

## Creative Destruction: Barriers to Urban Growth and the Great Boston Fire of 1872<sup>†</sup>

By RICHARD HORNBECK AND DANIEL KENISTON\*

*Urban growth requires the replacement of outdated buildings, yet growth may be restricted when landowners do not internalize positive spillover effects from their own reconstruction. The Boston Fire of 1872 created an opportunity for widespread simultaneous reconstruction, initiating a virtuous circle in which building upgrades encouraged further upgrades of nearby buildings. Land values increased substantially among burned plots and nearby unburned plots, capitalizing economic gains comparable to the prior value of burned buildings. Boston had grown rapidly prior to the Fire, but negative spillovers from outdated durable buildings had substantially constrained its growth by dampening reconstruction incentives. (JEL H76, N91, R11, R52, R58)*

Cities in the United States have undergone remarkable transformations, as modern metropolises have emerged from small towns. This historical process of building construction, obsolescence, and reconstruction has in large part been managed by private landowners, though substantial inefficiencies may arise when landowners' construction decisions do not internalize impacts on neighbors. Zoning regulations and building codes seek to prevent some negative externalities on neighbors, though small landowners are generally not compensated for building investments that generate positive externalities on neighbors. Landowners may then respond insufficiently to increased demand for urban spaces, constraining urban growth and a core component of overall economic growth.

\*Hornbeck: Professor of Economics and Neubauer Family Faculty Fellow, University of Chicago Booth School of Business, 5807 South Woodlawn Avenue, Chicago, IL 60637, and NBER (e-mail: Richard.Hornbeck@ChicagoBooth.edu); Keniston: Assistant Professor of Economics, Department of Economics, Yale University, 27 Hillhouse Avenue, Room 22, New Haven, CT 06520, and NBER (e-mail: Daniel.Keniston@Yale.edu). For comments and suggestions, we thank Nava Ashraf, Leah Boustan, Leah Brooks, Bill Collins, Brad DeLong, Bob Ellickson, Don Fullerton, Matt Gentzkow, Ed Glaeser, Claudia Goldin, Tim Guinnane, Hugo Hopenhayn, Matt Kahn, Emir Kamenica, Larry Katz, Michael Kremer, Naomi Lamoreaux, Gary Libecap, Neale Mahoney, Sendhil Mullainathan, Derek Neal, Trevor O'Grady, Chris Udry, John Wallis, Bill Wheaton, and seminar participants at American Bar Foundation, Berkeley, Chicago, Chicago Booth, Chicago Law, Colorado, EIEF, George Washington, Harvard, Illinois, Lincoln Institute of Land Policy, Massachusetts Institute of Technology, NBER, Northwestern, Pittsburgh, PUC-Chile, UCLA, and Yale. For financial support, we thank Harvard's Taubman Center for State and Local Government and Harvard's Warburg Fund. For excellent research assistance, we thank Louis Amira, James Feigenbaum, Jan Kozak, Julius Luetge, Michael Olijnyk, Joseph Root, Sophie Wang, Alex Weckenman, and Kevin Wu, in addition to many others for their data entry work. The authors declare that they have no relevant or material financial interests that relate to the research described in this paper.

<sup>†</sup>Go to <https://doi.org/10.1257/aer.20141707> to visit the article page for additional materials and author disclosure statement(s).

This paper analyzes the Great Boston Fire of 1872, which destroyed a section of downtown Boston, as an opportunity to explore constraints on urban growth that may have been released by the Fire. Contemporaries speculated that the Fire generated benefits from the opportunity for widespread reconstruction, though these reactions may have simply reflected the newness of buildings in the burned area and a desire to take positives from an otherwise disastrous event. We formalize this intuition with a model of urban growth in which the Fire might appear beneficial because destroyed buildings are replaced with newer more-valuable buildings, but forcing landowners to replace their buildings generates no economic benefits in the absence of cross-plot externalities. With cross-plot externalities, however, widespread simultaneous reconstruction after the Fire does generate economic gains: building reconstruction increases land value in nearby areas and encourages landowners to reconstruct even higher quality buildings that generate further positive spillover effects.

The empirical analysis uses a new plot-level dataset, covering all plots in the burned area and surrounding areas in 1867, 1869, 1871, 1872, 1873, 1882, and 1894. City tax assessment records provide data on each plot's land value, building value, land area, and occupant characteristics. Using supplemental data on plot sales from Boston's Registry of Deeds, we find that assessed values align closely with the available sales data in the burned and unburned areas both before and after the Fire. While there are challenges in separately assessing land value and building value, we also find no difference between assessed land values for developed plots and nearby vacant plots.

We estimate that the Fire generated substantial economic gains, capitalized in higher land values. Land values increased substantially in the burned area, and by a similar magnitude in nearby unburned areas, with the estimated impact declining in distance to the Fire boundary until leveling off at around 1,339 feet (25–30 buildings away). If we assume the Fire had no impact beyond 1,339 feet, the implied total increase in land value is comparable to the total value of buildings burned in the Fire.

Building values also increased substantially in the burned area after reconstruction. Some of this increase is mechanical, reflecting landowners upgrading buildings sooner than they would have preferred in the absence of the Fire, but the simultaneous reconstruction of many buildings appears to have encouraged even greater investments. Reconstruction of the burned area was followed by increased building values in nearby unburned areas. Building values also increased at even the highest quantiles of the distribution, as the Fire cleared out the lowest quantiles of building values that had discouraged further investment at the high-end.

Estimated impacts on land values and building values, both in the burned area and nearby unburned areas, appear to reflect positive spillover effects on nearby plots from higher-value reconstructed buildings. Forcing landowners to replace their own building could not increase their own land value, in principle, but forcing many neighbors to replace their buildings can raise landowners' own land value and encourage further investment in their own building. It was prohibitively difficult for individual landowners to negotiate direct compensation for positive spillover effects from their own reconstruction, given the small and disparate impacts on hundreds of nearby buildings, but the Fire temporarily mitigated this impediment to

urban growth by removing older low-value buildings and creating an opportunity for simultaneous widespread reconstruction that unleashed substantial economic value.

Comparing impacts of the Great Fire to the impacts of individual building fires around this period, we further see a contrast between the simultaneous reconstruction of many nearby buildings and the sequential reconstruction of individual buildings. Building values increased following individual building fires, but building values increased by more following the Great Fire and the simultaneous reconstruction of many nearby buildings. In addition, while land values increased following the Great Fire, burned plots' land values were unchanged following an individual building fire.

We consider several other mechanisms through which the Fire might have generated economic gains. Building reconstruction after the Fire was associated with a shift from residential to commercial occupants, and perhaps increased occupant wealth, which may have supported positive spillover effects across plots from upgraded buildings. The Fire prompted moderate changes to the road network in the burned area, though similar nearby changes to the road network a few years earlier had little impact on land values. Estimated impacts of the Fire are also similar when controlling for changes in plots' nearest road width. The Fire could have encouraged land assembly, though we estimate little increase in plot size and ownership concentration in the burned area. We also do not see increased agglomeration of industries after the Fire. Rather than leading to direct coordination across plots, the Fire appears to have temporarily reduced the negative consequences of uncoordinated reconstruction by forcing simultaneous widespread reconstruction.

The results relate to a literature on neighborhood spillovers from urban revitalization (Rossi-Hansberg, Sarte, and Owens 2010), home foreclosures (Campbell, Giglio, and Pathak 2011; Mian, Sufi, and Trebbi 2015), gentrification (Guerrieri, Hartley, and Hurst 2013), and rent control (Autor, Palmer, and Pathak 2014). Recognition of these neighborhood spillover effects can be seen in policy efforts toward large-scale urban renewal (Collins and Shester 2013), subsidies to attract large manufacturing plants (Greenstone, Hornbeck, and Moretti 2010), and rental payment structures within shopping malls (Pashigian and Gould 1998; Gould, Pashigian, and Prendergast 2005). While urban policy efforts have often focused on attracting investment to poorer declining areas, we find that these neighborhood spillovers are substantively important in wealthy growing areas. Indeed, we would only expect destruction from a Fire to generate economic benefits in a growing city, where landowners upgrade buildings and this forced reconstruction generates positive externalities. In a declining city, where older-vintage buildings may be of greater value than landowners choose to construct after a Fire, the forced reconstruction would lead to negative externalities and economic losses.

This paper is also related to a cross-city literature on cities' resilience to major shocks (Davis and Weinstein 2002; Miguel and Roland 2011; Brakman, Garretsen, and Schramm 2004; Sanzo-Navarro, Sanz, and Vera-Cabello 2014). This literature finds that long-run city size is robust to temporary shocks (e.g., city-wide bombing). We also find convergence between burned and unburned plots within Boston. We expect convergence to occur because the benefits of the Fire dissipate over time, as buildings constructed after the Fire become increasingly out-dated and discourage further investment if there is no subsequent Fire. While cities may be resilient to

shocks in the long run, these cities would not reach their long-run potential if land-owners do not internalize positive spillover effects from their own reconstruction. In principle, these positive spillover effects could also take particular functional forms that would generate multiple equilibria and long-run impacts from temporary shocks (Bosker et al. 2007; Bleakley and Lin 2012; Michaels and Rauch 2016; Jedwab and Moradi 2016; Jedwab, Kerby, and Moradi 2016).

The research design relates to a literature on major city fires (Fales and Moses 1972; Douty 1977; Rosen 1986; Macaulay 2007; Siodla 2015). Siodla (2015) shows increases in building density around the boundary of the San Francisco Earthquake and Fire of 1906 that, similar to our estimated increases in building value after the Boston Fire, are consistent with rigidities in urban growth but need not indicate economic gains from the Fire.<sup>1</sup> Siodla (2016) analyzes changes in the spatial pattern of land-use, related to our analysis of industrial agglomeration and occupant characteristics. Rosen (1986) also considers changes in spatial organization after the Boston, Chicago, and Baltimore Fires, and documents the institutional barriers to changes in road infrastructure, building codes, and spatial patterns that inhibited more radical transformations after the Fires. Destruction from a major city fire, or some other natural disaster, creates an opportunity for change and the economic responses to these disasters can provide a view into the city's underlying economic structure.

Boston's post-Fire reconstruction demonstrates that building investments can generate substantial externalities, and that encouraging investments with positive externalities can substantially increase urban growth. There should be no general expectation that city fires or other natural disasters generate economic gains, however, as these events may not encourage such investments in other contexts (e.g., in previously declining cities). Modern zoning regulations and stronger building codes may lead to better coordination of building investments than in historical Boston, though development restrictions may further discourage building investments that generate positive externalities (Turner, Haughwout, and van der Klaauw 2014). Modern cities also exhibit substantial heterogeneity in building age and land-use, often reflecting historical influences, which suggest potential gains from resetting urban spaces. The historical transformation of American cities occurred despite the potential for substantially better economic outcomes, to the point that burning a large section of Boston generated substantial economic gains in the nineteenth century. There are less destructive mechanisms than a Fire, however, to focus land-use regulations on discouraging negative externalities and to encourage investments with positive externalities.

<sup>1</sup> We do not estimate increases in density following the Boston Fire, but this reflects the density of pre-Fire Boston and building height limitations of construction technology in 1872. The unavailability of data on San Francisco land value, and a focus on the boundary around the Fire, make it more difficult to analyze spillover effects in urban reconstruction and the resulting economic gains from the San Francisco Fire.

## I. Historical Background and Data Construction

### A. *The Great Boston Fire of 1872*

In the nineteenth and early twentieth century United States, dangerous heating and lighting methods led to frequent small fires amongst densely-located fire-prone buildings (Wermiel 2000). These individual building fires occasionally developed into major conflagrations that spread through central business districts of major cities, perhaps most notably in the Chicago Fire of 1871 that destroyed downtown Chicago.

In November 1872, a fire spread through a portion of Boston's business district and destroyed 776 buildings in downtown Boston. Boston firefighters were unable to stop the initial fire before it spread, due partly to delays in sounding the alarm and sickness amongst the fire department's horses that prevented the rapid deployment of equipment to the burning area (Fire Commission 1873). The Fire burned for 22 hours and was eventually stopped with the arrival of massive firefighting resources from surrounding towns. The Fire caused approximately \$75 million in damages, or 11 percent of the total assessed value of all Boston real estate and personal property (Frothingham 1873).

There was tremendous private sector demand to rebuild Boston, as the Fire followed a period of strong growth in Boston real estate values. Insurance payouts partly funded reconstruction, and the Fire prompted substantial capital inflows from domestic and international sources.<sup>2</sup>

Reconstruction was largely managed privately, in this era prior to zoning regulations and strong building codes, with limited ability for the city government or other institutions to coordinate reconstruction. The city purchased land to widen and extend some downtown roads, though landowners' opposition stopped more ambitious efforts to modify the road network.<sup>3</sup> Similarly, calls for a strong building code were undermined, and the ultimate legislation was weak and substantially rescinded in 1873 (Rosen 1986). Technological constraints precluded the reconstruction of taller buildings after the Fire, but buildings could be improved along various more subtle dimensions. The burned area had been a densely developed commercial neighborhood, located adjacent to the central business district around the area of the Old State House, and the Fire was seen as an opportunity to create more suitable economic spaces.

