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Local regulation and land-use change: The effects of wetlands bylaws in Massachusetts[☆]

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ABSTRACT

As urban areas across the U.S. grow, open-space lands providing wildlife habitat and ecosystem services are lost to development. In response, many communities have experimented with local regulations to encourage land conservation, but little is known about their effects on land-use change or housing supply. Wetlands protection bylaws are a potentially important and highly controversial form of local land-use regulation in Massachusetts. This paper uses conditional variation in the timing of adoption of these bylaws across communities to analyze their effects on rates of land-use change and housing growth from 1971 to 1999. We find that bylaws significantly reduced the rate of land conversion from open space to residential uses in communities where they were enacted, but did not significantly reduce growth in housing units, housing values or housing density in those communities. We do not find strong evidence that land-use conversion was displaced to neighboring communities, but supply constraints may have encouraged additional development at alternate sites within communities or additional higher density housing development in communities where it was allowed.

1. Introduction

The rapid conversion of open space to developed land uses is a policy issue debated by both environmental and affordable housing advocates.[1] In the U.S., local governments play a key role, as most land-use decisions are made at the town, city, or county level. Communities across the country have used an array of policy tools for protecting open space, including zoning regulations, land development taxes, impact fees, public land acquisitions, and private land trusts. Although large numbers of communities are in essence experimenting with different local land-use policies, it is currently difficult to learn from this experience because there are few systematic evaluations of local policies (see Section 2). Restrictions on land development may protect wildlife habitat and maintain valuable ecosystem services such as water filtration or flood control, but potentially impose high costs by reducing the growth of housing supply and increasing prices or by encouraging inefficient development patterns.

In this study, we examine the case of local wetlands protection bylaws,[2] which give towns and cities in Massachusetts the power to regulate land use near wetlands more strictly than baseline state and federal environmental protection laws. Wetlands bylaws are particularly important and controversial because they are one of the few forms of local regulation that cannot be superseded by a statewide affordable housing law that allows developers to override other forms of local

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[1] According to the USDA, in the five years between 1992 and 1997 an estimated 11.2million acres (more than 2 million per year) were developed throughout the U.S. Kolankiewicz and Beck (2001) estimate that of the total open space conversion between 1970 and 1990, roughly half was due to population growth and half was due to increased per-capita land consumption. The environmental costs of land conversion include the loss and fragmentation of wildlife habitat as well as the increased air pollution and energy use that result from expanding urbanized areas.

[2] Local laws adopted by towns are called bylaws, those adopted by cities are called ordinances. In this paper, we use the term bylaws to refer to both bylaws and ordinances.

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zoning.[3] Supporters of bylaws such as the Massachusetts Association of Conservation Commissions have stressed the various environmental benefits of wetlands.[4] The Massachusetts Homebuilders Association, however, points to "local environmental regulations (regarding setbacks, wetlands, and related issues)" as one of the "major factors that limit their ability to permit new homes" (MHBA, 2004).

Our study considers three dimensions of the consequences of this local land-use policy. First, were wetlands bylaws effective in achieving their primary policy objective: did they slow development of wetlands or the conversion of undeveloped land to residential uses? Second, did bylaws affect the quantity or price of housing in the communities where they were enacted? Third, what were the pathways through which bylaws may have changed development patterns: did bylaws displace development to nearby communities, shift the locations of development within the same community, or induce changes in the density of new housing?

To estimate policy impacts, we combine new data on wetlands bylaws and other local-level housing regulations with statewide coverage of land use at three points in time (1971, 1985 and 1999) for communities in eastern and central Massachusetts. To identify effects, we take advantage of plausibly exogenous conditional variation in the timing of adoption of wetlands bylaws. We rely only on residual variation in timing, after controlling for potentially confounding factors that could reflect different underlying preferences for development or environmental protection. We control for community differences in two ways: first, with community-level fixed effects and second, with direct control variables including other zoning regulations, citizen environmental preferences, geographic determinants and demographic characteristics. The remaining residual variation in bylaw timing is assumed to result from factors exogenous to the community, such as increased press attention, single high profile projects, and the idiosyncrasies of local politics (see Section 4.1).

To test for potential displacement of development to neighboring communities, we construct a measure of bylaw adoption by each community's nearest neighbors. To test for changes in the location of development within communities, we use GIS analysis to construct variables for the distance from converted lands in each period in each town to the nearest wetlands area, the proportion of converted lands that intersect with wetlands, and the proportion that are within a 100 foot buffer of wetlands areas.

We find that each additional year of having a wetlands bylaw is associated with an estimated 7.9–10.1 fewer acres of land converted to residential use. Taking into account the number of years bylaws were in effect, this suggests more than 10,000 acres protected from 1971–1999 (approximately 6% of the total converted in study communities). However, we find no effect on changes in housing prices and a negative but not statistically significant effect on changes in the number of housing units and the number of new construction permits issued. We also do not find significant effects on the amount of land used per new unit of housing, a proxy for the density of new development. In general, we restrict our analysis to communities that had at least 50 acres of wetlands in 1971, excluding communities with little possibility to develop near wetlands. The magnitudes are robust, however, to including all communities in eastern and central Massachusetts.

Our results suggest that wetlands bylaws have indeed slowed some conversion of open space lands to residential uses. This reduction has not been accompanied by corresponding significant increases in local housing prices or reductions in housing supply growth. The potential reduction in housing supply from land-use restrictions appears to have been mitigated partially by shifts in development location within communities. After adopting bylaws, development within communities is more likely to occur on land patches which are further from wetlands and newly converted lands are less likely to overlap with wetlands. We do not find strong evidence for displacement of land conversion across towns, however: having more neighbors who adopt bylaws does not increase land conversion in the home community and has a positive but not statistically significant effect on construction permits. We do find that if neighboring communities adopt bylaws, this increases housing prices in the home community, suggesting possible supply constraints within housing sub-markets in different regions of Massachusetts.

