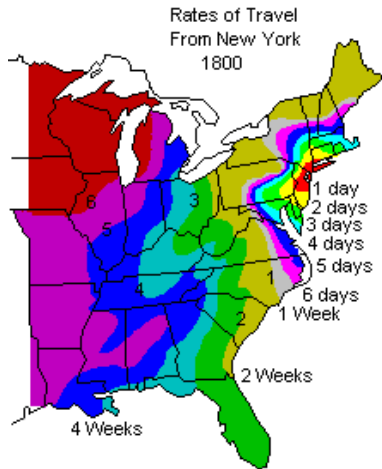
*Andrew J. Russell Railway construction in the Green River Valley, Wyoming, near Citadel Rock, 1868. Albumen print*

# 3. Market Access and Network Effects

- So embodiment matters...and natural setting matters (arguably the 'natural' embodiment in one case, the 'human' embodiment in the other) which leads to the issue of how the railways network changed access to markets for both inputs and outputs.
- Fogel's analysis was very unusual in transport because it explicitly looked at the effects of removal of an entire transport network from an economy which then had to fall back on its previous network (and in this case using a less advanced technology).
- This, of course, is not the question posed in most transport agglomeration analyses – but it is an important background issue that often needs to be considered in the foreground because networks don't just reduce travel times...they reshape and reform access.