Newspapers and other contemporaries noted that buildings in the burned area were often better after reconstruction. On the one year anniversary of the Fire, the *Evening Transcript* concluded that the "improved aspect of the entire district shows that occurrences calamitous in their first effects sometimes result in important

<sup>2</sup>Insurance covered three-fourths of total fire damages, though many insurance companies were bankrupted by the Fire and payouts were roughly half of total damages (Fowler 1873). Insurance payouts should not impact landowners' reconstruction decisions, given the excellent access to capital markets, though the empirical analysis will explore whether landownership becomes more concentrated in the burned region. Some landowners may have been liquidity-constrained after the Fire destroyed their property and the collateral needed to raise more capital. We have been unable to link particular plots to their insurance underwriter which would have allowed us to explore these channels more directly.

<sup>3</sup>The City of Boston had recently begun a program of street widening in nearby areas, and we also explore the impacts on nearby road widening prior to the Fire.





FIGURE 1. HISTORICAL DOWNTOWN BOSTON, THE BURNED AREA, AND SAMPLE PLOT LOCATIONS

*Notes:* The dark shaded area was burned during the 1872 Great Fire of Boston, overlaid on downtown Boston in 1867 (Sanborn Map Company). Small black points denote each geo-located plot in our main sample for 1867.

material good” (Rosen 1986). Even substantial upgrading of buildings need not imply any economic gains from the Fire, however, and our theoretical framework clarifies this intuition. We then highlight how, in the presence of cross-building externalities, the Fire might indeed result in important material good.

### *B. Digitization of Plot-Level Records*

The City of Boston sent tax assessors to each land plot annually to collect information for real estate and personal property taxes. We have digitized these handwritten records for 1867, 1869, 1871, 1872, 1873, 1882, and 1894, covering all plots in the area burned during the 1872 Fire (which occurred after that year’s tax assessment) and all plots in surrounding downtown areas. We assigned each plot its geographic location using geo-referenced plot-level fire insurance maps of Boston in 1867, 1873, 1883, and 1895 (Sanborn Map Company 1867–1895; G.W. Bromley and Co. 1883).<sup>4</sup>

Figure 1 maps the location of digitized land plots in 1867, and we limit the sample to land plots in this same region in each subsequent year. There are 44,543 land

<sup>4</sup>These maps indicate the location of each building and its street address, and often indicate the plot’s square footage and owner name, which were used in matching the assessed plots to their geographic location.

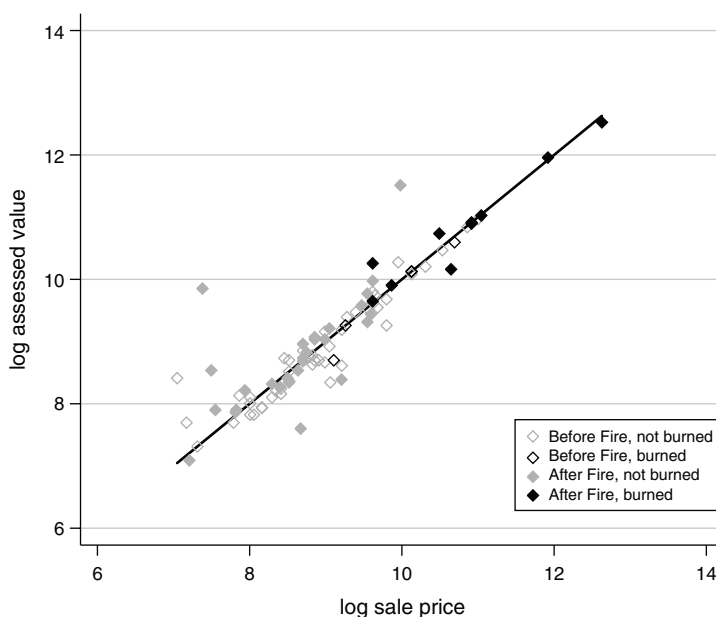


FIGURE 2. PLOT ASSESSED VALUE VERSUS PLOT SALE PRICE

*Notes:* log assessed value is plotted against log sale price for a sample of 88 plots: 16 plots in the burned area (black) and 72 plots outside the burned area (gray). Plot observations are hollow diamond shapes when observed before the Boston Fire, and solid diamonds when observed after the Fire; log assessed value comes from our tax assessment database, and log sale price is from Boston's Registry of Deeds. Plots are shown against the 45-degree line.

plots in our main sample, pooling across all 7 years.<sup>5</sup> We digitized the assessment data on each plot's land value, building value, land area, and street address. We also collected data on each commercial occupant's industry and value of business capital, and on each residential occupant's value of personal property.<sup>6</sup>

Tax assessors were instructed to assign market values to land and buildings, though a natural concern is whether assessed values accurately reflect economic conditions. We collected property sales data from Boston's Registry of Deeds, which show a close relationship between assessed values and transaction values (Figure 2). There is no systematic change in the relationship between assessed values and transaction values after the Fire in the burned area, relative to unburned areas (online Appendix Table 1). Contemporaneous statistical research particularly favored the use of Boston data because "[real estate] gains or losses, according to the assessor's figures, justly represent the proportionate change in real values" (Whitmore 1896). Further, as an indication that tax assessors effectively separated plots' land value and building value, there is no assessed land value premium for vacant plots compared to nearby plots with buildings. There is also substantial variation in the fraction of a plot's total value that reflects its building value, and the empirical analysis

<sup>5</sup>We exclude wharfs from our analysis, as the land area itself is endogenously determined, though our estimates are not sensitive to this restriction.

<sup>6</sup>Residential occupants included only males aged 20 and older. We did not collect residents' occupation because the land itself is used for housing and our analysis is focused on land-use. While residents' occupation would provide insight into their income, we instead have data on the value of their personal possessions.

TABLE 1—PRE-FIRE DIFFERENCES BETWEEN THE BURNED AREA AND UNBURNED AREA

	Full sample			Close sample			Distant sample		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
<i>Panel A. log value of land per square foot</i>									
1867 × burned	0.948 (0.100)	0.167 (0.034)	—	0.344 (0.103)	0.143 (0.037)	—	1.471 (0.092)	0.187 (0.036)	—
1869 × burned	0.826 (0.098)	0.044 (0.028)	—	0.239 (0.099)	0.038 (0.030)	—	1.326 (0.094)	0.042 (0.029)	—
1871 × burned	0.782 (0.086)	—	—	0.201 (0.087)	—	—	1.284 (0.083)	—	—
1872 × burned	0.772 (0.084)	−0.010 (0.012)	−0.014 (0.017)	0.179 (0.084)	−0.023 (0.014)	−0.024 (0.016)	1.282 (0.080)	−0.001 (0.012)	0.009 (0.029)
<i>Panel B. log value of building per square foot</i>									
1867 × burned	0.551 (0.164)	−0.146 (0.111)	—	0.132 (0.165)	−0.138 (0.115)	—	0.918 (0.168)	−0.140 (0.113)	—
1869 × burned	0.703 (0.118)	0.006 (0.047)	—	0.293 (0.119)	0.023 (0.052)	—	1.052 (0.122)	−0.006 (0.050)	—
1871 × burned	0.697 (0.112)	—	—	0.27 (0.114)	—	—	1.058 (0.114)	—	—
1872 × burned	0.730 (0.098)	0.033 (0.026)	0.029 (0.034)	0.306 (0.100)	0.036 (0.029)	0.027 (0.035)	1.084 (0.100)	0.026 (0.026)	0.079 (0.039)
<i>Controls</i>									
Year fixed effects	X	X	X	X	X	X	X	X	X
Burned region		X	X		X	X		X	X
Year FE × pre-1872 values			X			X			X
Number of plots	25,834	25,834	6,339	11,546	11,546	2,792	16,560	16,560	4,101

*Notes:* For log land value per square foot (panel A) and log building value per square foot (panel B), column 1 reports the cross-sectional difference in each pre-Fire year between all burned plots and all unburned plots. Column 2 reports the difference in value in the indicated year, relative to the difference in the omitted year 1871. Column 3 includes controls for each plot's nearest plot value in 1867, 1869, and 1871 (most often the value of those same plot boundaries) and controls for each plot's city block average value in 1867, 1869, and 1871. Columns 4–6 report corresponding estimates, but limiting the sample of unburned plots to those within 1,338 feet of the Fire boundary. Columns 7–9 report corresponding estimates, but limiting the sample of unburned plots to those beyond 1,338 feet from the Fire boundary. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses.

estimates different responses to the Fire among land values and building values. The online Appendix discusses additional details on the tax assessment data, and further explores potential biases in the data.

### C. Pre-Fire Values in Burned and Unburned Areas

The Fire began in downtown Boston and spread toward some of the most valuable parts of the central downtown area (Figure 1). Investigations and hearings following the Fire provide no accounts of the fire department prioritizing areas for protection, which were all relatively valuable at the time (Fire Commission 1873; Fowler 1873). Wide roads provided natural barriers, though the Fire sometimes crossed wide roads and sometimes ended within a block. Restricting our sample to plots within 100 feet of the Fire boundary, we estimate no substantial or statistically significant difference across the Fire boundary in plots' land value or building value in 1872.

Table 1 reports estimated pre-Fire differences in burned plots' land value (panel A) and building value (panel B). Column 1 reports cross-sectional estimates



in each year, regressing plots' value per square foot on year fixed effects, and year-interacted indicator variables for whether that plot was later burned in the Fire (after the assessment of values in 1872). Burned plots had substantially higher land value in each year prior to the Fire, and this difference was declining somewhat over time. Column 2 includes a main effect for the burned region, and omits the interaction with 1871, which then directly reports the difference in burned plots' land value relative to the difference in 1871 (i.e., differences-in-differences). Between 1871 and 1872, land values declined relatively by 1 percent in plots that would later burn. This difference becomes 1.4 percent when, in column 3, allowing for plots in more valuable areas to change differently over time by including year-interacted controls for each plot's value prior to 1872.<sup>7</sup>

Thus, while the burned area was more valuable prior to the Fire, we see burned and unburned plots changing similarly just prior to the Fire. The empirical analysis will draw on the assumption that these plots would have changed similarly between 1872 and 1873 (or beyond) in the absence of the Fire. As higher value plots might otherwise change differently over time, we examine results with and without controls for plots' pre-Fire values. Further, by including controls for multiple years of pre-Fire values, we also allow for plots to change differently after the Fire depending on differential pre-trends in earlier years. Some of our empirical specifications restrict the sample to plots within 1,339 feet of the Fire boundary, which correspond to the sample in columns 4–6 of Table 1. This “close sample” is problematic if the Fire generates spillover effects on non-burned plots, and so we also consider a “distant sample” that includes all burned plots and then unburned plots beyond 1,339 feet from the Fire boundary (which we estimate later as a cutoff point in the spillover effect). These alternative samples affect the cross-sectional differences (columns 4 and 7), but the relative changes over time are similar.

## II. Theoretical Framework

### A. Model Setup

The model illustrates the role of cross-building externalities in determining whether building destruction generates economic gains, and highlights a number of testable predictions that we take to the data. We consider the decisions of landowners choosing when to replace their durable building, which yields dynamics similar to one-sided s-S models of price-setting or vintage capital replacement.

Landowners construct a sequence of durable buildings to maximize the net present value of rents from their plot ( $r(q, Q, \omega)$ ), which depend on the quality of their building ( $q$ ), the average quality of nearby buildings ( $Q$ ), and the city's overall productivity ( $\omega$ ). Each landowner owns one plot and all landowners and plots are homogeneous.

<sup>7</sup> Plots' earlier values are predicted because we cannot always match each plot to its exact area in previous years. Instead, we control for the value of the nearest plot in each previous year, which most often corresponds to that same plot, and we also control for the average value of all plots in that same city block in each previous year. We discuss this in more detail along with the empirical methodology in Section III.

We allow for building rent to increase in the quality of nearby buildings ( $\partial r(q, Q, w_i)/\partial Q > 0$ ), and for the marginal return to building quality to increase in the quality of nearby buildings ( $\partial^2 r(q, Q, w_i)/\partial q \partial Q > 0$ ). By considering versions of the model with and without these spillover effects, we clarify how both of these effects are of central importance: the first spillover effect causes widespread post-Fire reconstruction to generate economic gains for landowners in the burned area (and nearby unburned areas), and the second spillover effect generates a multiplier effect in which simultaneous post-Fire reconstruction encourages even higher-quality reconstruction of burned buildings (and nearby unburned buildings).

We assume that building rent and the marginal return to building quality are increasing in city productivity ( $\partial r(q, \omega)/\partial \omega > 0$  and  $\partial^2 r(q, \omega)/\partial q \partial \omega > 0$ ). We focus on the case in which city productivity grows at a constant rate over time, which generates a dynamic in which landowners seek to upgrade buildings over time.<sup>8</sup>

Landowners can choose to replace their old building with a new building of quality  $q'$  by paying a cost  $c(q')$ .<sup>9</sup> We assume that buildings cannot be renovated incrementally and that buildings do not depreciate, which focuses attention on the dynamic aspects of the model that arise from building durability.<sup>10</sup> Individual buildings are occasionally destroyed with probability  $d$ , however, at which point the owner is left with only the value of the empty plot:  $V(0, Q, \omega)$ .