Wetlands bylaws are likely to reduce allowable density on directly affected parcels, but might induce higher density development on other properties within the same community through price effects. We do not find significant evidence for increased density within towns due to bylaws. This is not surprising, since zoning regulations are a binding constraint on density in most of these communities, and the amount of land converted to residential use per new housing unit varies considerably within our sample. However, we do observe that during this period of time a large share of new construction in the region occurred in already dense areas with few remaining wetlands and less restrictive zoning. To the extent that wetlands bylaws contributed to higher land or housing prices across the entire region, they may have increased the relative profitability of high density development in places where that was permitted by zoning.

The paper proceeds as follows: Section 2 briefly reviews previous research; Section 3 presents our data sources, trends in land-use change in Massachusetts, background on wetlands bylaws and a discussion of their expected effects. Section 4 outlines our empirical strategy to use variation in timing of bylaws; Section 5 discusses results, and Section 6 concludes.

2. Previous research

Local governments in the United States play a significant role in decisions regarding land use change. However, the effects of local land-use regulation on land-use change have not been studied extensively because of the difficulty of obtaining data at the local level on regulations and land-use change. Likewise, few studies in the housing literature have considered the effects of environmental regulations instead of conventional zoning restrictions.

2.1. Land-use regulations and housing supply

The theoretical question of how regulation may affect land values has been explored in a number of papers employing variations on a monocentric city model (see, for example, Capozza and Helsley, 1989; Fujita, 1982; Wheaton, 1982a,b). In general, the literature finds that growth controls—such as greenbelts or urban growth boundaries—will drive up the average values of existing developed land and housing by constraining the supply of additional land for development. Brueckner (1990) and Fischel (1985) argue that the effect of growth controls on the value of undeveloped land might be ambiguous. If controls reduce the allowable density of development below what would have been the profit-maximizing density, values of undeveloped land should decrease. Mild growth controls could theoretically increase undeveloped land values by ensuring that future negative population externalities are limited, although this is also likely to lead to inefficient leapfrog development patterns, as modeled by Wu and Plantinga (2003).

Although the magnitudes of the effects differ across studies, most empirical studies of the effects of regulations find that regulation increases housing prices and reduces the amount of new construction (see, for instance, Fischel, 1990; Glaeser and Gyourko, 2005, 2002; Green, 1999; Landis et al., 2002; Malpezzi, 1996; Pollakowski and Wachter, 1990; Quigley and Raphael, 2005; Rosen and Katz, 1981). Studies specifically concerned with supply response to regulations have concluded that heavily regulated metropolitan areas have lower levels of

[3] For more information on Chapter 40B of Massachusetts General Law, see http://www.mass.gov/dhcd.

[4] Wetlands bylaws should "protect the wetlands, water resources, and adjoining land areas…by controlling activities. . .likely to have a significant or cumulative effect upon…public or private water supply, groundwater, flood control, erosion and sedimentation control, storm damage prevention…water quality, water pollution control, fisheries, shellfisheries, wildlife habitat, rare species habitat…and recreation values. . ." (MACC, 2002).

new construction and more inelastic supply (Green et al., 2005; Levine, 1999; Malpezzi and Green, 1996; Mayer and Somerville, 2000).

Two recent studies examined the effects of land-use regulations on housing outcomes in Massachusetts, using the same database of regulations as this study. Glaeser and Ward (2006) find that single-family minimum lot size is negatively associated with number of new housing permits from 1980–2004 and with overall housing density in 2004. They find no significant impact of the presence of wetlands bylaws alone on the number of annual housing permits, but an index combining wetlands bylaws with septics and subdivision regulations yields a significant negative association. Schuetz (2008b) finds that strict regulation of multifamily housing is associated with lower levels of new permitting for multifamily and single-family housing but finds no significant effect on housing rents.

Our research adds to these existing studies in two ways. First, although the LHR Database was assembled partly because developers in Massachusetts believe that non-zoning regulations, including wetlands bylaws, have substantially constrained their ability to develop new housing, the effects of these non-zoning regulations have not been studied in detail. Second, both Glaeser and Ward (2006) and Schuetz (2008a) consider housing-related outcomes but do not focus on the potentially important outcomes with respect to land-use change.

2.2. Land-use regulations and land-use change

Several studies to date have considered how regulations will influence the pace of land-use change, usually within the framework of models of the optimal allocation of land across potential uses (e.g. Miller and Plantinga, 1999; Stavins and Jaffe, 1990). Focusing on national policies, Lubowski et al. (2008) find that transition probabilities across six categories of land use were influenced by national crop payments programs and the Conservation Reserve Program. CRP payments may also have enduring effects on land use in some areas by generating conservation beyond the contract period (Roberts and Lubowski, 2007), but where agricultural lands are close to metropolitan areas, these programs likely have little effect because of the relatively higher returns to residential or commercial uses (Parks and Schorr, 1997).

A limited number of previous studies directly examine the effects of local land-use policies or regulations on rates of conversion. Carrión-Flores and Irwin (2004) find that conversion from agricultural to residential land in the Cleveland suburbs reflects both market forces, such as population density, proximity to infrastructure and quality of land, and government policies, such as minimum lot sizes. Kline and Alig (1999) conclude that Oregon's statewide land-use planning law has done little to reduce conversion of designated farm and forest land, although land inside urban growth boundaries is significantly more likely to be converted. Cho et al. (2003) use a structural simultaneous equations model to estimate how urbanization, land-use regulations, and public finance interact across counties of five western states, finding that regulations significantly reduced the total developed area. Our study adds to this literature by exploiting variation in regulations across local jurisdictions in Massachusetts and examining an unexplored but potentially important form of local regulation.

Table 1
Key variables and summary statistics ($N=158$ communities).