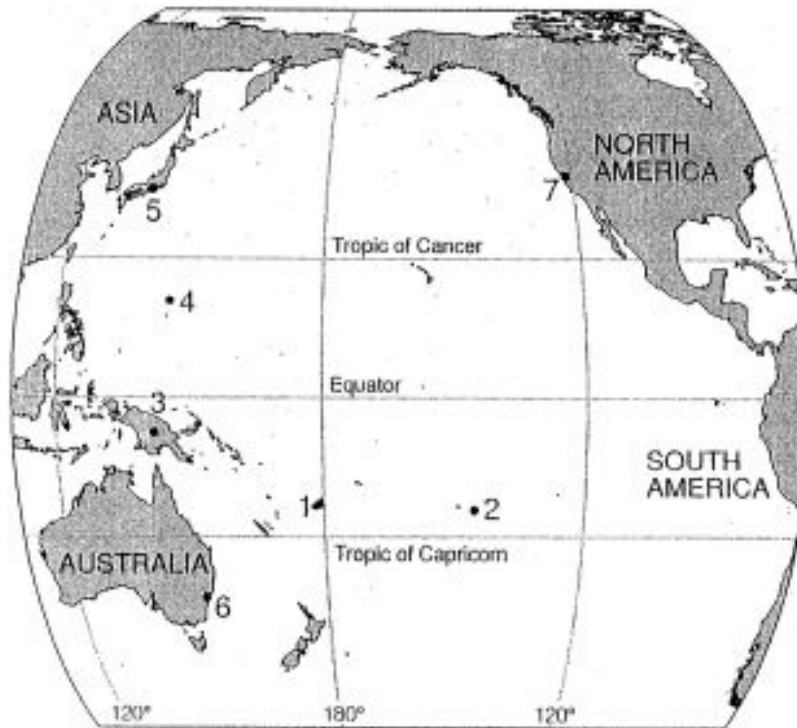


# Did these US transport improvements primarily deliver 'travel time saved?'



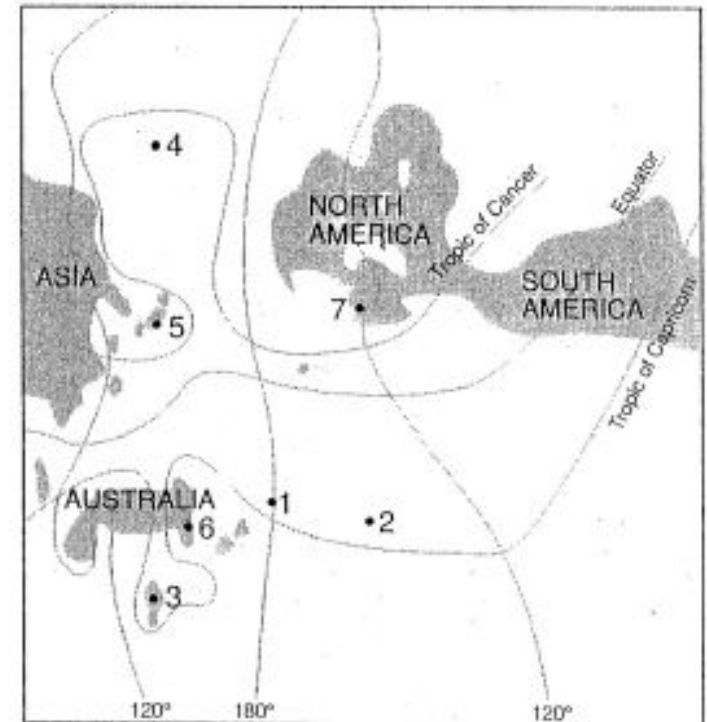
Source: Historical Atlas of the US

# Time-space convergence



1 Fiji 2 French Polynesia 3 Papua New Guinea 4 Trust Territories of the Pacific 5 Tokyo 6 Sydney 7 San Francisco

(a) 'Conventional' projection of the Pacific basin

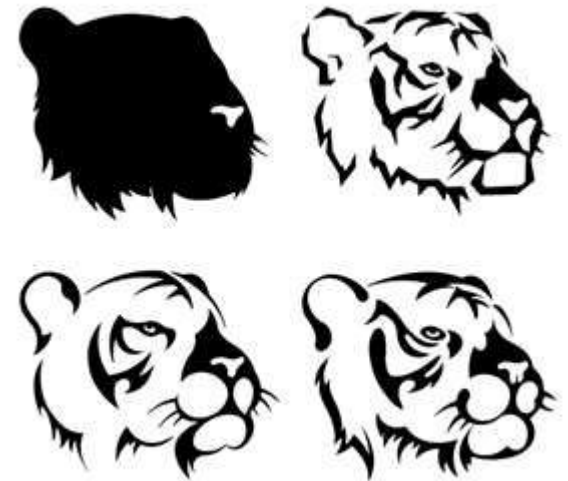


(b) Time-space map of the Pacific basin, based on relative time accessibility by scheduled airline in 1975

Fig. 4. Time-space map of the Pacific basin based on relative time accessibility by scheduled airline in 1975. (Source: Haggett, 1990, Fig. 3.3, adapted by Leyshon. Reproduced with permission.)

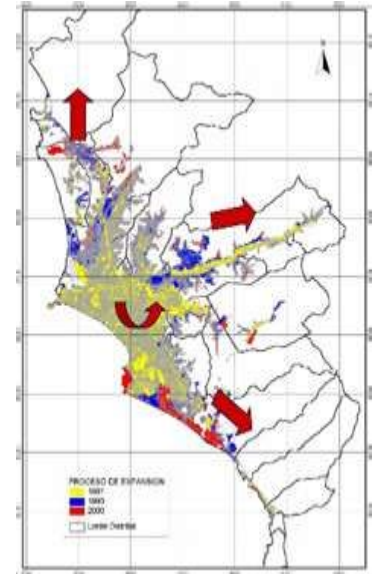
# When simplifying is too simple

- Simplifying assumptions are necessary for analysis.
- The Fogel debate shows that assumptions built into an evaluation may not match the likely facts at hand and may lead to incomplete understanding.
- Agglomeration economies epistemology is especially prone to this issue.



# Spatial economics

- The variety of fields of spatial economics (urban economics, regional economics, location theory, economic geography etc.) all arise (I argue) because basic simplifying assumptions are not closely enough matched in reality.
- Waiving one or more of these basic assumptions may help us to increase what our understanding of agglomeration cause and effect.



# The current “project” – part 1

- The current (very large) literature on agglomeration economies contains a wealth of useful material but a meta-understanding of that literature (i.e. a catalog of what we know and what we don't know about agglomeration economies) is not easy to extract.
- The first part of this 'project' is to develop such an understanding by cataloging different agglomeration (and spatial) effects according to how they arise from violations of simplifying assumptions.