A landowner's total value from owning a building of quality  $q$ , given quality  $Q$  of nearby buildings and city productivity  $\omega$ , is given by the following Bellman equation:

$$V(q, Q, \omega) = \max \begin{cases} r(q, Q, \omega) + \delta E[V(q, Q', \omega')] \\ r(q^*, Q, \omega) + \delta E[V(q^*, Q', \omega')] - c(q^*) \end{cases},$$

where  $q^*$  maximizes  $r(q, Q, \omega) + \delta[(1 - d)V(q, Q', \omega') + d \cdot V(0, Q, \omega')] - c(q^*)$ . Building quality  $q^*$  represents the landowner's optimal choice of building quality when choosing to replace an old building, or when forced to reconstruct a building because of its destruction.

Landowners face a trade-off between two choices: (i) receiving rent  $r(q, Q, \omega)$  and continuing with the old building of quality  $q$ ; and (ii) paying a cost  $c(q^*)$  to construct a higher-quality building, receiving higher rents, and continuing with the new building of quality  $q^*$ . Intuitively, landowners over-build for contemporaneous

<sup>8</sup>This case approximates historical growth in Boston, though we will return to explore how the estimated results generalize to other contexts in which city productivity is declining over time. Landowners could also be encouraged to replace their buildings when construction costs are declining over time, which produces similar predictions as our baseline model.

<sup>9</sup>Construction costs are fixed over time, though declining construction costs would have similar implications as faster growth in city productivity because both encourage faster building replacement. Construction costs are assumed to be convex in building quality, which guarantees an interior solution. We assume that building construction is instantaneous, although foregone rents could also be included in the cost of construction. We also assume there are no demolition costs, which could also be included as a fixed component of construction costs. Fire might reduce some portion of demolition costs, but these costs then become sunk and do not influence subsequent construction decisions or become capitalized into building value or land value.

<sup>10</sup>The model's qualitative predictions are robust to the introduction of building depreciation or partial renovation, as long as the optimization problem is not reduced to a separate static optimization within each period (e.g., as long as the cost of continuous incremental renovation eventually becomes greater than the cost of constructing a new building of that quality).

conditions and then wait for city productivity to increase sufficiently until replacing their then-obsolete building. We denote this obsolete “teardown” building quality as  $\underline{q}$ , which represents the building quality at which landowners choose to reconstruct.

The total value from owning a building of quality  $q$  can be naturally decomposed into land value and building value components. The land value component reflects the option value from owning a plot with no building:  $V(0, Q, \omega)$ . Notably, this is equal to the value of owning a “teardown” building:  $V(0, Q, \omega) = V(\underline{q}, Q, \omega)$ . The building value component then reflects any additional value from a building of higher quality:  $V(q, Q, \omega) - V(\underline{q}, Q, \omega)$ .

This decomposition provides a useful framework for interpreting how land value and building value respond to shocks. For example, when only one building is reconstructed following its idiosyncratic destruction (or chosen replacement), the plot’s building value increases and its land value is unchanged.

### B. Predicted Impacts from a Great Fire

We illustrate the model’s predicted impacts from a Great Fire, assigning a Cobb-Douglas functional form to building rents:  $r(q, Q, \omega) = q^\alpha (Q^\eta \omega^{1-\eta})^\beta$ . In particular, we compare cases without neighborhood spillover effects ( $\eta = 0$ ) and with neighborhood spillover effects ( $\eta = 0.8$ ).<sup>11</sup> We present results from a numerical simulation, as analytical solutions are difficult to obtain for models of this type.<sup>12</sup>

Figure 3, panel A, graphs the evolution of building quality in the absence of neighborhood spillovers ( $\eta = 0$ ). Black solid lines reflect changes in the absence of a Great Fire or, equivalently, changes in unburned areas following a Great Fire in period 0. Average building quality grows steadily (central thick black solid line). Newly constructed buildings are the highest quality  $q^*$  for one period (at the upper thin black solid line), until they eventually become the lowest quality  $\underline{q}$  buildings and are replaced (at the lower thin black solid line).

In panel A, red dashed lines reflect changes in the burned region following a Great Fire in period 0. The Fire causes all landowners in burned areas to reconstruct their building at quality  $q^*$ , which raises substantially the lowest building qualities (lower thin red dashed line) and raises average building quality in the burned region (central thick red dashed line). Buildings reconstructed in the burned area have the same quality as buildings newly replaced in the unburned area, as returns to quality are unchanged by the Fire. Over time, landowners in the burned region delay further replacement and landowners in unburned areas naturally replace their buildings, such that the distributions of building quality converge.<sup>13</sup>

<sup>11</sup> In both cases, we set  $\alpha = \beta = 0.5$ . Buildings are constructed at cost  $c(q) = cq^\gamma$ , with  $\gamma = 2$ , and  $c = 5$ . The probability of exogenous destruction ( $d$ ) is set to 0.01,  $\delta$  is set to 0.9, and the growth rate is set to 0.06.

<sup>12</sup> We generate a sample of 3,000 buildings and simulate the model until it reaches steady-state, i.e., until the growth rate of the distribution of buildings stabilizes. We assume that owners expect city productivity and neighboring building quality to grow at the same constant rate after the Fire as prior to the Fire, which are correct beliefs in the long run, and qualitative predictions are robust to alternative beliefs during this period of transition (e.g., making the opposite, and overly pessimistic, assumption that neighboring building quality will cease to grow entirely after the Fire).

<sup>13</sup> Average building quality in the burned region is relatively lower in some later periods, as there arises a large concentration of relatively older buildings that were constructed immediately after the Fire. The average quality of burned and unburned buildings then oscillates until random building destruction induces long-run convergence.

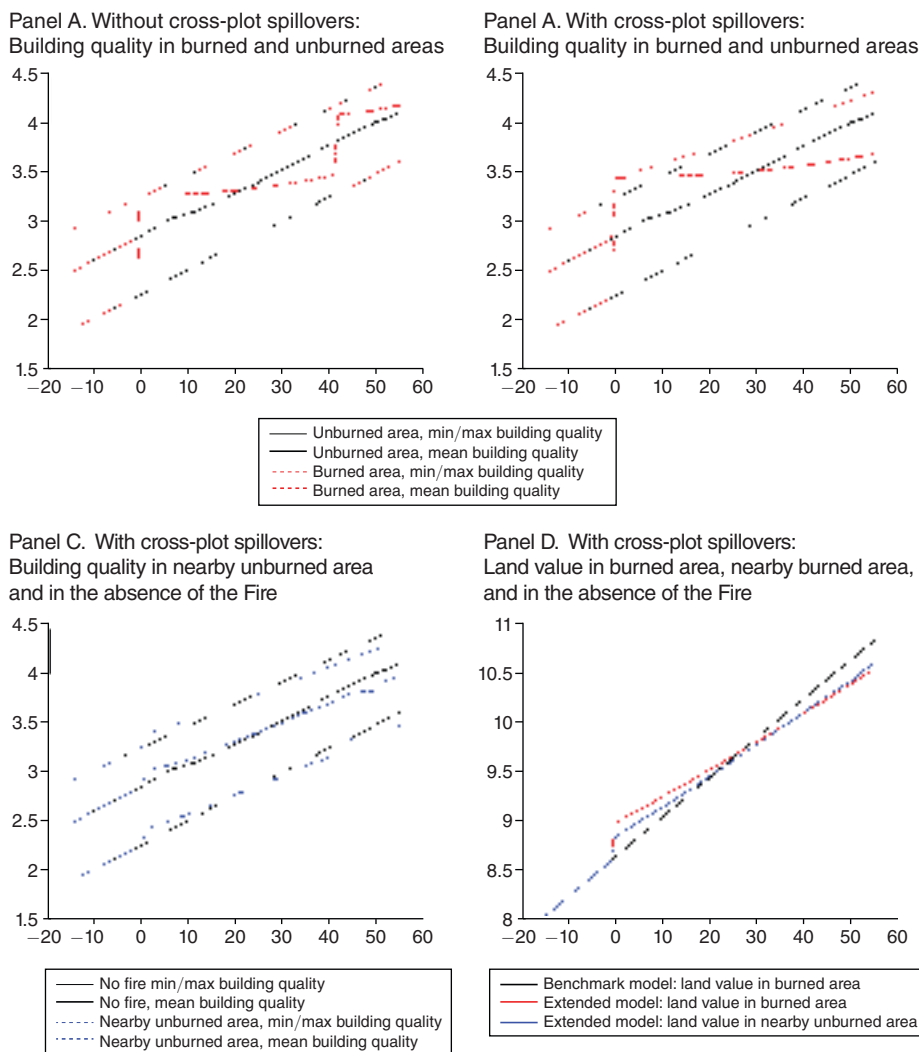


FIGURE 3. SIMULATED CHANGES IN BUILDING QUALITY AND LAND VALUE AFTER GREAT FIRE IN PERIOD 0

Notes: Panel A shows the simulated changes in building quality following a Great Fire in period 0, suppressing all crossplot spillover effects. The black lines represent the unburned area, and the red lines represent the burned area. Introducing cross-plot spillover effects, panel B shows the change in building quality in the burned area following a Great Fire in period 0 (red lines) and what the changes would have been in the absence of a Fire (black lines). Panel C shows the change in building quality in the nearby unburned area (blue lines) and what the changes would have been in the absence of a Fire (black lines). Panel D shows the simulated changes in land value following a Great Fire in period 0: the upper red line shows the change in land value in the burned area (allowing for cross-plot spillover effects); the middle blue line shows the change in land value in the nearby unburned area (allowing for cross-plot spillover effects); and the lower black line shows the change in land value in the absence of the Fire (or, equivalently, changes in all areas when suppressing all cross-plot spillover effects).

Figure 3, panels B and C, illustrate the effects of a Great Fire when allowing for neighborhood spillovers ( $\eta = 0.8$ ). In panel B, red dashed lines show changes in building quality for burned buildings whose neighborhood buildings all burned. In panel C, blue dashed lines show changes in building quality for unburned buildings

for whom half of their neighborhood buildings burned.<sup>14</sup> In both panels, solid black lines represent changes had there been no Great Fire in period 0.

Panel B shows that the presence of neighborhood spillover effects generates a positive multiplier effect from widespread simultaneous reconstruction after the Fire. In the burned region, due to higher neighboring building qualities, landowners reconstruct burned buildings to a discretely higher quality level than even the highest quality buildings recently reconstructed in period  $-1$ . That is, while the Fire's impacts continue to be greatest toward the bottom of the quality distribution, the Fire now has substantial impacts at even the highest quantiles of the quality distribution. This implies that, on average, a building's quality increases more after a Great Fire than after an isolated building fire. Over time, as in the case without neighborhood spillovers, building quality converges with oscillation to the same steady state had there been no Fire.<sup>15</sup>

Panel C shows that reconstruction of the burned region impacts building qualities in nearby unburned areas through neighborhood spillovers. A nearby group of landowners with lower-quality buildings, which had been getting closer to the optimal replacement time, choose to accelerate their building replacement and choose an even higher quality level than if the Fire had not occurred.<sup>16</sup> Average building quality increases in these nearby unburned areas, and these effects spread over time as landowners in further unburned areas also upgrade buildings in response. These geographic spillover effects complicate an analysis of the Fire's aggregate impacts, as even unburned areas are affected by the Fire, and we return to this issue in the empirical analysis.

Panel D shows predicted impacts of the Fire on land values, which are of particular use in capitalizing economic gains from the Fire. There is no distribution of land values in the model, as plots are assumed to be homogeneous, so we show changes in land values under alternative assumptions: as in panel A, when suppressing neighborhood spillovers, changes in the burned region or unburned areas (black line); as in panels B and C, allowing for neighborhood spillovers, changes in the burned region (red line) and nearby unburned areas (blue line). The black line also represents changes in land value in the absence of a Fire.

Importantly, the model predicts that land values increase after the Fire only when building rents are increasing in the quality of nearby buildings. In the absence of cross-building spillover effects, the destruction of a building does not change the option value associated with a vacant plot in that location. Indeed, the magnitude of this externality might be sufficiently large that increases in land value throughout the city are greater than the value of buildings destroyed in the Fire. Note that landowners do not coordinate their reconstruction in the model, or otherwise internalize these cross-building externalities, so the post-Fire reconstruction still falls below

<sup>14</sup>In particular, we simulate a nearby unburned area in which plots receive  $1/2$  the  $Q$  spillovers of plots with all burned neighboring plots.

<sup>15</sup>In principle, for other particular functional forms of neighborhood spillovers, the Fire could have persistent impacts due to multiple equilibria. We focus on a single equilibrium case, in which decreasing returns to quality cause the Fire's impacts to fade over time as city productivity increases and all buildings are replaced.

<sup>16</sup>In practice, if the Fire were to temporarily raise construction costs, then we might expect reconstruction of nearby unburned buildings to be delayed until after the burned area is reconstructed.

first-best levels of building quality and the potential gains in land value are even greater than those realized.

