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CREATIVE DESTRUCTION:
BARRIERS TO URBAN GROWTH AND THE GREAT BOSTON FIRE OF 1872

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ABSTRACT

Historical city growth, in the United States and worldwide, has required remarkable transformation of outdated durable buildings. Private land-use decisions may generate inefficiencies, however, due to externalities and various rigidities. This paper analyzes new plot-level data in the aftermath of the Great Boston Fire of 1872, estimating substantial economic gains from the created opportunity for widespread reconstruction. An important mechanism appears to be positive externalities from neighbors' reconstruction. Strikingly, gains from this opportunity for urban redevelopment were sufficiently large that increases in land values were comparable to the previous value of all buildings burned.

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Urban growth and economic growth are closely associated, and yet rapid economic growth may outpace the capacity of cities to evolve. Durable buildings create natural rigidities, and barriers to land assembly can impose large economic losses (Libecap and Lueck, 2011; Brooks and Lutz, 2012). Land owners' construction choices may not internalize their building's effects on neighbors, and the resulting lower quality structures in turn discourage future investment.

These challenges of urban redevelopment have come up repeatedly in American history, as modern metropolises grew from small cities. That American cities have faced these impediments, however, does not imply particular effectiveness in overcoming them. Indeed, in the aftermath of major city fires of the 19th and early 20th centuries, contemporaries speculated that these initially calamitous events would generate benefits through the opportunity for major reconstruction (Rosen, 1986). This intriguing hypothesis, if true, suggests inefficiencies in even wealthy urban areas.

By contrast, much of the focus on "urban renewal" has been directed at poorer urban areas. While policy interventions in poorer neighborhoods are widely studied and controversial (Jacobs, 1961; Anderson, 1964; Wilson, 1966; Collins and Shester, 2013), frictions in real estate markets may cause even wealthy urban areas to not reach their potential for economic development. Indeed, we examine how rapid economic growth can itself generate substantial inefficiencies.

This paper analyzes the Great Boston Fire of 1872, with a focus on gaining insights into the magnitudes and sources of inefficiencies in urban growth. We examine whether the Fire created real benefits and, if so, through what channels. This historical setting provides an opportunity to observe private landowners' responses to the opportunity for reconstruction during a period of rapid urban growth, avoiding challenges of the modern period in which tighter land-use regulations and government reconstruction efforts often obscure market incentives. The government had little role in the reconstruction of 1873 Boston, prior to zoning regulations or stronger building codes in Boston (Rosen, 1986; Fischel, 2004).

We develop a dynamic model of urban growth, which illustrates the conditions under which widespread urban destruction generates some benefits. In our benchmark case of no cross-plot externalities, the Fire might appear partly beneficial, as destroyed buildings are replaced with new more valuable buildings, but the destruction generates no real economic benefits. In the presence of neighborhood externalities, however, reconstruction after the Fire exhibits a multiplier effect that generates economic gains. This extended model provides a number of testable predictions that we take to the data: increases in land values in the burned area and nearby unburned areas; increases in building values in the burned area for even the most high-end buildings, and increases over time in nearby unburned areas; greater increases in building values following the Great Fire than following individual building fires; and no increase in land value following individual building fires.

The empirical analysis uses a new detailed plot-level dataset, covering all plots in the burned area and surrounding areas in 1867, 1872, 1873, 1882, and 1894. Our digitization of city tax assessment records provides data on each plot's value of land, value of building, size, owner name, and occupant characteristics. We begin by estimating impacts on plots in the burned area, relative to plots in the unburned area, and then allow the impacts to vary by distance to the burned area. The empirical specifications control flexibly for changes associated with pre-Fire characteristics. We mainly consider impacts of the Fire on average plot outcomes, but also use quantile regressions to examine changes in the distribution of outcomes predicted by the model. Using data on individual building fires that occurred around this period, drawn from Boston fire department records, we also compare the impacts of individual building fires to the Great Fire.

The striking initial result is that land values increased immediately in the burned area, relative to the unburned area. These estimates imply economically substantial gains from the opportunity for widespread reconstruction, as individual landowners previously had the opportunity to replace their own building. Land values continued to be higher through 1882 and, consistent with the model, had reversed by 1894.

Further, land values increased immediately in nearby unburned areas, relative to further unburned areas. The nearest unburned areas received an increase in land value similar to the burned area, and the estimated impact declines until leveling at around 1400 feet. Assuming no impact beyond that point, the implied total impact on land values is comparable to the total value of buildings burned in the Fire. Any increase in land value is consistent with inefficiencies being lessened by the Fire, regardless of whether those gains exceed the direct losses from the Fire, but the value of burned buildings provides a natural benchmark for the economically substantial magnitude of the impacts. We are unable to quantify all spillover effects at the city level, which might have positive and negative components, but increased land values imply at least large local gains from the opportunity for urban redevelopment.

Building values increased substantially in the burned area, following reconstruction, and converged over time. These impacts were greatest at the lowest quantiles of building values, reflecting replacement of the worst building stock, but building values increased even at the highest quantiles. Seen through the lens of the model, these results suggest that even the most recently constructed (and, therefore, the highest value) buildings were replaced with discreetly better buildings, consistent with neighborhood externalities. Likewise, in nearby unburned areas, estimated increases over time in building values are consistent with neighborhood spillover effects moving forward the time of optimal building replacement.

The great extent of the Fire appears central to its impacts, and perhaps the starkest indication of this phenomenon is seen in the comparison between the Great Fire's impacts and the impacts of individual building fires around this period. Building values increased following single building fires, but building values increased by more following the Great Fire. Further, while land values increased following the Great Fire, burned plots' land values were unchanged following an individual building fire. These estimates are again consistent with the Great Fire generating some multiplier effect, whether due to neighborhood externalities or some other mechanism.

Tax assessment data provide characteristics for all plots, though a main concern is whether assessed values accurately reflect market conditions. We collected supplemental data from Boston's Registry of Deeds on plot sales, and show that assessed values align closely with the available sales data in the burned and unburned areas both before and after the Great Fire. A particular concern is whether the fire caused a mechanical increase in the assessment of land value in the burned area, such as in the assessment of vacant plots. There is generally no assessed land value premium for vacant plots, however, and the impacts on land values persist into 1882 when burned buildings have been replaced. Further, land values increase immediately in nearby unburned areas that are not vacant after the Fire. By contrast, following individual building fires, there is no mechanical increase in burned plots' land value. Assessors appear to effectively separate building value and land value, consistent with their instructions, margin notes, and the great variation in the fraction of total assessed value that is assigned to buildings.

We also consider several additional potential mechanisms through which the Fire might generate economic gains. The Fire might provide an opportunity for industrial firms to change locations and improve the efficiency of their agglomeration, though we do not find systematic increases in industrial agglomeration. The Fire created an opportunity to improve public infrastructure in the burned area, though there were only moderate changes in the road network and water pipes. The Fire may have caused changes in the composition of residential and commercial occupants, which generate spillover effects along with changes in building quality.

The Fire might encourage plot assembly, by discouraging hold-up and reducing transactions costs, and thereby generate economic gains. We estimate only small increases in plot size, however, and only after adjusting for declines in plot size associated with road widening. These changes accompanied only a small decline in the number of unique landowners in the burned area, implying that large landowners could not buy up plots to coordinate reconstruction on a larger scale. Estimated increases in plot sizes would only explain a small portion of increased land values in the burned area, and none of the increase in nearby unburned areas, assuming a large premium to land assembly equal to that estimated for modern Los Angeles (Brooks and Lutz, 2012) or more primitively in our data. Our interpretation is that the removal of durable buildings did little to reduce the frictions preventing land assembly, rather than there being no frictions in land assembly. This interpretation is consistent with estimated land frictions in modern Los Angeles (Brooks and Lutz, 2012), and substantial land rigidities in even rural areas (Libecap and Lueck, 2011).

As an epilogue, we estimate modern plot-level differences in the burned area. There is some indication of positive impacts on the total value of land and buildings, though estimates are sensitive to the empirical specification. Our model and research design are not geared to understand very long-run dynamics, compared to city-level studies of convergence after destruction across broader geographic areas (Davis and Weinstein, 2002; Miguel and Roland, 2011). By focusing on plot-level data within Boston, we analyze the more short-run and medium-run dynamics and the mechanisms generating economic gains from reconstruction. While we examine only one city, we use plot-level data to exploit micro-level variation and the statistical inference for the main results is robust to correcting for spatial correlation across plots.

The Fire itself is not a policy proposal, but the Fire's impacts are indicative of substantial inefficiencies in even wealthy urban areas. Indeed, the implied magnitude of inefficiencies is even larger because even widespread reconstruction after the Fire is not predicted to obtain first-best land-use in the presence of neighborhood externalities. Our main interpretation, emphasizing neighborhood externalities, is consistent with research on neighborhood spillovers from rent control (Sims, 2007; Autor, Palmer and Pathak, 2014), home foreclosures (Campbell, Giglio and Pathak, 2011; Hartley, 2010; Mian, Sufi and Trebbi, 2014), gentrification (Guerrieri, Hartley and Hurst, 2013; Ioannides, 2003), and targeted housing investments (Schwartz et al., 2006; Rossi-Hansberg, Sarte and Owen, 2010). City governments might correct these externalities by subsidizing investments with positive spillovers, taxing investments with negative spillovers, and removing their own regulatory impediments to redevelopment. Various policies have been developed to address similar frictions, including eminent domain, building codes, and zoning regulations, though these policies' application may be ineffective or counterproductive (Munch, 1976; Chen and Yeh, 2013; Turner, Haughwout and van der Klaauw, 2014).

Overall, impacts of the Boston Fire demonstrate substantial economic gains from urban redevelopment. Our focus on wealthy areas, which had been growing rapidly, is complementary to research on the economic impacts of large-scale urban renewal in poor or declining areas. Indeed, it is the growth process itself, combined with the fixed costs of building replacement, that generates the inefficiencies that are partially alleviated by the opportunity for simultaneous reconstruction.[1] The results suggest there can be substantial barriers to urban growth amidst an otherwise prosperous economy.

I Historical Background

I.A Great Fires in the United States

Urban fires were a more common occurrence in the 19th and early 20th century United States. Dangerous heating and lighting methods led to frequent small fires amongst densely-located fire-prone buildings (Wermiel, 2000). Individual building fires exacted a substantial toll and, constrained only by primitive firefighting technologies, sometimes spread through central business districts completely destroying all buildings in a wide area.

Historians and contemporaries generally describe rapid recovery after major city fires, and even the potential for short-run losses to generate long-run gains (Rosen, 1986). Reconstruction was primarily managed by the private sector, though governments of burned cities considered improvements to public infrastructure. Political obstacles largely prevented the implementation of more ambitious proposals, however, as Rosen (1986) highlights following Great Fires in Boston, Chicago, and Baltimore. Following the San Francisco Fire (and Earthquake), estimates around the burned boundary find increases in residential density (Siodla, 2013) and firm relocation (Siodla, 2014).

I.B The 1872 Great Fire of Boston

In November 1872, a small fire spread through a large section of Boston's business district, eventually destroying 776 buildings over 65 acres of the downtown Boston area (Figure 1).[2] Boston firefighters were unable to stop the fire quickly, before it spread, due partly to 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, eventually stopping with the arrival of massive firefighting resources from surrounding areas. The Fire killed 20 people and caused approximately $75 million in damages, or 11% of the total assessed value of all Boston real estate and personal property (Frothingham, 1873).

In anticipation of the empirical analysis, a natural question concerns the endogeneity of which plots burned. The Fire began in the south-central part of the burned region and spread out and to the North, toward somewhat more valuable parts of the downtown area. Extensive investigations and hearings following the Fire provide no accounts of the fire department

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[1] In our model, areas with declining real estate demand would decline further after widespread destruction. Particular functional forms for neighborhood externalities could generate multiple equilibria, whereby widespread destruction could generate gains in both declining and growing areas.

[2] Figure 1 also shows the location of individual land plots in our main sample, which we discuss below.

protecting areas differentially, which were all fairly high value at the time (Fire Commission, 1873; Fowler, 1873). Wide roads provided a natural barrier to the fire spreading, though the fire sometimes crossed wide roads and sometimes ended within a block.[3] In practice, the empirical analysis will include controls for pre-Fire plot characteristics that allow for differential changes over subsequent periods.

In anticipation of the theoretical framework, we note that the Fire occurred following a period of rapid growth in Boston real estate values (Appendix Figure 1). Boston real estate values declined later in the 1870's, during the national "Long Depression," but subsequently resumed their upward growth.[4]

The Fire prompted substantial inflows of private sector capital to fund reconstruction, given the strong demand for real estate investment in Boston. Boston capital markets were well-integrated at this time, both domestically and internationally, so we will assume perfect capital markets in the model. Insurance payouts also partly funded reconstruction, though these payouts were often less than property owners were due.[5] Insurance payouts should not impact optimal land-use, in the presence of perfect capital markets, though we do explore in the empirical analysis whether landowners disproportionately exited the burned area.[6]

Reconstruction was privately managed and generally unconstrained by government regulation, as this was prior to zoning regulations. Although the weeks immediately after the fire saw calls for government action to coordinate reconstruction, the ultimate role of the city government in post-fire reconstruction was very limited. The city purchased some land to widen and extend downtown roads, though landowners' opposition limited more-ambitious proposals to modify the road network. Similarly, calls for a strong building code were undermined by lobbying from building contractors, and the ultimate legislation was weak and substantially rescinded in 1873 (Rosen, 1986). The city also widened underground water mains and installed new fire hydrants, though overall improvements in public goods fell short of their initial potential.

Interestingly, public reaction to the Fire was generally optimistic following the initial shock. On the one year anniversary of the Fire, the *Evening Transcript* wrote: "occurrences

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[3] We do not observe systematic differences in 1872 in land value and building value across the Fire boundary, using our data and restricting the sample to plots within 100 feet of the Fire boundary.

[4] We converted these valuations to constant 1872 dollars using the David-Solar CPI (Lindert and Sutch, 2006).

[5] Insurance coverage was worth three-fourths of total fire damages, but many insurance companies were bankrupted by the Fire. As a result, total insurance payouts covered closer to half of of the total damages (Fowler, 1873).

[6] In practice, some landowners may have been liquidity-constrained after the fire destroyed their property and the collateral needed to raise more capital. We would have been interested in testing this hypothesis more fully, though we have been unable to link particular plots to their insurance underwriter and the fraction paid out on the insurance policies.

calamitous in their first effects sometimes result in important material good.... That great fire ... furnished the opportunity for rebuilding the metropolis at its very center of operation on a comprehensive scale" (cited in Rosen, 1986). Newspapers and other contemporaries noted that buildings in the burned area were often better after reconstruction. These observed impacts need not imply any economic gains from the Fire, however, and we formalize this intuition below in our benchmark model. We then present an extended model, with neighborhood externalities, that highlights how the Fire might indeed result in important material good.

II Dynamic Model of Urban Growth

II.A Benchmark Model with Durable Buildings

Our benchmark model clarifies conditions under which the Fire may only *appear* to generate economic benefits. We consider the decisions of landowners choosing when to replace their building, but who experience no spillover impacts from nearby plots. This benchmark model formalizes our null hypothesis, in which the Fire does not generate any economic benefits.

We assume that each landowner owns one plot, and that all landowners and plots are homogeneous. Landowners construct a sequence of durable buildings to maximize the net present value of rents from their plot, which are assumed to depend solely on the quality of their building (q) and the city's overall productivity (ω_t). In each period, a building of physical quality q generates rent of $r(q, \omega_t)$. In particular, we assume that the marginal return to building quality is increasing in city productivity: $\partial^2 r(q, \omega_t) / \partial q \partial \omega_t > 0$.

We focus on the case in which city productivity is growing over time, which increases the return to building quality and encourages landowners to construct higher quality buildings. The predicted impacts of a Great Fire would differ in a city with declining productivity.[7]

For clarity, we assume that landowners may only completely replace their old building with a new building of quality q' by paying a convex cost $c(q')$.[8] In particular, we assume that buildings cannot be renovated and that buildings do not depreciate. These two assumptions make the model's predictions more apparent, but do not qualitatively change the predictions.[9] As a matter of notation, we assume that building construction is instanta-

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[7] Notably, the failure of declining cities to recover after disasters is not inconsistent with our predictions; indeed, we would predict that widespread destruction would hasten the decline of cities otherwise declining. Only in historically poor cities, with currently increasing returns to real estate investment, would we predict that destruction generates increased building quality.

[8] The assumption of convex costs guarantees an interior solution.

[9] The model's predictions are similar if buildings depreciate, or if buildings can be renovated to some higher quality at a cost that is greater than the costs of constructing new buildings with those two levels of quality (e.g., with fixed costs to renovation). As depreciation rates increase, and renovation becomes relatively cheaper, the dynamic optimization problem simply reverts to an effectively static optimization problem that negates the purpose of this theoretical framework.

neous.[10]

Building construction is a forward-looking dynamic optimization problem, in which each landowner considers the optimal time to replace a building. Landowners do not replace a building when it would generate higher static rents; rather, landowners solve for the optimal replacement policy incorporating the option value of retaining antiquated but still profitable real estate. This intuition is captured by the following Bellman equation, which reflects the landowner's value of owning a building of quality q when the city has productivity ω_t (and includes the option to rebuild):

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

where q^* maximizes $r\left(q,\omega_t\right)+\beta\mathbb{E}\left[V\left(q,\omega'\right)\right]-c\left(q\right)$. That is, q^* represents the optimal quality building to construct if the landowner chooses to construct a new building.

The landowner faces a tradeoff between two choices: (1) receiving rent $r\left(q,\omega_t\right)$ and continuing with the old building of quality q; and (2) paying a lump sum cost $c\left(q^*\right)$ to construct a higher-quality building, receiving higher rents, and continuing with the new building of quality q^*. Landowners' expectations reflect an exogenous fixed growth rate for city productivity, in addition to an exogenous probability d that the building will be destroyed.[11]

The random destruction of buildings, with some probability d, provides a mechanism to consider the impacts of an individual building fire. Notably, in this case of exogenous building destruction between periods, the landowner will choose to rebuild in the next period at quality q^*.

Landowners' optimal construction decisions involve periods of no activity and occasional quality upgrades. Given that city productivity is increasing, landowners over-build for contemporaneous conditions and then wait for city productivity to increase before replacing their then-obsolete building. To illustrate the equilibrium building growth paths, we assume $r\left(q,\omega\right)$ takes the Cobb-Douglas form $q^{\alpha}\omega^{\beta}$ $\left(\alpha\geq0,\ \beta\geq0,\ \alpha+\beta\leq1\right)$, with $c\left(q\right)=cq^{\gamma}$ $\left(c>0,\ \gamma>1\right)$.[12] We generate a sample of 3000 buildings and simulate the model until it reaches steady-state, i.e., until the growth rate of the distribution of buildings stabilizes.

Figure 2, Panel A, graphs the steady-state evolution of the building distribution. The

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[10] Equivalently, foregone rents could be included in the cost of construction.

[11] Owners' beliefs about future valuations can be written as $\mathbb{E}\left[V\left(q,\omega'\right)\right]=\left(1-d\right)V\left(q,\omega'\right)+d\cdot V\left(0,\omega'\right)$ if the owner does not rebuild, and $\mathbb{E}\left[V\left(q^{*},\omega'\right)\right]=\left(1-d\right)V\left(q^{*},\omega'\right)+d\cdot V\left(0,\omega'\right)$ if the owner does rebuild.

[12] In our quantitative simulations we set $\delta=0.9$, $\alpha=\beta=.5$, $\gamma=2$, and $c=5$. The probability of exogenous destruction (d) is set to 0.01, and the growth rate is set to 0.06.

thick central line shows the mean of log building quality, which grows at a constant rate in steady state along with the constant growth in city productivity. There are discrete jumps, however, in the growth paths of individual buildings. Newly constructed buildings are the highest quality buildings for one period, before being surpassed by more-recently constructed buildings. The upper thin line denotes the maximum of log building quality in steady state, which reflects the optimal building to construct when constructing a new building in that period (whether by choice or because the building was exogenously destroyed).[13] Surviving buildings are endogenously replaced once city productivity increases sufficiently, and this minimum threshold in log building quality is represented by the lower thin line.

One example building growth path, shown as a dashed line in Panel A, reflects periods of endogenous reconstruction and exogenous destruction. In period 0, the building is exogenously destroyed and is reconstructed at a higher quality level. The building remains at this quality level as city productivity grows, until in period 42 the landowner finds it optimal to finally tear down the building and replace it with a substantially higher quality building. This building happens to be exogenously destroyed a few periods later, and is rebuilt to only slightly higher quality.

Figure 2, Panel B, graphs the steady-state evolution of the building distribution for a city that experiences a "Great Fire" in period 0 that destroys half of the buildings. Outcomes for the burned buildings are shown using dashed lines, and outcomes for the unburned buildings are shown using solid lines. The Fire induces all landowners in the burned area to reconstruct their building at the current optimal quality, which raises average building quality. Further, the Fire compresses the distribution of building qualities in the burned area around the maximum: burned buildings are rebuilt to the same quality as newly reconstructed buildings in unburned areas, such that there is no impact at the highest quantiles of the distribution of building values. The Fire's impacts on building quality are greatest toward the bottom of the distribution, where the entire stock of older buildings is cleared out.

In this benchmark model, the Fire does not affect landowners in unburned areas. Over time, landowners in unburned areas choose to replace their buildings and landowners in the burned area delay further replacement, such that the distribution of building qualities converges. Notably, convergence is slower for the bottom of the distribution. As a result, the average quality of unburned buildings will surpass the average quality of rebuilt burned buildings for some periods and then oscillate until random building destruction induces long-run convergence.[14]

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[13] Note that the optimal new building is "over-built," as its quality is higher than the optimal quality if there were no expected future growth in city productivity.

