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Contents

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Brownfield Areas and Housing Value: Evidence from Milan

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Abstract Using a transaction price database, in this paper we evaluate the economic effect of abandoned and derelict real estate areas on housing prices in Milan Italy from 1993 to 2016. We find that brownfields are widespread throughout Milan, with larger abandoned and derelict areas prevalent in the suburbs. Standard hedonic price models show that nearby brownfield areas lower housing prices, with stronger effects for larger derelict and abandoned areas. Economic losses are more relevant to houses in the historical city center and are affected by real estate market trends.

Keywords brownfield areas; housing market; hedonic price model; housing price

The value of housing units depends on the asset characteristics and user amenities that could affect a buyer's willingness to pay (e.g., Rosen, 1974). The roles of location and amenities on a house's market price depend on buyer preferences and location choices, which change over an individual's life cycle (Van Duijn and Rouwendal, 2012), but, independently, with respect to demand, the existence of brownfield areas nearby will negatively affect the probability of selling real estate assets at the market price.

During the last decades, constraints on all real estate in Milan have increased significantly due to greater attention to quality of life and the environment and the fact that real estate assets can no longer be used in the same way as in the past. The main real estate assets negatively affected by stricter regulations are industrial buildings with production that has environmental quality implications and can therefore no longer be near residential areas (Page and Berger, 2006). The quality and features of existing buildings cannot be easily adjusted to the new demand requirements and the risk related to recovery intervention can reduce access to the credit market, which is potentially necessary to finance brownfield investments (Simons, Pendergrass, and Winson-Geideman, 2004).

The increase in urban sprawl is an unavoidable effect of government policy: the neighborhood life cycle goes from full occupancy to the downgrading and thinning out of the city (Hoover and Vernon, 1959). Vacant and abandoned areas contribute to a decline in the neighborhood and business district that undermines market demand and has a potentially negative effect on household wealth (Accordino and Johnson, 2000). The average condition of all buildings in the area starts to decline

because homeowners lower their economic expectations of the value of their real estate assets and lose any incentive to sustain costs related to ordinary and extraordinary maintenance (e.g., White, 1986).

Brownfield areas in a city require intervention planned by public authorities to avoid the negative effects in the long run related to the concentration of people outside the downtown area. In such scenarios, real estate demand at the city center is expected to decrease due to the increase in transportation quality. Hence, transportation costs for individuals declines, which increases the probability of having new brownfield areas (BenDor, Metcalf, and Paich, 2011). Moreover, if a neighborhood starts declining due to brownfield areas, the municipality will lose tax revenue and could be obliged to reduce services in the area, hastening the city's decline (Kim, Miller, and Nowak, 2018). The reduction in demand near brownfield areas potentially affects prices and rents in the housing sector, but the effect could be different depending on the type of building, the location, and the building's characteristics.

The literature shows that real estate markets are affected by foreclosures of abandoned houses. These have an economically significant impact, even within a one-block radius, due to the effect on the demand for all the neighborhood's properties (Immergluck and Smith, 2005). The negative effect abandoned houses have on the average value of houses in the neighborhood is mainly due to expectations that the average income of the people in the area will decrease because the property will be sold at a discount and, therefore, poorer citizens could choose to move into the neighborhood (e.g., Baxter and Lauria, 2000).

The aim of this paper is to measure the effect of brownfield areas in Milan Italy on the value of houses before their sale and to consider the implications for household wealth and the value of real estate assets. The results show that derelict buildings and areas are not only concentrated in the suburbs but also have a negative effect on real estate value that is proportional to the number and size of the brownfield areas. Housing prices react differently to abandoned or derelict areas/buildings downtown than in the suburbs: downtown, the mere existence of a brownfield area has a significant impact on price; whereas, in the suburbs, the size of the area matters the most. Overall, real estate market trends (bull vs. bear) affect the impact of abandoned and derelict areas on housing value: in a bull market, the existence of a brownfield is sufficient to reduce the price growth of a house; however, in a bear market, only large brownfield areas will have a negative effect on housing value.

In the next section, we review the literature on the benefits and costs for real estate developers and citizens related to requalifying the investments that are needed to start greenfield projects. In the empirical analysis section, we consider the municipality of Milan and evaluate the impact of brownfield areas on neighborhood housing prices and rents. In the final section, we summarize the results and discuss the implications of brownfield areas from an urban planning perspective.

Literature Review

The term ‘‘brownfield’’ was coined in the early 1990s when a side effect of new environmental regulation was to inhibit the investment in former industrial and commercial areas. Brownfield is normally used for identifying a property or a site, of which the expansion, redevelopment, or reuse may be impaired by real or perceived contamination (Hollander, Kirkwood, and Gold, 2010). The term brownfield generally describes different types of previously contaminated, derelict, underused, and vacant sites, and sites with poor ground conditions, characterized by different redevelopment risks (Loures and Vaz, 2018). The definition of a brownfield is not the same worldwide but, independent of the type of asset considered, brownfields have a negative effect on the quality of life in the area, which could be avoided through the intervention of public authorities or private developers (Adams, De Sousa, and Tiesdell, 2010).

In the next subsection, we summarize the role of developers in the urban recovery process, the impact of a brownfield property on a community, and the urban planning and market reaction to abandoned and derelict areas.

Urban Recovery and Developers

Real estate developers who start the recovery process of abandoned/derelict urban areas are exposed to different types of costs and risks than in standard greenfield real estate development. Urban recovery has higher and less predictable costs and execution times than real estate properties that are considered greenfields. The relevance of this difference increases with the costs of land reclamation and the administrative and community constraints on the urban recovery intervention (Amekudzi, Attoh-Okine, and Laha, 1997). The development of new areas, on the other hand, allows the costs of the intervention to be cut and profit margins to be potentially maximized, given the lower constraints on the construction of new buildings in areas not previously intended for development (Lubell, Feiock, and Ramirez de la Cruz, 2009). Additionally, unlike urban recovery operations, such projects are not affected by potential sustainability or consistency problems within the pre-existing urban context (Dixon, 2007).