In summary, the model clarifies that a Great Fire always leads to reconstruction and increased building values in a growing city, but that a Great Fire generates economic gains in the presence of cross-building externalities. Among the consequences of cross-building externalities, and testable predictions that we take to the data, are: (i) the Fire increases plot land values in the burned region and land values converge over time, perhaps even falling below land values in unburned areas; (ii) the Fire increases land values and building values in nearby unburned areas; (iii) while the Fire's impacts on building values in the burned region are highest at the lowest quantiles, there are temporary impacts at even the highest quantiles; (iv) the Fire has a greater impact on building values than individual building fires and, while an individual building fire should result in higher building value after reconstruction, an individual building fire has no impact on its own land value. None of these impacts would be present in the absence of cross-building externalities.

A Great Fire could also impact urban growth through several other mechanisms, aside from positive cross-building spillover effects from reconstruction. These other mechanisms are outside the model, though in the empirical analysis we explore potential impacts from: land assembly and ownership concentration, business agglomeration, occupant sorting, and infrastructure investment.

### III. Empirical Methodology

Our initial empirical specification estimates differences between burned and unburned plots in each year after the Fire, relative to the difference between burned and unburned plots in 1872 (i.e., differences-in-differences). We regress outcome  $Y$  for plot  $i$  in year  $t$  on year fixed effects ( $\alpha_t$ ), an indicator variable for whether the plot is within the burned area ( $I_i^{Fire}$ ), and interactions between the burned area indicator variable and indicators for each year after the Fire:

$$(1) \quad Y_{it} = \alpha_t + \rho I_i^{Fire} + \beta_{1873} I_i^{Fire} \times I_t^{1873} + \beta_{1882} I_i^{Fire} \times I_t^{1882} \\ + \beta_{1894} I_i^{Fire} \times I_t^{1894} + \varepsilon_{it}.$$

The estimated coefficient  $\beta_{1873}$  reflects the average change from 1872 to 1873 in the burned area, relative to the average change from 1872 to 1873 in the unburned area.<sup>17</sup> The identification assumption is that plots in the burned area would have changed the same as plots in the unburned area, on average, in the absence of the Fire. This identification assumption is more plausible over shorter periods of time, and becomes more demanding over longer periods of time after the Fire.

<sup>17</sup>To keep the reported sample size consistent across specifications, we include all years of data between 1867 and 1894 and also control for interactions between the burned area indicator and pre-1872 year indicators. The burned area coefficients for each year are the same when estimated jointly in a pooled sample or when estimated separately including only that year and 1872, as all the variables are interacted with year. Table 1 reported corresponding estimates for years 1867–1872, with changes reported relative to 1871.



An extended empirical specification relaxes the above identification assumption, controlling for plot characteristics ( $\mathbf{X}_i$ ) that may be associated with differential changes after the Fire:

$$(2) \quad Y_{it} = \alpha_t + \gamma_t \mathbf{X}_i + \beta_{1873} I_i^{\text{Fire}} \times I_t^{1873} + \beta_{1882} I_i^{\text{Fire}} \times I_t^{1882} \\ + \beta_{1894} I_i^{\text{Fire}} \times I_t^{1894} + \varepsilon_{it}.$$

The estimated coefficient  $\beta_{1873}$  now reflects the average change from 1872 to 1873 for burned plots relative to unburned plots with similar characteristics  $\mathbf{X}_i$ . We begin by including controls for plots' land value or building value in each year prior to the Fire (1867, 1869, 1871, 1872), which allows for higher value plots or plots with previously increasing values to change differently between 1872 and each year after the Fire.<sup>18</sup> Further robustness checks include other plot characteristics, such as distance to the Old State House and whether plots experienced changes in water service or road width.

One technical challenge, due to changes in plot boundaries, is that we cannot always uniquely match each plot to its own characteristics in previous years. We therefore assign each plot the characteristics of its nearest plot in years prior to the Fire, which is generally that same plot with the exact same boundaries. We also include controls for the average characteristics of all plots within its same block in years prior to the Fire, which may have additional predictive power for that plot's subsequent changes.<sup>19</sup>

Further specifications estimate how proximity to the Fire boundary also impacts unburned plots, as potential spillover effects on nearby plots are central to understanding why the Fire might generate economic gains through widespread reconstruction. We begin with nonparametric estimates of impacts by distance to the Fire boundary, and then parametrize this relationship with a piece-wise linear function: constant in the burned area, then declining in distance to the Fire, and then constant at zero beyond an estimated distance cutoff. While we are unable to estimate aggregate city-wide impacts, given some potential impact on all plots, we can observe whether the spatial spillover effect appears to dissipate within some observed distance from the burned boundary.

If there are positive spillover effects of the Fire on unburned areas, then the simple comparison between burned areas and unburned areas gives a downward biased estimate of the Fire's impact. For some specifications, we create a "distant" sample that includes all burned plots and unburned plots further than 1,339 feet from the Fire boundary (our estimated distance cutoff in the nonlinear analysis). As closer unburned plots are more similar to burned plots in years prior to the Fire, we also create a "close" sample that includes all burned plots and unburned plots within

<sup>18</sup>Note that  $\gamma$  is allowed to vary by year, such that plot characteristics  $\mathbf{X}_i$  can differentially affect changes between 1872 and each subsequent year. Including these controls also absorbs the Fire main effect ( $I_i^{\text{Fire}}$ ), as plot values in 1872 are perfectly explained by controls for their value in 1872.

<sup>19</sup>For the few cases in which the closest plot has missing or zero values, such as if the building was under construction, we substitute data from the closest plot with nonzero values. In a few cases when the block-level building value average is zero (e.g., due to construction), we set the log value equal to zero and include an indicator variable for those plots.

TABLE 2—IMPACT ON LAND VALUES IN THE BURNED AREA, RELATIVE TO THE UNBURNED AREA

	log value of land per square foot					
	Full sample		Close sample		Distant sample	
	(1)	(2)	(3)	(4)	(5)	(6)
1873 × burned	0.151 (0.019)	0.167 (0.019)	0.139 (0.021)	0.147 (0.020)	0.160 (0.019)	0.261 (0.031)
1882 × burned	0.160 (0.043)	0.143 (0.038)	0.103 (0.047)	0.130 (0.037)	0.210 (0.043)	0.284 (0.065)
1894 × burned	−0.100 (0.056)	−0.140 (0.058)	−0.229 (0.064)	−0.149 (0.060)	0.024 (0.057)	−0.143 (0.077)
<i>Controls</i>						
Year fixed effects	X	X	X	X	X	X
Year FE × pre-Fire values		X		X		X
$R^2$	0.142	0.956	0.103	0.926	0.504	0.958
Number of plots	44,543	44,543	19,944	19,944	28,438	28,438

*Notes:* For all specifications, the outcome variable is the log value of land per square foot of the plot. Column 1 reports the estimated difference in each post-Fire year between all plots in the burned area and all plots in the unburned area, relative to the difference in the omitted year 1872. Column 2 includes controls for each plot's nearest plot value in 1867, 1869, 1871, and 1872 (most often the value of those same plot boundaries) and controls for each plot's city block average value in 1867, 1869, 1871, and 1872. Columns 3 and 4 report corresponding estimates, but limiting the sample of unburned plots to those within 1,338 feet of the Fire boundary. Columns 5 and 6 report corresponding estimates, but limiting the sample of unburned plots to those beyond 1,338 feet from the Fire boundary. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses.

1,339 feet of the Fire boundary. This close sample exacerbates any downward bias from positive spillover effects; indeed, comparing the close sample estimates and distant sample estimates also provides an initial view of these spillover effects.

Two additional empirical details are worth noting. First, the main regressions are weighted by plot size to ensure that fixed geographic areas are handled comparably over time.<sup>20</sup> Second, the standard errors are clustered by block to adjust for serial correlation and within-block spatial correlation. We also report standard errors that allow for more continuous spatial correlation (Conley 1999).

## IV. Results

### A. Impacts on Land Value

Table 2 reports estimated impacts on land values in the burned area, relative to land values in unburned areas. Column 1 reports estimates from our initial specification: land values increased sharply from 1872 to 1873 by roughly 15 percent, remained

<sup>20</sup>Consider the case in which two smaller plots combine into one: the one plot continues to report land value for the same area covered by two plots previously, and weighting the analysis by plot size ensures this fixed geographic area is handled comparably over time. Otherwise, areas experiencing plot consolidation would mechanically receive less weight and there would be a shift in the composition of the area analyzed. In addition, weighting by plot size recovers the average effect per square foot, which is used in calculating the total impact in the burned area.

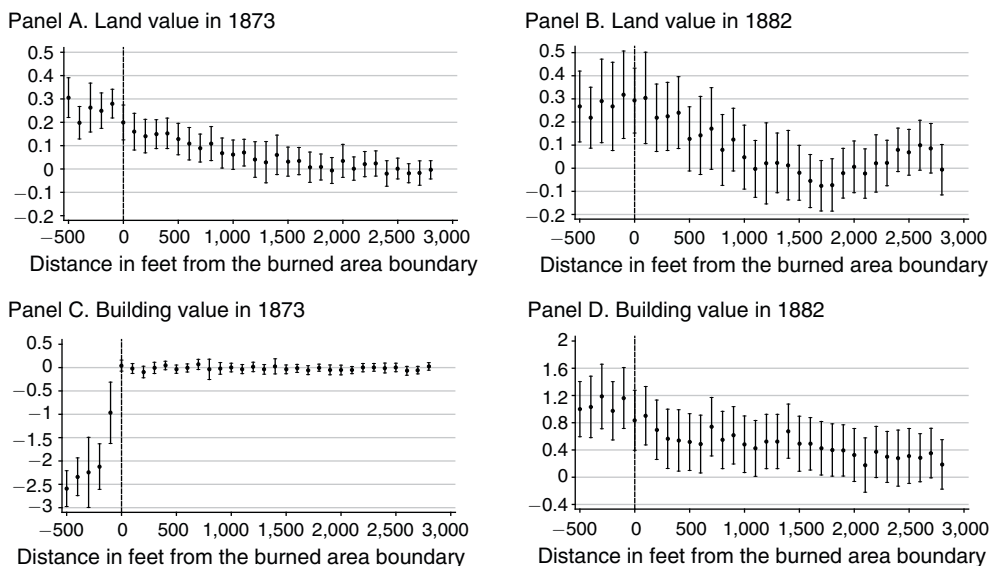


FIGURE 4. ESTIMATED IMPACTS ON LAND VALUE AND BUILDING VALUE IN 1873 AND 1882, BY DISTANCE TO THE FIRE BOUNDARY (Feet)

*Notes:* The vertical dashed line represents the boundary of the Fire. For the indicated distance from the boundary of the Fire, each circle reports the estimated impact on land value (panels A and B) or building value (panels C and D) in the indicated year, relative to the omitted category of plots more than 2,900 feet from the boundary of the Fire. The solid vertical lines reflect 95 percent confidence intervals. Negative distances reflect areas within the burned area, and burned plots more than 400 feet from the Fire boundary are grouped together. The empirical specifications include controls for plots' predicted land value in 1867, 1869, 1871, and 1872, based on the value of the nearest neighbor (most often that same plot in the earlier year) and the city block average.

similar from 1873 to 1882, and by 1894 had declined below 1872 levels relative to the unburned area. Column 2 reports similar estimates from our extended specification, which controls for plots' land value in each period prior to the Fire to adjust for pre-Fire relative differences in the burned area in both levels and trends. Estimated increases in land value are somewhat smaller when restricting the unburned sample to plots within 1,339 feet of the burned boundary (columns 3–4) and somewhat larger when restricting the unburned sample to plots further than 1,339 feet of the burned boundary (columns 5–6).

Figure 4, panel A, shows estimated impacts on land value in 1873, grouped into bins of 100 feet by plots' distance to the Fire boundary. The burned area is to the left of the dashed line, represented by negative distances, and the unburned area is to the right. The estimated coefficients are relative to the omitted category of plots more than 2,900 feet from the burned boundary, and the vertical lines represent 95 percent confidence intervals.<sup>21</sup> Land values increased in nearby unburned areas, by a similar magnitude as in the burned area, and this effect decreases with distance to the burned boundary until leveling off around 1,300 feet. By contrast, distance to the burned boundary was not similarly associated with relative changes in land value in years prior to the Fire.

<sup>21</sup> For the interior of the burned region, plots more than 400 feet from the burned boundary are grouped. The regression controls for plots' pre-Fire values, corresponding to the specification in column 2 of Table 2.

The Fire's total impact on land value is more challenging to calculate, and is likely understated by estimates in Table 2, given the spillover effects seen in panel A of Figure 4. First, relative comparisons between burned plots and nearby unburned plots understate the impact on burned areas when nearby unburned areas are also positively affected. Second, any positive impacts on nearby unburned areas should also be included in the total impact of the Fire. A within-city analysis is fundamentally limited in its ability to calculate city-wide impacts, but we could assume that unburned plots are unaffected by the Fire beyond some distance cutoff suggested by panel A of Figure 4. An important caveat is that observed spillover effects might reflect displacement of economic activity from unburned areas to the burned area, such that land values in further unburned plots are negatively affected by the Fire. Our sense is the downtown Boston economy was sufficiently integrated with the national and world economy that growth in the burned area need not have come at the expense of displacing growth in the unburned area, but the potential for both positive and negative spillovers is an important caveat to interpreting estimates of the Fire's total impact.