[14] The model generates a sharp reversal, as landowners in the burned area choose to replace a large number of surviving buildings reconstructed after the Fire, though this dynamic would be smoother with

While the burned area might appear more-developed shortly after the Fire, there are no economic gains from the Fire in this benchmark model. All landowners could choose to replace their buildings in period 0 in the absence of the Fire, but the large majority of landowners instead prefer to postpone reconstruction. There would be economic gains from forcing individual landowners to reconstruct buildings if there were positive externalities from reconstruction, however, which we explore in the next section.

This benchmark model yields five main testable predictions:

1. The Fire does not increase plot land values, which reflect the option value from each land plot, $V(0, \omega_t)$.
2. The Fire increases average building values in the burned area, following reconstruction, which then converge to average building values in unburned areas.
3. The Fire's impact on building values is decreasing in the quantile of building value, and is zero at the highest quantiles.
4. The Fire has the same impact on building values as individual building fires.
5. Building values and land values are unaffected in unburned areas.

II.B Extended Model with Neighborhood Externalities

We now extend the benchmark model, allowing for building rents to increase in the quality of nearby buildings. These spillover effects generate externalities, given assumptions that land ownership is fractured and perfect contracts are unavailable.[15] In this extended model, the Fire generates economic gains that may partially or fully offset the direct losses from the destruction, in contrast to our null hypothesis of the benchmark model in which the Fire generates no economic gains.

Consider a modified building rent function of $r(q, Q, \omega_t)$, where Q is a vector of nearby buildings' qualities with mean $\bar{Q}$. We assume that the number of surrounding buildings is sufficiently large that landowners take Q as given, such that neighborhood spillovers represent a pure externality. In particular, higher building quality generates positive externalities, as building rents are increasing in the quality of nearby buildings ($\partial r(q, Q, w_t) / \partial \bar{Q} > 0$). Further, the return to building quality is increasing in the quality of nearby buildings ($\partial^2 r(q, Q, w_t) / \partial q \partial \bar{Q} > 0$).

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some random shocks to the incentives for reconstruction.

[15] We assume that landowners are unable to contract with all neighbors to receive payments in proportion to the magnitude of spillover (i.e., that the associated transaction costs are prohibitive).

In equilibrium, the landowner's value of owning a building of quality q when the city has productivity ω_t is now given by:

$$V\left(q,Q,\omega_t\right)=max\begin{cases} r\left(q,Q,\omega_t\right) \; + \beta\mathbb{E}\left[V\left(q,Q',p'\right)\right] \\ r\left(q^*,Q,\omega_t\right)+\beta\mathbb{E}\left[V\left(q^*,Q',p'\right)\right]-c\left(q^*\right)\end{cases}$$

where q^* maximizes $r\left(q,Q,\omega_t\right)+\beta\mathbb{E}\left[V\left(q,Q',p'\right)\right]-c\left(q\right)$ and the vector Q reflects optimal building quality decisions of nearby landowners.

An individual building fire continues to have the same impacts as in the benchmark model. Following an individual building fire, with no change to the quality of nearby buildings, the burned building is reconstructed to quality q^*.[16]

The Great Fire, however, creates a positive multiplier effect because owners of burned properties take into consideration the simultaneous construction of many surrounding higher-quality buildings. This encourages even higher building qualities due to the assumption of complementarity, and higher overall rents due to the assumption of positive neighborhood spillovers. In nearby unburned areas, landowners immediately benefit from higher building qualities in the burned area and a set of neighbors who would otherwise have waited to upgrade do so immediately. Over time, landowners in nearby unburned areas also choose to reconstruct their buildings sooner and to a higher quality level due to increases in nearby buildings' quality. In this manner, the impacts of a Great Fire spread through the city.

Landowners' construction decisions are not completely efficient after the Fire, as the spillover effects are not internalized, but the Fire temporarily reduces the magnitude of inefficiency. Prior to the Fire, there is a disperse distribution of building qualities that includes some particularly low-quality buildings. Since landowners consider the whole distribution of neighbors when reconstructing properties, new buildings are lower quality than if all other buildings were also replaced. The Fire transforms this sequential-move game into a simultaneous-move game, and in a growing city landowners' best responses are to construct buildings of yet higher quality.

We focus on a single equilibrium case, in which non-increasing returns to quality cause the Fire's impacts to fade over time as city productivity increases and all buildings are replaced. Indeed, in some later periods, burned areas are relatively disadvantaged because of the large concentration of then-obsolete buildings constructed in the immediate aftermath of the Fire. By contrast, for particular functional forms of neighborhood spillovers, the Fire could have

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[16] We assume that one building makes a trivial contribution to the overall vector of neighborhood buildings. In principle, the earlier-than-expected reconstruction of that one burned building has some small unexpected benefit to nearby landowners and encourages them to reconstruct their buildings sooner. This small increase in the expected future quality of neighboring buildings would encourage the burned building to be rebuilt to slightly higher quality.

persistent impacts due to multiple equilibria.[17]

To illustrate these effects of the Fire, we extend the earlier numerical simulation to include neighborhood spillover effects. We modify the benchmark rent function, dividing the productivity term into the effect of city-wide productivity (ω_t) and the impact of neighborhood building quality (Q) : $r\left(q, Q, \omega\right) = q^{\alpha}\left(Q^{\eta}\omega^{1-\eta}\right)^{\beta}$.[18] We assume that the average quality of neighboring buildings summarizes the spillover effects from neighbors: if building i has N neighbors, $Q_i = \left(\sum_{n=1}^{N} q_n\right)/N$. Otherwise, the simulation is the same as for the benchmark model. In the steady state, there is a constant rate of growth in neighborhood productivity ($Q^{\eta}\omega^{1-\eta}$).[19]

Figure 3, Panel A, shows the changes in building quality after a Great Fire. The dashed lines show changes for the burned area, and the solid lines represent changes had there been no Fire. The presence of value spillovers creates a multiplier effect from simultaneous reconstruction that causes buildings' quality in the burned area to rise temporarily above that of the best buildings had there been no Fire. The Fire's impacts are again greatest toward the bottom of the distribution but, in contrast the baseline, continue to positively impact values at even the highest quantiles. Note that these effects would not apply to an individual building fire, where the milder predictions of the baseline model continue to hold. Over time, as in the benchmark model, building quality converges with oscillation to the same steady state had there been no Fire.

The Fire now affects landowners in unburned areas that are close enough to the Fire to experience changes in Q due to post-Fire reconstruction. Figure 3, Panel B, shows the growth path for nearby unburned areas, and the solid lines continue to represent changes had there been no Fire.[20] The Fire causes landowners in nearby unburned areas to upgrade their buildings sooner, due to reconstructed higher-quality buildings in the burned area. Indeed, the Fire's impacts would gradually spread through the city as landowners reconstruct buildings to reflect their neighbors' higher quality. These geographic spillover effects within

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[17] If building quality externalities exhibit increasing returns over some range of qualities, then burned areas could have been trapped in an inferior equilibrium in which landowners do not invest in high-quality buildings because nearby low-quality buildings lower the return to building quality. The Fire could then enable landowners to coordinate reconstruction at higher equilibrium building values, in which landowners find it optimal to construct high-quality buildings when nearby buildings are high quality. Of course, in the case of multiple equilibria, the Fire could also prompt a transition into the inferior equilibrium.

[18] In our simulation, we set $\eta = 0.8$ (and continue to set $\alpha = \beta = 0.5$).

[19] One technical challenge concerns owners' beliefs about the transitional dynamics immediately after the Fire. For simplicity, we assume that owners expect productivity and neighboring building quality to grow at the same rate after the Fire as prior to the Fire. These beliefs are correct in the long-run, and the main numerical results are not sensitive to alternative beliefs during this period of transition. In particular, model predictions are qualitatively robust to the opposite, and overly pessimistic, assumption that neighboring building quality will cease to grow entirely after the Fire.

[20] We simulate a nearby area in which plots receive 1/2 the $\bar{Q}$ spillovers of plots with all burned neighbors.

the city complicate an analysis of the Fire's aggregate impacts, as even the comparison group is affected by the treatment, and we return to this issue in a later section of the empirical analysis.

Predicted impacts on land values are of particular interest. In the model, a natural definition of land value is the option value from owning a plot with no building: $V(0, w_t)$.[21] There is no distribution of land values because plots are homogeneous, so we show changes in the value of land for each plot. Figure 4 shows the value of land in the benchmark model where the Fire has no impact on land value (lower black line). For the extended model with neighborhood spillovers, the upper red line shows increased land values in the burned area. The middle blue line shows smaller increases in land value for nearby unburned areas.[22] Land values converge over time, and even fall below the benchmark level due to the aging of buildings reconstructed immediately after the Fire.

The extended model with neighborhood externalities yields seven main testable predictions, of which five differ from predictions of the benchmark model:

1. The Fire increases plot land values in the burned area. Land values converge over time in the burned area, and may even fall below land values in unburned areas.

2. The Fire increases land values in nearby unburned areas.

3. As in the benchmark model: the Fire increases average building values in the burned area, following reconstruction, which then converge to average building values in unburned areas.

4. The Fire's impact on building values is decreasing in the quantile of building value, as in the benchmark model, but there are temporary impacts at the highest quantiles.

5. The Fire increases building values in nearby unburned areas.

6. The Fire has a greater impact on building values than individual building fires.

7. As in the benchmark model: individual building fires have no impact on land values.

II.C Additional Potential Mechanisms

There are several other potential channels through which a Great Fire might impact urban growth. We discuss informally some of these channels below, highlighting some potential

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[21] Note that this value equals the value of owning a building of quality $\underline{q}$ that would be chosen for replacement (i.e., a "tear down" building): $V(0, w_t) = V(\underline{q}, w_t)$.

[22] Plots on the boundary of the burned area experience the same impact on land value, regardless of whether burned status. Plots with a smaller fraction of burned neighbors experience correspondingly smaller spillovers.

empirical implications of each mechanism, and return to these channels in a later section of the empirical analysis.

Land Assembly and Ownership Concentration. We have assumed that post-Fire redevelopment occurs within fixed land plots, though the Fire might have impacts through land assembly. Land assembly, or the combination of plots, allows the construction of larger buildings and might create more value per-unit of land when there are otherwise rigidities preventing land assembly.

There are two main reasons why the Fire might increase plot sizes in the burned area. First, the Fire might reduce transaction costs resulting from hold-up or other aspects of bargaining between plot buyers and sellers.[23] Second, local heterogeneity in building quality may discourage otherwise profitable plot consolidation even within a single owner's neighboring holdings.[24] By destroying all buildings in an area, the Fire coordinates the timing of new construction and lowers the cost of land assembly.

The Fire might also concentrate land ownership, thereby improving the coordination of urban development. If plots are assembled across owners, there would be a natural decline in the number of owners. Further, the Fire might increase the concentration of land ownership by reducing hold-up, as above, even if landowners' goal is more to internalize neighborhood externalities than to assemble plots.

We will examine changes in plot sizes, in addition to the potential land value premium associated with observed changes in plot sizes. We will also examine whether there are increases in ownership concentration, perhaps that reflect many small landowners selling out in the aftermath of the Fire.

Business Agglomeration. The Fire may also impact urban development by improving the efficiency of firms' location decisions. Whereas firms often must make sequential location decisions, the Fire may allow firms to move simultaneously into a more-productive spatial distribution. Firms have a variety of reasons to locate near similar firms or firms producing inputs or complementary goods.[25] The size and location of industrial clusters may drift from the optimum over time, however, as the city develops and new technologies are introduced. The Fire might increase industrial agglomeration, or otherwise improve the efficiency of firm

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[23] 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, 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.

[24] When reconstructing an older building, the nearby newer buildings may be prohibitively costly to tear down early to build one larger building.

[25] Optimal industry locations can reduce transportation costs, attract customers interested in cross-shopping, signal competitive prices, allow monitoring of competitors, or encourage learning and productivity gains.

locations, by reducing moving costs and creating an opportunity for improved cross-firm coordination. We will examine whether the Fire increases industrial agglomeration in the burned area.

Residential Sorting. Similarly, the Fire might impact residential sorting along with replacement of the building capital stock (see, e.g., Brueckner and Rosenthal, 2009). If resident characteristics generate spillover effects, and residents' location is fairly persistent in the absence of the Fire, then these spillover effects could become capitalized into land values and influence land-use.

We will examine whether the Fire was associated with changes in residents' characteristics. In general, if resident characteristics are correlated with building characteristics then we would consider building spillover effects to be some potential combination of their physical and human components. Changes in occupant characteristics provide an additional mechanism through which building reconstruction generates spillover effects.

Infrastructure Investment. The Fire may benefit landowners by creating a unique opportunity for improvements in roads and other infrastructure. First, the absence of buildings lowers the costs of land acquisition and construction. Second, post-disaster solidarity may strengthen political will for public goods improvements.

We document the implemented changes in infrastructure and landowners' apparent support or opposition. We then consider whether the estimated changes in land values are consistent with fixed infrastructure investments, or whether land values converge over time. While infrastructure investments are not exogenous, within the burned area, we also consider whether areas are affected differently with differential exposure to infrastructure changes.

III Data Construction

III.A Annual Tax Assessment Records

Historically, the City of Boston sent tax assessors to each building to collect information for annual real estate and personal property taxes. The Boston Archives contain these handwritten ledgers from 1822 to 1944, typed records until 1974, and then digitized data.

Tax assessors recorded information for each building unit, each commercial establishment, and each residential occupant. For each building unit, data include: street name and number, assessed value of the building, assessed value of the land, plot size, and name of the building owner. For each commercial occupant, data include: detailed industry, value of business capital, and proprietor name. For each residential occupant, data include the value of personal possessions and the name and occupation of all males aged 20 or older. We collected all of these variables, aside from commercial proprietors' names and residential occupants names and occupation.[26] We digitized data for 1867, 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.[27]

III.B Plot-Level City Maps

The assessment data contain addresses, but not geographical proximity to the Fire. We generated this measure by plotting each assessment entry on high resolution scans of the plot-level Sanborn and Bromely fire insurance maps of Boston in 1867, 1873, 1883, and 1895 (Sanborn Map Company, 1867-1895; G.W. Bromley and Co, 1883). These maps indicate the location of each building and its street address (Appendix Figure 2), and often indicate the plot's square footage and owner name, which were used in matching the assessed plots to their geographic location. We "georeferenced" these historical maps to a contemporary digital map of Boston, defining each map in geographic space. 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 (Appendix Figure 3). There are 31,000 land plots in our main sample, pooling across all five years.[28]

Once the debate over street widening had been resolved, the City of Boston produced a detailed map of the burned area that shows the plot-level outline of the fire and the area of land to be taken from all plots affected by road widening (Appendix Figure 4). As with the fire insurance maps, we georeferenced images of this map to create a GIS polygon of the burned area and flagged all plots that lost area due to road widening.

By combining these resources we can identify the geographic location of each plot and calculate whether that plot is in the burned area and its distance from the burned area. Further, we can effectively analyze a panel dataset of fixed geographic locations despite potential changes over time in street addresses and plot boundaries. This allows us to match plots to their pre-Fire outcomes by city block or match plots to their nearest corresponding plot prior to the Fire. Within a year, we can also create measures of geographic industrial agglomeration and adjust for spatial correlation in the error term.

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[26] We collected commercial proprietors' industry, but did not collect residents' occupation because the land itself is used for housing and our analysis is focused on land-use. We also did not collect the names of commercial proprietors and residential occupants, as we would not be able to track individuals moving in/out of the neighborhoods analyzed.

[27] Through selective double-entry and back-checks, we have found initial entry and data cleaning to produce highly accurate data. Tax assessors totaled the numeric data at the bottom of each page (capital, possessions, land value, building value, plot size), which was used to validate the sum of entered data. The data include what are now the West End, North End, Financial District, Downtown Crossing, Leather District, Chinatown, and Fort Point. The data exclude more residential areas in what are now the South End, Back Bay, and Beacon Hill.

[28] We exclude wharfs, which are somewhat unusual in that the land area itself is endogenous. The estimated impacts on land and building value are similar, or somewhat higher, when including plots from wharfs.

III.C Validity of Tax Assessment Records

A main concern with tax assessment data is whether assessed values accurately reflect economic conditions. Assessors were instructed to assign market values to land and buildings, separately, and then also provide the total value. At that time, as in the modern period, properties were first assessed and then the tax rate was chosen to obtain the level of tax revenue targeted by the Boston City government (Fowler, 1873). Tax assessment ledger notes contain some references to disputed property valuations and sales valuations of that building or comparable units.

We collected supplemental data, from Boston's Registry of Deeds, to test the relationship between assessed values and the available data on property sales. We searched our assessment database for cases in which plots had changed owner names between 1867 and 1894, but retained the same street address and area in square feet. We then searched Boston's Registry of Deeds to confirm that a property sale had taken place, and obtained the sale price from the property's original deed of sale. This search yielded 72 preserved deeds for property sales outside the burned area and 16 property sales inside the burned area.

Appendix Figure 5 shows the relationship between properties' assessed value and sales value, along with the 45-degree line. Assessed values align closely with the available sales data in the burned and unburned areas, both before and after the Fire. Appendix Table 1 reports the average difference between assessed values and sales values, broken out by before and after the Fire in the burned and unburned areas. The estimated difference-in-difference estimate is small and statistically insignificant, although imprecisely estimated due to the small sample. Indeed, a main advantage of the tax assessment data is in providing valuations for all plots, both increasing power and avoiding selection bias in which plots are sold.

A related concern is whether assessors effectively provided separate valuations of land and buildings. The tax assessment ledgers contain some margin notes that indicate land assessments being calculated by multiplying plot size by an indicated value per-foot. Note, however, that the same per-foot valuation is not mechanically applied to all nearby plots (e.g., due to differences in street access and side of block). Assessors then appear to add an assessment of the building's value to obtain the recorded total value, and there exists much heterogeneity in the fraction of total value assigned to buildings.

In our discussion of the empirical results, we will explore ways in which the results may or may not be consistent with potential biases from the use of tax assessment data.

III.D Individual Building Fires

We have also obtained a sample of individual building fires, 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. We digitized these records, from 1866 to 1891, and merged them to our georeferenced tax assessment data. Using tax assessment data, we can then estimate impacts of idiosyncratic building fires on building values and land values, and compare these estimates to the impacts of the Great Fire.

Our goal is to obtain a sample of idiosyncratic fires that completely destroyed the building, comparable to damage in the Great Fire. Fire Department records do not consistently note the level of destruction, however, so we focus on fires with building damages greater than \$5000 or those with less damage for which the record specifically mentions that the building was "totally destroyed." This procedure naturally skews our sample toward more-valuable buildings, but we use our tax assessment data to control for these buildings' characteristics prior to their idiosyncratic fire. We impose two further conditions to highlight the comparison between individual fires and the Great Fire. First, we exclude single building fires that occurred within the burned area after the Great Fire. Second, we exclude all fires that are noted as having been caused by arson or were suspected to be arson. Our remaining sample contains 109 major single building fires to compare with the Great Fire.

IV Empirical Methodology

The main empirical analysis compares changes in the burned area to changes in unburned areas, and then separates the analysis by distance to the Fire boundary. Our data cover all land plots in the sample region in each sample year, but one technical issue is that there exists no direct link between every plot and its corresponding plot in other years. We circumvent this problem by estimating changes in fixed geographic areas, given that we know the location of each plot.

Our initial empirical specification estimates differences between the burned area and the unburned area in each year, relative to differences between the burned area and the unburned area in 1872 (just prior to the Fire). We regress outcome Y for plot i in year t on year fixed effects (α_t), an indicator variable for whether the plot is within the burned area ($\mathbb{I}_i^{Fire}$), and interactions between the burned area indicator variable and indicators for each year (other than 1872):

$$\begin{aligned}(1)\qquad Y_{it} = \alpha_t \quad &+ \quad \rho \mathbb{I}_i^{Fire} + \beta_{1867}\mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1867} \\ &+ \quad \beta_{1873}\mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1873} + \beta_{1882}\mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1882} + \beta_{1894}\mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1894} + \varepsilon_{it}.\end{aligned}$$

The estimated coefficient β_{1873} reports the change from 1872 to 1873 in the burned area, relative to the change in unburned areas. 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. In practice, we relax this assumption by including additional controls that may be associated with differential changes.

In our main specifications, we control for differential changes associated with plot characteristics prior to the Fire. While we cannot match each plot in later years to its own characteristics prior to the Fire, we can predict that plot's pre-Fire characteristics based on its precise geographic location. As a first approximation, we assign each plot the average pre-Fire values over all plots within its same fixed city block in 1867 and 1872. As a closer approximation, we assign each plot the characteristics of the nearest plot in 1867 and 1872. In practice, this "nearest neighbor" is very often that same plot in the earlier years.[29] We estimate a final specification including controls for both the nearest plot's value and the mean block value, as both may be independently predictive. That full empirical specification is similar to Equation 1, but includes interactions between year fixed effects and plot i's predicted characteristics from 1867 and 1872 based on its block average ($\bar{Y}^{block}_{i1867}$ and $\bar{Y}^{block}_{i1872}$) and based on its nearest neighbor ($\bar{Y}^{near}_{i1867}$ and $\bar{Y}^{near}_{i1872}$):[30]

$$\begin{aligned} (2) \qquad Y_{it} = \alpha_t \quad &+ \quad \eta_t \bar{Y}^{block}_{i1867} + \gamma_t \bar{Y}^{block}_{i1872} + \mu_t \bar{Y}^{near}_{i1867} + \kappa_t \bar{Y}^{near}_{i1872} \\ &+ \quad \beta_{1873} \mathbb{I}^{Fire}_i \times \mathbb{I}^{1873}_t + \beta_{1882} \mathbb{I}^{Fire}_i \times \mathbb{I}^{1882}_t + \beta_{1894} \mathbb{I}^{Fire}_i \times \mathbb{I}^{1894}_t + \varepsilon_{it}. \end{aligned}$$

The estimated coefficient β_{1873} continues to report the relative change in the burned area from 1872 to 1873, but adjusting for the possibility that initially-different plots might have changed differently, over each time interval, even in the absence of the Fire. Pre-Fire plot characteristics generally appear to summarize the relevant cross-sectional variation that might predict differential changes. For example, there is little additional predictive power from including additional year-interacted controls for distance to the Old State House, which land value data confirm is a marker of the historical center of the central business district.

