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Where and when to invest in infrastructure☆

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ABSTRACT

This paper analyzes an irreversible "where-and-when" investment decision, in which a government must decide not only when to invest in income-increasing infrastructure but also where to make the investment, doing so under imperfect observability of the investment gains. The two models considered in the paper differ in the source of the imperfection. In the signal model, the imperfection comes from imperfect observability of initial income gains from the investment, while in the option model, it comes from the stochastic nature of the income gains in the second period. In addition to providing the first treatment of this type of problem, the analysis shows that the influences of underlying parameters on whether or not the government waits to invest are similar in the two models.

1. Introduction

Starting with Aschauer (1989), a large literature has developed studying the productivity effects of public infrastructure investment. Most recently, Michaels (2008) and Duranton and Turner (2012) focus on the effect of transportation infrastructure, exploring the impact of highway investments on economic development in studies that build on earlier work.[1] The related connectivity benefits provided by airports can also stimulate local economies, and papers measuring this effect include Brueckner (2003), Sheard (2014) and others.[2] For earlier contributions to the infrastructure literature whose focus is broader than simply transportation investment, see the survey paper by Munnell (1992).[3]

All of this prior work has generated a broad consensus that public investment typically stimulates regional economies, and this view provides the starting point for the present paper.[4] The paper, however, considers a question that has received no attention (to our knowledge) in the infrastructure literature. Suppose that a government, facing a constraint on funds, can make only a single infrastructure investment and seeks to maximize the gain from investment. The question is: when faced with two location choices with different investment gains, as well as a timing choice (invest in period 1 or period 2), where and when should a government make its infrastructure investment? In other words, if the government can make one irreversible investment, which of the regions it serves should get the investment? Moreover, should the investment be made now, or should it be deferred until a later period?

These where-and-when questions are potentially intertwined because the regional impacts of the investment may be only partly observable, raising the possibility that the wrong location (with inferior gains) is chosen. Waiting to invest, however, may fully reveal the different regional gains from the investment, which allows the best location to be selected. The downside from waiting, though, is the foregone (but perhaps suboptimal) benefit from investing immediately.

There are two natural ways of portraying this lack of observability, which in turn lead to two different models of the government's decision problem. In the first model, the gains from the investments in the two regions, if made immediately, are observable. But region-specific random shocks shift the subsequent gains in an unpredictable fashion, possibly reversing the initial ranking. The realizations of these random shocks are observable, however, if the government waits to invest, allowing a better location (from the perspective of subsequent gains) to be chosen. This version of the decision problem is called the "option model" since it bears some connection to a standard investment problem under uncertainty, where waiting helps to resolve future risks.

The presence of two investment choices, however, creates some notable differences between the present option model and the standard one. Although greater uncertainty delays the investment date in the standard option model with a single potential investment, a higher return variance in the current option model need not making waiting more desirable. However, the benefit from waiting does depend on

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[1] See Fernald (1999) and Chandra and Thompson (2000). See also Donaldson (forthcoming) for recent work on the impact of railroads.
[2] See Green (2007) and Tittle et al. (2012).
[3] See also Morrison and Schwartz (1996) and Haughwout (2002).
[4] There are dissenting views: see, for example, Baade and Dye (1990)'s evidence that investment in a sports stadium need not benefit a city's economy.

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the covariance between the two random influences that help determine the second period's investment gains in the regions. If the covariance is high, the future is still uncertain but the gains from waiting are low because the random effects are unlikely to reverse the advantage of the region with the higher initial investment gain. This type of outcome, where waiting may not be optimal despite high future uncertainty, is not present in models with only a single investment opportunity.

Under the second model, the regional gains from the investment are initially unobservable, although they become observable if the government waits to invest. Despite their first-period unobservability, the gains are partly revealed by random signals received by the government in that period, which provide partial information about the business climates in the two regions. The government must decide whether to invest based on this (possibly misleading) signal information or to wait and act using full information. This version of the decision problem is called the "signal model." As seen in the next section of the paper, the option and signal models can be derived as special cases of a single framework. Observe that the two models are distinguished by the sources and the timing of the uncertainty they contain: uncertainty in the signal model comes from random signals, received in the first period, about (nonstochastic) investment gains in the two regions, and uncertainty in the option model comes from random shocks, occurring in the second period, affecting investment gains in that period.[5]

Like in the signal model, the role of information acquisition in determining the timing of investment has been studied by Cukierman (1980), Demers (1991), and Thijssen et al. (2001), although in contexts very different from the current one. Similarly, the option model is connected to previous work on investment decisions because both analyze the question of "when" to invest (see Dixit and Pindyck, 1994 and the references therein).[6] However, the existence of two different investment locations introduces a departure from the standard option model, making the question not only when but also where to invest. This departure is like the one studied by Dixit (1993) and Décamps et al. (2006), where the investor decides when to invest and which among a menu of production technologies to use, faced with stochastic evolution of the output price.