We estimate the Fire's total impact on land value by parameterizing the spatial relationship seen in panel A of Figure 4 with a continuous piece-wise linear function: constant within the burned area, decreasing linearly with distance outside the burned area, and then zero after some distance cutoff. The predicted impact on each plot's land value then depends on its distance to the burned area, and we sum these impacts across all plots to obtain an estimated total impact on land value.<sup>22</sup> The online Appendix discusses further details of the estimation, which uses nonlinear least squares to jointly estimate the distance gradient and distance cutoff, and explores the results' robustness to alternative functional forms.

Table 3, panel A, reports these estimates based upon the estimated spillover cutoff of 1,339 feet from the burned area (column 1). The Fire is estimated to have increased land values by \$5.3 million in the burned area (column 2), and by \$9.0 million in the unburned area (column 3). The percent impact is greater in the burned area, but the level impact is greater in the unburned area because many more plots are affected. The estimated total impact is \$14.3 million (column 4), or 1.12 times the 1872 value of buildings in the burned area (column 5). Panels B and C report estimated impacts when assuming the distance cutoff to be 1,119 feet or 1,559 feet (the 95 percent confidence interval for the estimated distance cutoff).

The estimated total impact on land values is comparable to the value of buildings burned, and may have been even greater.<sup>23</sup> This is not to imply that the Fire itself was value-enhancing, as the actual damages included lost property and goods and were estimated to be at least \$75 million. Yet this increase in land value, across both the burned area and nearby unburned areas, does suggest economically substantial inefficiencies from the failure to internalize cross-plot externalities from reconstruction of buildings.

Table 3, panels D–F, present analogous estimates of the total impact on land value in 1882. The Fire continues to have a substantial total impact on land values in 1882,

<sup>22</sup> We convert all dollar amounts to 1872 dollars using the David-Solar CPI (Lindert and Sutch 2006).

<sup>23</sup> We suspect that assessed building values may also overstate their true economic value, as buildings are rarely assessed at close to zero value even when they are a "tear down" and due for replacement.

TABLE 3—ESTIMATED TOTAL IMPACT ON LAND VALUES IN 1873 AND 1882

	Impact in 1000s of 1872 dollars				Ratio of (4) to burned building value (5)
	Distance cutoff (1)	Burned area (2)	Unburned area (3)	Total impact (4)	
<i>In 1873:</i>					
Panel A. Estimated cutoff	1,339 (112)	5,325 (537)	9,015 (1,091)	14,339 (1,582)	1.12 (0.12)
Panel B. 1,119 foot cutoff	1,119 (·)	5,122 (506)	7,604 (722)	12,726 (1,228)	0.99 (0.10)
Panel C. 1,559 foot cutoff	1,559 (·)	5,497 (538)	10,320 (971)	15,817 (1,508)	1.23 (0.12)
<i>In 1882:</i>					
Panel D. Estimated cutoff	1,392 (200)	7,341 (1,218)	12,606 (2,488)	19,947 (3,592)	1.55 (0.28)
Panel E. 999 foot cutoff	999 (·)	6,730 (1,183)	9,099 (1,523)	15,828 (2,705)	1.23 (0.21)
Panel F. 1,785 foot cutoff	1,785 (·)	7,499 (1,225)	15,129 (2,366)	22,628 (3,590)	1.76 (0.28)

*Notes:* Panels A to C consider the total effect on land value in 1873, adjusted to 1872 dollars using the David-Solar CPI (Lindert and Sutch 2006). We constrain the impact of the Fire to be constant within the burned area, declining linearly in the unburned area until an estimated distance cutoff, and then zero after that distance cutoff (see the online Appendix). Column 1, panel A, reports the estimated distance cutoff after which geographic spillover effects are zero. Column 1, panels B and C, report alternative assumed distance cutoffs that reflect the 95 percent confidence interval of the estimated distance cutoff. Column 2 reports the estimated total impact of the Fire on land value in the burned area, column 3 reports the estimated total impact of the Fire on land value in the unburned area, and column 4 reports the estimated total impact of the Fire in all areas. Column 5 reports the ratio of the estimates in column 4 to the total 1872 value of buildings in the burned area. Panels D to E report analogous estimates, but for the impact on land value in 1882 (converted to 1872 dollars). Robust standard errors clustered by block are reported in parentheses.

suggesting the initial increases in 1873 are not an artifact of over-exuberance in the immediate aftermath of the Fire. Similar to panel A of Figure 4, panel B of Figure 4 shows impacts on land value by distance to the Fire boundary in 1882. By 1882, land values remain higher in the burned area and have increased in nearby unburned areas relative to further unburned areas.

### B. Impacts on Building Value

Table 4 reports estimated impacts on building values in the burned area, relative to building values in unburned areas. Building values declined immediately due to destruction from the Fire, but building values became substantially higher by 1882 (column 1).<sup>24</sup> This reconstruction of buildings to substantially higher values is consistent with the immediate increases in land value, which anticipated this substantial upgrade of building stocks. Building values had generally converged somewhat by

<sup>24</sup> While vacant plots are excluded from analysis of the log value of buildings, many buildings were assessed in a partially-constructed state in the spring of 1873.

TABLE 4—IMPACT ON BUILDING VALUES IN THE BURNED AREA, RELATIVE TO THE UNBURNED AREA

	log value of buildings per square foot					
	Full sample		Close sample		Distant sample	
	(1)	(2)	(3)	(4)	(5)	(6)
1873 × burned	−1.800 (0.161)	−2.024 (0.168)	−1.792 (0.161)	−2.026 (0.169)	−1.806 (0.161)	−1.917 (0.178)
1882 × burned	0.404 (0.068)	0.509 (0.053)	0.383 (0.069)	0.462 (0.049)	0.430 (0.075)	0.700 (0.084)
1894 × burned	0.177 (0.078)	0.399 (0.079)	0.102 (0.085)	0.261 (0.073)	0.260 (0.086)	0.785 (0.108)
<i>Controls</i>						
Year fixed effects	X	X	X	X	X	X
Year FE × pre-Fire values		X		X		X
$R^2$	0.095	0.849	0.109	0.820	0.224	0.855
Number of plots	43,067	43,067	18,908	18,908	27,579	27,579

*Notes:* For all specifications, the outcome variable is the log value of building per square foot of the plot. Column 1 reports the estimated difference in each post-Fire year between all plots in the burned area and all plots in the unburned area, relative to the difference in the omitted year 1872. Column 2 includes controls for each plot's nearest plot value in 1867, 1869, 1871, and 1872 (most often the value of those same plot boundaries) and controls for each plot's city block average value in 1867, 1869, 1871, and 1872. Columns 3 and 4 report corresponding estimates, but limiting the sample of unburned plots to those within 1,338 feet of the Fire boundary. Columns 5 and 6 report corresponding estimates, but limiting the sample of unburned plots to those beyond 1,338 feet from the Fire boundary. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses.

1894, consistent with the model. Estimated impacts on building value are more sensitive to including controls for pre-Fire building values, compared to the estimated impacts on land value, but show a similar pattern of results (column 2). Similar to the land value estimates, the estimated impact on building values changes with sample restrictions in a manner consistent with positive spillovers on nearby unburned buildings (columns 3–6).

Higher building values after the Fire are predicted with or without cross-plot externalities, and need not indicate any economic gains from the Fire, but increases over time in nearby unburned buildings' value suggest positive spillovers from neighbors' reconstruction. Figure 4, panels C and D, show estimated impacts on building value in 1873 and 1882, grouped by plots' distance to the Fire boundary. In 1873, building values were largely unchanged in nearby unburned areas despite higher land values, as ongoing reconstruction of the burned area likely afforded little opportunity to upgrade nearby unburned buildings. By 1882, we see some increases in nearby unburned building values that decline with distance to the Fire boundary. By contrast, distance to the Fire boundary was not similarly associated with relative changes in building value in years prior to the Fire.

Building values are substantially higher in nearby unburned areas in 1894, compared to further unburned areas, and more similar to building values in the burned area (Figure 5, panel B). Landowners in nearby unburned areas appear to be upgrading their buildings to complement higher-quality buildings in the burned area, and this effect is spreading as further landowners respond to higher-quality buildings in nearby unburned areas. We expect building values in the burned area to converge



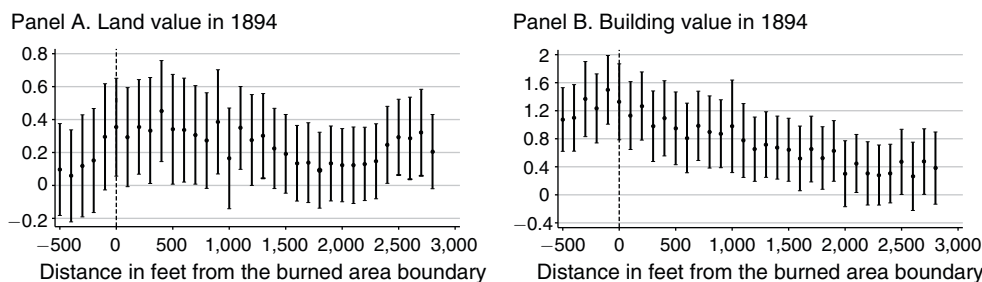


FIGURE 5. ESTIMATED IMPACTS ON LAND VALUE AND BUILDING VALUE IN 1894, BY DISTANCE TO THE FIRE BOUNDARY (Feet)

*Notes:* The vertical dashed line represents the boundary of the Fire. For the indicated distance from the boundary of the Fire, each circle reports the estimated impact in 1894 on land value (panel A) or building value (panel B), relative to the omitted category of plots more than 2,900 feet from the boundary of the Fire. The solid vertical lines reflect 95 percent confidence intervals. Negative distances reflect areas within the burned area, and burned plots more than 400 feet from the Fire boundary are grouped together. The empirical specifications include controls for plots' predicted land value in 1867, 1869, 1871, and 1872, based on the value of the nearest neighbor (most often that same plot in the earlier year) and the city block average.

over time, particularly as building technologies improved substantially in the late nineteenth and early twentieth centuries, and even to fall below building values in the unburned areas. We estimate lower land values in the burned region by 1894 (Figure 5, panel A), which may reflect expectations that the burned area will become relatively disadvantaged by a large cohort of increasingly obsolete buildings. The first skyscrapers in Boston were built between 1882 and 1894 a couple of blocks outside the burned area, perhaps because the construction technology became available when the burned area was recently upgraded and not yet worth reconstructing compared to nearby unburned areas.

We also estimate the Fire's impacts on the distribution of building values, which are consistent with the model's predictions. Figure 6 shows estimated impacts on building value by quantile, comparing changes in the burned area to changes in unburned areas.<sup>25</sup> Between 1872 and 1882, building values increase most at the lowest quantiles (panel A). Building values also increase significantly at even the highest quantiles, which suggests positive spillovers on landowners' reconstruction due to the upgraded construction of nearby buildings. By 1894, building values had converged for all but the lowest quantiles (panel B). In subsequent years, we expect the burned area to possess an increasingly aged stock of buildings that were built in the immediate aftermath of the Fire, which discourage future upgrading of nearby buildings and pull down land values.

The online Appendix further explores the robustness of the estimated impacts of the Fire on land value and building value. Given the estimated spatial spillovers in the Fire's impact, we allow for spatial correlation across plots that might otherwise overstate the statistical precision of the baseline estimates (Conley 1999). We also report unweighted estimates, and estimates that control for plots' distance to the Old

<sup>25</sup>The quantile regressions are bootstrapped at the block level, such that the standard errors are adjusted for within-block correlation. Dashed lines report 95 percent confidence intervals.

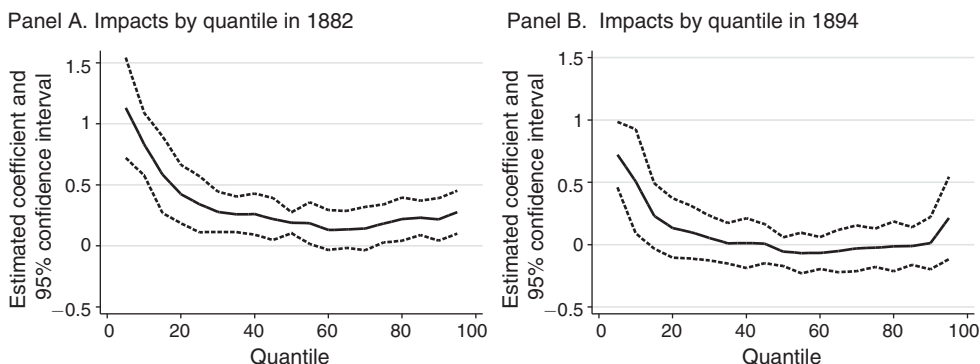


FIGURE 6. IMPACTS BY QUANTILE ON BUILDING VALUES IN THE BURNED AREA, RELATIVE TO THE UNBURNED AREA

Note: Each panel reports estimated impacts on the distribution of log building value in the indicated year, relative to the distribution in 1872.