Variable	Description	Source	Mean	S.D.
DEPENDENT VARIABLES				
Residential development	Acres of land converted to residential development (1971–85, 1985–99)	Mass GIS Landuse (1971, 1985, 1999)	532	428
Change in housing values	Change in median housing values ($), inflation adjusted (1971–85, 1985–99)	U.S. Census (1970, 1980, 1990, 2000)	70154	40698
Change in housing units	Change in number of housing units (1971–85, 1985–99)		1208	1307
Land used / new hsg	Residential dev./new housing units		0.647	0.496
Housing permits	Number of housing permits issued (1971–85, 1985–99)	U.S. Census New Residential Construction Index	1276	1226
Patch distance	Avg. distance converted land to wetlands / avg. dist. available land	Calculated from Mass GIS Landuse and DEP Wetlands	118	18.5
Intersects wetlands	Percent converted land overlapping with wetlands		35.9	13.3
WETLANDS BYLAW				
Years bylaw	Number of years wetlands bylaw in effect (1971–85, 1985–99)	Local Housing Regulation Database	3.39	5.16
Bylaw stringency	Index of stringency of wetlands bylaw		5.36	5.06
GEOGRAPHIC & DEMOGRAPHIC CONTROLS				
Wetlands	Acres of fresh and saltwater wetlands	Mass GIS Landuse (1971, 1985, 1999)	515	636
Total area	Land area of community		12642	7430
Land available	Undeveloped land in forest, fields, or other open space that is not protected	Mass GIS Landuse + Protected/OS (1971, 1985)	6791	5338
Greenvote	Pct of ballots voting "yes" on statewide environmental referenda	Mass Election Statistics (1972, 1982)	71.3	12.1
Population size	Number of residents	U.S. Census (1970, 1980, 1990)	18211	21522
Percent has BA	Percent of population with BA, graduate or professional degree		21.4	13.1
Percent white	Percent of population that is white		97.8	2.82
Percent kids	Percent of population under age 18		32.2	6.52
Distance to Boston	Distance to Boston in miles	Mass GIS (Towns)	23.7	9.19
Dist. to satellite city	Distance to other nearest city in MA		15.1	7.42
# Major routes	Major roads intersecting community	Mass GIS (Eotmajroads)	1.54	1.25
# Exits	Highway exits		1.58	2.16
OTHER LAND USE REGULATIONS				
Single family minimum lot size	Average single-family minimum lot size (sq ft), weighted by district size	Mass GIS (Zoning, 2000)	43077	20895
Multi family lots	Predicted no. of lots on which multifamily units could be built	Schuetz, 2008a	−44.1	6526
Commuter rail stops	Number of commuter rail stops		0.570	0.876
Rep. town mtg	Governed by representative meeting	DHCD community profiles (2004)	0.152	0.359
Council	Governed by city council		0.133	0.340
Cluster index	Index of stringency of cluster zoning	Calculated from Local Housing Regulation Database (2004)	4.31	3.58
Growth mgmt index	Stringency of growth management		1.44	2.71
Exclude wetlands	Wetlands excluded from min. lot size		0.987	0.813
Shape rule	Zoning imposes regular lot shape rule		0.456	0.499
Septic index	Stringency of septic system regs.		2.25	2.12
Subdivision index	Stringency of subdivision rules		13.57	4.92
Percent sewer	Index percent houses served by sewer		2.05	1.77

This paper also contributes to the small literature examining the spatial effects of regulations. McConnell et al. (2006) conclude that both zoning and economic variables determine density within subdivisions in a suburban Maryland county, and calculate that about 10 percent more lots would have been added in the absence of zoning limits on density. Lichtenberg et al. (2007) find some evidence that lot size standards and forest conservation regulations crowd out voluntarily provided shared open space within suburban residential subdivisions in Maryland. Irwin and Bockstael (2004) estimate a hazard model of land-use conversion using data from suburban Calvert County, Maryland, and find that the presence of public sewers, location within the state's Priority Funding Areas, and proximity to open space also speed up conversion, while cluster zoning and large minimum lot sizes decrease the probability of early conversion. Previous research in Massachusetts using case studies from a small number of towns finds that wetlands bylaws do influence where residential units are sited within a developable parcel, conditional on housing permits having been granted (Meyer and Konisky, 2007, 2005). We add to this literature by combining new sources of spatial and regulatory data and by explicitly considering how regulations may have displaced development within and across communities.

3. Land-use patterns and local regulation in Massachusetts

3.1. Data sources

Data on land-use patterns and local regulations in Massachusetts was compiled from several sources (see Table 1). The key source of regulatory data, including the timing of adoption of wetlands bylaws, is the Local Housing Regulation Database. This database on land-use regulations in eastern and central Massachusetts was assembled by the Pioneer Institute for Public Policy and the Rappaport Institute for Greater Boston (2005).[5] In addition to data on wetlands bylaws, the resulting database contains detailed information on zoning practices, including single- and multi-family dimensional requirements, cluster zoning, growth management practices, subdivision rules, and septic system regulations. To measure overall stringency of regulations, we created an index for each type of regulation listed above. More information on the creation of the wetlands stringency index can be found in Appendix A.[6] The communities included in the database, and thus in our study, are cities and towns roughly within a 50-mile radius of Boston (but not including Boston itself), as shown in Fig. 1. This geographic area spans several types of communities including older inner-ring suburban areas, industrial (or formerly industrial) satellite cities, bedroom communities, and relatively undeveloped towns on the urban fringe. The combined population of all communities in our study area was over 4 million in 2000, or just under two-thirds of the total population of Massachusetts.

Data on land-use patterns and other geographic variables come from the Massachusetts Geographic Information System. The land-use classifications available in this system were interpreted from 1:25,000 aerial photography of the state; complete statewide coverage is available only for 1971, 1985, and 1999. Within our sample communities, this dataset contains more than 126,000 patches[7] of land and their land classifications across the periods. Fig. 2 illustrates the spatial distribution of patches for a section of suburban land. The land-use layer includes easily visible patches of wetlands (non-forested freshwater wetlands and salt-water wetlands) and is used to calculate variables measuring wetlands area and land available for development at the start of each period and changes in residential land use. We also use a more detailed wetlands layer to calculate distances from patches converted to residential use to wetlands ("Wetlands DEP"; scale 1:12,000). This layer includes smaller patches of wetlands that may be covered by forest and that overlap with other primary land-use classifications, as shown in Fig. 2.