For some specifications, we restrict the main sample of 31,000 plots to the 11,000 plots that are within 1000 feet of the burned area or were themselves burned. This focuses the empirical analysis on initially more-similar areas. There are important limitations in focusing on areas near the boundary of the burned area, however, as nearby unburned areas may be indirectly affected by the Fire. These spillover effects would bias estimates of changes in the burned area, and this bias is exacerbated by focusing on areas closer to the burned boundary.

Spillover effects from the burned area are of direct interest, and we also examine how

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[29] 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 non-zero 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.

[30] Note that the inclusion of nearest neighbor controls in 1867 and 1872 absorbs the "main effect" of the Fire ($\rho \mathbb{I}^{Fire}_i$) and the relative change from 1867 to 1872 ($\beta_{1867} \mathbb{I}^{Fire}_i \times \mathbb{I}^{1867}_t$).

proximity to the burned boundary impacts unburned areas. We begin with a nonparametric estimate of relative changes by distance to the burned boundary, and then parameterize this relationship. 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.

Two additional empirical details are worth noting. First, the regressions are weighted by plot size. 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.[31] Second, the standard errors are clustered by block to adjust for serial correlation and within-block spatial correlation. We also explore estimating Conley standard errors, which allow for more continuous spatial correlation within periods. We introduce additional empirical specifications and details as they are used.

V Summary Statistics and Baseline Differences in the Burned Area

Table 1 reports summary statistics for plots' land value and building value prior to the Fire.[32] On average, in 1872, plots were higher value in the burned area (column 1) than in the unburned area (column 2). Column 3 reports this estimated difference, in logs, and indeed the overall cross-sectional differences in 1872 are substantial and statistically significant. Plot values had changed more similarly from 1867 to 1872, however, in the burned and unburned areas (column 4). Land value declined from 1867 to 1872, on average, for plots in the burned area relative to plots in the unburned area (at an annual rate of 3.5%).

The empirical methodology focuses on comparing changes after 1872 in the burned area, relative to changes in the unburned area. This research design avoids bias from fixed differences in the burned and unburned areas, though it is still a concern that initial cross-sectional differences might predict differential changes after 1872. For this reason, we focus on empirical specifications that control for differential changes associated with plots' pre-Fire characteristics in 1867 and 1872. We have greater confidence in the results when the estimates are less sensitive to inclusion of these controls.

When restricting the sample to plots within 1000 feet of the Fire boundary, plot values in 1872 are more similar in the burned area (column 1) and restricted unburned area (column 5). Column 6 reports this estimated difference, in logs, and there is no longer a substantial or statistically significant difference in land value. The cross-sectional difference in building

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[31] 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.

[32] Plot values per square foot are weighted by plot size to align exactly with the subsequent empirical analysis.

value is smaller, but remains statistically significant. Column 7 reports changes from 1867 to 1872 in the burned area, relative to the restricted unburned area, which are similar to the overall relative changes (column 4). We report results based on this restricted comparison group, though geographic spillover effects might be greater, and continue to control for plots' pre-Fire characteristics in 1867 and 1872.

VI Main Results

VI.A Impacts on Land Value

Table 2 reports estimated impacts on plot land values in the burned area, relative to plots in unburned areas. Column 1 reports estimates from our initial specification: land values relatively declined from 1867 to 1872 in the burned area, increased sharply from 1872 to 1873, remained similar from 1873 to 1882, and by 1894 had declined below 1872 levels relative to the unburned area. Column 2 reports similar changes after the Fire, controlling for plots' average block land value prior to the Fire (in 1867 and 1872). Column 3 reports similar estimates controlling for pre-Fire values of the nearest plot, which absorbs all pre-Fire variation. Column 4 controls for pre-Fire values of the nearest plot and block averages. We prefer these controls to projecting directly the negative annual trend of 3.5% (in column 1), as asset values in principle should not exhibit large predictable changes.[33] From an *ex post* perspective, however, initial differences may predict differential changes and so we control for pre-Fire characteristics. The estimated impacts after the Fire are robust to controlling for predicted plot characteristics in 1867 and 1872.[34]

Estimated increases in land values from 1872 to 1873, of roughly 15% to 18%, capitalize substantial economic gains from the opportunity for widespread reconstruction. Increased land values are consistent with the extended model with neighborhood spillovers, rather than the benchmark model in which land values are unchanged. Higher land values largely persist through 1882, suggesting that initial increases are not an artifact of tax assessment in the immediate aftermath of the Fire. Land values declined relatively in the burned area by 1894, which may reflect predictions of the model that these areas face future rigidities in replacing an entire cohort of obsolete buildings constructed just after the Fire. Estimates from later periods may be spurious, however, as the identification assumption becomes more tenuous in later periods.

Estimated increases in land value are smaller when restricting the sample to plots within

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[33] Land values may exhibit some predictable changes along with predicted changes in location fundamentals, as in the extended model, but these changes are smoothed due to land values capitalizing the net present value of rents associated with any expected changes.

[34] We have also explored using kernel regressions to predict plot characteristics, as an intermediate case between block controls and neighbor controls, and the estimates are robust to that approach.

1000 feet of the burned boundary (Table 2, columns 5 – 8), though this could be due to spillover effects on nearby unburned areas. Indeed, the extended model predicts the Fire will increase land values in nearby areas.

Figure 5 shows estimated changes in land value from 1872 to 1873, grouped by plots' distance to the burned boundary. The burned area is to the left of the dashed line, represented by negative distances, and the unburned area is to the right and grouped into bins of 100 feet. The estimated coefficients are relative to the omitted category of plots more than 2900 feet from the burned boundary, and the vertical lines represent 95% confidence intervals.[35] The empirical specification controls for plots' pre-Fire outcomes, corresponding to the specification in column 4 of Table 2. Estimates from Table 2 are essentially the average difference between points to the left and the right of the dashed line.

Land values increased in nearby unburned areas, and by a similar magnitude as the increase in land values throughout the burned area. Increases in land value become smaller as distance to the burned boundary increases, and appear to level off around 1500 feet. By contrast, Appendix Figure 5 (Panel A) shows that distance to the Fire boundary was not associated with systematic changes in land value from 1867 to 1872. The relative decline in the burned area, corresponding to column 1 of Table 2, was driven by some interior burned areas having higher land values in 1867.

Positive spillover effects generate two reasons why the Fire's total impact on land value would be understated by relative changes in the burned area (e.g., estimates from Table 2). First, the relative comparison understates the aggregate impact in burned areas because nearby unburned areas are also affected. Second, the impacts on nearby unburned areas should also be included in the aggregate impacts of the Fire. These problems could be overcome, however, if we assumed that further unburned areas are unaffected by the Fire. A within-city analysis is fundamentally limited in its ability to calculate city-wide impacts, but we can bound the Fire's impacts if spillovers are positive on net.

In principle, there could be negative spillover effects due to displacement of economic activity within Boston, which is not reflected in our model. For example, if the overall demand for some economic activity is fixed and increased activity is drawn into the burned area, then this comes at the expense of unburned areas. The downtown Boston economy was sufficiently integrated with the Greater Boston area, and even the world economy, that we suspect there is less scope for negative spillovers through displacement of economic activity. Furthermore, the ultimate relative decline of land values by 1894 suggests that any impacts on economic activity were, as predicted by the model, of a temporary nature. The potential

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[35] For the interior of the burned region, plots more than 400 feet from the burned boundary are grouped together.

for negative spillovers, however, is an important caveat to the estimated total impact.

We estimate the total impact on land value, subject to caveats, by parameterizing the spatial relationship seen in Figure 5. We begin by modeling the Fire's impact with a continuous linear function: constant within the burned area, decreasing linearly with distance outside the burned area ($dist_{it}$), and then zero after some distance cutoff (c):

$$Y_{it} \;=\; \beta_0 + \beta_1 \max\left\{\frac{c - dist_{it}}{c}, 0\right\} + \mu_t \bar{Y}_i^{near} + \eta_t \bar{Y}_i^{block} + \varepsilon_{it}. \tag{3}$$

This functional form is consistent with the non-parametric results in Figure 5, although a completely non-parametric analysis provides no formal quantitative estimate of where the spillovers end. The Appendix (Section A) discusses some details of the estimation and explores the results' robustness to alternative functional forms.[36] Defining Y_{it} as the log of land value per square foot, we substitute this piecewise linear function for the indicator function denoting the burned area, and simultaneously estimate the fire effect β_1 and distance cutoff c that best fits the data.

These estimation results provide a predicted impact of the Fire on each plot's land value, which depends on its distance to the burned area. Based on the value of each plot in 1873, we calculate the implied rise in land value due to the Fire. We then sum these impacts across all plots to obtain an estimated total impact on land value, and convert all dollar amounts to 1872 dollars using the David-Solar CPI (Lindert and Sutch, 2006).

Table 3, Panel A, reports these estimates for an estimated spillover cutoff of 1,394 feet from the burned area (column 1). The Fire is estimated to have increased land values by \$5.5 million in the burned area (column 2), and by \$9.7 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 \$15.2 million (column 4), or 1.17 times the 1872 value of buildings in the burned area (column 5). To give a sense of robustness, Panels B and C report estimated impacts when assuming the distance cutoff to be 1149 feet or 1639 feet (i.e., the 95% confidence interval for the estimated distance cutoff).[37]

The total impact on land values is comparable to the value of buildings burned, and may have been even greater.[38] This is not to imply that the Fire itself was value-enhancing,

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[36] The estimated functional shapes are visually similar to the piecewise linear function (Appendix Figure 9), and the implied total impacts are slightly larger than under piecewise linear specification.

[37] Note that the standard errors in Panel A, columns 2 to 5, do take into account the uncertainty in the estimated distance cutoff.

[38] We also suspect that assessed building values overstate their "true economic value," as buildings are never assessed at close to zero value even when they are a "tear down" and due for replacement.

as the actual damages included lost property and goods and were estimated to be at least \$75 million. The value of burned buildings provides a natural point of comparison, but the impact on land values does not need to exceed the value of buildings for there to be substantial inefficiencies. Indeed, the null hypothesis from the benchmark model is that the Fire has no impact on land values. For the Fire to have any substantial impact on land values, there must have been substantial inefficiencies in urban development.

In the immediate aftermath of the Fire, however, there may be something unusual about tax assessments and the city economy in general. Table 3, Panels D – F, presents analogous estimates of the total impact on land value in 1882. Estimates indicate that the Fire continues to exert a strong impact on land values. Appendix Figure 7 shows estimated changes in land value from 1872 to 1882 (Panel A) and from 1872 to 1894 (Panel B), grouped by plots' distance to the burned boundary. By 1882, land values remain higher in the burned area and have increased in nearby unburned areas relative to further unburned areas. Land values are lower in the burned region by 1894, though still higher in the nearby unburned area, which may reflect expectations that the burned area will become dragged down by a large cohort of increasingly obsolete buildings.

VI.B Impacts on Building Value

Table 4 reports estimated impacts on building values in the burned area, relative to unburned areas. Building values declined immediately with the destruction from the Fire.[39] Building values became substantially higher by 1882, however, and had partially converged by 1894. These results are similar when restricting the sample to within 1000 feet of the burned area, though the magnitudes are smaller in a manner consistent with positive spillover effects on nearby areas.

Figure 6 shows estimated changes in building value, grouped by plots' distance to the burned boundary. From 1872 to 1873, building values decline in the burned area and are mostly unchanged in the unburned area (Panel A). Note that some buildings just inside the "burned area" appear not to have been completely burned, or may have simply been repaired or reconstructed quickly. Buildings outside of the burned area do not appear to have been damaged by the Fire.

Building values increased substantially throughout the burned area from 1872 to 1882 (Figure 6, Panel B). Nearby unburned buildings also appear to have increased in value, relative to further unburned buildings. This geographic spillover effect appears to level off quickly, around 300 feet, although there is some downward trend at much further distances. By 1894, there appear to be impacts on nearby unburned areas that decline in geographic

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[39] 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.

distance up to 1500-2000 feet (Panel C). Note that these estimates are conditional on plots' predicted building value prior to the Fire, and there were not clear relative changes in these areas' building value from 1867 to 1872 (Appendix Figure 6, Panel B). While reconstruction of burned buildings might have contributed to temporarily higher building costs in Boston, by 1882 these nearby unburned areas had also been systematically upgraded.

The increase in building values in the burned area is consistent with both the benchmark and extended models, but the apparent rise in building values in nearby unburned areas is indicative of the spillovers present in the extended model. The data suggest nearby landowners upgraded their buildings sooner to complement the increased quality of buildings in the burned area, and the distance of geographic spillovers appears to spread from 1882 to 1894 as further landowners react to upgrading in nearby unburned areas. By contrast, in the benchmark model, landowners in all unburned areas do not change their building construction decisions.

Impacts on the distribution of building values in the burned area may also be indicative of neighborhood spillover effects. While both the benchmark model and extended model predict increases in building quality, the extended model is associated with a multiplier effect that increases building quality at even the highest quantiles. We estimate quantile regressions that are analogous to the mean impacts reported in column 1 of Table 4.[40]

Figure 7, Panel A, shows estimated changes from 1872 to 1882, by quantile, for building values in the burned area. Building values increased significantly at even the highest quantiles, which is consistent with even the highest-quality buildings being replaced with buildings of discreetly higher quality due to the Fire's multiplier effect generated by neighborhood spillovers. Building values increase much more at the lowest quantiles, which reflects the removal of less-valuable buildings and a compression in the bottom of the distribution. This result is consistent with both models, but illustrates a mechanism through which neighborhood quality increases. By contrast, there is a relatively consistent effect across quantiles of plot land value (Appendix Figure 8).

Figure 7, Panel B, shows that building values had converged by 1894 for all but the lowest quantiles. Both models predict that convergence would be slowest for the bottom of the distribution, and these estimates highlight that the moderate convergence reported in Table 4 is a combination of slow and fast convergence at different points in the distribution. There is even some indication of lower building quality in the burned area at higher quantiles. Thus, while average building values continue to remain higher in 1894 (Table 4), the decline

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[40] Estimates are similar from conditional quantile regressions, including controls for pre-Fire characteristics, but the interpretation of the conditional quantile results is less clear: the theory predicts that the worst buildings are upgraded the most, rather than the worst buildings conditional on their previous nearest neighbor value.

seen in land values by 1894 may be more forward-looking about growth potential in future periods (Table 3). In the coming periods, the burned area will possess an aging stock of buildings, built in the immediate aftermath of the Fire, that may reduce relative rents.

VI.C Robustness to Spatial Correlation and Weighting

One natural question concerns potential spatial correlation in plots' land value and building value, which might cause the empirical analysis to overstate the statistical precision of the estimates. Our main empirical specifications allow for spatial correlation within blocks, but we now consider allowing for spatial correlation across plots that declines linearly in geographic distance up to some distance cutoff (Conley, 1999). Appendix Table 2 presents the estimated impacts on land value and building value, along with standard errors that assume different distance cutoffs. The estimated coefficients correspond exactly to those in Table 2 and Table 4, and the estimated standard errors generally rise and then decline with further distance cutoffs. The statistical precision remains similar, however, and the main results remain statistically significant.

The main specifications are weighted by plot size, for reasons discussed above, but we also consider whether the estimates are sensitive to this specification choice. Appendix Table 3 reports similar estimated impacts of the Fire on land value and building value, with and without controls, as in the main results reported in Table 2 and Table 4.

VI.D The Great Fire vs. Individual Building Fires

We next compare the impacts of the Fire to impacts of individual building fires, which provides a natural test of whether the Fire has an additional multiplier effect from widespread reconstruction. Both the benchmark model and extended model predict that individually-burned buildings will be replaced with higher quality buildings, but in the benchmark model this increase in quality is the same if a Great Fire destroys all buildings in an area. By contrast, the extended model predicts larger increases in building value due to the simultaneous reconstruction of neighboring buildings to higher quality.

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 τ, we assign the indicator $\mathbb{I}_i^{IF}$ equal to 1 if the plot experienced an individual building fire and $\mathbb{I}_{it}^{\tau}$ equal to 1 for individual fire data approximately τ years prior to a round of digitized assessment data. [41] For plot i in

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[41] 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 2-year window of this target. For example, we

year t, the interaction of these two indicator variables defines whether that plot experienced an individual building fire τ years ago ($\mathbb{I}_i^{IF} \times \mathbb{I}_{it}^{\tau}$). The full estimating equation then becomes:

$$
\begin{aligned}
(4) \qquad Y_{it} = \alpha_t \quad &+ \quad \eta_t \bar{Y}_{i1867}^{block} + \eta_t \bar{Y}_{i1872}^{block} + \mu_t \bar{Y}_{i1867}^{near} + \mu_t \bar{Y}_{i1872}^{near} \\
&+ \quad \beta_{1873} \mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1873} + \beta_{1882} \mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1882} + \beta_{1894} \mathbb{I}_i^{Fire} \times \mathbb{I}_t^{1894} \\
&+ \quad \delta_1 \mathbb{I}_i^{IF} \times \mathbb{I}_t^{1} + \delta_{10} \mathbb{I}_i^{IF} \times \mathbb{I}_t^{10} + \delta_{22} \mathbb{I}_i^{IF} \times \mathbb{I}_t^{22} + \varepsilon_{it}.
\end{aligned}
$$

The estimated coefficient δ_1 represents the 1-year impact from an individual building fire, and can be compared to the estimated impact of the Fire in 1873 (β_{1873}). Similarly, δ_{10} and δ_{22} can be compared to β_{1882} and β_{1894}, respectively.

Table 5 reports estimated impacts of both the Great Fire and individual building fires.[42] Building values are higher 10 years and 22 years after individual fires, but the increase in building values are smaller than increases in building value after the Great Fire (columns 1 and 2). These differences are mostly statistically significant, consistent with the extended model's prediction of a multiplier effect following the Great Fire.

We do not know the magnitude of selection bias associated with individual building fires, i.e., whether these buildings would have experienced differential changes in building values. We suspect that the bias is positive, however, as older buildings might be at greater risk of catching on fire and these older buildings may be due for upgrades. The analysis controls for buildings' characteristics in 1867 and 1872, however, which partly addresses these concerns.

There was no immediate increase in land value following individual building fires, in contrast to the immediate increase in land value following the Great Fire (Table 5, columns 3 and 4). One concern with the main analysis, discussed above, is that the Great Fire might cause a spurious increase in the assessment of land value (e.g., if assessors value land higher for vacant plots). The absence of higher land values immediately following individual building fires suggests that fires are not mechanically associated with increased assessment of land value. There is generally no assessed land value premium for vacant plots,[43] and land values also increased immediately in nearby unburned areas that are not vacant after the Great Fire. Assessors appear to effectively separate building value and land value, consistent

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estimate 10-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 2-year window. The individual fire indicator $\mathbb{I}_{it}^{\tau} = 1$ if $\left| t - t_i^{IF} - \tau \right| < 2$. To control for when the fire occurred within this 2-year window, we interact $\mathbb{I}_i^{IF} \times \mathbb{I}_{it}^{\tau}$ with $t - t_i^{IF} - \tau$ and report the impact of $\mathbb{I}_i^{IF} \times \mathbb{I}_{it}^{\tau}$ when $t - t_i^{IF} = \tau$.

[42] We control for pre-Fire plot values in all specifications, since by restricting focus to individual building fires with damages greater than \$5000 there is a mechanical association between individual building fires and higher-value plots.

[43] We do not estimate a substantial or statistically significant difference in the log value of land per square foot for vacant plots, compared to non-vacant plots within 100 feet.

with their instructions, margin notes, and the great variation in the fraction of total assessed value that is assigned to buildings.[44]

Overall, it appears that the Fire's inherent largeness is fundamental to its impacts on land values and building values. We attribute much of this impact to spillover effects from the widespread reconstruction and upgrading of nearby plots. In the next section, we consider some additional mechanisms through which the Fire may impact urban redevelopment.

VII Additional Potential Mechanisms

VII.A Infrastructure Investment

Along with the opportunity for private landowners to reconstruct buildings, the Boston city government had an opportunity to improve public infrastructure in the burned area. Government plans were largely limited by resistance from landowners, but there were some moderate improvements to the road network.

Changes in the road network are certainly not exogenous, but we begin by considering whether plots on non-widened roads experienced increases in land value and building value. Appendix Table 4 reports these results, which show similar increases in land value and building value in these burned areas relative to unburned areas.