State House (interacted with year) as a proxy for distance to peak land values at the center of the city.

### C. The Great Fire versus Individual Building Fires

The theoretical framework, and the estimated impacts on land value and building value, suggest how the Great Fire generated economic gains through its geographic scale: the reconstruction and upgrading of many nearby buildings raised plot land values and encouraged even higher quality building reconstruction. By contrast, the destruction of an individual building would be expected to have no impact on its land value and less impact on its building value. A natural empirical test would compare impacts of the Great Fire to impacts of individual building fires.

We have collected data on individual building fires between 1866 and 1891, drawing on archived records of the Boston Fire Department. These records contain the address of every fire to which the department responded, as well as the owner of the building and an estimate of damages. Fire Department records do not consistently note the level of destruction, but we focus on fires with building damages greater than \$5,000 or those with less damage for which the record specifically mentions that the building was “totally destroyed.”<sup>26</sup> We exclude all fires that are noted as having been caused by arson or were suspected to be arson.<sup>27</sup> Our sample includes 109 major individual building fires, which we merge to our main tax assessment dataset. We can then compare impacts on land values and building values for plots destroyed by the Great Fire and plots destroyed by individual building fires.

<sup>26</sup>This definition of an individual building fire naturally skews our sample toward more-valuable buildings, but we use our tax assessment data to control for differential changes associated with these plots’ baseline land value or building value. Controlling for these baseline characteristics also partly addresses potential selection bias associated with nonrandom individual building fires. We suspect the potential selection bias is positive, as older buildings might be at greater risk of catching on fire and these older buildings may otherwise be due for upgrades.

<sup>27</sup>We also exclude individual building fires that occurred within the region of the Great Fire, which enables a cleaner comparison between individual fires and the Great Fire.

We extend the previous estimating equation to include both the impact of the Great Fire and the impacts of individual building fires. For a direct comparison with the 1872 Great Fire's impacts in 1873, 1882, and 1894, we analyze the impacts of individual building fires after approximately 1 year, 10 years, and 22 years have passed since the individual building fire. To estimate individual fire effects after time interval  $\tau$ , we assign the indicator  $I_i^{IF}$  equal to one if the plot experienced an individual building fire and  $I_{it}^\tau$  equal to one for individual fire data approximately  $\tau$  years prior to a round of digitized assessment data.<sup>28</sup> For plot  $i$  in year  $t$ , the interaction of these two indicator variables defines whether that plot experienced an individual building fire  $\tau$  years ago ( $I_i^{IF} \times I_{it}^\tau$ ). The full estimating equation then becomes

$$(3) \quad Y_{it} = \alpha_t + \gamma_t \mathbf{X}_i \\ + \beta_{1873} I_i^{Fire} \times I_t^{1873} + \beta_{1882} I_i^{Fire} \times I_t^{1882} + \beta_{1894} I_i^{Fire} \times I_t^{1894} \\ + \delta_1 I_i^{IF} \times I_t^1 + \delta_{10} I_i^{IF} \times I_t^{10} + \delta_{22} I_i^{IF} \times I_t^{22} + \varepsilon_{it}.$$

The estimated coefficient  $\delta_1$  represents the one-year impact from an individual building fire, and can be compared to the estimated impact of the Fire in 1873 ( $\beta_{1873}$ ). Similarly,  $\delta_{10}$  and  $\delta_{22}$  can be compared to  $\beta_{1882}$  and  $\beta_{1894}$ , respectively.

Table 5 reports estimated impacts of the Fire and individual building fires. There was no immediate increase in land value following individual building fires, in contrast to the immediate increase in land value following the Fire (column 1). That is, building destruction is not itself associated with increases in land value when the surrounding buildings are not also destroyed. Building values were higher 10 years after individual fires, though less so than after the Fire, and building values had converged by 22 years after individual fires. Contrasting the impacts of the Fire and individual building fires, the Fire's geographic scale appears fundamental to its impacts on land values and building values. We attribute much of this impact to positive spillover effects from the widespread reconstruction and upgrading of many nearby plots.

#### D. Additional Potential Mechanisms

We consider several other channels through which land values and building values may have been impacted by the Fire: investments in public infrastructure, increased land assembly, increased concentration of ownership, changes in business agglomeration patterns, and changes in sorting of building occupants. These channels relate to ways in which large-scale displacement and redevelopment may

<sup>28</sup> Since very few individual fires occurred exactly 1 year, 10 years, or 22 years prior to a round of digitized assessments, we consider individual fires that occurred within a two-year window of this target. For example, we estimate ten-year effects on plots that experienced individual building fires between 1870 and 1874 (using 1882 tax assessment data) or between 1882 and 1886 (using 1894 tax assessment data). We then control for when the individual fire occurred in this two-year window. The individual fire indicator  $I_{it}^\tau = 1$  if  $|t - t_i^{IF} - \tau| < 2$ . To control for when the fire occurred within this two-year window, we interact  $I_i^{IF} \times I_{it}^\tau$  with  $t - t_i^{IF} - \tau$  and report the impact of  $I_i^{IF} \times I_{it}^\tau$  when  $t - t_i^{IF} = \tau$ .

TABLE 5—IMPACT OF INDIVIDUAL BUILDING FIRES VERSUS IMPACT OF 1872 GREAT FIRE

	log value of land per square foot (1)	log value of building per square foot (2)
1873 × burned	0.163 (0.019)	−1.960 (0.174)
1882 × burned	0.141 (0.039)	0.514 (0.056)
1894 × burned	−0.150 (0.057)	0.401 (0.082)
~1 year after individual fire	−0.039 (0.050)	−0.135 (0.171)
~10 years after individual fire	0.089 (0.106)	0.344 (0.154)
~22 years after individual fire	−0.214 (0.274)	0.014 (0.087)
Test of equality of individual fire and Great Fire effects ( <i>p</i> -value):		
~ 1 year interval	0.000	0.000
~ 10 year interval	0.647	0.295
~ 22 year interval	0.822	0.000
<i>Controls</i>		
Year fixed effects	X	X
Year FE × pre-Fire values	X	X
<i>R</i> <sup>2</sup>	0.902	0.627
Number of plots	17,914	17,163

*Notes:* The reported specifications jointly estimate the impact of individual building fires and the impact of the 1872 Great Fire. The first three rows report the estimated impacts of the Great Fire in 1873, 1882, and 1894 (corresponding to estimates in column 2 of Table 2 and Table 4), and the next three rows report the impact of individual building fires after approximately 1 year, 10 years, and 22 years. We then report the statistical significance of the difference between the Great Fire impact and the corresponding individual fire impact. The sample excludes plots in the 1872 burned area that also experienced individual building fires, as well as individual building fires that were suspected to be arson. The sample is limited to 1873, 1882, and 1894. Robust standard errors clustered by block are reported in parentheses.

influence neighborhoods, and are often complementary to ways in which reconstruction of neighboring buildings generates positive spillovers.

*Infrastructure Investment.*—The Fire provided an excellent opportunity to improve public infrastructure in the burned area. Initial proposals to substantially reorganize the road network in the burned area were resisted by local landowners, however, who were focused instead on rapidly constructing new and better buildings (Rosen 1986; Fire Commission 1873). The final plan included more moderate steps to widen some roads, extend some roads, and create Post Office Square (online Appendix Figure 1). Changes to the road network cost \$5.7 million, including \$0.5 million spent on road paving, with most of the funds going to landowners for the required land.<sup>29</sup> An additional \$85,000 was spent on widening water mains in the burned area, with another \$389,000 spent in the rest of Boston as part of

<sup>29</sup> From a welfare perspective, we would not subtract this \$5.2 million cost from the estimated total increase in land value because the money was transferred to landowners rather than used up in construction.

ongoing efforts to rebuild the water pipe system.<sup>30</sup> As a comparison, the total value of reconstructed buildings in the burned area was \$14.8 million in 1882.

In order to estimate whether infrastructure investments are driving a large portion of the increases in plot land values, we linked the plot assessment data with information on nearby road width and pipe diameter. Including these controls, online Appendix Table 3 reports estimated impacts on land value (column 2, panel A) and building value (column 2, panel B).<sup>31</sup> Column 3 reports estimates when controlling for plots' distance to Post Office Square, interacted with year. Column 5 includes all of these controls, in addition to controlling for distance to the Old State House. Column 1 reports our baseline estimates, as a basis for comparison, which are similar to the estimates when introducing these additional controls.

Similar changes to the road network had been launched a few years earlier in the adjacent area around Washington Square (online Appendix Figure 2), which could help separate the impacts of post-Fire reconstruction and road widening. While initially proposed in 1866, the plans were finalized and implemented from 1869 to 1870.<sup>32</sup> We estimate changes in land values after 1867 for all plots within 50 feet of this road widening initiative, relative to changes among further plots. Online Appendix Table 4 reports declining land values between 1867 and 1869, as landowners sought to avoid the area under construction. Land values had partially recovered by 1871, and there was no detectable change between 1867 and 1872.<sup>33</sup> This previous episode of road widening suggests that city efforts to widen roads are not associated with substantial immediate increases in nearby plots' land value.

*Land Assembly.*—The Fire also created an opportunity to assemble land plots into larger parcels, which may increase the value of land per square foot when there are otherwise rigidities preventing land assembly (see, e.g., Brooks and Lutz 2016). By destroying all buildings in an area, the Fire lowers the cost of land assembly by coordinating the timing of new construction.<sup>34</sup> This effect exists even within a single owner's neighboring land holdings, but the Fire could also concentrate landownership and improve the coordination of urban development. The Fire may also reduce transaction costs resulting from hold-up or other aspects of bargaining between plot buyers and sellers.<sup>35</sup>

<sup>30</sup>Roads and water pipes were the two main forms of public infrastructure in 1870s Boston. Gas service (and later electricity) was provided by competing private firms, and the sewer system was completed in 1884.

<sup>31</sup>Road widths were either recorded explicitly on the plot-level maps, or we measured them using the maps. We collected data on pipe diameters from two sources. First, we digitized the first map of the public water system as originally laid out in 1852. Second, we used the database of new pipe construction, collected by Costa and Fogel (2014), to update the width of each pipe segment in every year that new investments were made. These infrastructure data were then assigned to street centers, based on the GIS maps, and then merged to our maps of plot locations. We assigned each plot the width of the closest road and the diameter of the closest water pipe.

<sup>32</sup>Following demolition and road construction, these plots were 82 percent vacant in 1871, 77 percent vacant in 1872, and 60 percent vacant in 1873. Our baseline estimates of the Fire's impact are robust to controlling for whether plots are in this construction region (interacted with year).

<sup>33</sup>An important caveat in estimating the impact of road widening is that plots selected for road widening might otherwise have changed differently than other plots, either positively or negatively, though the estimates are similar when controlling for baseline values interacted with year.

<sup>34</sup>When reconstructing a "tear-down" building, the nearby buildings may continue to have sufficient value that they are not worth also tearing down to build one larger building.

<sup>35</sup>The bargaining power of some landowners may decline after a Fire; their outside option has worsened because they cannot live in the building or continue to operate a business without substantial reconstruction costs,

TABLE 6—IMPACT ON PLOT SIZE IN THE BURNED AREA, RELATIVE TO THE UNBURNED AREA

	log plot size			
	Full sample		Excluding plots made smaller by road widening	
	(1)	(2)	(3)	(4)
1873 × burned	0.008 (0.023)	−0.025 (0.024)	0.061 (0.021)	0.035 (0.022)
1882 × burned	0.092 (0.047)	0.057 (0.032)	0.157 (0.055)	0.125 (0.036)
1894 × burned	0.090 (0.052)	0.025 (0.035)	0.165 (0.061)	0.085 (0.044)
<i>Controls</i>				
Year fixed effects	X	X	X	X
Year FE × pre-Fire values		X		X
$R^2$	0.069	0.811	0.055	0.809
Number of plots	46,697	46,697	45,312	45,312

*Notes:* For all specifications, the outcome variable is the log number of square feet per plot. Column 1 reports the estimated difference in each post-Fire year between all plots in the burned area and all plots in the unburned area, relative to the difference in the omitted year 1872. Column 2 includes controls for each plot's nearest plot size in 1867, 1869, 1871, and 1872 (most often the size of those same plot boundaries) and controls for each plot's city block average size in 1867, 1869, 1871, and 1872. Columns 3 and 4 report corresponding estimates, but excluding plots that had land taken for widening of roads after the Fire. The regressions are unweighted. Robust standard errors clustered by block are reported in parentheses.

Table 6 reports estimated impacts on log plot size in the burned area, relative to unburned areas. There is little immediate change in average plot size from 1872 to 1873, though there are some indications of larger plot sizes in later periods following reconstruction (columns 1 and 2).<sup>36</sup> Excluding plots that had land taken for road widening, there are some increases in plot size from 1872 to 1873, and larger increases in later periods (columns 3 and 4).