Construction companies with urban regeneration operations suffer from higher capital rationing by borrowers, which could hamper the development of available projects. Lenders consider brownfield investments very opaque and granting credit for such transactions exposes one, ceteris paribus, to a higher risk of counterparty default (Wernestedt, Meyer, and Alberini, 2006). Moreover, the overall cost of the refurbishment can be unpredictable due to liability and cleanup issues (Loures, 2015). The cost related to environmental and regulatory due diligence activities can also be a disincentive for developers, who can choose to avoid a real estate project unless they obtain guarantees for the maximum cost of the renewal (Wernestedt, Meyer, and Alberini, 2006) and the maximum expenses for third-party claims (Wernestedt, Meyer, Alberini, and Heberle, 2006).

Brownfield revitalization can be accomplished using different options that affect both the cost of the development and the market value of the released building.

The impact on the net performance of the brownfield project varies case by case, based on the expectations of the demand, the project's capability to improve the quality standards, and the sustainability of the recovery projects (Schadler et al., 2011).

The literature shows that, even if a private developer is not interested in a requalification project, the municipality or other public authorities can decide to intervene directly to avoid the negative effects of the brownfield area. Brownfield areas can be used improperly by developers who might adopt a flipping strategy, investing only in refurbishing a façade instead of a full requalification of the area before reselling the asset (Cohen, 2001). Public interventions often require local governments to coordinate with multiple actors across sectors due to the fact that the financial burden of remediation and redevelopment is often larger than what any single local government can afford or market can absorb (Alexander, 2015).

Brownfield Areas and Community Needs

The potential benefits for builders from the development of new areas must be matched with the needs of the community, which, in many cases, can benefit more from the recovery interventions of derelict areas than from the development of new urban projects in previously unoccupied areas (De Sousa, 2003). The main factors to be considered are: mobility planning, public health, security, employment impact, and the provision of basic public services.

The choice to carry out urban redevelopment interventions has potentially positive externalities for the community in organized and efficient urban contexts where the development of a range of collective mobility services has been planned. The choice to not excessively widen an urban area and to exploit derelict areas rationally can increase the convenience of using public transportation instead of private vehicles and lessen traffic congestion and pollution (Northridge et al., 1999). In addition to the elements related to the mobility of individuals, the concentration of communities in limited areas improves the accessibility of collective services whose delivery times have a significant impact on their effectiveness (e.g., first aid services). Urban regeneration also allows one to limit, ceteris paribus, land use and minimize the potentially negative effects of the excessive use of land in the development of real estate projects and the potential damage to ecosystems (Edgens and Staley, 1999).

The removal of degraded areas, especially industrial buildings, has a positive effect on the quality of public health in terms of potential environmental pollution from abandoned buildings featuring earlier, non-ecologically compatible technologies (Meyer, 2001). Redevelopment measures for derelict buildings, although more expensive than greenfield development, should, therefore, consider the potential positive externalities of demolishing and requalifying structures that could harm the community over time (Greenberg et al., 2001).

Urban regeneration interventions reduce the number of abandoned real estate units that could have adverse effects on the value of the area, depending on the greater risks associated with area degradation and increased crime. Brownfield or

abandoned areas are normally perceived as no man's lands, which, by discouraging residential interaction, reduce pedestrian presence while increasing crime by making criminals feel more at ease (Troy and Groove, 2008). The presence of derelict properties is thus assumed to be closely linked with urban degradation and crime, although it is not the only condition necessary for the community development of such social problems (Ross and Mirowsky, 1999). Empirical evidence shows that, of the different types of crimes, robbery and assaults have a more significant impact on housing value; other types of delinquencies show no clear direct effect on price or time on the market (Ihlanfeldt and Mayock, 2010).

Real estate development projects provide short-term growth in jobs related to urban recovery projects that normally require widely diverse skills. At the end of the recovery, conditions can also be created for stable employment growth in service activities for the developed properties, the benefits of which are reflected in higher tax revenues (Turvani and Tunin, 2009).

Urban recovery interventions reduce the costs associated with delivering public services to the community for the local government by concentrating activities in central areas. Delocalization from the original urban core incurs new administrative costs related to the provision of infrastructure (roads, sewers, water, electricity, etc.) that are necessary to access and provide basic services to the residents in these newly-developed areas (schools, hospitals, etc.). Sprawling costs can be unsustainable for consolidated economies whose administrative budget for the delivery of public services is expected to remain stable or decrease over time (Burchell et al., 1998).

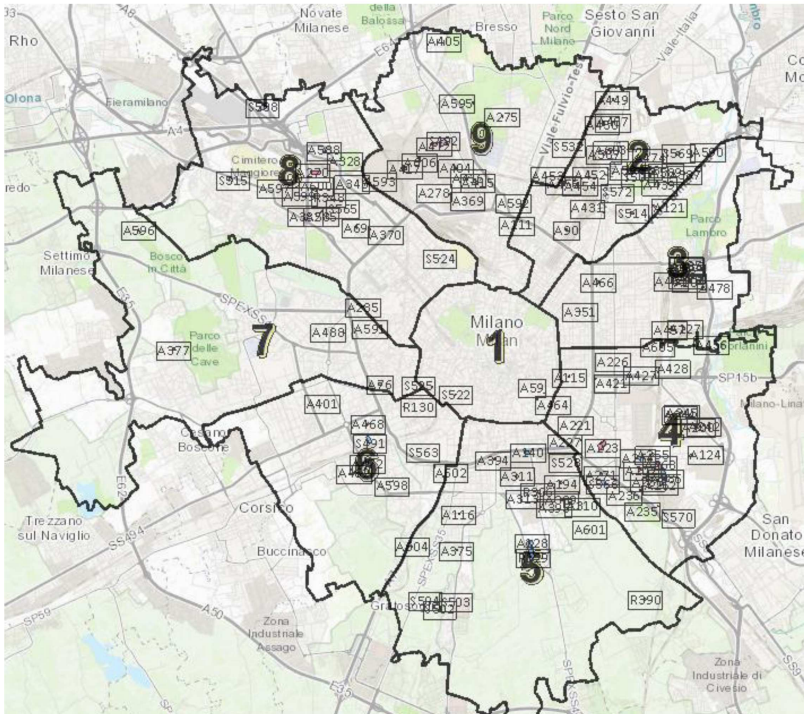
Brownfield and Real Estate Prices

The literature provides empirical evidence on the impact of brownfield areas on the value of nearby buildings, and the consensus is that even a simple, lower investment in the housing stock (e.g., ordinary and extraordinary maintenance expenses) can affect the value of nearby property (Simons et al., 1998).

