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History and the Sizes of Cities

Hoyt Bleakley and Jeffrey Lin*

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Abstract

We contrast evidence of urban path dependence with efforts to analyze calibrated models of city sizes. Recent evidence of persistent city sizes following the obsolescence of historical advantages suggests that path dependence cannot be understood as the medium-run effect of legacy capital but instead as the long-run effect of equilibrium selection. In contrast, a different, recent literature uses stylized models in which fundamentals uniquely determine city size. We show that a commonly used model is inconsistent with evidence of long-run persistence in city sizes and propose several modifications that might allow for multiplicity and thus historical path dependence.

Keywords: multiple equilibria, locational fundamentals, path dependence
JEL Classifications: N90, R12, F12

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1 Introduction

Oxford, England, is renowned as a center of higher learning, but its name betrays its more humble origins. The word "ford," referring to a shallow place convenient for traversing a river, recalls the city's early importance as a crossing for oxen. Similarly, the suffix "-furt" suggests a comparable first-nature advantage for Frankfurt, Germany. Yet today, these cities have little to do with fording the Thames or the Main.

Like -fords and -furts, many cities are noted for contemporary advantages that long ago superseded their historical *raison d'être* (Cronon, 1991). In many cases, long-obsolete endowments continue to determine the relative sizes and locations of cities. For example, large cities persist at sites where it was once convenient to carry cargo over land around obstacles to water navigation, called *portages* in North America and *voloks* in Russia. Manufacturing was drawn to waterpower during early industrialization, and it remained there despite electrification and cheaper sources of power. And river confluences long ago provided the superior access to markets that roads and rail do today. These natural advantages were all made obsolete by new technologies a century or more ago.

The persistence of these cities—despite the obsolescence of their first-nature advantages—suggests that city sizes are *not* uniquely determined by locational fundamentals. Instead, in the presence of localized aggregate increasing returns, the sizes and locations of cities may be characterized by multiple steady states. Intuitively, if endogenous amenities are important for location decisions, then agglomerations might be possible at *many* sites, especially if they share similar exogenous natural characteristics. Persistence following obsolescence might then be understood as a long-run effect of equilibrium selection, thus allowing for patterns of history dependence.

Evidence of path dependence has implications for the recent quantitative literature using models in which locational fundamentals uniquely determine the sizes of cities. Such work often uses calibrated models following Rosen (1979) and Roback (1982) to recover productivity and amenity locational "fundamentals." But this exercise conflates exogenous natural features with endogenous amenities, which may not be uniquely determined by nature. We review recent studies of path dependence and show how a commonly used model in which fundamentals uniquely determine city size is inconsistent with this evidence. Finally, we suggest modest relaxations of this model that allow multiplicity and thus path dependence.

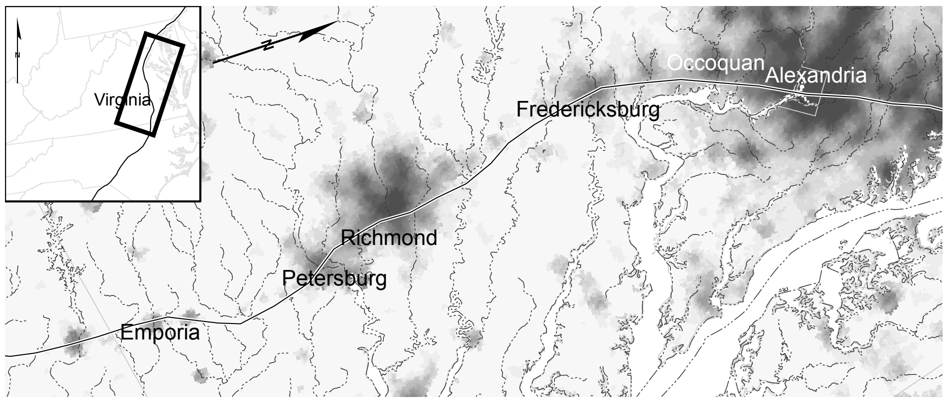

Figure 1: Fall line portage cities in contemporary Virginia

This map shows major cities at the intersections of the fall line (solid line) and rivers (dot-dash) and the present-day distribution of economic activity using 2003 nighttime lights from NationalAtlas.gov.