Demographic and economic characteristics of communities in our sample were assembled from the Decennial Census of Population and Housing, the Massachusetts Department of Housing and Community Development, and the Massachusetts Municipal Profiles (Garwood, 1986). To measure the environmental preferences of local citizens, we collected data on the percentage of votes in favor of state-wide referenda on environmental issues conducted in 1972 and 1982 (Secretary of the Commonwealth of Massachusetts 1972, 1982).[8]

3.2. Patterns of land-use change in Massachusetts

Using the patch-level land-use data, we calculate an aggregate transition matrix for 8 major categories of land use between 1971–85 and 1985–99, shown in Table 2. By far the largest transitions in both periods were the conversion from forests, fields and other open space land use to residential land use. Between 1971 and 1985, residential land use expanded by more than 73,000 acres and between 1985 and 1999 by more than 106,000 acres. We will focus on the effects of wetlands bylaws on the expansion of residential land use, which is the largest transition and could potentially be affected by bylaws across all communities.[9] Conversely, we ignore potential transitions from residential to open space uses; this matches the reality that land already converted to residential use is very unlikely to be converted subsequently to other uses: 99.7 percent of residential land in 1985 was still in that use in 1999. Finally, this transition matrix reveals that baseline state and federal laws do seem to be preventing most conversion of visible (non-forested) wetlands across time. Between 1971–1985, 0.5 percent of wetlands were converted to residential or commercial use, and 0.3% were converted between 1985–1999.

3.3. Wetlands bylaws: regulatory meaning and context

In Massachusetts, decisions to allow new construction are made at the city or town level, in accordance with local zoning bylaws/ordinances and other regulations that govern the development process. All land in Massachusetts is incorporated within city or town boundaries; there is no regulation of land by county governments.

Massachusetts has a statewide Wetlands Protection Act, originally passed in 1972, that regulates development activities in and near certain types of wetlands.[10] While the state Department of Environmental Protection provides oversight of the law, primary responsibility for implementation is granted to local conservation commissions, volunteer boards of three to seven citizens who are appointed by the board of selectmen or city council. By state law, conservation commissions review applications for development in or near (within 100 feet of) designated wetlands areas and decide whether the proposed development would violate the wetlands protection law (Dain, 2006). The commissions may reject applications or impose conditions on the building project in order to protect wetlands resources. Conservation commissions have leeway in

5 For the methodology used to construct the Local Housing Regulation Database, see: http://www.masshousingregulations.com/.

6 Methodology of the indices created for other types of regulation is available from the authors.

7 Parcel level data corresponding to ownership boundaries is not available statewide.

8 The 1972 vote is to approve the adoption of an amendment "...which declares that the people have the right to clean air and water, freedom from excessive and unnecessary noise, and the natural, scenic, historic and esthetic qualities of their environment. It further declares that the protection of the right to the conservation, development and utilization of the agricultural, mineral, forest, water, air and other natural resources is a public purpose..." The 1982 vote is on the "Bottle Bill" which required that a refundable deposit be paid for certain beverage containers sold in Massachusetts (Secretary of the Commonwealth of MA, 1972, 1982).

9 Conversion from undeveloped uses to commercial or industrial land is generally concentrated in a few communities along major transportation corridors and is substantially restricted by zoning.

10 Specifically, state law protects wetlands that border surface waters (also called "bordering wetlands"), land subject to flooding, riverfront areas, and submerged land.