The value of residential assets near a brownfield area is significantly affected by the risks arising from the derelict area because the existence of a vacant lot has an impact on the quality of life for all the neighborhoods. Brownfield areas that are characterized by a risk of contamination have a significant effect on prices (Zhao, Liu, and Chen, 2017) and frequently have a contagion effect on all nearby areas (Winson-Geideman, Krause, Wu, and Warren-Myers, 2017). When the risk of contamination is lower or there is a program to reduce the liability and the risk for the owners, the impact on the price of the surrounding buildings is lower because the brownfield area will be redeveloped faster (Linn, 2013).

Commercial real estate assets provoke the greatest positive reaction from the real estate market to brownfield recovery interventions, demonstrating that such assets are penalized by the presence of derelict or abandoned areas (De Sousa, Wu, and Westphal, 2009). In fact, derelict or abandoned areas have a negative impact on the reputation of the area and it may represent a disincentive to open a business in the area. Independently, with respect to the type of new asset redeveloped, once

Exhibit 1 | Map of Milan



Notes: The labelled points in the areas are the brownfield areas classified by the Municipality of Milan. Source: Municipality of Milan.

the recovery intervention is completed, all the commercial buildings in the area will experience an increase in their appraisal values and prices due to the higher demand for investments in the area.

The literature shows that even the conversion of a brownfield area into a green area (parkette, local park, district/city park, or natural heritage area) could have an impact on nearby housing values due to the improved quality of life offered (De Sousa, 2003). The greater impact is normally in bigger cities when the population and its density are at the maximum and there is a lack of public open spaces (Németh and Hollander, 2016).

Empirical Analysis

Sample

Data are collected from a survey by the municipality of Milan, with information on all the city districts, by number, including the size, address, and features of derelict and abandoned areas (Exhibit 1). The municipality of Milan is 181.76 km^2 with 1,353,882 inhabitants[1] and is administratively organized into nine zones

Exhibit 2 | City of Milan Zones

Zone	Description	Size (km^2)	Population (000)	Population / km^2 (000)	# of Brownfields	# of Brownfields / km^2
1	Historical center	9.67	96.31	11.07	12	1.24
2	Central station, Gorla, Turro, Greco, Crescenzago	12.58	153.11	13.03	14	1.11
3	Città Studi, Lambrate, Porta Venezia	14.23	141.23	10.79	11	0.77
4	Porta Vittoria, Forlanini	20.95	156.37	8.07	52	2.48
5	Vigentino, Chiaravalle, Gratosoglio	29.87	123.78	4.49	22	0.74
6	Barona, Lorenteggio	18.28	149.00	9.00	8	0.44
7	Baggio, De Angeli, San Siro	31.34	170.81	6.09	7	0.22
8	Fiera, Gallaratese, Quarto Oggiaro	23.72	181.67	8.33	26	1.10
9	Porta Garibaldi, Niguarda	21.12	181.60	9.20	20	0.95
—	Overall	181.76	1,353.88	8.16	172	0.95

Notes: One kilometer is equal to ~0.62 miles. Source: Municipality of Milan.

of different sizes, number of inhabitants, population densities, and brownfield areas (Exhibit 2).

The smallest zone is the historical center while larger zones are located in the southwest area of the city (zones 5 and 7). The population is more concentrated in the historical center and in the northeast (zones 1 to 3). Brownfield areas exist in all city zones, but the southeast (zone 4) has the highest number of abandoned and derelict areas (52 of 172 areas) but, considering the number of brownfields by square kilometer, the areas that have above the average incidence of brownfield are the historical center: Porta Vittoria Forlanini e Fiera, Gallaratese, and Quarto Oggiaro (zones 1, 4, and 8).

The types and sizes[2] of the brownfield areas are significantly heterogeneous, with clear differences between the sizes and numbers of brownfield areas in terms of the distance from Milan's central business district (CBD), as shown in Exhibit 3. Milan has many (172) brownfield areas, the majority of which were previously production sites or residential units (23.26% and 34.88%, respectively) that, as in other cities worldwide (e.g., Simons, 1998), cannot be easily adapted to new market standards and demand. Although the derelict and abandoned areas are not strictly downtown, the majority are not too far from there (53% are within 5 km of the CBD) and, as expected, the larger brownfield areas are outside the city (5 km or more from the CBD).

Exhibit 3 | Brownfield Areas in the City of Milan

Type of Asset			Distance from the CBD			
	#	%		# of Units	Average Size	Overall Size
Retail	10	5.81%	≤ 1 km	1	14,616.82 m²	14,616.82 m²
Residential	40	23.26%	≤ 2 km	8	2,232.47 m²	17,859.73 m²
Offices	31	18.02%	≤ 3 km	25	2,198.08 m²	54,951.95 m²
Industrial	60	34.88%	≤ 4 km	23	5,186.97 m²	119,300.33 m²
Rural buildings	31	18.02%	≤ 5 km	34	24,222.65 m²	823,570.14 m²
Overall	172	100%	> 5 km	83	10,201.44 m²	826,316.96 m²

Note: Source: Municipality of Milan data processed by the authors.

Information about derelict land or properties is supplemented with data on the prices for each area in Milan from 1993 to 2016 (half-year frequency) from a proprietary housing transaction database provided by the Chambers of Commerce of Milano, Monza–Brianza, Lodi, and FIMAA Milano Monza & Brianza. Data allow evaluating separately the transaction price of new houses, existing houses, and old houses: the first ones are newly developed real estate assets while the others are, respectively, residential units constructed more or less than 30 years before the transaction in the secondary real estate market (Exhibit 4).