2 The footprint of history

Many cities founded near historical portage sites persist today (Bleakley and Lin, 2012a). During the early settlement of North America, portage sites were convenient places for carrying boats and their cargo over land around obstacles to navigation. These obstacles obliged traders to get out of their canoes, which made such sites focal points for commerce. But this natural advantage became obsolete a century or more ago, thanks to improvements in transportation technology. Similarly, some falls at these sites provided waterpower during early industrialization, an advantage that was made obsolete by the advent of cheaper power sources.

Yet, the footprint of portage is evident even today. Prominent examples can be found along rivers at the intersection of the *fall line*—a geomorphological feature describing the last set of falls or rapids experienced before emptying into the Atlantic. Along rivers in the colonial era, towns tended not to form in the coastal plain, where plantations had their own wharves served by ocean-going ships: "[The coastal plain] being much intersected with navigable waters, and trade brought generally to our doors, instead of our being obliged to go in quest of it, has probably been one of the causes why we have no towns of any consequence" (Jefferson, 1781).

Instead, towns appeared at the fall line, where obstacles to water transport required the offloading of goods sourced upstream:

> In the interior [South] the principal group of trade centers [...] were those located at the head of navigation, or "fall line," on the larger rivers. To these points the planters and farmers brought their output for shipment, and there they procured their varied supplies [...] It was a great convenience to the producer to be able to sell his crop and buy his goods in the same market. Thus the towns at the heads of navigation grew into marked importance as collecting points for produce and distributing points for supplies of all sorts (Phillips, 1905).

Today, these rivers are no longer used for commercial transportation, yet major cities persist at fall line portage sites. Figure 1 shows several such cities in present-day Virginia; e.g., Richmond (at the falls of the James River), Petersburg (Appomattox), and Fredericksburg (Rappahannock). Even as their initial advantage declined, portage cities did not shrink compared with either the average location or locations that were similarly dense historically. Contemporary prices and quantities of sunk legacy capital stocks (e.g., infrastructure, housing, or literacy) in portage cities are comparable with those in other cities of similar sizes, suggesting that persistence is not a medium-run effect of oversupplied legacy capital. (In any case, historically sunk investments in housing and infrastructure likely have depreciated completely over the 20th century, and, with a growing population, sunk factors from the 19th century are almost certainly inframarginal.) Finally, the relatively smooth landscapes of the coastal plain and Piedmont means that there is an absence of natural factors that might explain persistence in other contexts (Lee and Lin, 2013).

Recent studies find important effects of temporary historical factors on the sizes and types of cities. For example, German division resulted in a permanent diversion of air traffic from Berlin to Frankfurt (Redding et al., 2011). Dramatic but temporary reductions in the supply of raw cotton to the British textile industry during the U.S. Civil War had a long-run impact on English towns where cotton production had been concentrated before the war (Hanlon, 2014). Within Manhattan, historical marshes affect housing prices even today, despite sewers having rendered their initial disadvantages moot (Villarreal, 2014). And rail lines that are subsequently scuttled appear to have permanent effects on the spatial distribution of activity, both across (Jedwab and Moradi, 2014) and within cities (Brooks and Lutz, 2014).