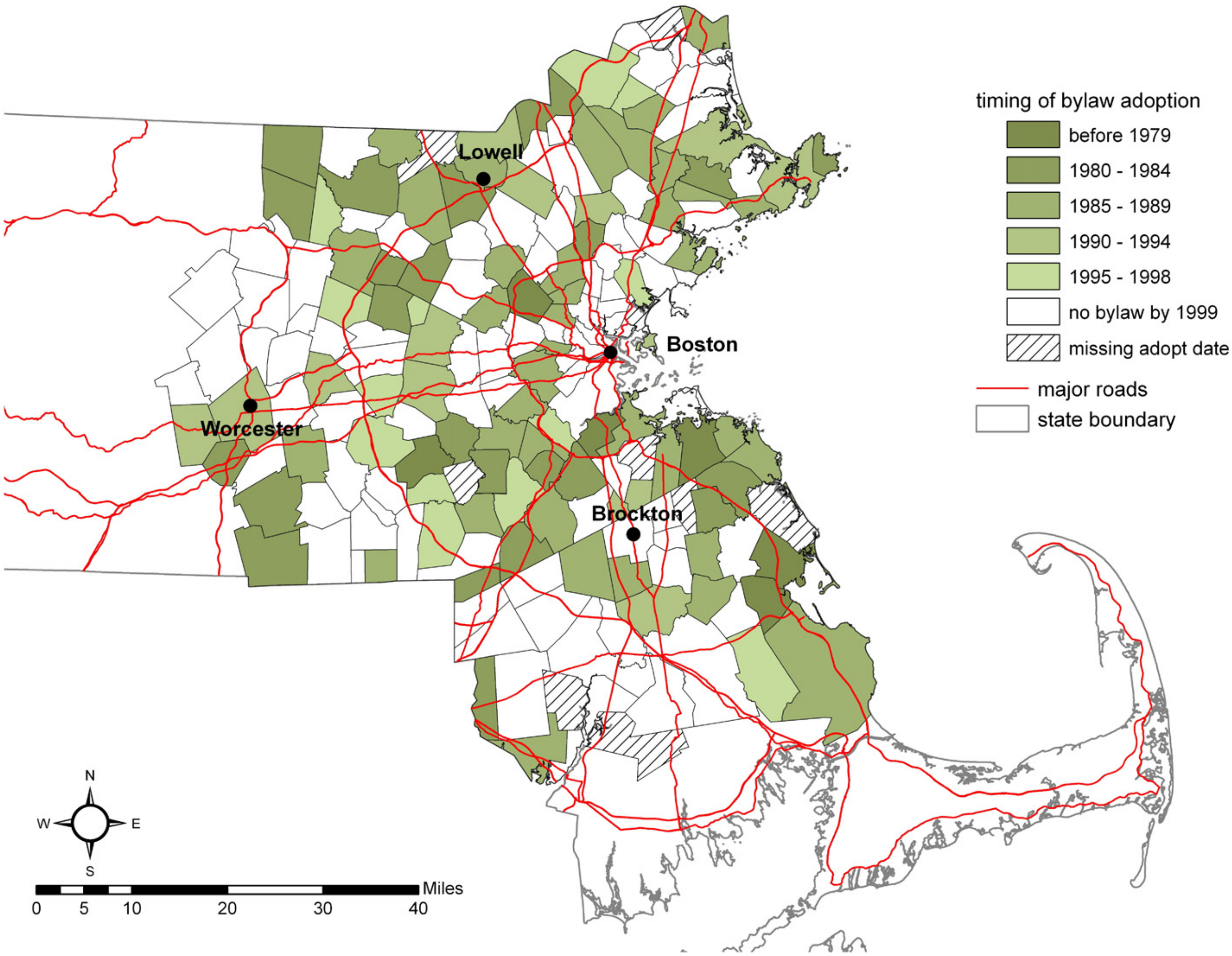

Fig. 1. Study area and spatial variation in the timing of wetlands bylaw adoption. Data source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts.

terms of details, but are bound to uphold minimum protection as specified by the state law (Meyer and Konisky, 2005, 2007).[11]

In addition to the state law, cities and towns may adopt local wetlands regulations that expand jurisdiction in various ways. For instance, state law only protects wetlands that border bodies of water, but local bylaws may extend protection to isolated vegetated wetlands or may regulate development in larger buffer zones around the wetlands.[12] Communities cannot adopt a bylaw unless it offers additional protection beyond the state law.

Wetlands bylaws are just one piece of the complex local regulatory framework governing new residential construction in Massachusetts (Altshuler and Gomez-Ibanez, 1993). The Pioneer/Rappaport Initiative on Local Housing Regulation collected data on more than 100 different details of local regulations pertaining to new residential construction. Every city or town has a local zoning bylaw/ordinance that enumerates where different uses and structure types may be built, sets minimum lot sizes and other dimensional requirements, and outlines procedures for obtaining building permits for each use type. Besides zoning bylaws, all but six of the communities in our sample have subdivision regulations that set design standards for road construction in new residential subdivisions, and nearly sixty percent of the cities and towns in our study have rules regulating installation of septic systems.[13] We control for these other forms of regulation both directly and with community fixed effects.

3.4. Potential effects of wetlands bylaws

Before turning to our empirical strategy, we consider briefly how wetlands bylaws might be expected to influence land-use change and

[11] In addition, federal law under the Clean Water Act specifies that any dumping of fill material into wetlands requires a certification from the state that the project would not violate state water quality standards. The major costs of developing in wetlands areas are likely to be the costs of the permitting process. Physically filling and building on wetlands would also create direct costs, but given the large amount of land near Boston that has been filled and built on in the city's history, it seems probable that it would be profitable to fill wetlands if that were allowed. Meyer and Konisky's (2005, 2007) review of individual projects found only 10% that involved any direct disturbance to wetlands. Conservation Commissions can also stipulate that if projects fill in wetlands, these wetlands must be replicated in another location, which adds additional cost. For a study that assesses whether replication policies are environmentally effective, see Brown and Veneman (2001).

[12] Although the contents of local bylaws may vary, there is considerable agreement on a number of provisions. Nearly two-thirds of communities with wetlands bylaws granted buffer zones to vernal pools, almost 90% regulated buffer zones around isolated vegetated wetlands. Over three quarters expanded the state's definition of “land subject to flooding,” created “no-build” zones around wetlands, or allowed the conservation commission to delay certification of wetlands during certain seasons or weather conditions.

[13] This is only a partial list of land use regulations commonly used in the state; for more detailed discussion see Dain (2006), Glaeser, et al. (2006) or Glaeser and Ward (2006).