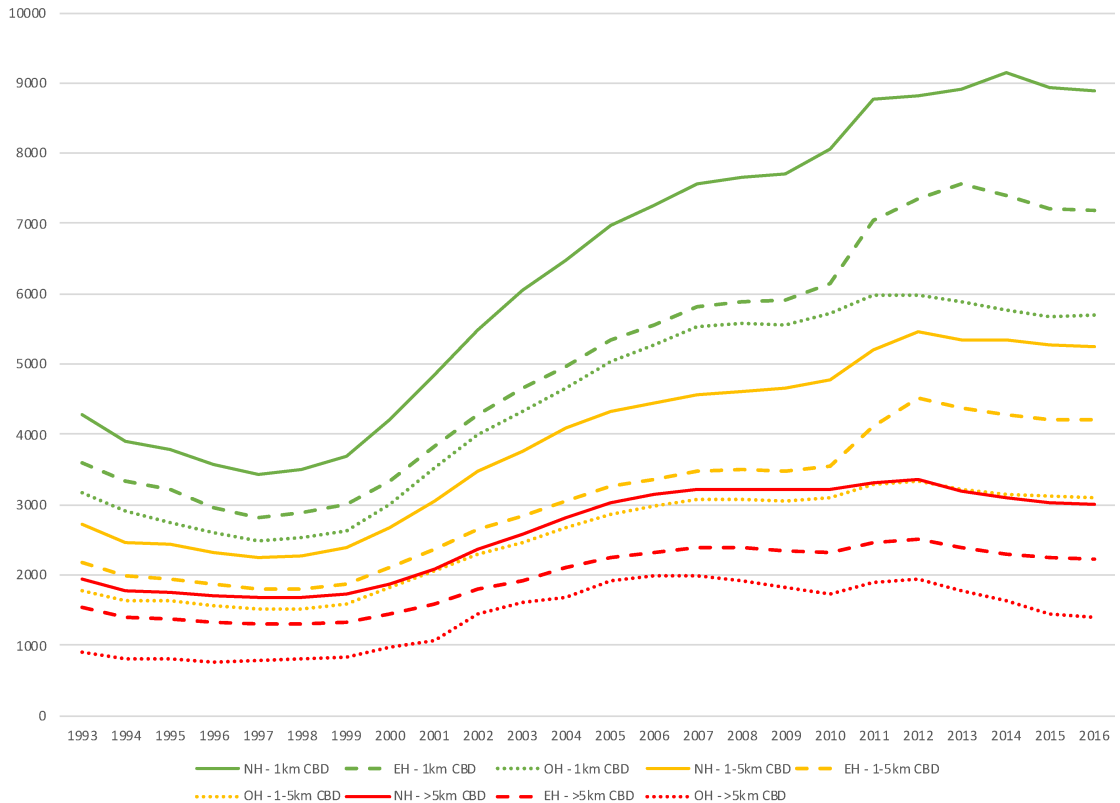
The average price per square meter paid for new houses is always higher than any other type of residential unit, increasing with the distance from the city center. From 1999 to 2012, housing prices increased significantly year by year and from 2013, the market started to suffer from the real estate crisis with a greater penalization for old and existing houses. In the period considered, existing houses experienced greater growth in average prices over time than old houses and this effect was even greater for areas significantly farther from downtown.

Methodology

Our analysis of the impact of brownfield areas on the housing market considers the price dynamics of all real estate units sold near these buildings (e.g., Immergluck and Smith, 2005). For each city district, a distance proxy is constructed by considering the standard Euclidean distance measures that compare the area of the center of the district with the longitude and latitude of the brownfield area. The literature shows that the shorter the distance from a brownfield area, the higher the price reduction relative to other buildings in the area (Linn, 2013).

We examine the impact of brownfield areas on the price for residential real estate using the concentration of derelict lands or properties in the area. The two proxies are the percentage of brownfield areas ($NBF_{it}^{\alpha km}$) and the square meters of the

Exhibit 4 | Average Price per Square Meter Statistics for Residential Real Estate in Milan Classified on the Basis of the Distance from the CBD



Notes: NH = new houses that were not previously owned; EH = existing houses not older than 30 years; OH = old houses developed more than 30 years ago; and CBD = Central Business District. The price per square meter is 10.764 times the price per square foot. For example, a housing price of 1000 €/m^2 is equivalent to 92.90 €/ft^2. Source: Chambers of Commerce of Milano, Monza–Brianza, and Lodi, and FIMAA Milano Monza and Brianza data processed by the authors.

derelict land or properties with respect to the size of buildings ($SBF_{it}^{\alpha km}$) α kilometers from the city district. For both measures, to define the neighborhood, we consider the distances from the CBD (α varies from 1 km to 5 km).

To measure the contribution of the proximity of brownfield areas to housing prices, we consider the hedonic price model proposed by Rosen (1974) and evaluate the net price effect with respect to the distinctive characteristics of each real estate unit, as follows:

$$P_{it} = \alpha + \lambda_i DistCBD_i + \Sigma_{k=1}^{m} \beta_i^k F_{it}^k + \varepsilon_{it} \quad (1)$$

$$P_{it}^j = \alpha + \lambda_i DistCBD_i + \tau_i BF_{it} + \Sigma_{k=1}^{m} \beta_i^k F_{it}^k + \varepsilon_{it}, \quad (2)$$

where the price (P_{it}) per square meter is regressed with respect to the housing characteristics (F_{it}^k), the distance from the CBD ($DistCBD_i$), and a proxy for the brownfield areas. The proxy of derelict lands or abandoned properties is the percentage within one kilometer of the district center ($\%NBF_{it}$) (equation (1)) or their size with respect to the overall number of square meters constructed ($\%SBF_{it}$) (equation (2)). As a robustness test, the models consider alternative distance thresholds that vary from two kilometers to five kilometers.