We have emphasized the gain to landowners from widespread reconstruction of neighboring buildings, but in principle these gains could be due to any new amenity in the burned area that also generates spillover effects. While we emphasize the amenity created by higher-quality nearby buildings, these impacts are difficult to distinguish formally from another amenity such as higher-quality roads, wider water mains, or new fire hydrants. Whereas these changes in infrastructure are potentially long-lasting, however, we see convergence in land values and building values that appear more to reflect temporary upgrades to the building capital stock. Immediate increases in land value could reflect changes seen in the road network, though this is also somewhat inconsistent with landowners' coordinated resistance to changes in the road network despite compensation paid for lands used (Rosen, 1986). Given these considerations, and the limited effectiveness of changes in the road network in reducing traffic problems (Rosen, 1986), we do not expect this to be the primary source of the Fire's impacts.

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[44] On average, building value makes up 37% of the combined value of buildings and land. In considering variation across plots in the fraction of total value assigned to buildings, the standard deviation across all plots and years is 19 percentage points. Conditional on block-by-year effects, which explain 49% of the variation in the fraction of total plot value assigned to the building, the standard deviation across plot residuals is 13 percentage points. Thus, even within a block and year, there remains substantial variation in the fraction of total assessed value that is assigned to a plot's building or land.

VII.B Land Assembly

The Fire may also impact land values by lowering the cost of land assembly, i.e., combining land plots into larger units. There may be returns to scale in plot size, and yet various rigidities might prevent the assembly of plots into larger units that would increase the value of land per square foot (see, e.g., Brooks and Lutz, 2012).[45]

Table 6 reports estimated impacts on log plot size in the burned area, relative to unburned areas, based on the same estimating equations as before. In the main sample (columns 1 and 2) and the restricted sample within 1000 feet (columns 3 and 4), there is little immediate change in average plot size from 1872 to 1873. There is some indication of higher plot sizes in later periods, following reconstruction, which is more consistent with the returns to land assembly increasing with neighborhood quality. If the immediate increase in land values were driven by declines in the cost of land assembly, then we should expect to see greater land assembly in 1873.

Some plots in the burned area were made smaller, however, due to road widening. Table 6, columns 5 to 8, report estimates that exclude plots of land in the burned area that were subject to road widening. Excluding those plots directly impacted by road widening, there are small increases in plot size from 1872 to 1873 and larger increases in later periods.[46]

Quantitatively, the observed increases in plot size would not explain the estimated increases in land value. Focusing on the increase in plot sizes for areas without road widening, and assuming that the doubling of plot size provides a land premium of 40% (Brooks and Lutz, 2012), the observed increases in plot size would generate approximately a 2% increase in land value. In addition, this premium would be offset by areas losing plot size along with road widening.

If we assume there are returns to land assembly, then it is interesting to consider the absence of substantial land assembly immediately 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 is consistent with the importance of rigidities even in rural agricultural areas (Libecap and Lueck, 2011).

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[45] Indeed, in our setting, we find that log land value per square foot is positively correlated with log plot size in the cross-section prior to the Fire (coefficient of 0.481, standard error of 0.038). We do not have an appropriate empirical setting to estimate plausibly a causal relationship between plot size and land value, however, and do not claim that these estimates are causal. Indeed, the estimated cross-sectional premium declines substantially when we control for distance and direction from the State House as a proxy for the central business district (coefficient of 0.172, standard error of 0.022).

[46] Quantile regressions indicate that these average impacts are driven by a decline in the number of small plots.

VII.C Ownership Concentration

The Fire might also lead to a concentration of land ownership in the burned area. Landowners might combine their own existing plots, buy-out neighbors to combine plots, or buy-out neighbors without combining plots to better coordinate redevelopment. Ownership might also concentrate in the burned area if some landowners were liquidity-constrained and induced to sell by the Fire.

Appendix Table 5 reports some basic statistics on the number of unique landowners in the burned area and unburned areas, over time.[47] There was a general decline in the number of unique owners over time, and a more rapid decline from 1872 to 1873 (columns 1-4). The magnitudes are fairly small, however, and 8 of the 19 owners that exited were a direct consequence of road changes eliminating their landholdings in the burned area.

A similar exercise shows changes over time in the number of plots in the burned area and unburned areas (Appendix Table 5, columns 5-8). There were general declines in the number of plots over time, with a more rapid decline from 1872 to 1873. The magnitudes are also small, however, and 20 of the 61 plots eliminated were a direct consequence of road changes.

Overall, there were some small relative declines in the number of landowners. There is no indication, however, of small landowners in the burned area systematically selling off their properties. Landownership remained highly fractured, and there were few mechanisms for landowners to internalize their spillover effects on neighbors. Despite the Fire, we expect that reconstruction was still well below efficient levels of quality due to the inability to internalize spillover effects on nearby areas.

VII.D Business Agglomeration

The Fire may have allowed business owners to locate more efficiently, thereby increasing productivity in the burned area. We focus on whether industries took advantage of potential vacancies to agglomerate more closely, which is one of the more standard desirable features in firms' location decisions. We calculate a measure of spatial agglomeration (Ripley's L function) for the 18 industries that had more than three establishments inside and outside the burned area in all sample years. We then consider how these industry-level statistics changed relatively in the burned area.

The L function provides a normalized measure of the number of same-industry establishments within a radius r of each establishment, relative to the number of establishments

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[47] Measuring the number of unique owners 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.

that would be expected under perfect spatial randomness (following Ripley, 1977). The Appendix (Section B) provides some additional details, but values of $L_{ib} > 0$ are associated with greater agglomeration, whereas negative values signify a more uniform dispersion than would occur given a random distribution of points. We calculate $L_{ib}(r)$ for three radius values (50, 100, 200) for 18 industries in 1867, 1872, 1882, and 1894.[48]

Appendix Table 6 presents these estimates of agglomeration, by industry, for the burned area and unburned areas.[49] Most industries display some clustering, but is no systematic increase in industry agglomeration in the burned area, relative to the unburned area, from 1872 to 1882 (column 8) or from 1872 to 1894 (column 9). Industries appear to become somewhat less agglomerated over time, especially the more common industries.

Appendix Table 7 reports estimated impacts on industry agglomeration in the burned area, relative to unburned areas. The estimating equations are analogous to before, but use the calculated $L_{ib}(r)$ values to characterize the degree of agglomeration in each industry and year, and weighting each observations by the total number of sample establishments in its industry-year.[50] There is no indication of increased agglomeration in the burned area, and some indication of a decline in industrial agglomeration when controlling for industries' level of agglomeration in 1867 and 1872 (columns 2, 4, 6).

These results do not immediately support the hypothesis that changes in business location are driving the observed increases in land values, as much of the existing literature has argued that industry agglomeration is productivity enhancing. The literature has primarily examined the equilibrium relationship between clustering and productivity, however, rather than the transitional dynamics. It is possible that certain industries had become overly clustered prior to the Fire, and the increases in dispersion were associated with efficiency gains.

VII.E Occupant Sorting

The Fire may induce differential sorting of residents and commercial establishments, along with changes in building quality. The spillover effects we estimate may work both through the direct effects of building quality as well as through the characteristics of the occupants of higher quality buildings.

We begin by considering the number of commercial and residential occupants, which we measure as the number of assessed occupants per 1000 square feet.[51] Appendix Table 8, columns 1 and 2, report increases in the number of commercial occupants following the

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[48] We exclude 1873 when many buildings were unoccupied at the time of assessment in the burned area.

[49] For this Appendix Table, the distance radius is set to 100 feet.

[50] The results are robust to unweighted regressions.

[51] Tax assessment data report the number of commercial establishments and the number of male residents over 20 years of age.

initial decline in the immediate aftermath of the Fire. By contrast, columns 3 and 4 report declines in the number of residential occupants. Overall, there was a temporary decline in the total number of occupants. These results suggest the fire caused a shift in neighborhood composition towards commercial uses, which may have been one channel through which positive spillovers operated.[52]

An analysis of occupants' capital value is greatly complicated by censoring, which is unfortunately inherent to the assessment of taxable property. Property was only taxed, and therefore assessed, for occupants whose income was greater than $1000. We have an extreme censoring problem – even the median is censored – as many occupants had lower incomes and so their value of capital is unobserved. Appendix Table 8, columns 5 – 8, report estimated impacts on log capital per square foot when assigning a value of 500 to these missing values.[53] There is some indication of increased capital values of commercial establishments (column 6), but only after controlling for pre-Fire values and there is a differential trend in commercial capital value from 1867 to 1872. In contrast to the analysis of land value, there is no sense in which capital values in 1872 would already capitalize expected changes after 1872. There is also some indication of higher residential capital value after the Fire (column 7), but not after controlling for pre-Fire values.

In the end, there may be changes in building occupancy and capital investment that are one channel through which building reconstruction generates economic gains and influences neighbors. The estimates are sensitive to the empirical specification, however. In addition, it is ultimately the replacement of buildings that drives changes in occupancy patterns (as in Brueckner and Rosenthal, 2009). Thus, our interpretation generally focuses on spillovers from higher quality buildings, with the understanding that these spillovers may operate in part through "higher quality" occupants.

VIII Epilogue: Estimated Impacts in 2012

As an epilogue, we consider whether the burned area differs from unburned areas in the modern period. We use data on Boston property values from plot assessments in 2012, which are assessed at market value.[54] Separate valuations for land and buildings are unavailable for condominiums, which make up a substantial portion of the downtown Boston area, so we are limited to analyzing the total value of plots.

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[52] These results should be interpreted with caution, however, as there was a pre-Fire trend towards lower residential density. In contrast to the analysis of land value, there is no sense in which 1872 residential density already capitalizes future changes in residential density.

[53] 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.

[54] For details on assessment methodology, see: http://www.cityofboston.gov/assessing/assessedvalues.asp. We assigned plot locations by merging on plot ID to the Boston parcels map: http://boston.maps.arcgis.com.

Appendix Table 9 reports changes from 1872 to 2012 in the burned area, relative to changes in the unburned area. There is no statistically significant difference in the basic specification (column 1), but the burned area appears to become substantially more valuable conditional on controls for plots' pre-Fire characteristics (column 2). The influence of pre-Fire controls is somewhat surprising, as we expected plot characteristics in 1867 and 1872 to have little predictive power in 2012 data. The estimates are smaller, and statistically insignificant, when limiting the sample to areas within 1000 feet of the burned boundary. In principle, there may continue to be spillover effects on unburned areas, though a variety of confounding factors would be difficult to control for over such a long period of time. There is no indication that the burned area was disadvantaged over the long-run, though we suggest caution in interpreting these results as evidence of long-run gains. The most plausible channel for long-run impacts is perhaps persistent changes in plot boundaries, but we found only small impacts on plot size. Given cross-sectional differences between the burned area and unburned areas, the identification assumption of parallel trends becomes increasingly tenuous over longer periods of time.

IX Conclusion

Following the 1872 Great Fire of Boston, burned plots and nearby unburned plots experienced substantial increases in land value. These increased land values capitalize substantial economic gains, which we attribute to neighborhood spillover effects from the simultaneous reconstruction of many nearby buildings. Changes in building values, by distance to the Fire boundary and by quantile, are consistent with predicted impacts of neighborhood spillover effects on building reconstruction. By contrast, individual building fires had no impact on land value and generally smaller impacts on building value. While our data provide various indications of cross-plot spillover effects, there is less evidence for substantial impacts through increased plot sizes, increased urban density, or increased industry agglomeration.

The Fire temporarily mitigated substantial inefficiencies in urban growth, as individual landowners fail to internalize cross-plot externalities. Indeed, in this case, burned buildings' value was entirely offset by increased land values. While "urban renewal" is almost always associated with poorer urban areas, these results indicate the potential for substantial land-use inefficiencies in even wealthy and growing cities. Our within-Boston empirical analysis is unable to quantify all spillover effects at the city level, though positive spillover impacts by distance to the Fire boundary appear to dissipate within the sample region. Even if some spillover effects are negative, increased land values imply at least large relative gains in the burned area from the opportunity for simultaneous reconstruction at higher levels of building quality.

The historical growth of American cities generally occurred in the absence of major city fires, but the example of Boston highlights the potential magnitude of inefficiency within a generally successful urban area. The Boston Fire provides a clear exogenous shock, and the opportunity to collect a rich dataset covering private reconstruction responses in the absence of modern regulatory constraints. Our empirical analysis focuses on plot-level differences within Boston, in contrast to long-run economic analyses of city-level impacts after destruction. While all data are drawn from one city, the statistical inference is robust to correcting for spatial correlation across plots.

Our focus on wealthy areas of Boston is complementary to research on the economic impacts of large-scale urban renewal in poor or declining areas. The Fire's impacts are indicative of substantial inefficiencies in even wealthy areas, and suggests that the study of such frictions in today's rapidly growing cities – both in the United States and in rapidly urbanizing nations of the developing world – is an important area of research. The ability of the Great Fire to generate substantial gains through simultaneous reconstruction also suggests that policy interventions might achieve some of the same goals without the associated destruction.

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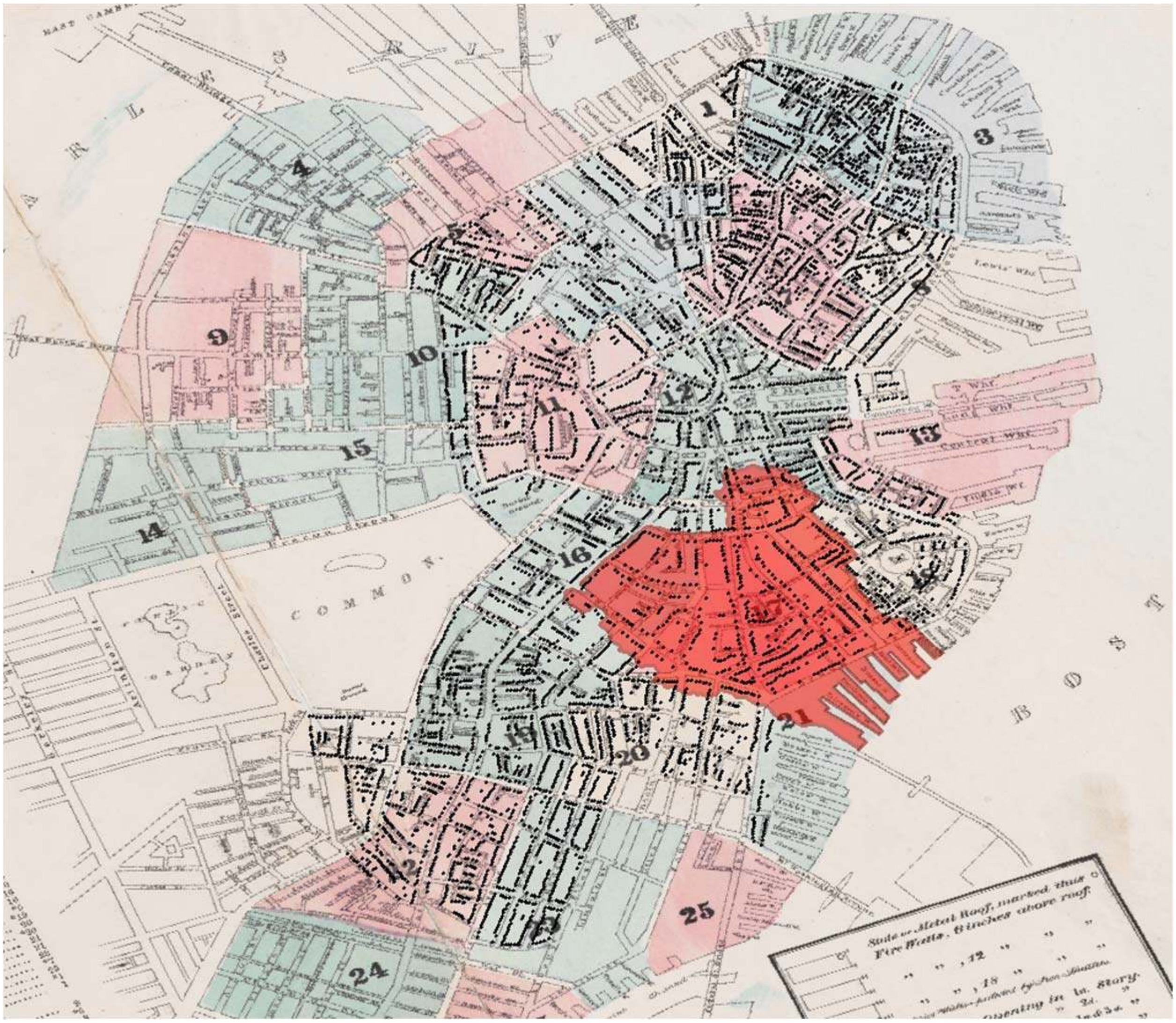
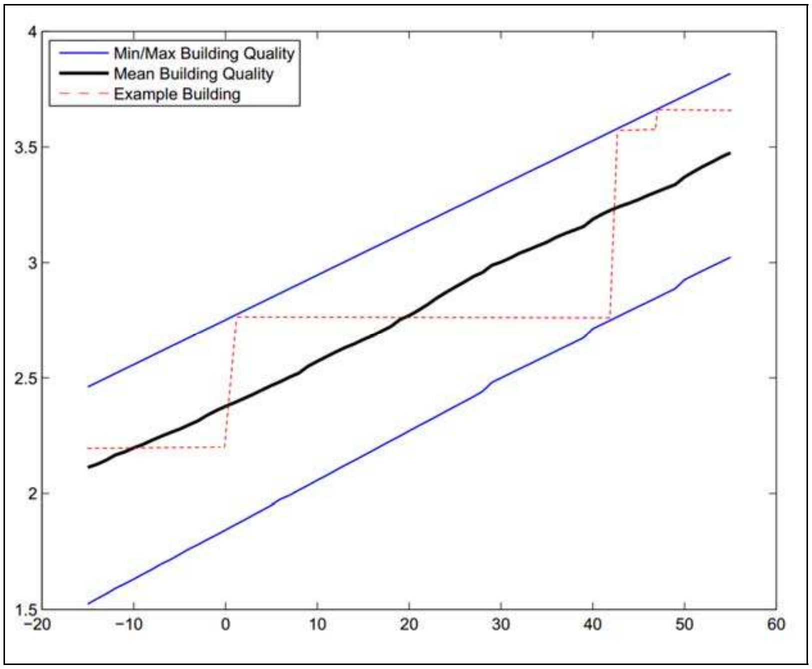
Figure 1. Historical Downtown Boston, the Burned Area, and Sample Plot Locations



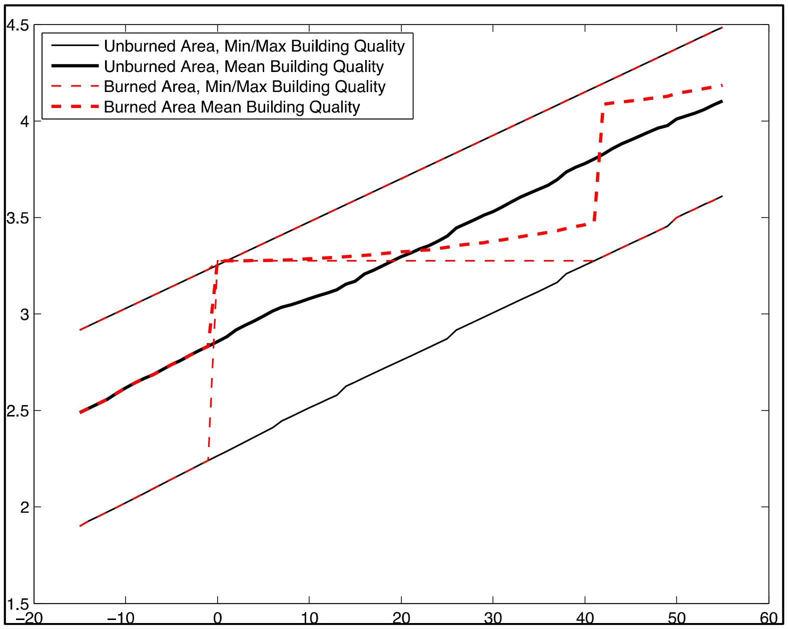
Notes: The shaded red area was burned during the 1872 Great Fire of Boston, and this is overlaid on the land mass of downtown Boston in 1867 (Sanborn Map Company). Small black points denote each geo-located plot in our main sample for 1867.