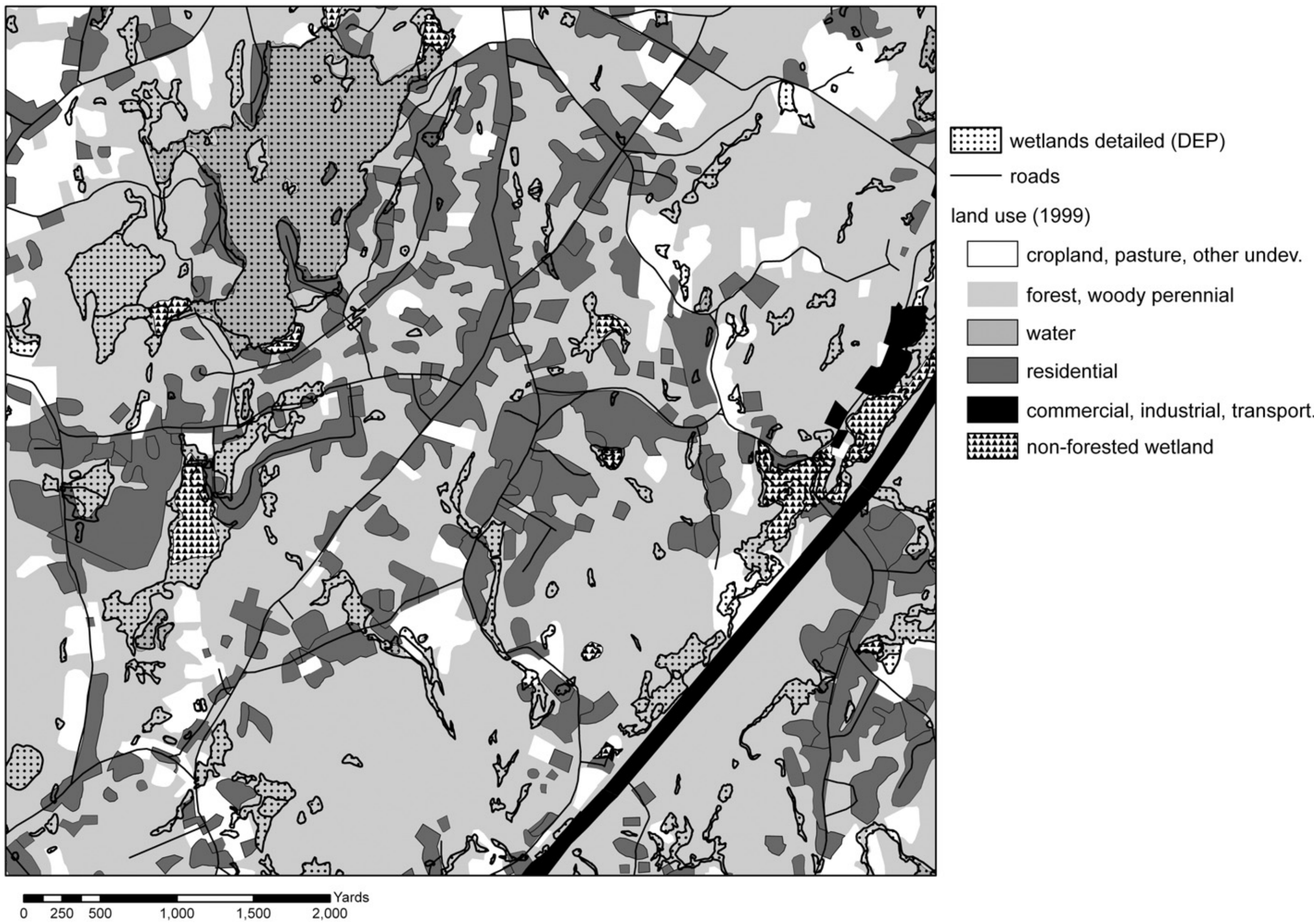

Fig. 2. Illustration of land use categories and detailed wetlands layer. Data source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts.

housing development outcomes in Massachusetts. Although shaped by local policies and constraints, most decisions to convert land to residential uses are made by private actors. Two potential frameworks are useful for thinking about these private decisions: the optimal allocation of a parcel of land to different land-use shares (e.g. Lubowski et al., 2008), and the optimal timing and density of urban development (e.g. Arnott and Petrova, 2006).[14] The first framework is most useful for understanding how wetlands bylaws may impact rates of conversion from open space to residential land use, while the second provides additional insight on how bylaws may influence the quantity, price and density of newly developed housing.

We assume that the direct effects of wetlands bylaws on an individual property owner (with land in or near wetlands) are likely to be twofold: bylaws will increase construction costs and decrease the proportion of a parcel potentially available for development. As noted in the previous section, bylaws will potentially reduce the proportion of a parcel available for development by expanding buffer zones and land defined as "wetlands." Conversion costs are likely to be higher because bylaws add time and complexity to the permitting process, bring additional lands under conservation commission review, and increase rejection risk. Meyer and Konisky (2005) also suggest that local bylaws in Massachusetts significantly increase transactions costs by changing the permitting appeals process.[15]

We consider first the potential impact of increasing construction costs. In the context of optimal land allocation models, greater construction costs mean a higher hurdle to overcome in transitioning a share of land from undeveloped use to residential use. This will tend to lower the equilibrium share of land allocated to residential use and the probability of conversion in each time period. In the context of decisions about the optimal timing of development, higher construction costs will reduce the expected returns to development and thus tend to delay housing construction on parcels affected by wetlands bylaws. The immediate direct effect of higher construction costs is thus to reduce the probability of land-use conversion or residential development on parcels with wetlands. In communities that enact bylaws (and have wetlands), we therefore expect that the supply of

[14] In the first framework, landowners face a choice in each period of how much land to allocate to different uses, such as agriculture, forestry, residential development, etc. Landowners consider the net present value of returns from each type of land use as well as the conversion costs of switching from one use to another. These models have been used to explain the probabilities of parcel-level conversions (Lubowski et al., 2008; Irwin and Bockstael, 2002; Kline and Alig, 1999; McMillen, 1989), the aggregate shares of land converted in larger jurisdictions (e.g., Stavins and Jaffe, 1990; Hardie et al., 2000), and the existing equilibrium shares of land in particular use categories at a single point in time (e.g., Miller and Plantinga, 1999; Parks and Murray, 1994). In the second framework, landowners decide at what time to develop and choose a capital-land ratio for development. These models have been used to explain the chronological and spatial patterns of urban growth and redevelopment (Arnott et al., 1999; Braid, 2001; Brueckner, 1980; Capozza and Helsley, 1989; McGrath, 2000; Rosenthal and Helsley, 1994; Turnbull, 1988; Wheaton, 1982). This framework has also been adapted to explain the impacts of housing and land use policies, including rent regulation, impact fees and land taxation, on housing growth and prices (Arnott and Petrova, 2006; Brueckner, 1997; McFarlane, 2003).

[15] When there is no local bylaw, permit applicants or neighbors can make appeals to the Massachusetts Department of Environmental Protection and go through the state administrative court system. When a local bylaw is in effect, appeals are made through the Massachusetts Superior Court; these judicial appeals tend to have higher costs for all parties (Meyer and Konisky, 2005).

Table 2
Land use transitions 1971–1985 and 1985–1999.

	Land use in 1999 by land use in 1985 (acres)								
Land use 1985	**Agriculture**	**Forest/wp**	**Other land**	**Wetlands**	**Residential**	**Comm/ind**	**Transp**	**Water**	**1985 Total**
Agriculture	99,079	5008	11,769	90	16,148	1753	150	34	134,031
Forest/wp	3246	1,000,540	19,151	1298	78,592	7647	780	254	1,111,508
Other land	1768	17,879	134,574	195	11,325	5800	568	340	172,449
Wetlands	31	1975	173	84,906	183	109	5	161	87,543
Residential	16	61	282	0	495,104	876	43	3	496,385
Comm/ind	20	34	701	2	194	68,748	50	1	69,749
Transp	5	54	329	4	44	90	33,413	2	33,940
Water	3	32	79	305	1	9	0	68,952	69,381
1999 Total	104,168	1,025,583	167,059	86,799	601,591	85,031	35,008	69,748	2,174,986
	Land use in 1985 by land use in 1971 (acres)								
Land use 1971	**Agriculture**	**Forest/wp**	**Other land**	**Wetlands**	**Residential**	**Comm/ind**	**Transp**	**Water**	**1985 Total**
Agriculture	127,973	513	4165	8	11,168	2281	357	68	146,533
Forest/wp	5338	1,109,800	17,557	238	52,907	7648	2946	877	1,197,311
Other land	635	909	150,025	28	9305	6076	586	258	167,822
Wetlands	76	268	213	87,176	260	206	77	254	88,528
Residential	3	3	232	0	422,608	621	140	0	423,607
Comm/ind	5	0	170	0	108	52,840	61	0	53,185
Transp	0	0	9	0	25	76	29,718	0	29,828
Water	1	15	78	93	4	2	54	67,925	68,173
1985 Total	134,031	1,111,508	172,449	87,543	496,385	69,749	33,940	69,381	2,174,986