# The Nine Basic Assumptions of Neoclassical Economics

- (1) The primary unit of analysis is an atomistic actor
- (2) Everyone has the same 'complete' information
- (3) All actors are rational, maximising and self-interested
- (4) All goods are purely private in the economic theory sense
- (5) All space is 'homogeneous'
- (6) Returns to production and consumption are constant and continuous
- (7) There are no transport costs
- (8) Perfect competition in all markets
- (9) no interdependence in production and consumption (in other words, no externality),

# Agglomeration Effects: a preliminary catalog

- “(7) **There are no transport costs**” is waived to create “**central place theory**”. People agglomerate because it costs money to transport things so people locate to minimise transport costs.
- “(5) **All space is 'homogeneous'**” is waived to create **Ricardian trade theory and other successors**. People agglomerate because of some sort of locational natural advantage (e.g. a port or coal seam) or endowment of production inputs (e.g. lots of labour) which gives them a comparative trade advantage

- **“(6) Returns to production and consumption are constant and continuous”** waived to create two of the “Marshallian Trinity” – **input sharing** (i.e. agglomerations of inputs across a concentration of firms in an industry in one location create economies of scale) and **labour market pooling** (closely related, in which 'thick' labour markets which congregate around concentrations of firms create efficiencies in search and matching).
- Waiving of this assumption is also key to the **“New Economic Geography”** and are a fundamental rationale behind the existence of cities, i.e. there ARE positive returns to SPATIAL CONCENTRATION.



- “**(9) no interdependence in production and consumption (in other words, no externality)**” waived to create the third part of the Marshallian Trinity, i.e. “**knowledge spillovers**” (i.e. people learn more from each other when in close proximity to each other and become more skilled and create more ideas as a result).
- This is also the basis of **Richard Florida's 'creative' economy** idea in which cities offer amenities desired by well-educated, creative people who concentrate there with resulting positive economic returns.
- Externality is often correspondent with scale economies, and sometimes difficult to disentangle.

- **“(4) All goods are purely private in the economic theory sense”** waived to create some models of public capital productivity, i.e. the notion that some **network infrastructure is quasi-public ('club' goods)** and creates a benefit beyond its mere private returns.
- **Cultural and other 'urban' social and institutional amenities** might fall into this camp and any location-specific concentration of a public good with positive returns could well be a cause of agglomeration as well as an effect.
- This is obviously closely related to the externality notion (indeed a public good by its nature creates externality) and the knowledge spillover argument of Marshall could also be seen to be a public good argument.
- For a public good to lead to agglomeration economies, generally some positive returns to scale in the production of that good are generally required.

- “**(8) Perfect competition in all markets**” is waived in many urban economics models and is a key component of the “**New Economic Geography.**” A very typical assumption is some sort of monopolistic competition which gives firms some differentiation of offering to consumers and some individual producer pricing power.
- By itself this might generate agglomerations and agglomeration economies, but combined with, e.g. positive transport costs and/or positive returns to scale, there then become incentives for firms to concentrate in 'market areas' with desirable access to consumers and workers.

- **“(2) Everyone has the same 'complete' information”** is waived in many fields of finance and information economics but its **implications in spatial economics has not been explored very deeply.**
- There is certainly the possibility that spatial concentration might have benefits in a world of uncertainty or asymmetric information if such concentration could be shown to minimise some uncertainty or increase the sharing of information. **(In a certain way this is the essence of Hotelling's simple location 'game')**
- Although not explicitly about information or uncertainty, **knowledge spillovers and learning regions etc. might arise as responses, in part, to such real-world imperfections.**

- “(1) **The primary unit of analysis is an atomistic actor**” is waived in some fields of urban economics and location theory and business strategy and history fields.
- For example, rather than look at individual agents, **some urban economics models have made developers the unit of analysis**, and indeed much land development is done not by agents within a firm or a labour market but by large scale entities devoted to this purpose.
- Since land development has such a large impact on location decisions (especially with imperfect foresight, a key part of models that use developers as the unit of analysis) this may more closely capture real-world agglomeration dynamics.
- Chandler and Porter, among others, have argued that **the firm is the relevant unit of analysis and look at COMPETITIVE ADVANTAGE as a driver of location not COMPARATIVE ADVANTAGE.**