Figure 2. Simulated Steady-State Evolution of the Building Quality Distribution

Panel A. Benchmark Model



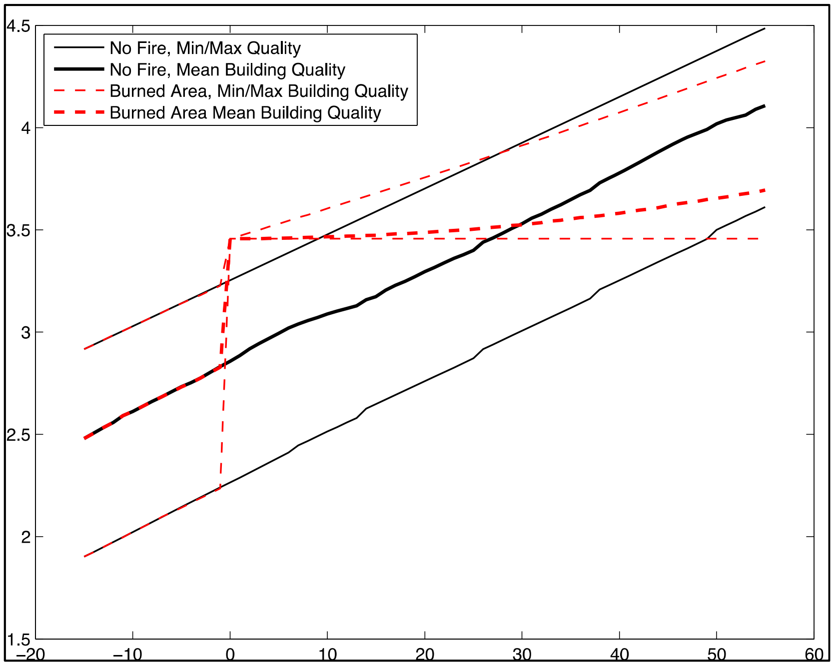
Panel B. Benchmark Model: Unburned and Burned Areas after a Great Fire in Period 0



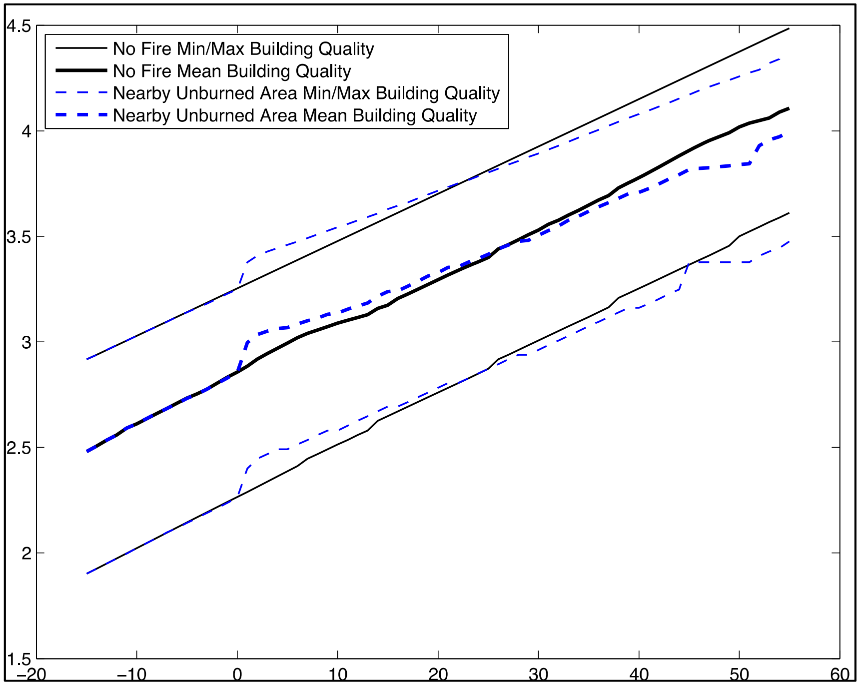
Notes: Panel A shows the simulated evolution of the steady-state in our benchmark model. The thick central line shows the mean of log building quality, and the upper/lower thin lines show the max/min of the building quality distribution. The thin dashed line shows the evolution of a particular example building. Panel B shows the simulated evolution of the steady-state in our benchmark model, following a Great Fire in period 0. The black lines represent the Unburned Area (same as in Panel A), and the red lines represent the Burned Area.

Figure 3. Simulated Steady-State Evolution of the Building Quality Distribution

Panel A. Extended Model: Burned Area after a Great Fire in Period 0

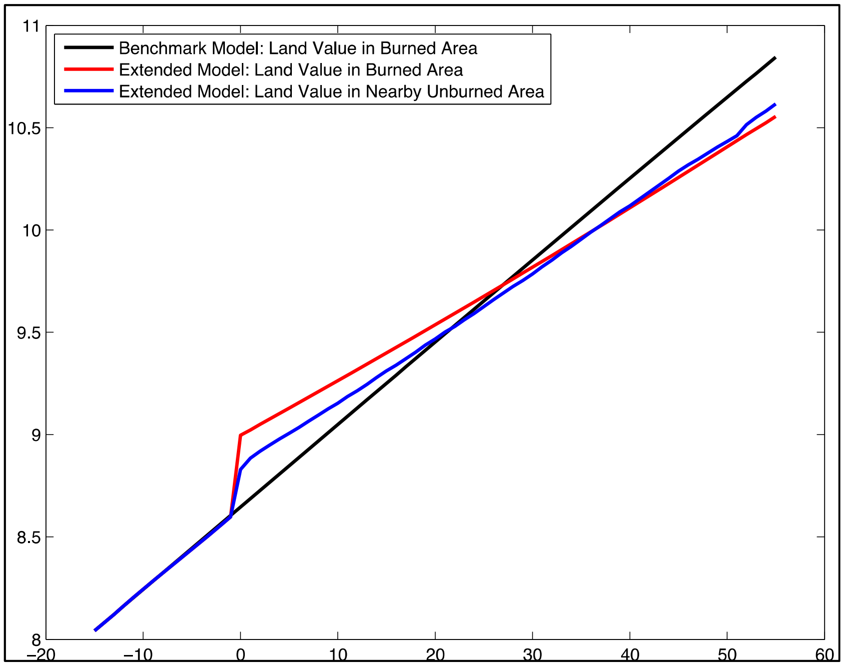


Panel B. Extended Model: Nearby Unburned Area after a Great Fire in Period 0



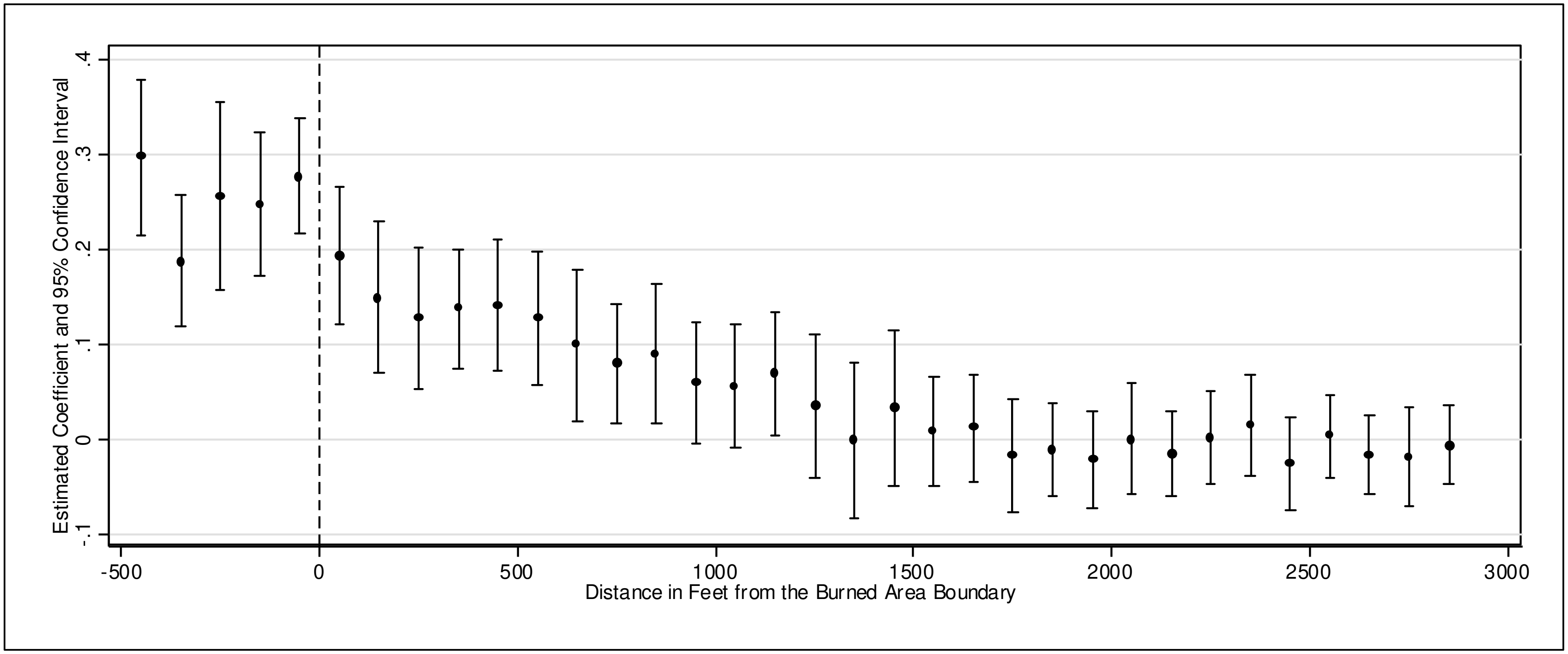
Notes: For our extended model with neighborhood externalities, Panel A shows the Burned Area following a Great Fire in period 0 (red lines) and the steady-state in the absence of a Fire (black lines). Panel B shows the steady-state in Nearby Unburned Areas (blue lines) and the steady-state in the absence of a Fire (black lines).

Figure 4. Simulated Steady-State Evolution of Land Value after a Great Fire



Notes: Following a Great Fire in period 0, the upper red line shows the simulated evolution of land value in the Burned Area in our extended model with neighborhood externalities. The middle blue line shows the evolution of land value in a Nearby Unburned Area in our extended model. The lower black line shows the simulated evolution of land value in the Burned Area (or Unburned Area) in our benchmark model, which is the same as if there had been no Fire.

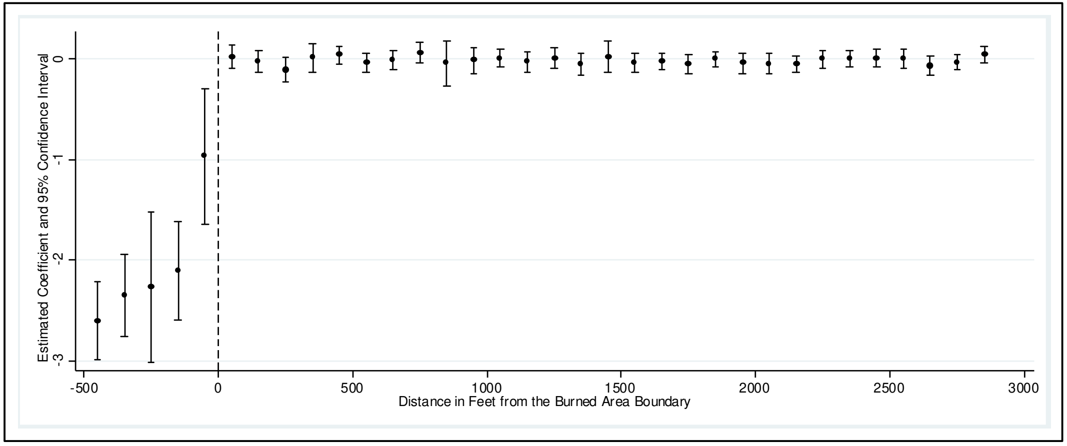
Figure 5. Estimated Changes in Land Value from 1872 to 1873, by Distance to the Fire Boundary (in Feet)



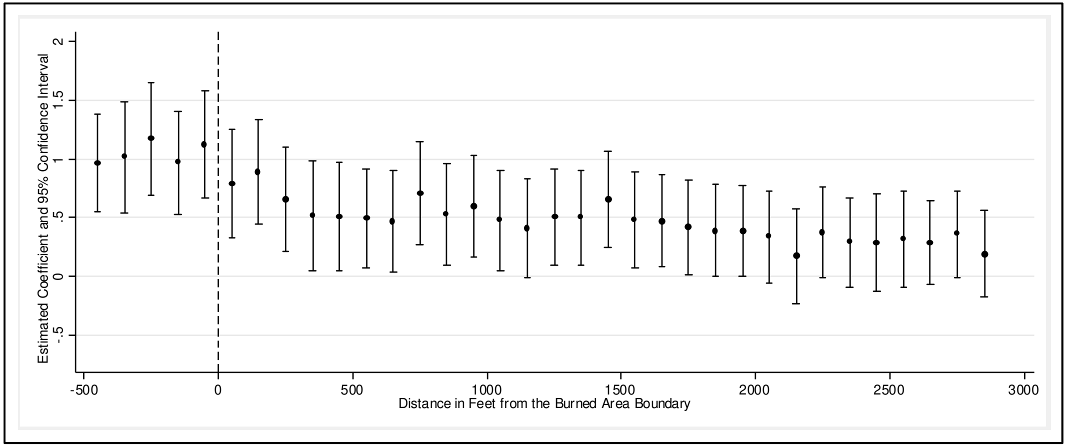
Notes: For the indicated distance from the boundary of the burned area, each circle reports the estimated change in land value from 1872 to 1873 (and the vertical lines reflect 95% confidence intervals). The omitted category is plots more than 2900 feet from the burned area. Negative distances reflect areas within the burned area, and burned plots more than 400 feet from the Fire boundary are grouped together. The empirical specification includes controls for plots' predicted land value in 1867 and 1872 based on block average and nearest neighbor.

Figure 6. Estimated Impacts on Building Value, by Distance to the Fire Boundary (in Feet)

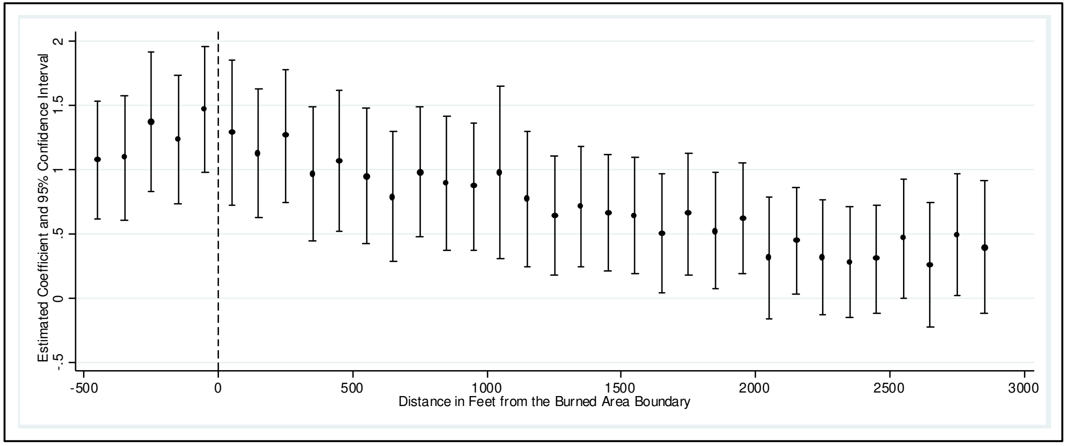
Panel A. Estimated Impacts in 1873



Panel B. Estimated Impacts in 1882



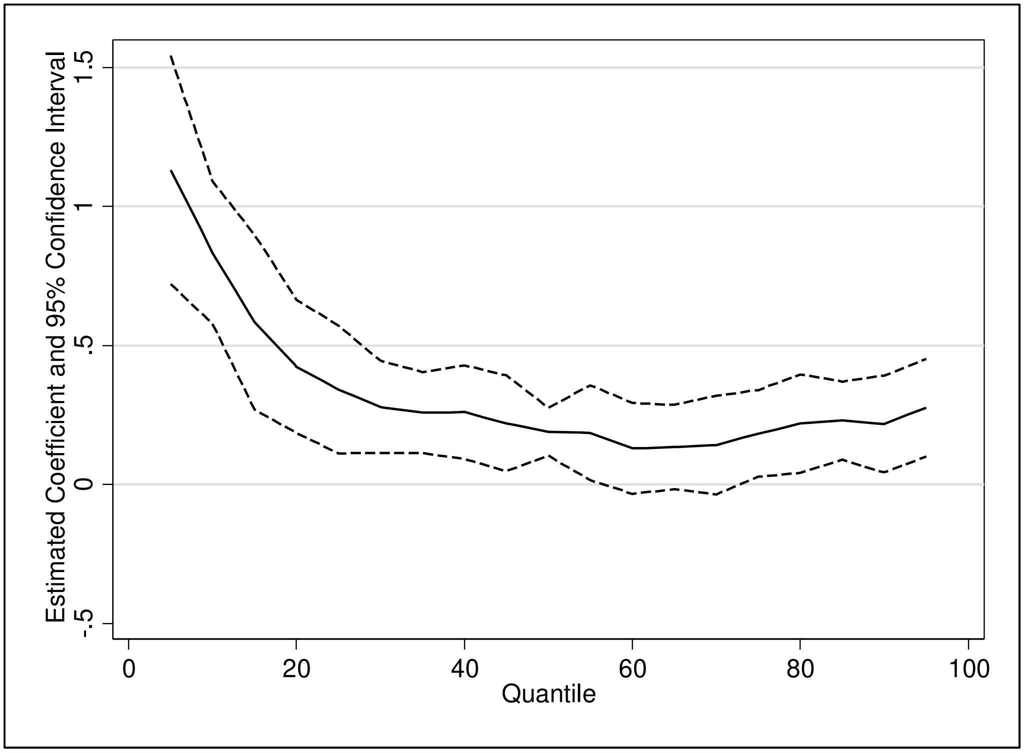
Panel C. Estimated Impacts in 1894



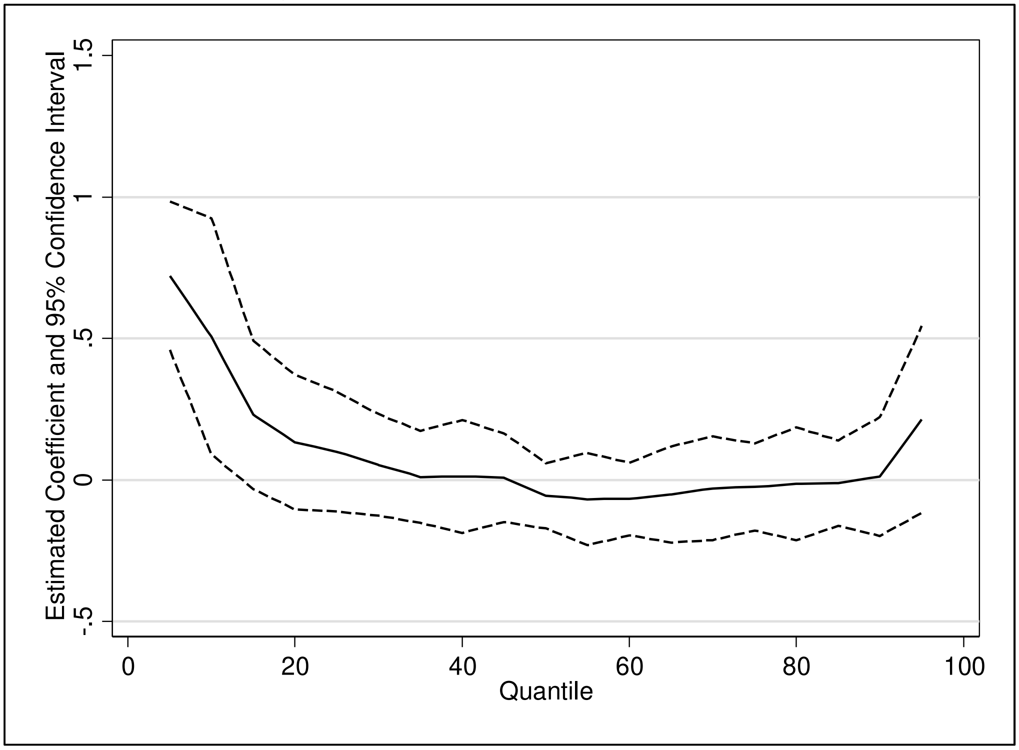
Notes: For the indicated distance from the boundary of the burned area, each circle reports the estimated change in land value from 1872 to the indicated year (by Panel). The vertical lines reflect 95% confidence intervals. The omitted category is plots more than 2900 feet from the burned area. Negative distances reflect areas within the burned area, and burned plots more than 400 feet from the Fire boundary are grouped together. The empirical specification includes controls for plots' predicted land value in 1867 and 1872 based on block average and nearest neighbor.

Figure 7. Estimated Impacts on Building Value in the Burned Area, by Quantile

Panel A. Estimated Quantile Effects in 1882



Panel B. Estimated Quantile Effects in 1894



Notes: Each Panel reports estimated impacts on the distribution of log building value, for that year relative to 1872.