The independent variables consider the distance from the CBD ($DistCBD_j$) and a set of other district characteristics that are available in the database.[3] Based on the information available for each area, the control variables for the building and district characteristics are as follows:

Quality high$_{jt}$ = Dummy that takes the value of one if the price is related to houses of outstanding quality in the district:

Quality low$_{jt}$ = Dummy that takes the value of one if the price is related to low-quality houses in the district;

New construction$_{jt}$ = Dummy that takes the value of one if the price is related to new houses with no previously owner;

Old construction$_{jt}$ = Dummy that takes the value of one if the price is related to old houses constructed more than 30 years ago but never refurbished:

Distance airport$_{jt}$ = Shortest distance to one of the city's airports (Linate or Malpensa);

Distance train station$_{jt}$ = Shortest distance to one of the high-speed train stations (Milan Central, Cadorna, or Garibaldi);

Distance universities$_{jt}$ = Shortest distance to the nearest (public or private) university in the city;[4]

Distance hospital$_{jt}$ = Shortest distance to the nearest hospital;

Green areas$_{jt}$ = Dummy variable that takes the value of one if the district has a public green area;

Schools$_{jt}$ = Number of schools within 1 kilometer of the district center;

$Commercial\ activities_{jt}$ = Number of square meters for commercial activities in the district with respect to the total number of square meters available in the city;

$Metro\ station_{jt}$ = Number of metro lines servicing the district;

$Population_{jt}$ = Percentage of people living in the area with respect to the population of Milan; and

$Foreigners_{it}$ = Percentage of foreigners living in the district with respect to the overall population of the district.

We conduct panel regressions with random effects for the 1993–2016 period. The role of brownfield areas in housing prices can differ significantly across different areas of the city and, normally, the better the average quality of the properties, the higher the expected loss from abandoned and derelict areas. We examine the different impacts of building quality by distinguishing between the historical downtown area and the suburbs, as follows:

$$P_{it}^{j} = \alpha + \lambda_i DistCBD_i + \delta_i HC_i \times BF_{it}^{\alpha km} + \eta_i(1 - HC_i) \times BF_{it}^{\alpha km} + \Sigma_{k=1}^{m} \beta_i^k F_{it}^k + \varepsilon_{it}, \quad (3)$$

where HC_i is a dummy variable that takes the value of one if the house is in Milan's historical downtown and is zero otherwise.

We employ two dummy variables to distinguish between bull and bear markets as an additional test of price sensitivity. Each city district is classified by its growth with respect to the average growth of the market, as follows:

$$P_{it}^{j} = \alpha + \lambda_i DistCBD_i + \delta_i Bull_{it} \times BF_{it}^{\alpha km} + \eta_i Bear_{it} \times BF_{it}^{\alpha km} + \Sigma_{k=1}^{m} \beta_i^k F_{it}^k + \varepsilon_{it}, \quad (4)$$

where $Bull_{it}$ is a dummy variable that takes the value of one if the district's growth is above the market average and is zero otherwise. $Bear_{it}$ is a dummy variable that takes the value of one if the district's growth is lower than the market average and is zero otherwise.

Results

Exhibit 5 presents the results of a preliminary analysis of prices for areas classified by different incidences of brownfield areas throughout the city. Independent of the distance considered (1 km to 5 km), a simple analysis of the price per square meter does not allow us to identify a linkage between brownfield areas and the real estate market dynamics for new, existing, or old houses. The lack of evidence

Exhibit 5 | Statistics on the Price in Euros and the Amount of Brownfield Areas in the Neighborhood

	1 km		2 km		3 km		4 km		5 km	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
New house										
I	€3604.21	€1047.17	€3609.12	€1063.46	€3376.72	€970.32	€3022.66	€795.74	€2839.72	€720.39
II	€3985.39	€1258.36	€4360.49	€1359.20	€4331.93	€1368.38	€3246.60	€944.88	€3464.56	€1009.85
III	€5553.04	€1800.78	€3615.17	€1064.45	€3625.47	€1019.94	€4566.90	€1464.76	€3793.34	€1115.56
IV	€3257.98	€937.47	€3457.85	€1010.44	€3830.64	€1192.11	€4327.17	€1365.92	€5113.96	€1749.00
Existing house										
I	€2812.32	€815.05	€3065.61	€949.68	€2677.62	€777.55	€2267.30	€593.95	€2201.49	€566.98
II	€3174.56	€1019.59	€3469.60	€1096.73	€3697.47	€1226.26	€2849.15	€869.59	€2897.11	€865.67
III	€4207.29	€1377.74	€2795.06	€840.22	€2895.29	€863.36	€3615.09	€1190.75	€3037.41	€973.91
IV	€2889.20	€846.99	€2769.18	€780.62	€2966.45	€857.29	€3561.85	€1099.87	€4129.31	€1329.99
Old house										
I	€2495.85	€672.40	€2289.81	€572.44	€1941.45	€459.03	€1920.78	€452.50	€1894.12	€460.25
II	€2596.68	€776.22	€2894.20	€840.39	€3039.29	€902.35	€2652.75	€734.85	€2392.23	€624.24
III	€3430.45	€1032.45	€2706.01	€783.51	€2847.10	€818.55	€3037.31	€906.70	€2696.52	€765.95
IV	€2221.32	€578.40	€2251.69	€639.67	€2363.57	€670.91	€2605.47	€766.43	€3193.16	€989.52

Notes: The price per square meter is 10.764 times the price per square foot. For example, a housing price of 1000 €/m^2 is equivalent to 92.90 €/ft^2. Areas were classified into quartiles (from I to IV) on the basis of the percentage of brownfield areas in *j* kilometers from area center (with *j* varying from 1 to 5 km). Source: Chambers of Commerce of Milano, Monza–Brianza, and Lodi, and FIMAA Milano Monza and Brianza data processed by the authors.

could be due to differences in real estate units available throughout different areas of the city (at least based on size, type, and quality) that do not allow for a comparison of their value and the expected income produced. The lack of clear evidence of a linkage between prices and nearby brownfield areas could be due to the different characteristics of those areas with more abandoned and derelict buildings (Exhibit 6).

Exhibit 6 presents the results of a random effect panel regression of housing prices with respect to distance to CBD ($DistCBD_i$), percentage of brownfield areas (NBF_{it}), the relative size of brownfield areas (SBF_{it}), and the historical downtown dummy (HC_i). *Bull* is a dummy variable that takes a value of one (1) if the average prices in the area are growing and zero otherwise. *Bear* is one minus the *Bull* dummy variable.[5] As expected, the results show that the higher the concentration of brownfield areas in the district, the lower the housing prices. The impact of each 1% increase in derelict or abandoned areas with respect to overall constructed and developed areas near the center of the district is more than ten times the impact of the distance from the CBD. Larger brownfields penalize homeowners the most, with a proportionally higher impact when the area has undergone less construction and is thus characterized by high-quality houses (villas and townhouses).