# Holy Grail



- “(3) **All actors are rational, maximising and self-interested**” is the one simplifying assumption that appears to be sacrosanct in studies of agglomeration economies.
- Of course this assumption is being tested in fields of behavioural finance and behavioural economics more generally.
- It might be possible that one profitable course of study is to **use primarily inductive methods to study location and agglomeration** (i.e. use close empirical study of spatial decisions as the basis of theory building rather than the standard use of deduction based on premises to build theory then tested against the data)

# When to use 'standard' analysis

- All of this is not to say that 'traditional' methods are inappropriate or inapplicable.
- To make an analogy, the classic Newtonian system in physics has been shown to be a limited case (relativity being the more general case), the system remains very useful if applied correctly.
- Similarly for economic analysis.
- The key is to think first about the situation being analysed and whether there are likely to be conditions or effects that may significantly diverge from the assumptions under which B-C analysis functions best.

# Research Project – step 2

- The next step in this 'project' is to see how the 'catalog' might (a) inform choice of research methods and approaches (e.g. if we think the primary driver of location choice might be some kind of nonrationality, we might use an 'inductive' method more akin to economic history) and (b) adjust benefit-cost analysis methods for specific projects and programs.



# One possibility: criteria for conditions for which 'standard' analysis work best

- Projects with no or few likely network effects.
- Relatively 'small' projects of relatively short duration in execution.
- Short-lived projects
- Projects designed primarily to speed flow over limited segments with no practical alternative route
- Projects in environments with few institutional distortions or rigidities.
- -- an intuitive 'screen' – would a private firm likely be attracted to this project based on a financial rate-of return analysis?

# Conditions under which analysis may need to be adapted

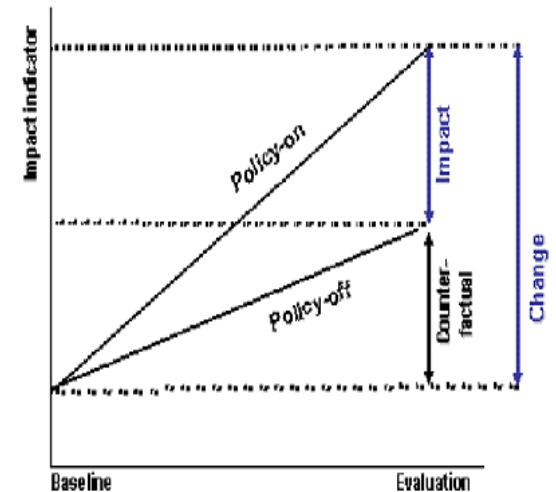
- Projects significantly altering or building an entirely new network
- Very large projects, of long duration in execution and/or very long-lived effects afterwards
- Projects in environments with institutional rigidities and distortions including imperfect competition
- Public-Private Partnerships (at least with respect to key variables such as discount rate since these may well differ between the partners)
- Projects primarily devoted to improving access (e.g. for a particular industry) or accessibility (e.g. making a peripheral location more 'central')
- Projects where there are likely to be 'general equilibrium effects'

# Adaptations if agglomeration economies seem likely

- The Fogel debate is relevant here.
- Jeffrey Williamson (1975) decided that modelling of dynamic, multisectoral effects was necessary (Fogel's analysis being a static partial equilibrium analysis) and used a computable general equilibrium (CGE) model to get at the broader effects of railways.
- Other historians did not look to models but looked more deeply at the data, in particular focusing on market and cost structures of competing modes (especially canals) to see how much  $P$  diverged from  $MC$ . They also looked to come up with reasonable transport supply and demand elasticity estimates.
- This information was then used to run sensitivity analyses on key variables to see how social saving estimates changed and what the key drivers of those changes were.
- Much analysis was 'qualitative' in the sense of looking at analogous situations elsewhere (e.g. overseas) to apply to the US situation to increase understanding of underlying dynamics.