The table shows how land that was in a given land use in 1971(1985) was allocated in 1985(1999). The diagonals (highlighted) represent no change. The categories correspond to the following Mass GIS categories ("21 land use classification"):
Agriculture = cropland (1), pasture (2).
Forest/wp = forest (3), woody perennial (21).
Other land = open land (6), mining (5), participation recreation (7), spectator recreation (8), water rec. (9), urban open space (17), waste disposal (19).
Wetlands = non-forested wetlands (4), salt-water wetlands (14).
Residential = multifamily (10), single-family <0.25 acre (11), single-family 0.25–0.5 acres (12), single-family >0.5 acres (13).
Comm/ind = commercial (15), industrial (16).
Transportation = transportation (18).
Water = water (20).

developable land shifts in. However, this will then have an indirect effect of raising the equilibrium price of land within that community, thereby increasing the price of housing.

The second channel through which wetlands bylaws may have a direct effect is through restricting the "footprint" available for residential development within a parcel. In a model of land-use allocation this will reduce the equilibrium shares allocated to residential use and constrain supply in a similar fashion to raising construction costs. In the durable structures model, the direct effect would be to decrease density by shrinking the allowable footprint. However, if density is assumed to be variable, developers might respond by building higher structures to compensate for the reduced footprint (maintaining the capital-land ratio on that parcel). In reality, most communities in our sample have zoning restrictions which would not allow increased height. In that case, restrictions on the footprint size would again result in an inward shift in supply and higher housing values.[16]

Both higher construction costs and restricted footprints are expected to lead indirectly to higher housing values. This might then induce conversion of marginal properties that otherwise would have remained undeveloped (this inducement occurs through higher housing rent in the durable structures model and through higher returns to residential land use in the land allocation model).[17] Higher housing values would also tend to encourage greater density on other properties in the community with the bylaw. (Since developers in many communities face limits from zoning, we may not actually observe large changes in density as a result of the bylaws). Both of these responses would mitigate the initial reduction in supply of housing.

Higher housing values in one community would also be expected to increase demand for substitutes: e.g. housing in nearby communities. We could potentially observe increased land conversion or housing development in communities where several neighboring communities have adopted bylaws. Higher housing values might also encourage greater density in neighboring communities, conversion of existing industrial or commercial land to housing or re-development at higher densities.

Although price signals are likely to induce shifts in the pattern of development as a result of bylaw adoption, it may be difficult to observe price effects directly. To the extent that surrounding communities are close substitutes and buyers are mobile, equilibrium prices should be similar across towns with and without bylaws.[18] A price effect might still be felt within housing submarkets (e.g. South Shore vs. North Shore) if home buyers are tied to specific work or family locations and there is differential adoption of bylaws across regions.

4. Estimating the effects of wetlands bylaws

4.1. Using variation in the timing of wetlands bylaws

In order to estimate the effects of wetlands bylaws in Massachusetts, we take advantage of the natural experiment created by having

[16] The inward shift due to restricting density might be partially offset: e.g. in the Arnott and Petrova (2006) model, a constraint on density should make it profitable to develop earlier.

[17] Bylaws could also raise housing values within a community by ensuring that nearby wetlands with amenity value will not be developed in the future. Previous hedonic studies have found limited amenity values of proximity to wetlands. Doss and Taff (1996) find that only scrub-shrub and open-water wetlands increase property values, while much of the Massachusetts wetlands are forested. Mahan et al (2000) find significant but substantively very small (0.003% of median house price) positive impacts of wetlands in Portland, OR.

[18] For example Schuetz (2008b) finds that local multifamily zoning restrictions significantly decrease permits for new units within the restrictive locality but do not lead to significant rent differences by town.

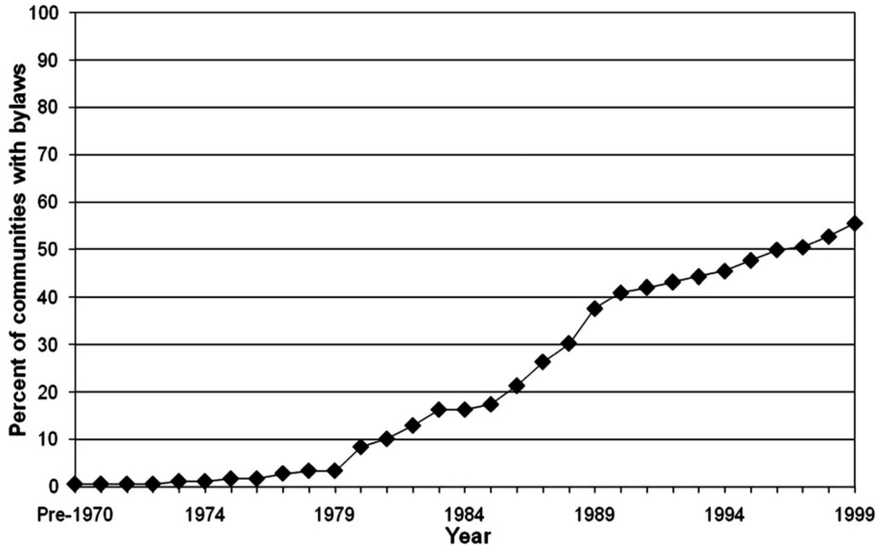

Fig. 3. Cumulative adoption of wetlands bylaws. Data source: Local Housing Regulation Database. Note: An additional 23 communities in the LHR sample adopted wetlands bylaws between 2000 and 2004. We show only the cumulative adoption within the time period that corresponds to our analysis.

bylaws passed at different times across different communities. Our identifying assumption is that after controlling for underlying systematic differences at the community level, we can take advantage of plausibly exogenous residual variation in adoption timing.