Table 1. Plot Values in 1872, and Differences in the Burned Area

			Differences in Logs: Burned vs. Unburned			Differences in Logs: Burned vs. Restricted Unburned	
	Burned Area	Unburned Area	Difference in 1872: (1) - (2)	Difference in Changes: 1867 to 1872	Restricted Unburned Area	Difference in 1872: (1) - (3)	Difference in Changes: 1867 to 1872
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Land Value	$13.95	$8.44	0.774***	-0.174***	$14.69	0.087	-0.165***
per Square Foot	(6.77)	(8.83)	(0.084)	(0.041)	(11.32)	(0.093)	(0.045)
Building Value	$7.48	$4.14	0.733***	0.182	$5.94	0.246**	0.136
per Square Foot	(4.35)	(3.77)	(0.097)	(0.120)	(4.75)	(0.106)	(0.127)
Number of Plots	580	6013			1837		
Total Plot Area	1,724,877	10,642,991			3,753,481		

Notes: For the indicated outcome variable, columns 1 and 2 report the average value across plots in the burned area and unburned area, respectively. Column 3 reports the estimated log difference in 1872 for plots in the burned area, relative to plots in the unburned area. Column 4 reports this estimated log difference in changes from 1867 to 1872, i.e., the difference in the burned area in 1872 (relative to the unburned area in 1872) relative to the difference in the burned area in 1867 (relative to the unburned area in 1867). Columns 5 to 7 correspond to columns 2 to 4, but for a restricted sample of plots within 1000 feet of the Fire boundary. All means and regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Table 2. Estimated Impact on Land Values in Burned Area, Relative to 1872

	Log Value of Land per Square Foot							
	Full Sample				Restricted Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1867 x Burned	0.174***	0.019	-	-	0.165***	0.016	-	-
	(0.041)	(0.013)	( )	( )	(0.045)	(0.014)	( )	( )
1872 x Burned	0	0	0	0	0	0	0	0
	( )	( )	( )	( )	( )	( )	( )	( )
1873 x Burned	0.149***	0.169***	0.168***	0.172***	0.125***	0.124***	0.131***	0.133***
	(0.020)	(0.020)	(0.017)	(0.018)	(0.023)	(0.022)	(0.020)	(0.021)
1882 x Burned	0.157***	0.137***	0.139***	0.144***	0.059	0.073	0.052	0.083*
	(0.043)	(0.044)	(0.040)	(0.042)	(0.049)	(0.049)	(0.044)	(0.046)
1894 x Burned	-0.102*	-0.147**	-0.172***	-0.145**	-0.250***	-0.196***	-0.234***	-0.188**
	(0.056)	(0.061)	(0.056)	(0.060)	(0.069)	(0.073)	(0.067)	(0.073)
Controls:								
Year Fixed Effects	X	X	X	X	X	X	X	X
Year FE x Pre-Fire Block Average		X		X		X		X
Year FE x Pre-Fire Neighbor Value			X	X			X	X
R-squared	0.153	0.797	0.934	0.938	0.116	0.689	0.885	0.888
Number of Plots	31302	31302	31302	31302	11367	11367	11367	11367

Notes: For all specifications, the outcome variable is the log value of land per square foot. From estimating equation 1 in the text, column 1 reports the estimated difference between plots in the burned area and plots in the unburned area in the indicated year, relative to the omitted year of 1872. From estimating equation 2 in the text, columns 2 to 4 include controls for plots' predicted characteristics prior to the Fire, based on their block and/or nearest neighbor (which is generally that same plot in the earlier year). Columns 5 to 8 correspond to columns 1 to 4, but for the restricted sample of plots within 1000 feet of the Fire boundary. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Table 3. Estimated Total Impact of Fire on Land Values in 1873 and 1882

		Impact in $1000's of 1872 Dollars:			
	Distance Cutoff (1)	Burned Area (2)	Unburned Area (3)	Total Impact (4)	Ratio of (4) to Burned Building Value (5)
In 1873:					
Panel A. Estimated Cutoff	1,394	5,545	9,666	15,211	1.18
	(125)	(536)	(1,150)	(1,632)	(0.13)
Panel B. 1149 Foot Cutoff	1,149	5,305	8,039	13,343	1.03
	( )	(502)	(728)	(1,229)	(0.10)
Panel C. 1639 Foot Cutoff	1,639	5,735	11,133	16,869	1.31
	( )	(535)	(994)	(1,529)	(0.12)
In 1882:					
Panel D. Estimated Cutoff	1,412	7,236	12,561	19,797	1.53
	(189)	(1,313)	(2,562)	(3,781)	(0.29)
Panel E. 1040 Foot Cutoff	1,040	6,749	9,408	16,157	1.25
	( )	(1,287)	(1,714)	(3,001)	(0.23)
Panel F. 1784 Foot Cutoff	1,784	7,376	14,894	22,270	1.73
	( )	(1,328)	(2,572)	(3,899)	(0.30)

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). From estimating equation 3 in the text, we constrain the impact of the Fire to be constant within the Burned Area, declining linearly in the Unburned Area until some distance cutoff, and then zero after that distance cutoff (i.e., fitting the points in Figure 5). 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. 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 3 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 analagous estimates, but for the impact on land value in 1882 (converted to 1872 dollars). Robust standard errors clustered by block are reported in parentheses.

Table 4. Estimated Impact on Building Values in Burned Area, Relative to 1872

	Log Value of Building per Square Foot							
	Full Sample				Restricted Sample			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1867 x Burned	-0.182	-0.053	-	-	-0.136	-0.043	-	-
	(0.120)	(0.052)	( )	( )	(0.127)	(0.059)	( )	( )
1872 x Burned	0	0	0	0	0	0	0	0
	( )	( )	( )	( )	( )	( )	( )	( )
1873 x Burned	-1.803***	-1.881***	-1.961***	-2.016***	-1.800***	-1.890***	-1.965***	-2.011***
	(0.161)	(0.160)	(0.167)	(0.168)	(0.161)	(0.160)	(0.167)	(0.171)
1882 x Burned	0.401***	0.478***	0.637***	0.511***	0.357***	0.402***	0.493***	0.441***
	(0.067)	(0.069)	(0.056)	(0.055)	(0.070)	(0.066)	(0.050)	(0.049)
1894 x Burned	0.174**	0.371***	0.546***	0.410***	0.090	0.203**	0.274***	0.246***
	(0.078)	(0.087)	(0.068)	(0.080)	(0.089)	(0.081)	(0.066)	(0.069)
Controls:								
Year Fixed Effects	X	X	X	X	X	X	X	X
Year FE x Pre-Fire Block Average		X		X		X		X
Year FE x Pre-Fire Neighbor Value			X	X			X	X
R-squared	0.108	0.474	0.775	0.788	0.163	0.467	0.735	0.743
Number of Plots	30198	30198	30198	30198	10595	10595	10595	10595

Notes: For all specifications, the outcome variable is the log value of building per square foot. From estimating equation 1 in the text, column 1 reports the estimated difference between plots in the burned area and plots in the unburned area in the indicated year, relative to the omitted year of 1872. From estimating equation 2 in the text, columns 2 to 4 include controls for plots' predicted characteristics prior to the Fire, based on their block and/or nearest neighbor (which is generally that same plot in the earlier year). Columns 5 to 8 correspond to columns 1 to 4, but for the restricted sample of plots within 1000 feet of the Fire boundary. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Table 5. Estimated Impact of Fire: Great Fire vs. Individual Fires

	Log Value of Building per Sqr. Ft.		Log Value of Land per Sqr. Ft.	
	Full Sample (1)	Restricted Sample (2)	Full Sample (3)	Restricted Sample (4)
1873 x Burned	-1.950***	-1.944***	0.170***	0.129***
	(0.173)	(0.178)	(0.018)	(0.022)
1882 x Burned	0.514***	0.445***	0.142***	0.080*
	(0.059)	(0.053)	(0.042)	(0.046)
1894 x Burned	0.413***	0.247***	-0.156***	-0.200***
	(0.083)	(0.072)	(0.060)	(0.072)
~7 Months After Individual Fire	-0.127	-0.005	-0.054	-0.019
	(0.131)	(0.028)	(0.062)	(0.042)
~10 Years After Individual Fire	0.346**	0.128*	0.084	-0.008
	(0.152)	(0.068)	(0.102)	(0.156)
~22 Years After Individual Fire	0.012	-0.013	-0.210	-0.205
	(0.085)	(0.083)	(0.269)	(0.298)
Test of Equality of Individual Fire and Great Fire Effects (p-value):				
~7 Month Interval	0.000	0.000	0.001	0.002
~ 10 Year Interval	0.299	0.000	0.606	0.600
~ 22 Year Interval	0.000	0.003	0.848	0.988
Controls:				
Year Fixed Effects	X	X	X	X
Year FE x Pre-Fire Block Average	X	X	X	X
Year FE x Pre-Fire Neighbor Value	X	X	X	X
R-squared	0.788	0.744	0.938	0.889
Number of Plots	30128	10525	31219	11284

Notes: The reported estimates are from equation 4 in the text, which jointly estimates the impact of the 1872 Great Fire and the impact of individual building fires. The first three rows report the estimated impacts of the 1872 Great Fire in 1873, 1882, and 1894 (corresponding to estimates in Table 2 and Table 4), and the second three rows report the impact of individual building fires after approximately 1 year, 10 years, and 22 years. Below, we report the statistical significance of the difference between the Great Fire impact and the corresponding individual fire impact. Columns 1 and 2 report impacts on building value, corresponding to columns 4 and 8 of Table 4. Columns 3 and 4 report impacts on land value, corresponding to columns 4 and 8 of Table 2. Note that this 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. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Table 6. Estimated Impact on Plot Sizes in Burned Area, Relative to 1872

	Log Plot Size							
					Plots Unaffected by Road Widening			
	All Plots		Restricted Sample		All Plots		Restricted Sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1867 x Burned	-0.069	-	-0.063	-	-0.094	-	-0.089	-
	(0.043)	( )	(0.043)	( )	(0.064)	( )	(0.064)	( )
1872 x Burned	0	0	0	0	0	0	0	0
	( )	( )	( )	( )	( )	( )	( )	( )
1873 x Burned	0.006	-0.014	-0.001	-0.021	0.061***	0.050**	0.055**	0.040
	(0.023)	(0.025)	(0.024)	(0.026)	(0.021)	(0.023)	(0.023)	(0.025)
1882 x Burned	0.090*	0.067**	0.094*	0.057	0.156***	0.137***	0.160***	0.126***
	(0.046)	(0.033)	(0.047)	(0.038)	(0.055)	(0.036)	(0.056)	(0.040)
1894 x Burned	0.088*	0.029	0.023	0.011	0.165***	0.091**	0.100	0.067
	(0.051)	(0.036)	(0.057)	(0.041)	(0.061)	(0.044)	(0.066)	(0.045)
Controls:								
Year Fixed Effects	X	X	X	X	X	X	X	X
Year FE x Pre-Fire Block Average		X		X		X		X
Year FE x Pre-Fire Neighbor Value		X		X		X		X
R-squared	0.058	0.818	0.074	0.805	0.039	0.819	0.056	0.811
Number of Plots	31353	31353	11381	11381	30340	30340	10368	10368

Notes: For all specifications, the outcome variable is the log number of square feet per plot. From estimating equation 1 in the text, column 1 reports the estimated difference between plots in the burned area and plots in the unburned area in the indicated year, relative to the omitted year of 1872. From estimating equation 2 in the text, column 2 include controls for plots' predicted characteristics prior to the Fire, based on their block and nearest neighbor (which is generally that same plot in the earlier year). Columns 3 and 4 correspond to columns 1 and 2, but for the restricted sample of plots within 1000 feet of the Fire boundary. Columns 5 to 8 correspond to columns 1 to 4, but excluding plots that had land taken for the widening of roads (Appendix Figure 4). The regressions are unweighted. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

X Appendix

This Appendix has four sections. In the first section, we provide additional details on the estimation of the Fire's total impact on land value and alternative functional forms for parameterizing geographic spillover effects. The second section provides additional details on our measurement of within-industry agglomeration using Ripley's L function. The third section contains the Appendix Figures, and the fourth section contains the Appendix Tables.

X.A Estimating the Total Impact of the Great Fire on Land Value

In our baseline specification of the total impact of the Great Fire on land value, we model impacts on both the burned area and nearby buildings using a piecewise linear function. Using the log of land value per square foot in 1873 as the outcome variable Y_{it}, we estimate the following function via non-linear least squares:

$$Y_{it} \quad = \quad \beta_0 + \beta_1 \max\left\{\frac{c - dist_{it}}{c}, 0\right\} + \mu_t \bar{Y}_i^{near} + \eta_t \bar{Y}_i^{block} + \varepsilon_{it}, \tag{5}$$

where $dist_{it}$ is the distance of point i from the burned area.[55] Here, $\hat{\beta}_1$ represents the estimated effect of the fire, and $\hat{c}$ the estimated cut-off point beyond which the fire has no further effects.

We calculate each plot's predicted log land value per square foot $\hat{Y}_{it}$ using coefficients estimated from equation 5 above, as well as the value without the fire: $\tilde{Y}_{it} = \hat{\beta}_0 + \hat{\mu}_t \hat{Y}_{i1867} + \hat{\eta}_t \hat{Y}_{i1872}$. The impact of the fire on land values, combining the burned area and the spillover zone, is then:

$$V_t = \sum_{dist_{it} < c} plotsize_{it} \left(\exp\left(\hat{Y}_{it}\right) - \exp\left(\tilde{Y}_{it}\right)\right)$$

As a robustness check in the estimation of the spillover effects, we experimented with three alternative formulas for the spillover function:

1. A variant allowing the spillover to be non-linear:

$$Y_{it} = \beta_0 + \beta_1 \max\left\{\left(\frac{c - dist_{it}}{c}\right)^{\gamma}, 0\right\} + \mu_t \hat{Y}_{i1867} + \eta_t \hat{Y}_{i1872} + \varepsilon_{it}$$

2. An asymptotic variant with no cut-off:

$$Y_{it} = \beta_0 + \beta_1 \left(\frac{1}{1 + \beta_2 dist_{it}}\right)^{\gamma} + \mu_t \hat{Y}_{i1867} + \eta_t \hat{Y}_{i1872} + \varepsilon_{it}$$

---

[55] This distance is zero for points within the burned area.

3. A polynomial with no cut-off:

$$Y_{it} = \beta_0 + \sum_{n=1}^{4} \beta_n dist_{it}^n + \mu_t \hat{Y}_{i1867} + \eta_t \hat{Y}_{i1872} + \varepsilon_{it}$$

Appendix Figure 9 shows these four estimated functions, including the baseline linear model, which are all fairly similar in approximating the relationship apparent in Figure 5. The three non-linear specifications estimate the mean in the burned area to be slightly greater than the baseline model, and generally show the spillover effects continuing into more distant parts of the city. Divergent properties of polynomials are visible past 3000 feet, where the third function turns back upwards, as only 6.3% of the sample lies beyond 3000 feet from the burned area.

The first and second alternative models allow us to generate alternative estimates of the Fire's total impact, as they include an estimate of where spillover effects end. The first model estimates a total impact of \$16 million (with a standard error of \$3.8 million), which is only slightly larger than our baseline estimate. Estimates are less similar with the second alternative formula, as we must assume the Fire's spillover effects disappear only when distance goes to infinity, and the estimated impact is \$124 million. Identification of the the second alternative model is tenuous, however, as the within-sample functional form is used to project impacts on distances far out of sample. Our baseline estimates are more conservative, assuming that the spillover effects go to zero at some cutoff within the sample region. Within the sample region, all four functional forms provide a broadly similar parameterization of the basic relationship seen in Figure 5.

X.B Measuring Agglomeration

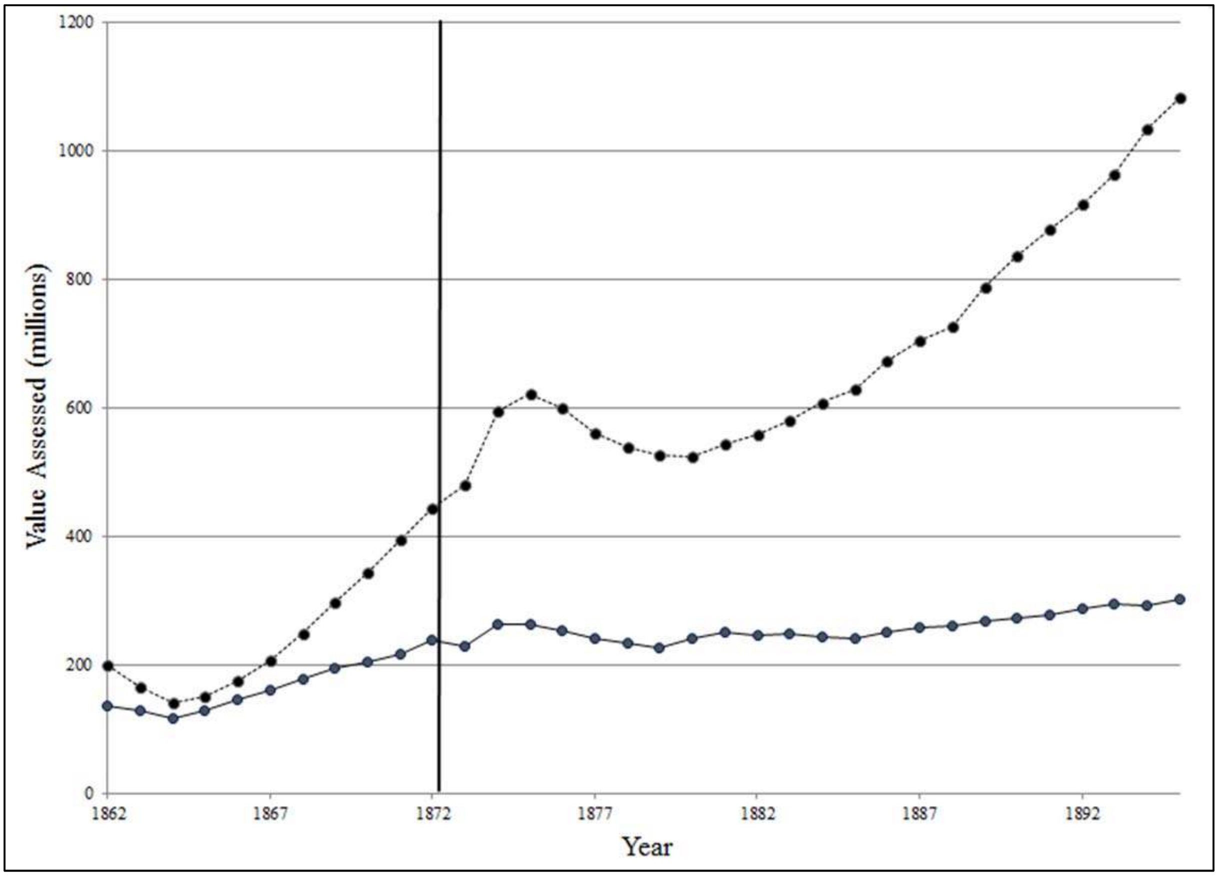
We measure within-industry agglomeration using Ripley's L function. For industry i with N_{ib} establishments in an area b with square footage A_b, let λ_{ib} be the sample estimate of the density of establishments per square foot: $\lambda_{ib} = N_{ib}/A_b$. The value of L_{ib} for radius r, is then given by:

$$L_{ib}(r) = \sqrt{\lambda_{ib}^{-1} \sum_{k=1}^{N_i} \sum_{j=1, j \neq k}^{N_{ib}} \mathbb{I}\left[d(k,j) < r\right] / \pi N_i - r}, \tag{6}$$

where $\mathbb{I}\left[d(k,j) < r\right]$ is an indicator function equal to one if firms k and j are within distance r of each other. Higher values of L_{ib} are associated with greater agglomeration. A value of L_{ib} equal to $-r$ is associated with complete dispersion (i.e, no establishments in industry i have other establishments from industry i with r feet). A value of L_{ib} equal to $\sqrt{A_b/\pi} - r$ is associated with complete agglomeration (i.e., all establishments in industry i are within r feet of each other).

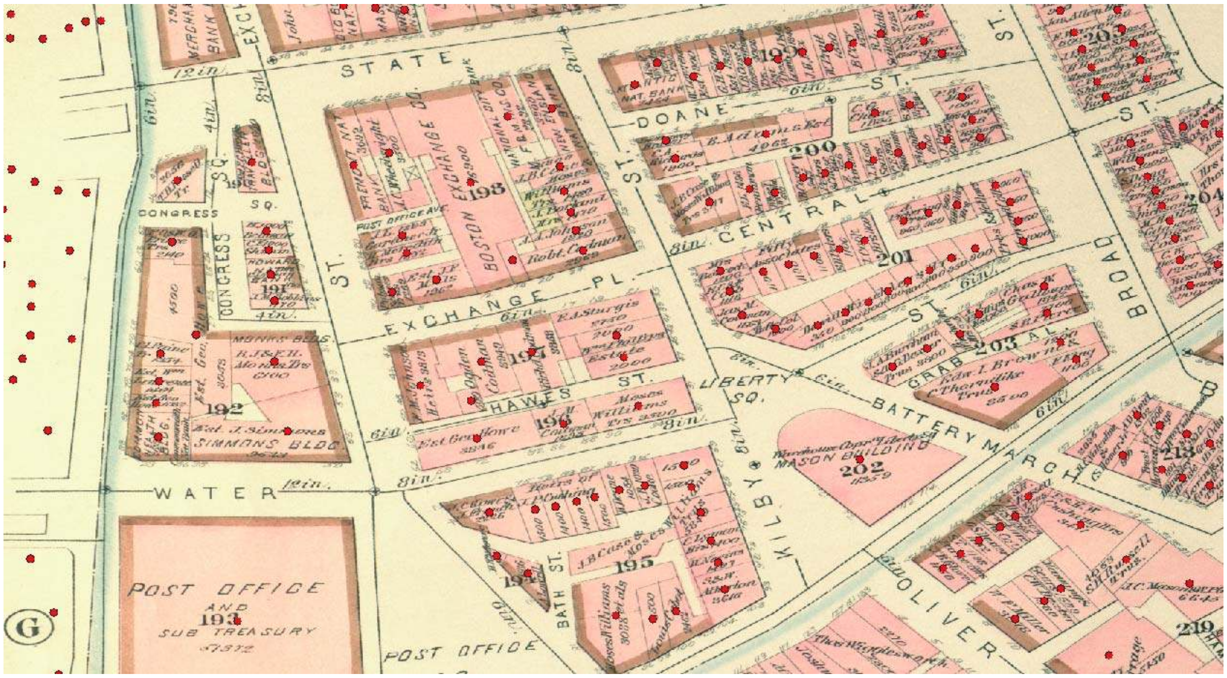
To mitigate "edge effects," we do not consider firms within r feet of the sample boundary in the outer summation, indexed by k, in equation 6. These firms near the boundary are included as potentially being part of clusters of firms near the non-boundary firms and are included in the j-indexed inner summation. Similarly, firms across the boundary of the burned area are counted as potentially being part of the cluster of firms on the other size of the boundary. Edges of the sample area that intersect with the ocean or the Boston Common (a large park) are not counted as boundaries since firms near these edges chose to locate in spots where the potential for agglomeration was naturally limited.