The estimated increases in land value do not appear to be explained substantially, however, by the magnitude of increases in plot size. We estimate that doubling plot size is associated with a 13 percent increase in land value per square foot.<sup>37</sup> Increases in average plot size of 6 to 16 percent would then generate approximately a 0.8 to 2.1 percent increase in land value.

If there are indeed returns to land assembly, as we suspect, then it is interesting to consider why there was not more land assembly after the Fire. The Fire provided an opportunity to assemble land without the need to coordinate on demolition of neighboring buildings, which suggests that rigidities in land assembly are more related to hold-up and transactions costs associated with the land itself. This interpretation

and some may lack liquidity and become impatient (e.g., if they are less-wealthy or less-diversified). The Fire also reduces imperfect information about the value of burned plots, as there is no uncertainty regarding building value.

<sup>36</sup>Estimates are similar restricting the unburned area to include only plots within 1,339 feet or only plots beyond 1,339 feet because, as one might expect, we see little spillover effect on plot size in unburned areas.

<sup>37</sup>Log land value per square foot is positively correlated with log plot size (coefficient of 0.119, standard error of 0.047), prior to the Fire and controlling for plots' distance from the Old State House as a proxy for distance from the central business district. We do not claim that this estimate reflects the causal impact of plot size on land value, but the assumed land value premium of 13 percent reflects this cross-sectional estimate.



is consistent with the importance of land market rigidities in rural agricultural areas (Libecap and Lueck 2011) and following other urban disasters (Ellickson 2013).

*Ownership Concentration.*—The Fire may also have impacted urban redevelopment by concentrating land ownership in the burned area, which might reduce inefficient gridlock among landowners (see, e.g., Heller 2010). Ownership might also concentrate in the burned area if some landowners were liquidity-constrained and induced to sell by the Fire.

Boston was experiencing a general decline in the number of unique landowners, which was hastened by a few percentage points in the burned area between 1872 and 1873 (online Appendix Table 5, columns 1–4).<sup>38</sup> The magnitude represents only a few years of annual trend, however, and 8 of the 19 owners that exited were a direct consequence of road changes eliminating their landholdings in the burned area. Further, we do not see evidence of some particular landowners greatly increasing their landholdings: only two landowners owned three more plots in the burned region in 1873 than in 1872. There were also general declines in the number of plots over time, with a more rapid decline from 1872 to 1873 in the burned area (online Appendix Table 5, columns 5–8). This percent decline represents around 8 years of the previous trend, although 20 of the 61 plots eliminated were a direct consequence of road changes.

The Fire might have concentrated landownership amongst larger landowners, though we find little evidence for this. We do not estimate differential changes in the concentration of landownership in the burned area, either in the log number of plots per owner or in the log land area per owner.

Overall, landownership remained highly fractured, and there were few mechanisms for landowners to internalize their spillover effects on neighbors. Thus, despite the positive spillover effects of the post-Fire reconstruction, we expect that building quality was still substantially below the optimal level because of the inability to internalize spillover effects on nearby plots.

*Business Agglomeration.*—The Fire may have improved the efficiency of business locations. Firms have many reasons to agglomerate near similar firms or co-agglomerate near firms producing inputs or complementary goods.<sup>39</sup> The size and location of business clusters may drift from the optimum over time, however, as the city develops and new technologies are introduced. Whereas businesses generally make sequential location decisions, the Fire forces businesses to move and may allow them to return together in a more-productive spatial distribution.

We focus on whether businesses took advantage of potential vacancies to re-locate near other firms in their same industry, thereby increasing agglomeration in the burned area relative to the unburned area. We calculate a measure of spatial agglomeration (Ripley's  $L$  function) for the 18 industries that had more than

<sup>38</sup> Measuring the number of unique landowners is challenging, due to multiple alternative spellings and ownership vehicles (trusts, associations, partnerships, etc.) under which a single individual might register land ownership. We have attempted to reconcile as many of these as possible through manual matching; nevertheless, ownership names remain noisy.

<sup>39</sup> Business agglomeration can reduce transportation costs, attract customers interested in cross-shopping, signal competitive prices, allow monitoring of competitors, or encourage learning.

TABLE 7—IMPACT ON INDUSTRY AGGLOMERATION IN THE BURNED AREA, RELATIVE TO UNBURNED AREA

	Ripley's <i>L</i> function					
	Radius = 50 ft.		Radius = 100 ft.		Radius = 200 ft.	
	(1)	(2)	(3)	(4)	(5)	(6)
1882 × burned	−25.6 (67.7)	−57.9 (36.2)	−147.9 (113.2)	−129.1 (81.6)	−227.0 (171.0)	−141.8 (81.7)
1894 × burned	−35.6 (40.7)	−106.6 (27.8)	−163.4 (80.4)	−195.0 (80.4)	−208.7 (148.0)	−189.0 (85.1)
<i>Controls</i>						
Year fixed effects	X	X	X	X	X	X
Year FE × pre-Fire values		X		X		X
<i>R</i> <sup>2</sup>	0.195	0.682	0.134	0.441	0.117	0.436
Industry-by-year observations	144	144	144	144	144	144

*Notes:* For these specifications, the unit of observation is an industry-year pair in the burned area or unburned area. For each industry-year, its level of agglomeration is calculated using Ripley's *L* function for a distance radius of 50 feet (columns 1 and 2), 100 feet (columns 3 and 4), or 200 feet (columns 5 and 6). The online Appendix provides details on the calculation of Ripley's *L* function, but more positive values are associated with greater industry agglomeration. Each column then reports the estimated difference in each post-Fire year between industry-year pairs in the burned area and in the unburned area, relative to the difference in the omitted year 1872. Columns 2, 4, and 6 include controls for each industry's level of agglomeration in the burned area or unburned area in 1867 and 1872. The regressions are weighted by industry size. Robust standard errors clustered by industry are reported in parentheses.

3 establishments inside and outside the burned area in 1867, 1872, 1882, and 1894.<sup>40</sup> We then estimate how these industry-level statistics changed in the burned area, relative to changes in the unburned area, estimating equations analogous to those before.

Table 7 reports estimated impacts on industry agglomeration in the burned area, relative to unburned areas, with greater values of the outcome variable associated with greater agglomeration. There is little indication of systematic increases in business agglomeration in the burned area after the Fire, and some evidence for relative decreases in business agglomeration depending on the assumed distance radius and whether controlling for changes associated with industries' level of agglomeration in 1867 and 1872. These estimates do not immediately suggest that changes in business location are driving the increases in land value, as the existing literature generally finds that industry agglomeration is productivity enhancing, though it is possible that businesses in the burned area were overly clustered prior to the Fire and this dispersion was associated with efficiency gains.

*Occupant Sorting.*—Similarly, the Fire may induce differential sorting of residents and commercial establishments, along with the estimated upgrades in building value (see, e.g., Brueckner and Rosenthal 2009; Siodla 2017). While businesses did not become systematically more agglomerated in the burned area, particular

<sup>40</sup>The online Appendix includes additional details on how this measure is defined, and its sensitivity to an assumed distance radius around each business. We exclude 1873 from this analysis because many buildings were unoccupied then in the burned area. For 1869 and 1871, we only collected data on plot land value, building value, and square footage.

TABLE 8—IMPACT ON OCCUPANT DENSITY AND CAPITAL VALUE IN THE BURNED AREA, RELATIVE TO THE UNBURNED AREA

	Number of assessed occupants per 1,000 square feet				log value of capital per square foot (assigning 500 to missing values of capital)			
	Commercial		Residential		Commercial		Residential	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1873 × burned	-0.294 (0.043)	-0.371 (0.052)	-0.327 (0.064)	-0.200 (0.069)	-4.409 (0.233)	-3.905 (0.243)	-0.064 (0.049)	-0.124 (0.050)
1882 × burned	0.267 (0.066)	0.250 (0.075)	-0.403 (0.072)	-0.327 (0.089)	-0.061 (0.213)	1.015 (0.196)	0.267 (0.075)	-0.068 (0.090)
1894 × burned	0.340 (0.066)	0.289 (0.077)	-0.283 (0.080)	-0.157 (0.097)	-0.346 (0.227)	0.892 (0.227)	0.218 (0.088)	-0.361 (0.107)
<i>Controls</i>								
Year fixed effects	X	X	X	X	X	X	X	X
Year FE × pre-Fire values		X		X		X		X
$R^2$	0.020	0.534	0.053	0.559	0.139	0.659	0.045	0.687
Number of plots	31,352	31,352	31,352	31,352	31,352	31,352	31,352	31,352

*Notes:* In columns 1 to 4, the outcome variable is the number of assessed occupants per 1,000 square feet (commercial occupants for columns 1 and 2, and residential occupants for columns 3 and 4). In columns 5 to 8, the outcome variable is the log value of capital per square foot. The value of capital is censored for many observations, and we assign a capital value of 500 to all missing values (after summing across all occupants in that plot). We then divide by the plot square footage and take its log value. Each column reports the estimated difference in each post-Fire year between all plots in the burned area and all plots in the unburned area, relative to the difference in the omitted year 1872. Columns 2, 4, 6, and 8 include controls for each plot's nearest plot value in 1867 and 1872 (most often the value of those same plot boundaries) and controls for each plot's city block average value in 1867 and 1872. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses.

low-value businesses may have been displaced that generated negative spillovers on neighbors. Spillover effects from upgraded buildings may not only reflect the buildings themselves, but the characteristics of the occupants of higher value buildings.

Table 8, columns 1–4, report estimated impacts on the number of commercial occupants and residential occupants per 1,000 square feet in the burned area, relative to unburned areas.<sup>41</sup> The number of commercial establishments increased relatively in the burned area, following a decline due to vacancies immediately after the Fire (columns 1 and 2). By contrast, the number of residential occupants remained lower by a similar magnitude (columns 3 and 4). We explore whether increased commercial activity might be driving the estimated increases in land value and building value, controlling for the fraction of surrounding activity that is commercial.<sup>42</sup> We estimate similar impacts of the Fire on land value and qualitatively similar impacts on building value, though these estimates are only suggestive because nearby commercial activity is endogenous.

Table 8, columns 5–8, report estimated impacts on occupants' capital value, as an indication of the general value of the business or wealth of the resident. Capital was only assessed for taxes when the occupants' income was greater than \$1,000,

<sup>41</sup> The tax assessment data report the number of commercial establishments and the number of male residents over 20 years of age.

<sup>42</sup> We control for the fraction of surrounding buildings that are commercial, interacted with year fixed effects, based on alternative radius values of 50 feet, 100 feet, or 200 feet (similar to the business agglomeration specifications).

however, which creates a substantial censoring problem. Even the median value is censored, as most occupants had lower incomes and so their value of capital is unobserved. We report estimated impacts on log capital per square foot when assigning a value of 500 to these missing values.<sup>43</sup> There are indications of increased capital values for commercial establishments (column 6), but not when omitting controls for pre-Fire capital values (column 5). Conversely, there are indications of increased capital values for residential occupants without controls for pre-Fire capital, (column 7), but not when these controls are including (column 8).

Overall, there are some indications that changes in building occupancy may be a channel through which post-Fire building reconstruction generates spillover effects on neighboring plots and economic gains. These estimates are more sensitive to the empirical specification, however. It seems to be the replacement of buildings that drives changes in occupancy patterns (as in Brueckner and Rosenthal 2009), and so we focus on positive spillovers from higher quality buildings with the understanding that these spillovers may operate in part through associated changes in occupant characteristics.

## V. Interpretation

Historical Boston provides an opportunity to explore how urban areas might react to the opportunity to start fresh, freed from the potential constraints imposed by existing durable structures. In particular, the Boston Fire's impacts suggest how increased building investment encourages nearby building investment in a virtuous circle that generates substantial economic gains. In this section we consider how features of historical Boston might influence the impacts of the Fire and how these impacts might vary across other times and places.

Boston real estate values were growing by 4.8 percent annually in the 20 years prior to the Fire, in real terms, with increased demand encouraging the construction of new and improved buildings once landowners chose (or were forced) to replace their buildings. However, the same spillover effects that generate economic gains in a growing city might generate economic losses in a declining city and accelerate its decline. For example, in modern Detroit where real estate assessed values declined by 0.24 percent annually in real terms between 1995 and 2015, burned buildings might be replaced with newer worse buildings or left vacant.<sup>44</sup> We see the substantive importance of neighborhood spillover effects as the more general result, whereas the impact of a major city disaster will vary depending on the local incentives for investment afterward.

The available construction technologies also shape the impacts of a major city fire, particularly any changes in construction technology since many pre-Fire buildings were constructed. Pre-Fire Boston was densely developed in the burned area,

<sup>43</sup>Capital values of 500 are among the lower common values, and the estimates are similar when assigning values of 50 or 100 that are among the lowest values observed. We also estimated similar patterns for an outcome variable that is equal to one for all positive capital valuations and equal to zero for all censored capital valuations.