Historical downtown areas suffer the most from derelict or abandoned areas and, in the suburbs, the sizes of brownfield areas have the greatest impact on housing prices. This evidence is consistent with the analysis of the geographical distribution of brownfield areas in the city.[6] Only a few brownfield areas are located downtown and, therefore, districts in the historical center with at least one such type of dilapidated building perform significantly worse with respect to the other areas. In the suburbs, only large derelict/abandoned sites have a price impact.

Brownfield areas have different effects at different stages of a real estate market trend, with clearer differences related to growing (bull) and declining (bear) markets. The number of brownfield areas in a district has a negative impact on housing prices mostly during bull market phases, reducing the potential appreciation of real estate assets over time, with even just one small abandoned area potentially negatively affecting prices. In a bear market, the presence of any brownfield area does not significantly affect the price trend and additional losses related to brownfield sites are economically significant only when the size of the area/building is economically significant.

We conducted a standard Dickey-Fuller test to check the existence of a unit root for the dependent variable (simple, with drift, and with deterministic trend) and the test rejected the hypothesis. Overall, the models offer a reasonable R^2 value (higher than 58% for all the specifications) and the fitness of the model increases when the brownfield variables are included among the independent variables. The set of controlling variables (see Exhibit A1 in the Appendix) show signs that are consistent with the literature and, independently, with respect to the model selected, the main characteristics that affect the housing prices are the building age, number of schools, percentage of commercial activities in the area, number

Exhibit 6 | Regression Results of an Analysis of Price of Housing by Distance from the CBD and Brownfield Areas in the District

	(1)	(2)		(3)		(4)	
$DistCBD_i$	−801.91**	−902.89**	−893.34**	−747.20**	−865.26**	−638.57**	−865.26**
$\%NBF_{it}$		−89.37*					
$\%SBF_{it}$			−11,883.22*				
$HC_i \times NBF_{it}$				−1,412.64**			
$HC_i \times SBF_{it}$					−10,762.96*		
$(1 - HC_i) \times NBF_{it}$				−2,433.64			
$(1 - HC_i) \times SBF_{it}$					−11,621.85*		
$Bull_{it} \times NBF_{it}$						−5,823.75*	
$Bull_{it} \times SBF_{it}$							−10,762.96*
$Bear_{it} \times NBF_{it}$						−2,238.68	
$Bear_{it} \times SBF_{it}$							−11,621.85*
α_{it}	3,822.86**	5,018.04**	4,599.08**	3,210.44**	5,621.00**	4,002.19**	5,621.00**
# of control Variables	15	15	15	15	15	15	15
City districts	66	66	66	66	66	66	66
R^2 Overall	58.19%	58.43%	58.61%	58.38%	59.44%	61.40%	59.44%

Notes: There are 28,434 observations. Source: Chambers of Commerce of Milano, Monza–Brianza, and Lodi, and FIMAA Milano Monza and Brianza data processed by the authors.
*Statistically significant at the 95% level.
**Statistically significant at the 99% level.

of metro lines servicing the area, population density, and the incidence for foreigners.

Robustness Test

The robustness of the results is analyzed by constructing brownfield proxies (both $\%NBF_{it}$ and $\%SBF_{it}$) involving an alternative distance measure that considers the walking distance instead of the Euclidean distance and brownfield areas that are more distant (2 km to 5 km) from the real estate assets. Analysis of the walking distance proxies for both the distance from the CBD and brownfield areas confirms the results obtained with the Euclidean distance (Exhibit 7).

Exhibit 7 presents the results of a random effect panel regression of housing prices with respect to walking distance to CBD ($WalkingDistCBD_i$), the percentage of brownfield areas (NBF_{IT}), the relative size of brownfield areas (SBF_{IT}), and the historical downtown dummy (HC_i). *Bull* is a dummy variable that takes a value of one if the average prices in the area are growing and zero, otherwise. The *Bear* dummy is one minus the *Bull* dummy. In order to consider the specific characteristics of the area and building, we use a standard set of controlling variables.[7] Both the number and size of brownfield areas have an impact on housing prices like the one identified using the Euclidean distance, but the impact of the number of brownfield areas is a little bit higher with respect to the baseline scenario, which shows that when the brownfield asset is on a walking route used by the owner it matters the most. The impact of the brownfield area is always more relevant and statistically significant in the city center and there is no significant difference in the effect during bull and bear markets.

Exhibit 8 presents the results of a random effect panel regression of housing prices with respect to percentage of brownfield areas ($NBF_{it}^{\alpha km}$) in the district, the relative size of brownfield areas ($SBF_{it}^{\alpha km}$), and the historical downtown dummy (HC_i). *Bull* is a dummy variable that takes a value one if the average prices in the area are growing and zero otherwise. The *Bear* dummy is one minus the *Bull* dummy. We analyze brownfield areas at different distances from the center of the district (from 1 km to 5 km) using a standard set of controlling variables.[8] The results show that the impact of brownfield areas is still negative and statistically significant independent of the distance for the brownfield proxies but, from an economic point of view, the impact is less relevant.

The analysis that considers the relative size of brownfield areas with respect to larger reference areas (3 km and upward) does not provide statistically significant results. The lack of evidence is justified because, independent of the numbers and sizes of the brownfield areas, the greater the area considered, the smaller the relative proportion of derelict or abandoned areas. Therefore, the analysis does not yield strong or significant results.