Appendix Figure 1. Total Assessed Value of Boston Real Estate and Personal Property



Notes: The upper line reflects the total assessed value of real estate, and the lower line reflects the total assessed value of property from the City of Boston's assessment record books (Boston Tax Records). All values are converted to constant 1872 dollars using the David-Solar CPI (Lindert and Sutch 2006). The vertical line denotes the year of the Boston Fire.

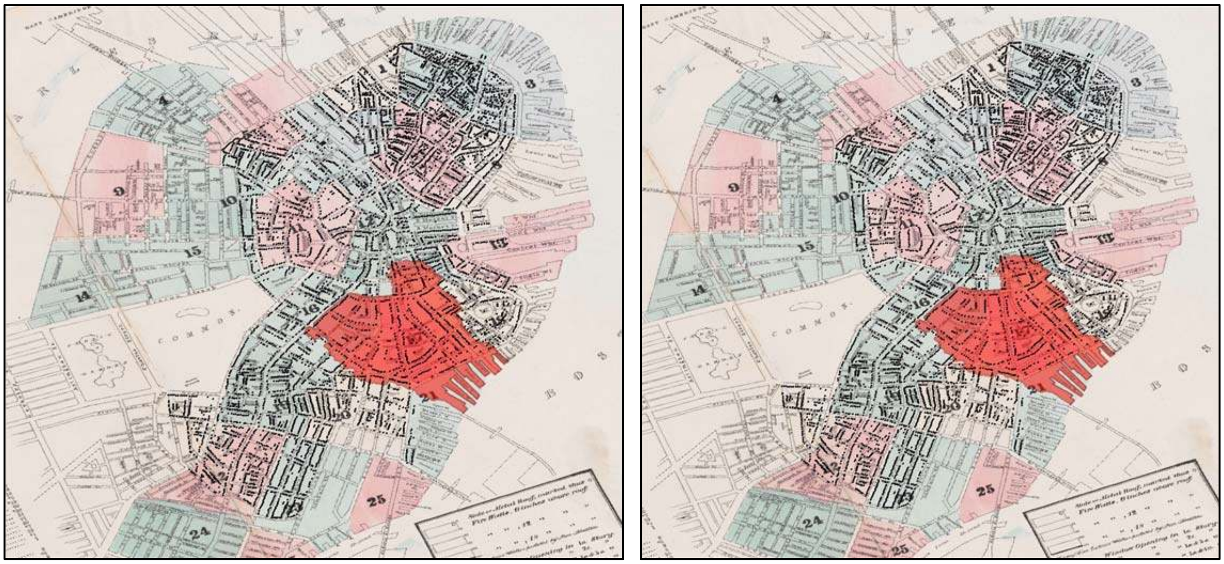
Appendix Figure 2. Plot-level Map with Detailed Information and Geo-Located Points



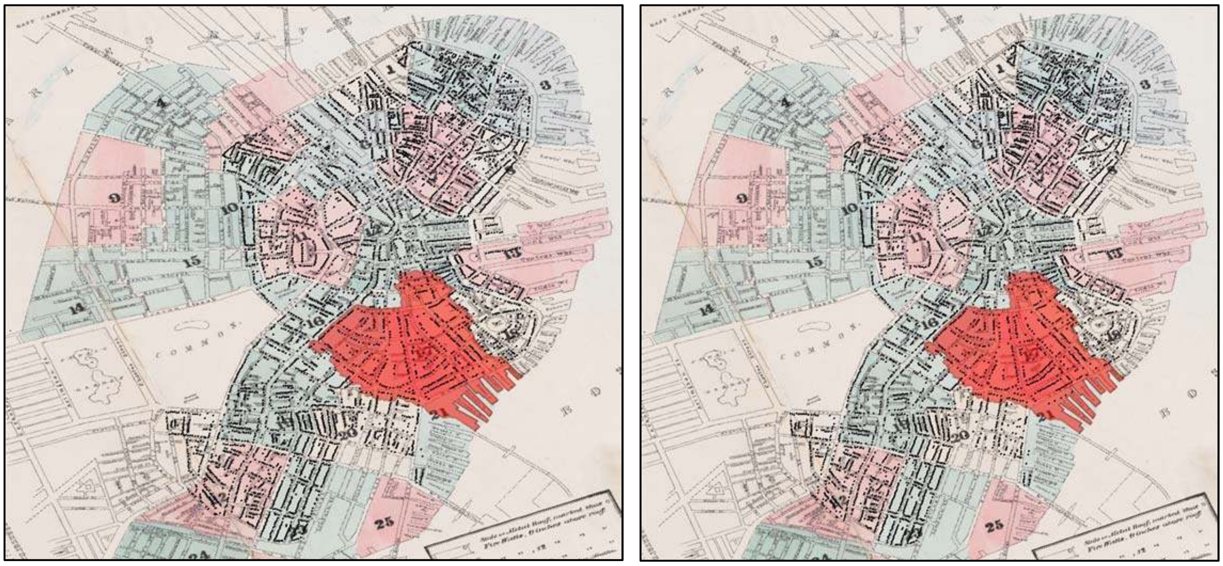
Notes: Detailed plot-level maps, such as the one above, are georeferenced to the Boston-wide map. These detailed maps often provide the plots' square footage and owner name. The overlaid red dots correspond to each plot and are assigned to particular tax assessment records.

Appendix Figure 3. Sample Plot Locations in Each Subsequent Year

Panel A. Plot Locations in 1872 Panel B. Plot Locations in 1873

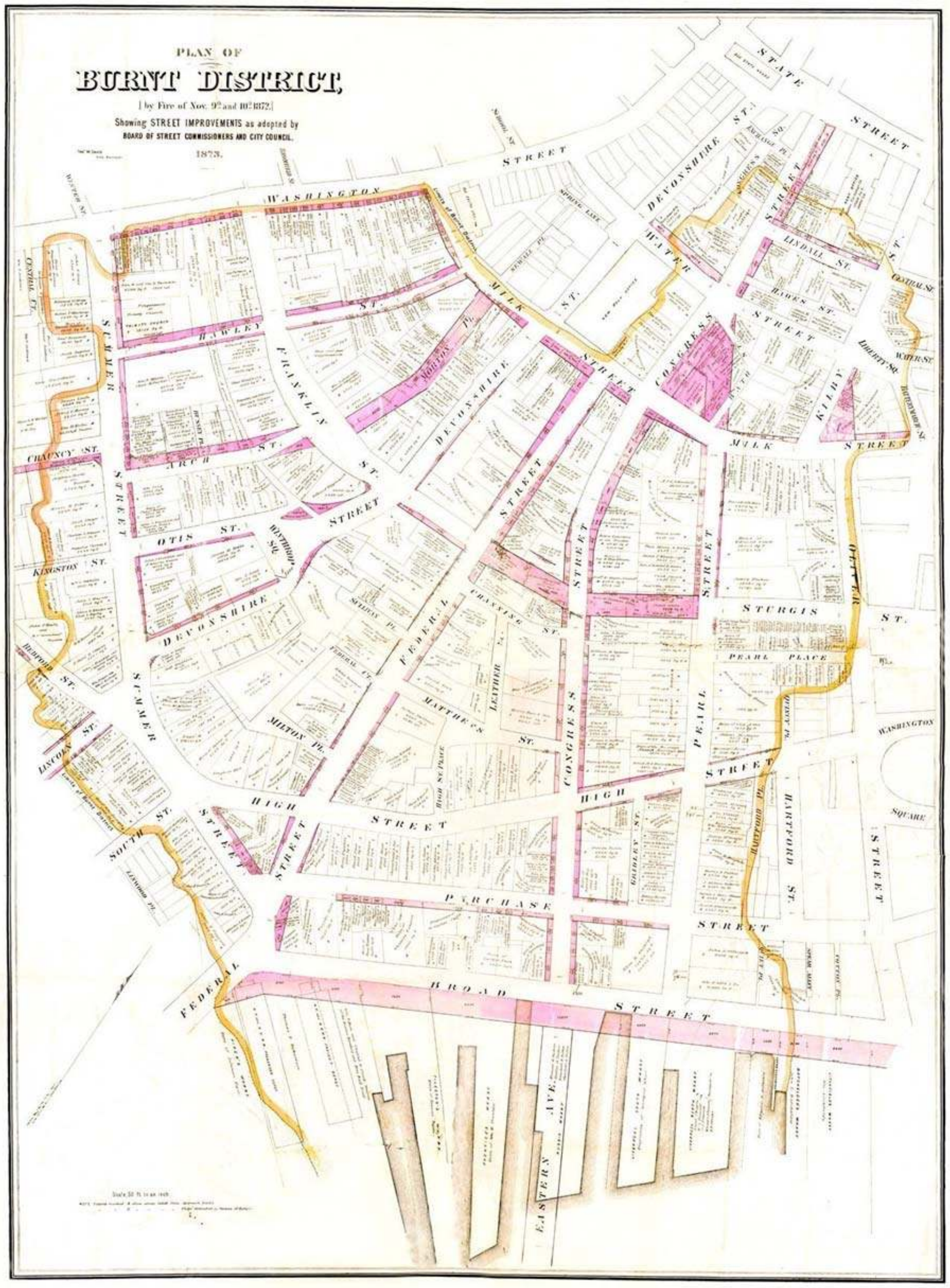


Panel C. Plot Locations in 1882 Panel D. Plot Locations in 1894



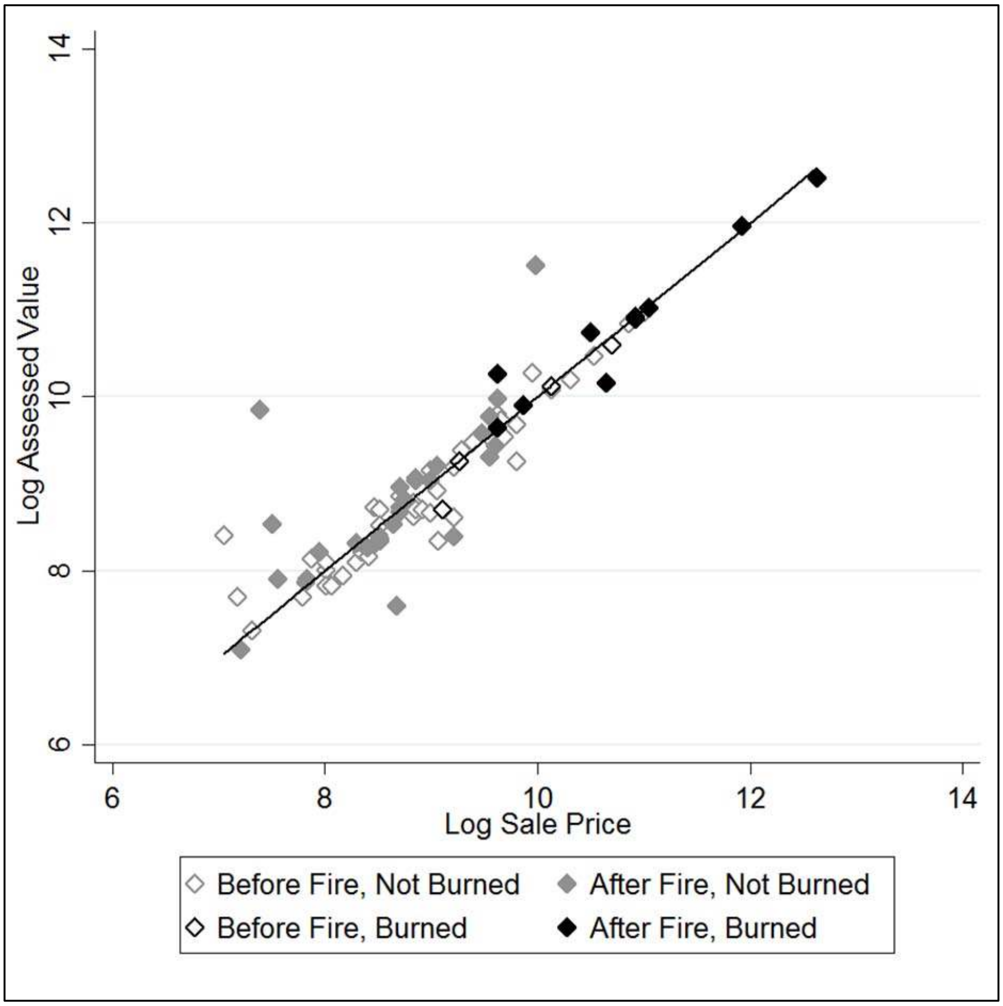
Notes: As in Figure 7, each point reflects one geo-located plot in our main sample for the indicated year. These points are overlaid on a map of Boston in 1867 and the area burned in 1872 (as in Figure 1).

Appendix Figure 4. Post-Fire Changes in Boston Roads



Notes: This map of the burned district indicates areas (shaded in pink) that were purchased by the City for road widening and the creation of Post Office Square.

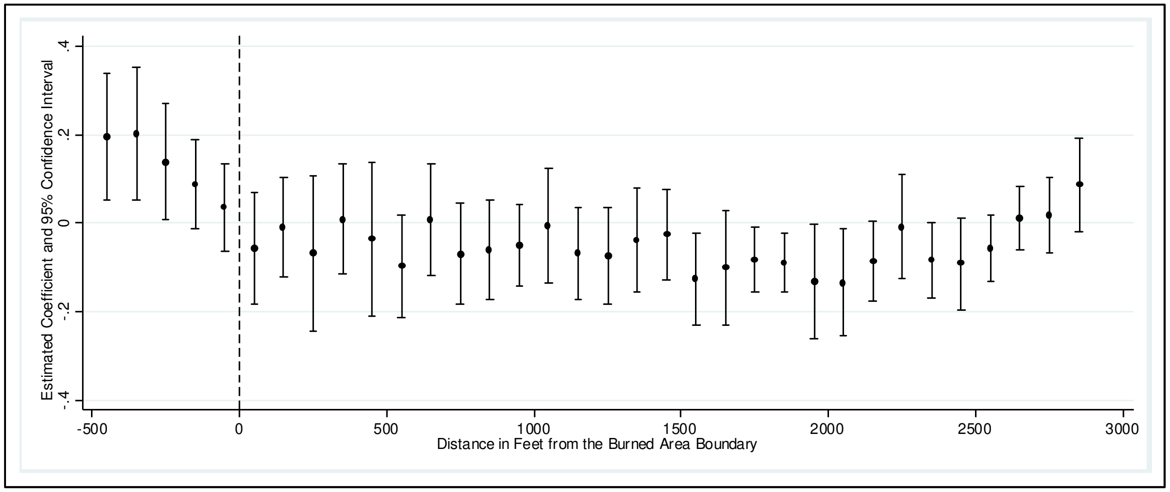
Appendix Figure 5. Plot Assessed Value vs. Plot Sale Price



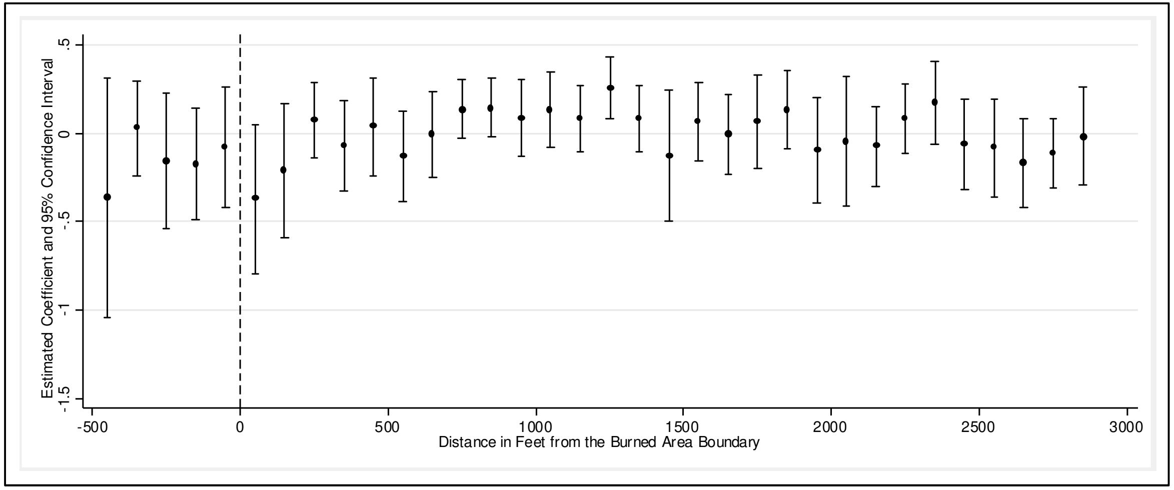
Notes: Log Assessed Value is plotted against Log Sale Price for a sample of 88 plots: 16 plots in the burned area (black) and 72 plots outside the burned area (gray). Plot observations are hollow diamond shapes when observed before the Boston Fire, and solid diamonds when observed after the Fire. Log 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.

Appendix Figure 6. Estimated Differences in Values in 1867, Relative to 1872, by Distance to the Fire Boundary (in Feet)

Panel A. Estimated Differences in Land Value



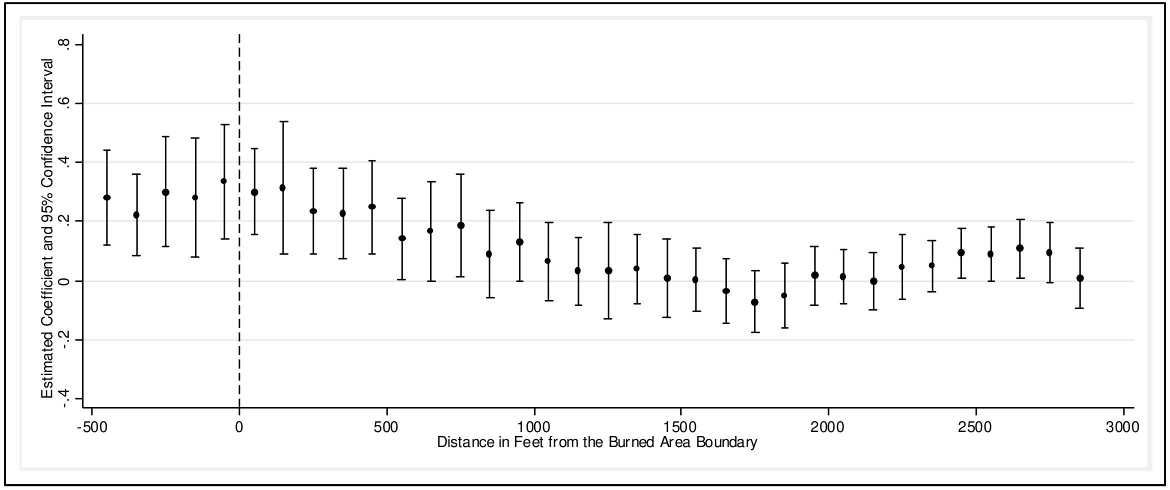
Panel B. Estimated Differences in Building Value



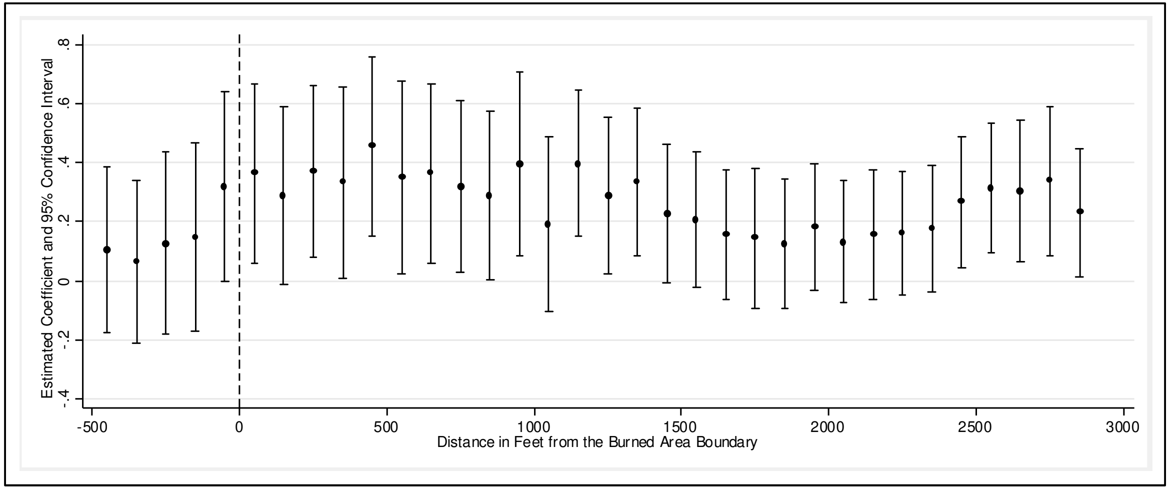
Notes: For the indicated distance from the boundary of the burned area, each circle reports the estimated impact on value in 1867 relative to 1872 (e.g., positive coefficients represent a decline from 1867 to 1872). Panel A presents estimates for the log value of land per square foot, and Panel B presents estimates for the log value of building per square foot. The specification does not include controls for plots' pre-Fire outcomes. The omitted category is plots more than 2900 feet from the burned area. Negative distances reflect areas within the burned area, and burned plots more than 400 feet from the Fire boundary are grouped together.