Several transportation-investment examples serve to illustrate the option and signal models. The first example concerns the Green Line, a portion of the Los Angeles light rail system whose routing was chosen based on job location patterns that had changed dramatically by the time the system was complete, impairing ridership and making a different routing look better with hindsight. This outcome illustrates the option model, with the job-pattern change corresponding to an unfavorable realization of future uncertainty for one investment location. The relevant details are presented in the following excerpt from Wikipedia (n.d., b):

> Construction on the Green Line began in 1987. One of the reasons for construction was that the Green Line would serve the aerospace and defense industries in the El Segundo area. Construction of the line cost $718 million. By the time the Green Line opened in 1995, the Cold War was over, and the aerospace sector was hemorrhaging jobs. … As a result, ridership has been below projected estimates, averaging approximately 44,000 daily weekday boardings in June 2008.
> The Green Line's western alignment was originally planned and partially constructed to connect with LAX [Los Angeles International Airport], but the airport was planning a major remodeling during the line's construction. Los Angeles World Airports wanted the connection to LAX to be integrated with this construction, but there were concerns that the overhead lines of the rail would interfere with the landing paths of airplanes. In addition, citizens of neighboring communities to LAX opposed the expansion of the airport. …
> The Green Line's eastern terminus also suffers from the fact that it stops two miles (3 km) short of the heavily used Norwalk/Santa Fe Springs Metrolink station, where several Metrolink lines operate. Because of this, and the Green Line's re-routed western alignment away from LAX, critics have labeled the Green Line as a train that goes "from nowhere to nowhere."

This discussion shows that, while the initial employment pattern made a Green Line routing to El Segundo look attractive relative to a routing to LAX, shocks to the economy (analogous to the random future influences in the option model) reduced aerospace employment and made the routing inferior ex post. If the future had been predictable, the LAX routing would presumably have been chosen despite the hurdles it faced, which appear relatively minor in retrospect. In the absence of such foresight, the poor Green Line routing decision could have been avoided by waiting to make the choice.[7]

Two other transportation examples illustrate the signal model. Both involve privately financed tollways designed to extend existing highway networks. The Dulles Greenway was completed in 1995 as an extension of the Dulles Toll Road, which connects Dulles International Airport to central Washington, D.C. The Greenway extended 12 miles beyond the airport, serving Virginia's Loudoun county, and initial traffic was projected at 20,000 vehicles per day (Jain, 2010). As explained by Jain, the outcome was different:

> Within six months of opening in late 1995, the project was in financial distress. Average daily traffic demand was an abysmally low 10,500. Toll rates were reduced from an initial $1.75 to $1.00 by March 1996, and future toll hikes were deferred in an attempt to increase ridership… By July 1996, road usage increased to 21,000 daily travelers, averaging 1% to 2% monthly growth. However, the net effect on projected revenues was marginal, as decreased toll rates offset the increase in ridership.

The result was default on the project's debt, with the owners beginning "discussions with the … creditors in the summer of 1996 to work out a plan for deferring debt payments and restructuring loan contracts…" (Jain, 2010).

This outcome can be viewed in the context of the signal model, with the project planners relying on signals that proved to be faulty predictors of latent transportation demand in the area, either because of low quality or randomly favorable realizations. Waiting for more demand information could have led to a different decision, with the developers choosing a project designed to increase freeway capacity elsewhere in the highly congested Washington region.

A similar example involves the State Route 125 tollway in San Diego, built to extend an existing highway network in the inland part of the region closer to the Mexican border. Like the Dulles Greenway, traffic on the SR 125 fell seriously short of projections, leading to bankruptcy of its developer in 2010 (Schmidt, 2010). Moreover, misleading signals appeared to have played a role, with the toll road built partly in anticipation of relocation of the San Diego International Airport to an inland location near its route, an event that never took place.[8] Again, waiting to invest (allowing resolution of the airport issue) might have led the developers to a different decision, building elsewhere in a region that, like the Washington area, is highly congested and in need of extra freeway capacity.

[5] A different approach would be to assume that the benefit of an investment is not observed until it is actually carried out. However, this approach would require a different type of analysis.

[6] For studies that use the option approach to land development, see Capozza and Helsley (1990) and Capozza and Li (1994).

[7] Redding et al. (2011) show that the location of misplaced infrastructure may be hard to alter, focusing on the location of the major German hub airport in Frankfurt. The hub would have been located in Berlin had the country not been divided prior to the 1990s, but irreversibility of the investment means that relocation of the airport to Berlin in the current unified country is impractical.

[8] This view is due to Professor Gordon J. Fielding, a noted expert on transportation policy in the Southern California region (expressed in private conversation).