Comparison of the impacts in the historical center and in the suburbs yields results consistent with the analysis based on a one-kilometer distance, because, independent of the distance considered from the brownfield area (2–5 km), the

Exhibit 7 | Regression Results of an Analysis of Price of Housing by Walking Distance from the CBD and Brownfield Areas in the District

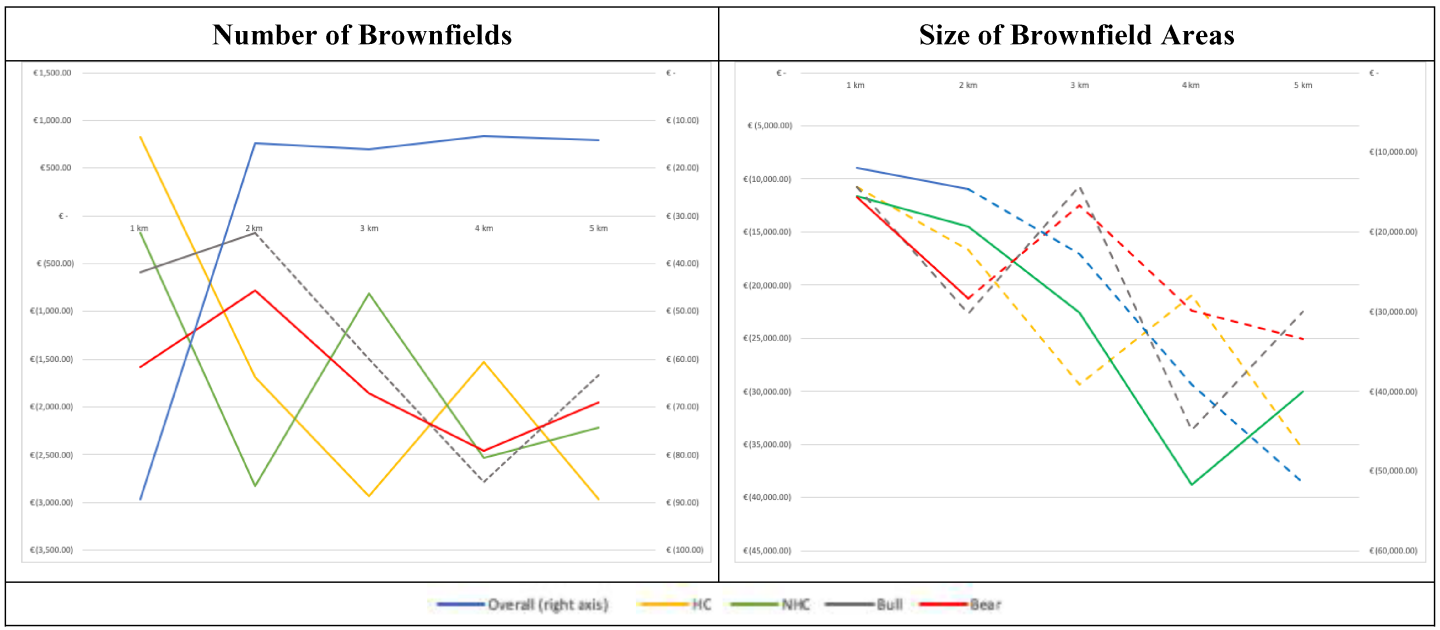
	(1)	(2)		(3)		(4)	
$WalkingDistCBD_i$	−721.16**	−634.04**	−644.04**	−587.81**	−657.40**	−697.17**	−697.17**
$\%NBF_{it}$		−133.81*					
$\%SBF_{it}$			−8,692.18*				
$HC_i \times NBF_{it}$				−820.17**			
$HC_i \times SBF_{it}$					−14,290.02*		
$(1 - HC_i) \times NBF_{it}$				−183.32			
$(1 - HC_i) \times SBF_{it}$					−18,831.60**		
$Bull_{it} \times NBF_{it}$						−5,904.94*	
$Bull_{it} \times SBF_{it}$							−5,034.58*
$Bear_{it} \times NBF_{it}$						−1,581.42	
$Bear_{it} \times SBF_{it}$							−8,199.32*
α_{it}	3,822.86**	4,538.04**	4,719.08**	3,250.44**	5,251.00**	4,302.19**	5,521.00**
# of control Variables	15	15	15	15	15	15	15
City districts	66	66	66	66	66	66	66
R^2 Overall	58.19%	56.73%	55.85%	57.68%	59.44%	58.74%	55.80%

Notes: There are 28,434 observations. Source: Chambers of Commerce of Milano, Monza–Brianza, and Lodi, and FIMAA Milano Monza and Brianza data processed by the authors.

*Statistically significant at the 95% level.

**Statistically significant at the 99% level.

Exhibit 8 | Regression Results of an Analysis of Price of Housing by Distance from the CBD, Brownfield Areas, and Real Estate Trend in the District



Notes: Continuous lines represent estimates that are statistically significant at least at the 95% confidence level, while dotted lines are coefficients that are not statistically significant. Source: Chambers of Commerce of Milano, Monza–Brianza, and Lodi, and FIMAA Milano Monza and Brianza data processed by the authors

number of derelict and abandoned areas matters for the historical city center; in the suburbs, only the sizes of the areas matter. The higher relevance of the size of brownfields for the suburbs is justified by the fact that the probability of having a derelict or abandoned area near a residential unit is higher outside of the downtown area (especially in former industrial areas) and, due to the low density of population in the suburbs, the effect on housing price is mainly related to brownfield areas that are above average in size.

Brownfield areas affect prices only in a bull market if they are located no more than two kilometers from the building. The impact of the size of the brownfield area is normally higher in a bear market than in a bull market, independent of the distance considered in the analysis of the area.

Conclusion

Housing prices are significantly affected by the location and the presence of derelict and abandoned areas, which can change the demand for residential real estate. Brownfield areas have a negative effect on the quality of life because the number and type of public and private services offered to area residents will be negatively affected. Losses for homeowners are higher the closer the brownfield areas and, for example, for every brownfield area in a one-kilometer area, house value will decrease around €89 per square meter (around 2.9% of the average price per square meter). The price reduction is normally related to abandoned and derelict areas of significant size with respect to the total amount of square meters of buildings in the city district. In fact, areas with the 0.01% of construction classified as a brownfield are characterized by an average price less than €119 per square meter (around 3.9% of the average price per square meter) with respect to areas without abandoned and derelict areas.

The analysis of the downtown area with respect to the suburbs allows for the identification of interesting differences between the two submarkets: central areas lose value if brownfield areas are nearby (€1412 per square meter for every 1% of brownfields in the area equals a reduction of 23% of the average price per square meter), independent of their size, whereas suburban areas suffer losses only if large abandoned and derelict areas are nearby. The results support the hypothesis already tested in the literature (e.g., Reichert, Small, and Mohanty, 1992) that homeowners who own more expensive residential assets are more sensitive to brownfield proximity and the prime location could experience higher price reduction due to the higher probability of homeowners' flight.