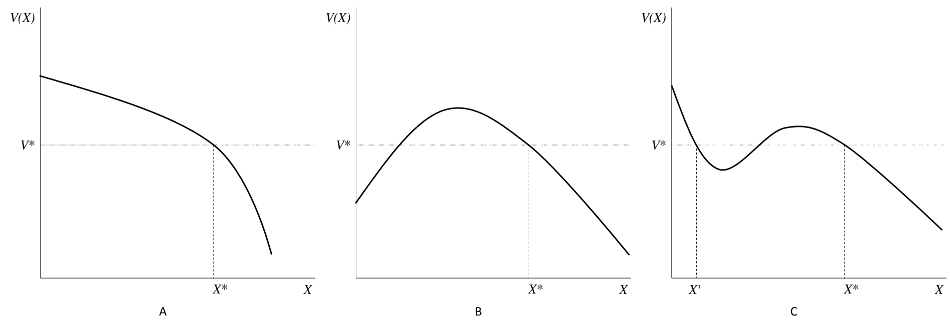

Figure 2: Utility curves with unique (A, B) and multiple (C) stable equilibrium city sizes

3 History and theory

What can explain persistence in city sizes in cases where natural advantages became obsolete and historical legacy capital long ago depreciated? Localized aggregate increasing returns are a natural explanation for path dependence in city sizes. Importantly, in the presence of increasing returns, a particular location may feature multiple equilibria in city sizes. Then, persistent differences in city size can be rationalized even in the absence of differences in natural advantages or sunk capital.

In models of city sizes, a convenient way to describe equilibrium at a particular site is to derive indirect utility $V(X)$ as a function of total city population or employment X. In long-run spatial equilibrium, city size is such that the marginal mobile household receives the same utility in that city as a reservation level of utility (V^*, which may be endogenous) available in other cities.

The shapes of these utility curves depend on the agglomeration and dispersion forces considered. Figure 2 shows these utility curves as a function of total city size X, under three different assumptions about the number and types of such forces.

Recent studies have attempted to quantify equilibrium models of city sizes.[1] Many assume functional forms or parameter values that imply unique equilibrium city sizes. But to take path dependence seriously, it may be useful and important to work with a more flexible model that admits more

[1]Examples include Albouy and Stuart (2014); Chatterjee (2006); Diamond (2013); Desmet and Rossi-Hansberg (2013); Haughwout and Inman (2001); Lee and Li (2013); and Rappaport (2008a, 2008b).

features, including multiple equilibria.[2]

A model featuring a single dispersion force is the easiest to analyze. For example, each location might feature a fixed land endowment that is diluted with increasing population. Without an offsetting agglomeration force, the essential feature of such a model is a downward sloping pseudo-demand curve for labor at a location (Panel A). Then, a unique long-run equilibrium city size exists at X^*, where the utility curve intersects V^*. In this model, size differences can be rationalized by natural variation in production or consumption amenities, which correspond to vertical translations of the utility curve. In the medium run, path dependence in city sizes among locations with similar fundamentals might be explained by the legacy value of sunk investments that have not depreciated yet. However, in the long run, if factors are mobile, then persistent differences in city sizes are difficult to explain absent differences in fundamentals. In this case, there can be no long-run path dependence.

Even the addition of an agglomerative force may not yield predictions consistent with path dependence. Consider the production function $Y = \phi \bar{X}^{\delta} f(X, L, K)$, where $f()$ is a firm-level constant returns to scale production function in labor, land, and capital, ϕ is a local productivity shifter, and $0 < \delta < 1$ is the degree of (external) increasing returns to scale in city-level employment ($\bar{X}$).[3] For large enough δ, a typical utility curve may feature a single-peaked hump shape (Panel B).

Though there are two points where the utility curve crosses the reservation utility level, only the larger city size X^* is a stable equilibrium.[4] Thus, these assumptions also yield the result of a unique stable equilibrium city size for each location. Two cities may be of different size because of variation in locational fundamentals. But again, it is difficult to explain path dependence in city sizes in this framework.

Path dependence is ruled out because the restrictive form assumed for agglomeration economies ensures that fundamentals uniquely determine city size. Spillovers of the form $\bar{X}^{\delta}$ imply marginal benefits to agglomeration that are very large at small scales and strictly declining with size. Some types of agglomeration have the strongest benefits at small scales; for example,

[2]Helpman (1998) shows that the welfare properties of equilibrium are very different in models featuring unique versus multiple equilibria.