# Another possibility: baseline pick

- Most standard B-C analysis uses a simple 'with/without' benchmark to assess net benefits of a project.
- Fogel himself argued that he was not looking for a 'realistic' base case but one that would provide an 'upper bound' for the social saving estimate.
- This indicates that one can apply 'standard' B-C but choose a baseline that best answers the question at hand (e.g. 'best' or 'worst' case rather than true net gain) or that best reflects facts on the ground (for example, if a project has a very long execution time we may want to choose a baseline that reflects a situation later on, closer to project opening, when there may have been substantial change in the meantime, as opposed to a simple 'no project now' versus 'project exists then'.



# Adding metrics

- One may want to add various metrics to a B-C such as distributional analysis, accessibility measures and even maps of space-time contours.
- Showing how trip matrices might change during a project implementation (these are often assumed to be fixed between the start and end of a project) is also often useful, even necessary.
- Of course adding metrics and information to B-C is nothing new but perhaps should be approached more systematically, based on the criteria offered here.

# Adding relevant analytics

- Finally (and again the Fogel debate is a guide here), one can amplify the traditional analysis by adding relevant analytics.
- For example, Vickerman (2007) shows how B-C should be altered in the case of a simple monopolist, where MC and MB curves provide the market equilibrium, not S and D.
- The change in benefits is now the difference between the two rectangles  $EFGC'_1$  minus  $ABDC'_0$  which, depending on the relative elasticity of the demand curve and the price/marginal cost mark-up, this could be greater or smaller than the usual benefit  $C_0XYC_1$

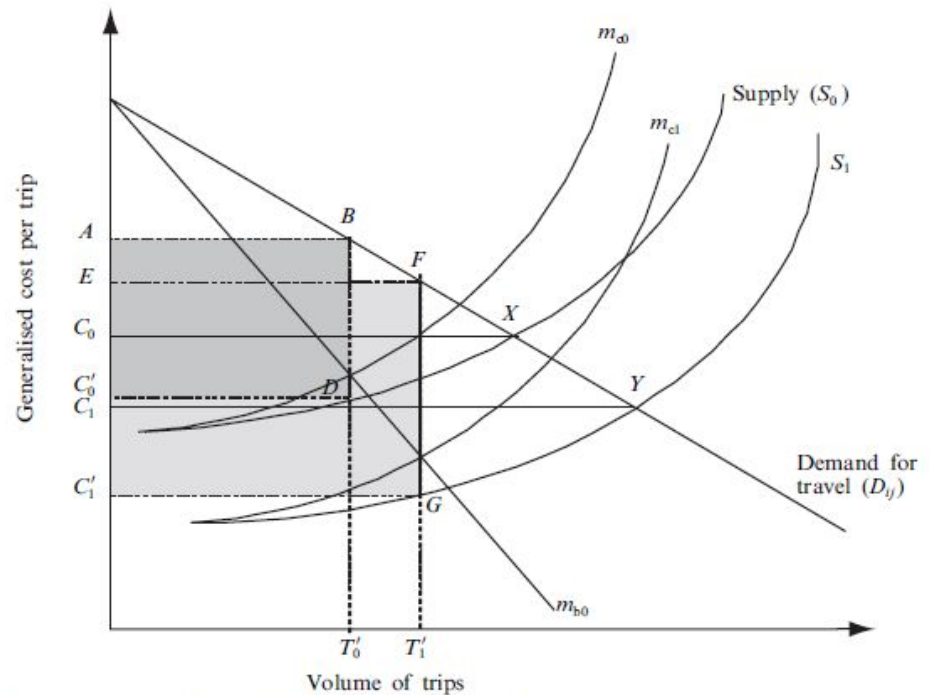


Figure 4. Cost-benefit analysis under imperfect competition.

# Conclusions

- We know that transport infrastructure can have significant agglomeration effects and that this may often be its primary benefit.
- We also know that many spatial effects occur as a result of transport investments, and many of these might actually be driven by conditions that deviate from standard assumptions.
- First let's build up a systematic catalog of meta-knowledge of spatial effects and use that to improve both understanding and methods of analysis, particularly in instances where the likely facts on the ground might be expected not to match standard assumptions.

## *Euro Tunnel*



## *Panama Canal*



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