<sup>44</sup>Other cities' growth during the 1995–2015 period is more comparable to historical Boston: Boston grew at 5.1 percent, New York City at 3.5 percent, Seattle at 3.7 percent, Los Angeles at 2.6 percent, and San Francisco (with data from 2004–2015) at 3.4 percent. These data come from cities' annual reports on the change in total assessed values, adjusted to real terms. While assessed valuations align with our observed market transactions in historical Boston, we do not know this relationship for the modern cities.

and building heights were already at feasible limits, such that post-Fire building upgrades were focused on building quality and not building density or building height.<sup>45</sup> More rapid improvements in building technology would generate greater economic gains from a fire, similar to more rapid growth in real estate demand, as older buildings would become obsolete more quickly and discourage nearby investment.<sup>46</sup> The potential gains from internalizing spillover effects from reconstruction might then be largest in many developing country cities, which are experiencing both rapid growth and improvements in construction methods. By contrast, in contexts where the costs of building quality have increased along some dimensions and there has been less increase in the returns to building quality, the destruction of older high-quality buildings may lead to worse new construction and negative spillover impacts from a fire. It is not the destruction of older buildings that itself leads to gains from a fire, but the induced replacement of lower-value buildings generating negative spillovers with higher-value buildings generating positive spillovers.

Cross-plot spillover effects could be partly internalized in some settings, particularly by large real estate developers who might raise the returns to their own nearby investments. This coordination of cross-plot development generates economic gains initially, though inefficiencies from externalities arise over time after units are sold to individual owners. Modern Boston has somewhat more heterogeneous real estate values per square foot than pre-Fire Boston, with a coefficient of variation equal to 1.22 in 2012 and 0.85 in 1872. Average building age is 83 years in modern Boston, with a standard deviation of 34 years, and each year of building age is associated with a 0.34 percent decrease in total value per square foot.

Local governments can also try to mitigate inefficiencies associated with cross-plot spillover effects, using zoning regulations or building codes to prevent buildings that generate negative externalities. The Boston Fire predated modern zoning regulations, and perhaps zoning regulations might have prevented some particular industrial activities that discouraged nearby investment. The burned area had contained little industrial activity, however, and the Fire was associated with some shift from residential to commercial occupants. Rigid zoning regulations may prevent building investments that generate positive externalities, and particularly large building investments after a fire. Similarly, while stronger building codes might have maintained higher building qualities in the absence of a fire, the associated regulatory costs could also raise the costs of building reconstruction and discourage investments that generate positive externalities.

Modern governments may also play a more substantial role in post-disaster reconstruction, not only through zoning regulations and building codes, but by directly funding reconstruction efforts and influencing reconstruction choices. By contrast, historical Boston was rebuilt within a few years by private landowners who largely resisted further city involvement that was seen as delaying reconstruction. Post-disaster reconstruction in the modern era may then be influenced more by

<sup>45</sup> For example, taller buildings required thicker structural walls that sacrificed square footage on the ground floor and road frontage that was valued at a premium.

<sup>46</sup> More rapid post-Fire improvements in building technology would also lead to faster convergence between the burned and unburned areas. Convergence may have been particularly rapid in historical Boston, with relatively lower land values in the burned area by 1894, as technological improvements led to the construction of the first skyscrapers in Boston between 1882 and 1894 in the nearby unburned area.

political pressures, though this historical setting provides a clearer view of market incentives and private landowners' response to the opportunity for reconstruction during a period of urban growth.

## VI. Conclusion

Following the Great Fire of Boston in 1872, burned plots and nearby unburned plots experienced substantial increases in land value. Estimated total impacts on land value capitalize substantial economic gains from the Fire (\$13–\$23 million in 1872 dollars), which suggests substantial inefficiencies in urban growth that were mitigated by the opportunity for simultaneous widespread reconstruction after the Fire. The total increase in land value was even comparable to the value of buildings burned (\$13 million in 1872 dollars), though the Fire also destroyed occupants' capital goods and materials.

We largely attribute this increase in land value to positive externalities from building investment. The forced reconstruction of burned buildings initiated a virtuous circle, in which building upgrades encouraged further upgrades of nearby buildings and raised nearby plots' potential returns. By contrast, individual building fires had no impact on burned plots' land value and smaller impacts on building value. The Fire may also have contributed to increased land values through road widening, increased plot sizes, and a shift toward more commercial establishments, though the impacts through these channels appear substantively smaller. There may be further aggregate spillover effects of the Fire at the city-level, including both positive and negative components, but increased land values imply at least large local gains from the opportunity for widespread urban redevelopment that overcomes rigidities in urban growth.

The impacts of a major city fire, or other urban destruction, could be expected to vary across contexts depending on underlying trends in building demand and supply. For example, in a city with declining real estate demand, a major fire would be expected to accelerate a city's decline when landowners' decreased building values discourage nearby building investments. Modern zoning regulations and building codes may sustain some minimum levels of building investment and lessen the impacts from widespread reconstruction, though these regulatory mechanisms may also impede real estate investments and magnify the inefficiencies from cross-plot externalities. While land-use regulations may also obscure the impacts of market incentives in other settings, the Boston Fire occurred during a period of relatively limited land-use regulation and government oversight of reconstruction.

There appear to be substantial economic gains from better coordination of building construction in dense urban areas, though the transaction costs may be prohibitively high for landowners to coordinate amongst themselves. The Boston Fire did not reduce these transaction costs directly, but temporarily mitigated their economic importance by forcing widespread reconstruction. Landowners' building investments were still below the social optimum after the Fire, as landowners still did not internalize the positive spillover effects from their own reconstruction, but the Fire generated substantial economic gains by removing older low-quality buildings that were discouraging further growth. Indeed, whenever there are returns to coordinated investment, we might expect simultaneous investment decisions to generate



better economic outcomes than sequential investment decisions. Less dramatic mechanisms than a Great Fire might encourage building investments with positive externalities, or discourage building investments with negative externalities, but the Boston Fire provides a stark demonstration of the potential economic gains in dense urban settings.

## REFERENCES

- Autor, David H., Christopher J. Palmer, and Parag A. Pathak.** 2014. "Housing Market Spillovers: Evidence from the End of Rent Control in Cambridge, Massachusetts." *Journal of Political Economy* 122 (3): 661–717.
- Bleakley, Hoyt, and Jeffrey Lin.** 2012. "Portage and Path Dependence." *Quarterly Journal of Economics* 127 (2): 587–644.
- Bosker, Maarten, Steven Brakman, Harry Garretsen, and Marc Schramm.** 2007. "Looking for Multiple Equilibria When Geography Matters: German City Growth and the WWII Shock." *Journal of Urban Economics* 61 (1): 152–69.
- Brakman, Steven, Harry Garretsen, and Marc Schramm.** 2004. "The Strategic Bombing of German Cities during World War II and Its Impact on City Growth." *Journal of Economic Geography* 4 (2): 201–18.
- Brooks, Leah, and Byron Lutz.** 2016. "From Today's City to Tomorrow's City: An Empirical Investigation of Urban Land Assembly." *American Economic Journal: Economic Policy* 8 (3): 69–105.
- Brueckner, Jan K., and Stuart S. Rosenthal.** 2009. "Gentrification and Neighborhood Housing Cycles: Will America's Future Downtowns be Rich?" *Review of Economics and Statistics* 91 (4): 725–43.
- Campbell, John Y., Stefano Giglio, and Parag Pathak.** 2011. "Forced Sales and House Prices." *American Economic Review* 101 (5): 2108–31.
- Collins, William J., and Katharine L. Shester.** 2013. "Slum Clearance and Urban Renewal in the United States." *American Economic Journal: Applied Economics* 5 (1): 239–73.
- Conley, T. G.** 1999. "GMM Estimation with Cross Sectional Dependence." *Journal of Econometrics* 92 (1): 1–45.
- Costa, Dora L., and Robert W. Fogel.** 2014. "Historical Urban Ecological Data, 1830–1930." ICPSR35617-v1. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2015-11-16 <http://doi.org/10.3886/ICPSR35617.v1>.
- Davis, Donald R., and David E. Weinstein.** 2002. "Bones, Bombs, and Break Points: The Geography of Economic Activity." *American Economic Review* 92 (5): 1269–89.
- Douty, Christopher Morris.** 1977. *The Economics of Localized Disasters: The 1906 San Francisco Catastrophe*. New York: Arno Press.
- Ellickson, Robert C.** 2013. "The Law and Economics of Street Layouts: How a Grid Pattern Benefits Downtown." *Alabama Law Review* 64 (3): 463–510.
- Fales, Raymond L., and Leon N. Moses.** 1972. "Land-Use Theory and the Spatial Structure of the Nineteenth-Century City." *Papers in Regional Science* 28: 49–82.
- Fire Commission.** 1873. *Report of the Commissioners Appointed to Investigate the Cause and Management of the Great Fire in Boston*. Boston: Rockwell & Churchill City Printers.
- Fowler, William Worthington.** 1873. *Fighting Fire*. Hartford: Dustin, Gilman & Co.
- Frothingham, Frank E.** 1873. *The Boston Fire*. Boston: Lee & Shepard Publishers.
- Gould, Eric D., B. Peter Pashigian, and Canice J. Prendergast.** 2005. "Contracts, Externalities, and Incentives in Shopping Malls." *Review of Economics and Statistics* 87 (3): 411–22.
- Greenstone, Michael, Richard Hornbeck, and Enrico Moretti.** 2010. "Identifying Agglomeration Spillovers: Evidence from Winners and Losers of Large Plant Openings." *Journal of Political Economy* 118 (3): 536–98.
- Guerrieri, Veronica, Daniel Hartley, and Erik Hurst.** 2013. "Endogenous Gentrification and Housing Price Dynamics." *Journal of Public Economics* 100: 45–60.
- G. W. Bromley & Co.** 1883. *Atlas of the City of Boston*. Boston: G. W. Bromley & Co.
- Heller, Michael.** 2010. *The Gridlock Economy: How Too Much Ownership Wrecks Markets, Stops Innovation, and Costs Lives*. New York: Basic Books.
- Hornbeck, Richard, and Daniel Keniston.** 2017. "Creative Destruction: Barriers to Urban Growth and the Great Boston Fire of 1872: Dataset." *American Economic Review*. <https://doi.org/10.1257/aer.20141707>.
- Jedwab, Remi, and Alexander Moradi.** 2016. "The Permanent Effects of Transportation Revolutions in Poor Countries: Evidence from Africa." *Review of Economics and Statistics* 98 (2): 268–84.

- Jedwab, Remi, Edward Kerby, and Alexander Moradi.** 2016. "History, Path Dependence and Development: Evidence from Colonial Railroads, Settlers and Cities in Kenya." *Economic Journal* 98 (2): 268–84.
- Libecap, Gary D., and Dean Lueck.** 2011. "The Demarcation of Land and the Role of Coordinating Property Institutions." *Journal of Political Economy* 119 (3): 426–67.
- Lindert, Peter H., and Richard Sutch.** 2006. "Consumer Price Indexes, for All Items: 1774–2003." Table Cc1–2 In *Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition*, edited by Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright. New York: Cambridge University Press.
- Macaulay, Dendy.** 2007. *The Importance of Neighborhood Ties: Relocation Decisions after the Chicago Fire of 1871*. Chicago: University of Chicago.
- Mian, Atif, Amir Sufi, and Francesco Trebbi.** 2015. "Foreclosures, House Prices, and the Real Economy." *Journal of Finance* 70 (6): 2587–634.
- Michaels, Guy, and Ferdinand Rauch.** 2016. "Resetting the Urban Network: 117–2012." *Economic Journal*. doi:10.1111/ecoj.12424.
- Miguel, Edward, and Gerard Roland.** 2011. "The Long–Run Impact of Bombing Vietnam." *Journal of Development Economics* 96 (1): 1–15.
- Pashigian, B. Peter, and Eric D. Gould.** 1998. "Internalizing Externalities: The Pricing of Space in Shopping Malls." *Journal of Law and Economics* 41 (1): 115–42.
- Rosen, Christine.** 1986. *The Limits of Power: Great Fires and the Process of City Growth in America*. Cambridge, UK: Cambridge University Press.
- Rossi-Hansberg, Esteban, Pierre-Daniel Sarte, and Raymond Owens, III.** 2010. "Housing Externalities." *Journal of Political Economy* 118 (3): 485–535.
- Sanborn Map Company.** 1867, 1873, and 1895. Boston: Sanborn Map Company.
- Sanso-Navarro, Marcos, Fernando Sanz, and Mara Vera-Cabello.** 2014. "The Impact of the American Civil War on City Growth." *Urban Growth* 52 (16): 3070–85.
- Siodla, James.** 2015. "Razing San Francisco: The 1906 Disaster as a Natural Experiment in Urban Redevelopment." *Journal of Urban Economics* 89: 48–61.
- Siodla, James.** 2016. "Clean Slate: Land-Use Changes in San Francisco after the 1906 Disaster." <https://jamesiodla.wordpress.com/research> (accessed April 10, 2017).
- Turner, Matthew A., Andrew Haughwout, and Wilbert van der Klaauw.** 2014. "Land Use Regulation and Welfare." *Econometrica* 82 (4): 1341–403.
- Wermiel, Sara E.** 2000. *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City*. Baltimore: Johns Hopkins Press.
- Whitmore, H.** 1896. "Real Estate Values in Boston." *Journal of the American Statistical Association* 5: 1–17.