[3]Henderson's (1974) canonical model includes a similar specification for increasing returns to scale at the city level. His dispersion force is a commuting cost that increases with the size of the city. Several of the above-cited studies use this $\bar{X}^{\delta}$ form of agglomeration.

[4]This equilibrium is stable in the sense of Henderson (1974) or Helpman (1998). As Henderson notes, there may be another unstable equilibrium at zero in Panel B.

matching as in Diamond's (1982) coconut model. (See also Murphy (1986); Bleakley and Lin (2012b).) But agglomeration economies might have the opposite pattern: negligible effects at very small scales that kick in only after some important threshold is crossed (e.g., due to fixed costs). "Big Push" models have this flavor (Murphy et al., 1989). In addition, under this specification for agglomeration economies, the model has strong predictions about the pattern of city sizes: It is difficult to explain small, nonempty sites without requiring them to be in an unstable equilibrium.[5]

For these reasons, it seems desirable to choose a different set of assumptions about agglomeration and dispersion forces. Helpman (1998) uses fixed costs, transport costs, and a fixed endowment of housing to generate utility curves as in Panel C. In this formulation, utility curves are S-shaped, and the S-shape reflects different ranges of city size where dispersion or agglomeration forces dominate. There are now two stable, nonzero equilibrium city sizes, labeled X' and X^*. Note that locations that are otherwise identical in terms of locational fundamentals might have very different long-run city sizes. Across locations, which equilibria are selected might depend on history (Krugman, 1991). Thus, an early but temporary shock to fundamentals might lead to persistent differences. Additional curvature in utility yields multiple equilibria, providing a way to understand path dependence in city sizes.

However, such a specification would now have difficulty in explaining *intermediate* city sizes, corresponding to the range where utility is upward sloping, without requiring them to be in unstable equilibrium. (Note that the empirical distribution of city sizes does not exhibit bimodality around X' and X^*.) This implication arises because of how fundamentals enter the model: Natural production or consumption amenities shift utility curves across locations up or down. An amenity is neutral with respect to density, thus yielding the same proportional benefit to a large or small city.

This neutrality assumption seems at best incomplete. One can think of a whole host of investments or endowments that might complement density: for example, infrastructure, congestion pricing (Brinkman, 2013), or geographic barriers to development (Harari, 2014) might all affect the congestion penalty associated with increased size.

On the other hand, the strength of agglomeration forces might also vary across cities. Differences in industrial specialization might affect returns to scale (Henderson, 1974). The nonneutrality of fundamentals also echoes the time-honored concept of "economic base" from regional economics (Jacobs,

[5]This observation was made by Chatterjee (2006).

1969). Economic base matters because, roughly speaking, products that can be exported are not subject to a sharply downward-sloping local demand curve. Market access complements density because sites with better access can get larger without depressing prices received for their output.

Taken together, these arguments suggest that agglomeration and dispersion forces vary across locations. Thus, one way that an equilibrium model of city sizes can accommodate both the historical evidence of path dependence and the empirical size distribution of cities is to allow for (i) marginal agglomeration benefits that increase over some range of sizes and (ii) heterogeneous agglomeration and dispersion forces. In recent work (Bleakley and Lin, 2015), we develop a model relaxed in this manner. Of course, if many forces, potentially idiosyncratic to each site, are allowed to explain city size, then such a model is likely to be underidentified. We use partial-identification methods to construct bounds on the scope for multiplicity in contemporary U.S. counties. These bounds are quite wide: The data and revised model are consistent with the existence of alternative equilibrium sizes for both very few and very many cities. We then suggest tightening these bounds using obsolete endowments (e.g., portage) to constrain the model.

4 Conclusions

Recent empirical studies document examples of path dependence in the sizes of cities following the obsolescence of initial endowments. But these findings contrast with recent efforts to analyze calibrated models in which locational "fundamentals" uniquely determine city sizes. We suggest that such models might better match the empirical results on path dependence by allowing for multiplicity in size in many locations. These relaxations may also help better identity the effects of exogenous fundamentals versus endogenous history in the spatial distribution of economic activity.

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