Appendix Figure 7. Estimated Changes in Land Value by Distance to the Fire Boundary (in Feet)

Panel A. Estimated Impact in 1882, Relative to 1872



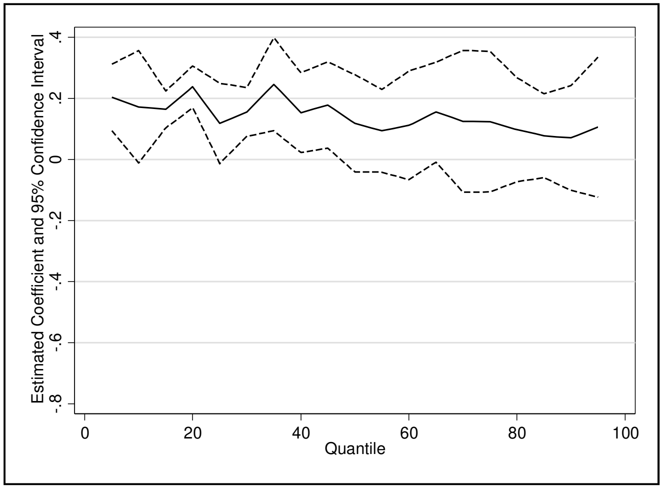
Panel B. Estimated Impact in 1894, Relative to 1872



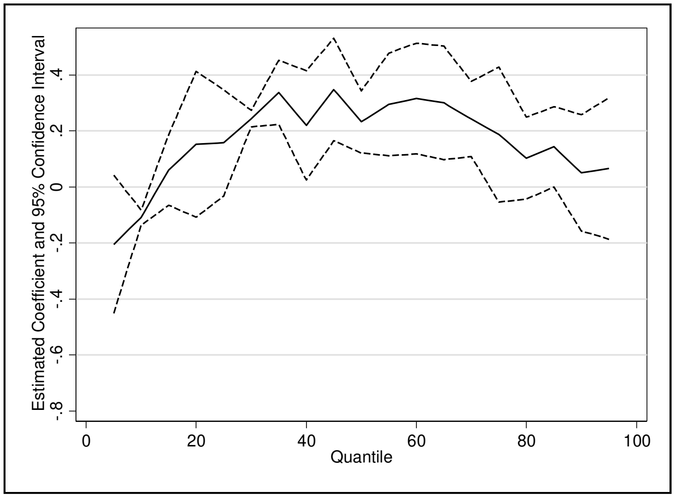
Notes: For the indicated distance from the boundary of the burned area, Panel A reports estimated changes from 1872 to 1882 and Panel B reports estimated changes from 1872 to 1894 (each circle reports the point estimate and the vertical lines reflect 95% confidence intervals). The omitted category is plots more than 2900 feet from the burned area. Negative distances reflect areas within the burned area, and burned plots more than 400 feet from the Fire boundary are grouped together. The empirical specification includes controls for plots' predicted land value in 1867 and 1872 based on block average and nearest neighbor.

Appendix Figure 8. Estimated Impacts on Land Value in the Burned Area, by Quantile

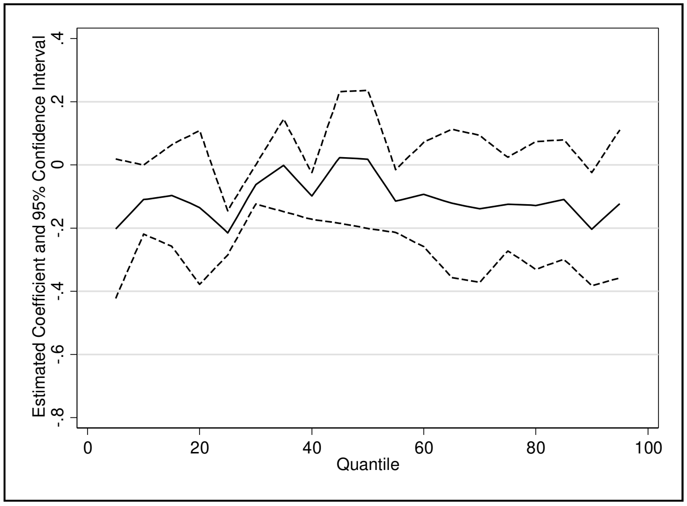
Panel A. Estimated Quantile Effect in 1873



Panel B. Estimated Quantile Effect in 1882

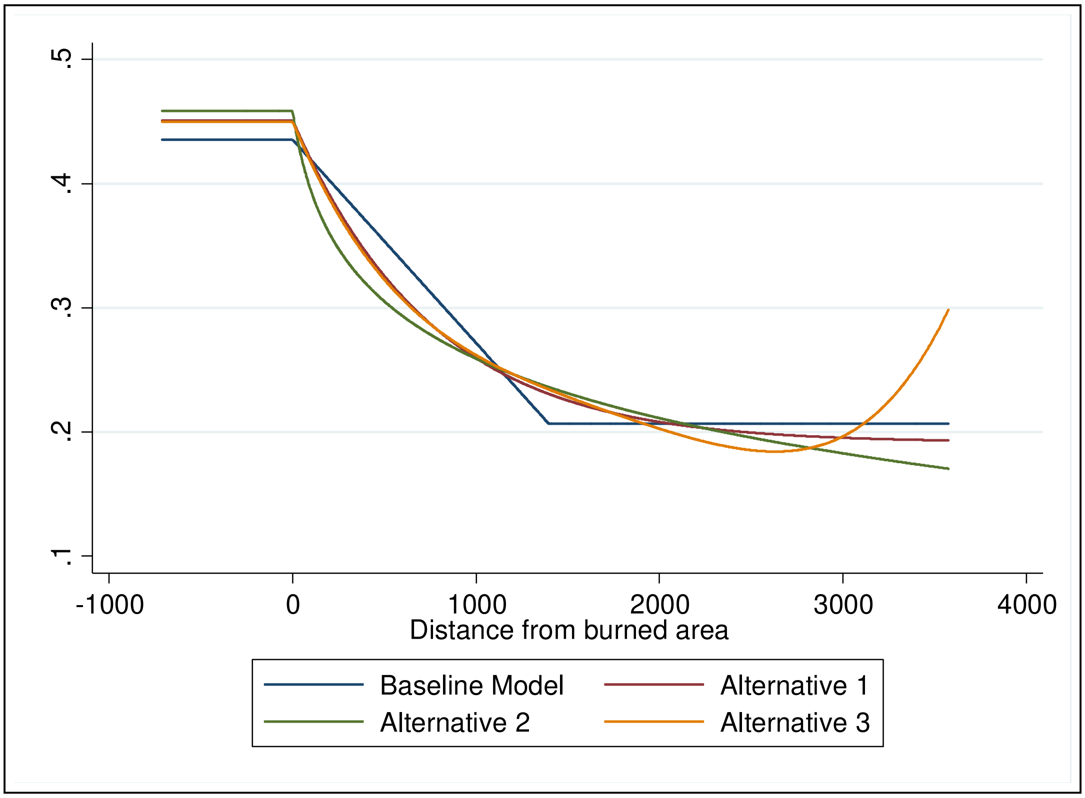


Panel C. Estimated Quantile Effect in 1894



Notes: Each Panel reports estimated impacts on the distribution of log land value, for that year relative to 1872.

Appendix Figure 9. Functional Forms for Estimating Total Impact on Land Value



Notes: The baseline model shows the estimated functional form, based on equation 3 in the text, which parameterizes the results shown in Figure 5. Alternative models 1 to 3 report alternative estimated functional forms, as described in Section A of the Appendix.

Appendix Table 1. Average Log Sale Value Minus Log Assessed Value

	After Fire: 1882 and 1894 (2)	Before Fire: 1867 and 1872 (1)	Difference: (2) - (1) (3)
Burned Area	-0.042	0.083	-0.125
	[0.297]	[0.162]	(0.119)
Unburned Area	-0.143	0.030	-0.173
	[0.631]	[0.312]	(0.124)
Difference	0.102	0.054	0.048
	(0.151)	(0.078)	(0.169)

Notes: Based on data from Boston's Registry of Deeds, matched to our tax assessment database, cells report the average log difference in sale price and assessed value of plots (sale price - assessed value). Column 1 reports estimates from after the Fire (in 1882 and 1894), and Column 2 reports estimates from before the Fire (in 1867 and 1872). Row 1 reports estimates in the Burned Area, and Row 2 reports estimates in the Unburned Area. Standard deviations are reported in brackets. Row 3 reports the difference in the Burned Area, relative to the Unburned Area; and Column 3 reports the difference after the Fire, relative to before the Fire. Column 3, row 3, reports the difference-in-difference estimate. The sample includes 72 plots in the Unburned Area, and 16 plots in the Burned Area. Robust standard errors are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Appendix Table 2. Main Results with Conley Standard Errors at Varying Cutoffs

	Log Value per Square Foot			
	Land Value		Building Value	
	Full Sample	Sample	Full Sample	Sample
	(1)	(2)	(3)	(4)
1873 x Burned	0.172	0.133	-2.016	-2.011
Clustered by Block	(0.018)	(0.021)	(0.168)	(0.171)
250 foot cutoff	(0.019)	(0.020)	(0.164)	(0.167)
750 foot cutoff	(0.021)	(0.025)	(0.257)	(0.259)
1,250 foot cutoff	(0.022)	(0.027)	(0.247)	(0.247)
1,750 foot cutoff	(0.018)	(0.022)	(0.208)	(0.209)
1882 x Burned	0.144	0.083	0.511	0.441
Clustered by Block	(0.042)	(0.046)	(0.055)	(0.049)
250 foot cutoff	(0.039)	(0.041)	(0.059)	(0.058)
750 foot cutoff	(0.058)	(0.061)	(0.065)	(0.062)
1,250 foot cutoff	(0.064)	(0.068)	(0.051)	(0.048)
1,750 foot cutoff	(0.058)	(0.064)	(0.045)	(0.039)
1894 x Burned	-0.145	-0.188	0.410	0.246
Clustered by Block	(0.060)	(0.073)	(0.080)	(0.069)
250 foot cutoff	(0.054)	(0.062)	(0.076)	(0.071)
750 foot cutoff	(0.094)	(0.115)	(0.096)	(0.095)
1,250 foot cutoff	(0.112)	(0.133)	(0.081)	(0.079)
1,750 foot cutoff	(0.109)	(0.133)	(0.081)	(0.066)
Controls:				
Year Fixed Effects	X	X	X	X
Year FE x Pre-Fire Block Average	X	X	X	X
Year FE x Pre-Fire Neighbor Value	X	X	X	X
R-squared	0.987	0.991	0.902	0.934
Number of Plots	31302	11367	30198	10595

Notes: The reported coefficients correspond exactly to those reported in Table 2 and Table 4: column 1 corresponds to Table 2, column 4; column 2 corresponds to Table 2, column 8; column 3 corresponds to Table 4, column 4; and column 4 corresponds to Table 4, column 8. For each coefficient, alternative standard errors are reported based different assumed distance cutoffs in the estimation of Conley standard errors (Conley 1999): 250 feet, 750 feet, 1,250 feet, and 1,750 feet. As a basis of comparison, we also report our main standard errors that are clustered by block.

Appendix Table 3. Main Results, Unweighted Specifications

	Log Value per Square Foot			
	Land Value		Building Value	
	Full Sample (1)	Restricted Sample (2)	Full Sample (3)	Restricted Sample (4)
1873 x Burned	0.192***	0.152***	-1.693***	-1.695***
	(0.020)	(0.021)	(0.158)	(0.166)
1882 x Burned	0.147***	0.091*	0.543***	0.494***
	(0.048)	(0.052)	(0.058)	(0.051)
1894 x Burned	-0.116*	-0.102	0.480***	0.377***
	(0.064)	(0.074)	(0.064)	(0.060)
Controls:				
Year Fixed Effects	X	X	X	X
Year FE x Pre-Fire Block Average	X	X	X	X
Year FE x Pre-Fire Neighbor Value	X	X	X	X
R-squared	0.944	0.904	0.806	0.771
Number of Plots	31302	11367	30198	10595

Notes: The reported specifications correspond to those reported in Table 2 and Table 4, but not weighting the regressions by plot size. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Appendix Table 4. Main Results Excluding Plots With Road Widening

	Log Value per Square Foot			
	Land Value		Building Value	
	Full Sample (1)	Restricted Sample (2)	Full Sample (3)	Restricted Sample (4)
1873 x Burned	0.148***	0.108***	-1.852***	-1.841***
	(0.019)	(0.023)	(0.202)	(0.211)
1882 x Burned	0.100**	0.040	0.439***	0.374***
	(0.046)	(0.048)	(0.051)	(0.047)
1894 x Burned	-0.192***	-0.239***	0.353***	0.178**
	(0.067)	(0.078)	(0.097)	(0.081)
Controls:				
Year Fixed Effects	X	X	X	X
Year FE x Pre-Fire Block Average	X	X	X	X
Year FE x Pre-Fire Neighbor Value	X	X	X	X
R-squared	0.937	0.890	0.784	0.739
Number of Plots	30289	10354	29320	9717

Notes: The reported specifications correspond to those reported in Table 2 and Table 4, but the sample excludes plots that lost land for road widening (Appendix Figure 4). Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Appendix Table 5. Number of Unique Owners and Number of Plots, by Burned and Unburned Areas

	Number of Owners		Annual Percent Change		Number of Plots		Annual Percent Change	
	Burned (1)	Unburned (2)	Burned (3)	Unburned (4)	Burned (5)	Unburned (6)	Burned (7)	Unburned (8)
Panel A. Full Sample								
1867	402	3,534			620	6,120		
1872	367	3,390	-1.74	-0.81	580	6,013	-1.29	-0.35
1873	346	3,401	-5.72	0.32	519	5,970	-10.52	-0.72
1882	322	3,287	-0.77	-0.37	486	5,504	-0.71	-0.87
1894	309	3,097	-0.34	-0.48	465	5,076	-0.36	-0.65
2012					112	1,964	-0.64	-0.52
Panel B. Restricted Sample								
1867	402	1261			620	1911		
1872	367	1160	-1.74	-1.60	580	1837	-1.29	-0.77
1873	346	1177	-5.72	1.47	519	1808	-10.52	-1.58
1882	322	1108	-0.77	-0.65	486	1693	-0.71	-0.71
1894	309	971	-0.34	-1.03	465	1462	-0.36	-1.14
2012					112	439	-0.64	-0.59

Notes: Columns 1 and 2 report the number of unique owner names in the burned area and unburned area, respectively. Columns 3 and 4 report the annual percent change from the period before in the number of unique owners. Columns 5 and 6 report the number of individual land plots in the burned area and unburned area, and columns 7 and 8 report the annual percent change in this number from the period before. Note that 8 of the 19 owner decline between 1872 and 1873, and 20 of the 61 plots eliminated between 1872 and 1873, were a direct consequence of road changes (Appendix Figure 4).

Appendix Table 6. Industry-by-Industry Changes in Agglomeration (Ripley's L Function, 100 foot radius)

		Clustering Index						Difference-in-Difference	
		Burned Area			Unburned Area			Burned vs. Unburned	
	Obs.	1872	1882	1894	1872	1882	1894	1872 to 1882	1872 to 1894
Industry	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Shoes	297	215	143	189	229	555	376	-398	-173
Leather	159	171	178	185	222	1167	1100	-937	-864
Clothes	112	93	154	166	153	134	238	80	-13
Liquors	110	224	287	-100	199	202	185	60	-310
Dry Goods	107	108	101	-100	276	380	283	-111	-214
Hats	107	169	412	204	200	233	231	210	3
Tailor	88	311	457	142	211	350	295	7	-254
Machinery	50	248	130	28	498	331	223	49	54
Hardware	48	62	118	221	422	276	254	203	327
Jewelry	48	571	648	703	373	553	638	-103	-133
Printer	48	78	99	105	283	197	221	107	89
Fancy Goods	46	140	-100	318	161	-100	414	21	-75
Teams	45	26	-11	24	210	329	-100	-156	308
Kitchen Goods	37	87	216	-100	181	500	289	-190	-295
Cigars	35	318	318	-100	98	235	188	-137	-509
Paper	34	145	169	111	351	115	219	260	98
Clothing Accessories	18	152	412	142	627	264	289	624	328
Cotton	13	165	71	-100	-100	659	-100	-853	-265

Notes: For the 18 most common identifiable industries, column 1 reports the number of times that industry is observed in 1872. Columns 2 to 4 report agglomeration index values for that industry in the burned area in 1872, 1882, and 1890. Higher values correspond to greater agglomeration: these values are generated by Ripley's L function with a distance radius of 100 feet, and refer to Section B of the Appendix for details. Columns 5 to 7 report estimates for the unburned area in 1872, 1882, and 1894. Column 8 reports the change from 1872 to 1882 in the burned area, relative to the change in the unburned area; Column 9 reports the change from 1872 to 1894 in the burned area, relative to the change in the unburned area.

Appendix Table 7. Estimated Impacts on Industrial Agglomeration, Relative to 1872

	Ripley's L Function					
	Radius = 50 ft.		Radius = 100 ft.		Radius = 200 ft.	
	(1)	(2)	(3)	(4)	(5)	(6)
1867 x Burned	-4.9	-	-35.3	-	-69.0	-
	(65.7)	( )	(62.1)	( )	(87.0)	( )
1872 x Burned	0	0	0	0	0	0
	( )	( )	( )	( )	( )	( )
1882 x Burned	-23.9	-62.5	-160.8	-148.6*	-236.6	-156.1*
	(69.4)	(38.3)	(115.3)	(82.1)	(177.8)	(87.4)
1894 x Burned	-33.6	-106.4***	-161.5*	-187.5**	-209.6	-194.2*
	(41.7)	(31.4)	(84.1)	(87.7)	(155.6)	(96.5)
Controls:						
Year Fixed Effects	X	X	X	X	X	X
Year FE x Industry L Value in 1867		X		X		X
Year FE x Industry L Value in 1872		X		X		X
R-squared	0.199	0.68	0.136	0.433	0.114	0.431
Industry-by-Year Observations	144	144	144	144	144	144

Notes: For these estimates, 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 for columns 1 and 2, 100 feet for columns 3 and 4 (as shown in Appendix Table 6), or 200 feet for columns 5 and 6. Refer to Section B of the Appendix for details on this formula. As in the main estimating equations, each column then reports differences in the burned area relative to the unburned area for the indicated year, relative to differences in 1872. Columns 2, 4, and 6 include controls for that industry's level of agglomeration in 1867 and 1872. Standard errors are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Appendix Table 8. Estimated Impacts on Occupant Density and Value of Capital, Relative to 1872

	Number of Assessed Occupants per 1,000 Square Feet				Log Value of Capital per Square Foot (Assigning 500 to Zero Values of Capital)			
	Commercial		Residential		Commercial		Residential	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1867 x Burned	0.146**	-	0.362***	-	-0.616***	-	-0.029	-
	(0.067)	( )	(0.067)	( )	(0.218)	( )	(0.054)	( )
1872 x Burned	0	0	0	0	0	0	0	0
	( )	( )	( )	( )	( )	( )	( )	( )
1873 x Burned	-0.294***	-0.368***	-0.327***	-0.202***	-4.438***	-3.752***	-0.073	-0.174***
	(0.043)	(0.052)	(0.064)	(0.069)	(0.225)	(0.218)	(0.051)	(0.053)
1882 x Burned	0.268***	0.251***	-0.404***	-0.328***	0.047	1.253***	0.258***	-0.070
	(0.066)	(0.075)	(0.072)	(0.088)	(0.199)	(0.185)	(0.078)	(0.094)
1894 x Burned	0.340***	0.289***	-0.283***	-0.158	-0.331	0.997***	0.209**	-0.246**
	(0.066)	(0.077)	(0.080)	(0.097)	(0.225)	(0.203)	(0.090)	(0.113)
Controls:								
Year Fixed Effects	X	X	X	X	X	X	X	X
Year FE x Pre-Fire Block Average		X		X		X		X
Year FE x Pre-Fire Neighbor Value		X		X		X		X
R-squared	0.02	0.534	0.053	0.559	0.121	0.65	0.044	0.681
Number of Plots	31353	31353	31353	31353	31353	31353	31353	31353

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, as discussed in the text, and we assign a capital value of 500 to all missing values (after summing across all occupants in that plot). For all observations, we then divide by the square footage and take logs.

The estimating equations are otherwise as before. From estimating equation 1 in the text, the odd columns report the estimated difference between plots in the burned area and plots in the unburned area in the indicated year, relative to the omitted year of 1872. From estimating equation 2 in the text, the even columns include controls for plots' predicted characteristics prior to the Fire, based on their block and nearest neighbor (which is generally that same plot in the earlier year). The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.

Appendix Table 9. Estimated Impact on Land and Building Value in 2012

	Log Total Value per Square Foot			
	Full Sample		Restricted Sample	
	(1)	(2)	(3)	(4)
1867 x Burned	0.081	-	0.069	-
	(0.050)	( )	(0.054)	( )
1872 x Burned	0	0	0	0
	( )	( )	( )	( )
2012 x Burned	0.123	0.569***	0.108	0.266
	(0.217)	(0.207)	(0.233)	(0.209)
Controls:				
Year Fixed Effects	X	X	X	X
Year FE x Pre-Fire Block Average		X		X
Year FE x Pre-Fire Neighbor Value		X		X
R-squared	0.842	0.928	0.863	0.932
Number of Plots	15382	15382	5491	5491

Notes: For all specifications, the outcome variable is the log total value of land and buildings per square foot. From estimating equation 1 in the text, column 1 reports the estimated difference between plots in the burned area and plots in the unburned area in the indicated year, relative to the omitted year of 1872. From estimating equation 2 in the text, column 2 includes controls for plots' predicted characteristics prior to the Fire, based on their block and nearest neighbor. Columns 3 and 4 correspond to columns 1 and 2, but for the restricted sample of plots within 1000 feet of the Fire boundary. The regressions are weighted by plot size. Robust standard errors clustered by block are reported in parentheses: *** indicates statistical significance at the 1% level, ** at the 5% level and * at the 10% level.