The impact on prices in a bull market depends mostly on the number of abandoned or empty areas nearby (around €591 per square meter for every 1% of brownfields in the area is a reduction of 18.9% of the average price); losses in a bear market are predominately related to the presence of large brownfield areas nearby (a reduction of €1162 per square meter for every 0.1% of the constructions in the area classified as brownfields, a reduction of 37.3% of the average price). Milan is characterized by strict land consumption rules and several levels (state, region, and municipality) of controls (OECD, 2017) that frequently

encourage developers in a growing housing market to invest in recovering abandoned or derelict areas. Therefore, areas that even in a growing market do not regenerate brownfield areas will be considered a second choice for the buyers and their average selling price will be lower. The higher relevance of the size of the brownfield in a real estate market crisis is related to the lower margins and the higher risks that developers may encounter due to the large size of the investment. This may reduce the probability of these areas being targets for regeneration projects during a declining real estate market, in the short term, due to the lack of demand for new houses (Dixon, Otsuka, and Abe, 2011).

The results show that households can incur a direct loss due to nearby brownfield areas, and the real estate market may be less liquid until it has recovered because homeowners that invested before the brownfield appeared will not easily choose to sell their assets and incur losses. Urban planning policies cannot be defined without considering the cost of delaying interventions in brownfield areas. The cost to residents will be higher the larger the area considered.

There are many derelict lands and properties in downtown Milan and these could represent profitable investment opportunities for developers due to the high value of the locations and the lack of greenfield areas with comparable features in the city (Greenberg and Schneider, 1995). Requalifying investments normally involves the development of new retail and residential areas instead of abandoned buildings even though, after brownfield intervention, the frequency and value of local real estate market transactions increase due to the above-average quality of buildings in the area (Heberle and Wernstedt, 2006). International evidence on developed economies shows that there are defined plans to transform derelict lands or properties into new real estate assets as requested by the market. Recovery interventions avoid increasing the population or causing unsustainable land consumption in the medium to long term and reduce the negative effects of city growth on the natural environment (e.g., Dixon and Adams, 2008).

A more detailed analysis of the issue could consider the most important characteristics of brownfield areas in the housing market to identify the types of derelict or abandoned areas that are potentially riskier for citizens. Moreover, the effects cannot be evaluated properly if the market conditions for the housing sector in the city are not considered in detail, because the effect of a brownfield area will be completely different according to the liquidity of the market and the number of buyers/renters interested in investing in the area.

Appendix

Exhibit A1 | Coefficient Estimation for Controlling Variables in the Panel Regression Model

	(1)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Quality high$_{it}$	0.52	0.68	0.62	0.44	0.76	0.56	0.79
Quality low$_{it}$	−0.58	−0.76	−0.69	−0.48	−0.85	−0.59	−0.83
New construction$_{it}$	19.71	2.59	23.72	1.65	2.88	2.03	2.89
Old construction$_{it}$	−9.72**	−12.76**	−11.70**	−8.17**	−14.29**	−10.16**	−14.27**
Distance airport$_{it}$	−2.04	−0.32	−0.74	−0.57	−0.76	−0.29	−1.19
Distance train station$_{it}$	−2.61*	−3.41*	−2.53	−1.39	−0.35	−0.41	−2.01
Distance universities$_{it}$	−3.60*	−3.82	−6.06*	−1.44	−7.58	−2.47*	−6.02*
Distance hospital$_{it}$	−5.63	−7.16	−6.61	−6.29*	−8.81*	−3.00	−5.90*
Green areas$_{it}$	3.60	2.25	5.03	0.23	1.89	1.85	5.76
Schools$_{it}$	1.64**	1.83**	2.05**	0.47	1.53*	1.34*	2.24
Commercial activities$_{it}$	183.21**	238.07**	221.22**	195.59**	346.14**	151.42**	235.37**
Metro station$_{it}$	6.18**	9.12*	5.70*	7.39**	7.54*	7.68**	6.49*
Population$_{it}$	533.81**	678.01**	598.51**	479.96**	974.69**	440.58**	586.39**
Foreigners$_{it}$	−235.32**	−312.59**	−283.36**	−225.62**	−396.00**	−206.98**	−298.39**

Notes: The table presents the results for the controlling variables used in the random effect panel regression of housing prices (Exhibit 6). The control variables are the quality of the house (high, medium, and low), the vintage of the house (old, existing, and new), the distance from the nearest airport, the distance from the nearest high speed train station, the distance from the nearest university, the number of public green areas, the number of schools, the square meters for commercial activities in the district, the number of metro lines that serve the district, the percentage of population of the city that lives in the area, and the percentage of foreigners among the population of the district. The sample period is 1993–2016 using half-year data for each of the 66 districts of Milan. The sources are the Chambers of Commerce of Milano, Monza–Brianza, and Lodi, and FIMAA Milano Monza and Brianza data processed by the authors.

*Statistically significant at the 95% level.

**Statistically significant at the 99% level.

Endnotes

[1] The number of citizens refers to the results of the last official municipality survey, in 2014.

[2] The size of the brownfield is measured by considering the size (in square meters) of all the floors in the original building project (gross floor area).

[3] Data about other standard characteristics of the residential buildings (like bedrooms, bathrooms, floor, etc.) are not available for the full time horizon and cannot be considered in the analysis.

[4] The universities considered were the University of Milan, the University of Milano–Bicocca, the Polytechnic University of Milan, Bocconi University, the Catholic University of the Sacred Heart, the IULM University of Milan, the Vita-Salute San Raffaele University, Brera Academy, and the Conservatory of Milan.

[5] As control variables for the housing prices, the model considers the quality of the house (high, medium, and low), the vintage of the house (old, existing, and new), the distance from the nearest airport, the distance from the nearest high speed train station, the distance from the nearest university, the number of public green areas, the number of schools, the square meters for commercial activities in the district, the number of metro lines that serve the district, the percentage of population of the city that lives in the area, and the percentage of foreigners among the population of the district.

[6] For further details, see Exhibit 2.

[7] For further details about the controlling variables, see the methodology section.

[8] For further details about the controlling variables, see the methodology section.

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