Local wetlands bylaws or ordinances in Massachusetts are adopted if they win a two-thirds vote of approval from either the town meeting or city council. In a simple political economy model, adoption would be influenced both by community preferences and by idiosyncrasies of the political process (Feiock, 2004; McDonald and McMillen, 2004; Schuetz, 2008a; Meltzer and Schuetz, 2008). Suppose that wetlands bylaws are written and put on the ballot by two groups: environmentally concerned citizens seeking to protect wetlands and/or anti-development citizens simply seeking to stop development by any convenient tool. Once a bylaw is on the ballot, it must then be passed by a super-majority of registered voters in the community. Given this process, bylaws are more likely to be put on the ballot and passed if the community has a high proportion of environmentally concerned citizens or a high proportion of anti-development citizens. Through residential sorting, these preferences could be correlated with other community characteristics influencing land development outcomes (e.g. resident income and education, distance to Boston, pre-existing open space land or wetlands, other forms of regulation). Our empirical strategy seeks to eliminate these potential systematic differences across communities and take advantage only of residual variation.

In reality, the adoption process for wetlands bylaws also contains an element of randomness. Plausibly exogenous residual sources of variation in the timing of adoption include specific “trigger events,” closely contested votes, and statewide events or media attention. Trigger events are specific unsightly or poorly implemented projects that can catalyze community action even though they do not necessarily reflect overall rates of conversion. Von Hoffman's (2006) case study of Arlington, Massachusetts found that development restrictions tended to be triggered not by overall levels of new development but by particularly unattractive or otherwise objectionable individual projects. With respect to wetlands bylaws, a historical search of local newspapers revealed several events of this nature. For instance, the town of Tewksbury adopted its bylaw in 1991, shortly after the Zoning Board of Appeals ordered town workers to dredge and fill wetlands on a piece of town-owned land in clear violation of the state law (Hart, 1990, 1991). The town of Brewster “overwhelmingly adopted” a wetlands bylaw giving broader authority over development to the Conservation Commission in 1988, in direct reaction to a controversial incident 18 months previously when a developer cleared vegetation and bulldozed a specific parcel (Boston Globe, 1988).

Turnout for local votes may also be swayed by the presence of other ballot measures or election timing. Many ballot measures pass or fail by only a few votes, particularly in small towns. In communities with an open town meeting form of government (unique to New England), residents who strongly favor or oppose a particular measure can often swing the outcome by recruiting like-minded neighbors to attend (Fiorina, 1999). In addition, communities may respond to external events, such as changes in the state law, responses to legal challenges to existing laws, or media attention to environmental issues. For example, in 1987 two planning organizations, the South Shore Coalition and the Metropolitan Area Planning Council, held a meeting to discuss loss of wetlands and published their recommendations. In 1989, *The Boston Globe* published a three-part series entitled “Losing Our Wetlands.” The largest annual adoption rates for wetlands bylaws were between 1987 and 1989, suggesting some adoption happened in response to this statewide media attention.

The data from Massachusetts communities suggest that the adoption of bylaws can be explained partly by systematic community characteristics, but that there is considerable remaining variation in timing.[19] Fig. 1 illustrates the spatial distribution of bylaw adoption across time: there is no clear geographic pattern or appearance of clustering.[20] Across our sample, the adoption of wetlands bylaws has proceeded at a fairly even rate from the early 1980s to the recent past, with a small increase in adoptions in the late 1980s and early 1990s (see Fig. 3 for the cumulative adoption of bylaws across time).

A remaining potential concern with using conditional variation in adoption timing is the possibility that communities are adopting wetlands bylaws in response to high rates of land conversion. We might expect to see communities adopt bylaws just after a period of rapid development. To test whether adoption of bylaws follow a spike in development, we compare the number of permits granted in the calendar year prior to the year of adoption to average annual permits

[19] Using a Cox-proportional hazard model of adoption time as a function of community covariates, we find that higher income (proxied by education) and fewer commuter rail stops are the only significant predictors of adoption (results available on request). Environmental voting records have the expected signs but are not significant determinants of adoption. With a standard linear regression, only 10% of the variation in the number of years that towns had a bylaw is explained by the full set of community level covariates.

[20] Data on the adoption year of nine towns is unavailable (see Fig. 1); these are excluded from the analysis.

Table 3
Testing for a spike in permits prior to bylaw adoption.

Years prior to bylaw adopted	Total permits, year before bylaw adopted	Avg. annual permits period before bylaw adopted	Difference	N
3 years	104.3 (12.5)	104.9 (12.6)	−0.6 (−0.088)	116
5 years	104.3 (12.8)	101.5 (13.4)	2.8 (0.284)	113
10 years	107.3 (14.0)	95.9 (10.8)	11.4 (1.193)	102

Columns 1 and 2 show the mean and standard error (in parentheses) of housing permits issued. Column 3 shows the difference in means and *t*-statistics from two-tailed *t*-tests for difference in means between columns 1 and 2. *T*-tests exclude communities for which permit data are not available for the full period.

granted over several longer periods prior to adoption.[21] We do not find evidence that adoption of bylaws follows a sudden increase in development. The numbers of permits granted in the year prior to adoption are statistically indistinguishable from the average annual permits over the preceding three, five, and ten-year periods (Table 3). If however, it is still the case that higher levels of development in the early part of one of the periods do significantly influence the timing of adoption, this will bias our estimates towards zero (making it less likely that we would see an effect on land conversion rates). Ideally, we would have instruments for wetlands bylaws, but unfortunately we do not have convincing instrumental variables in this case. Given the situation described above, however, our results can be interpreted as a lower bound on the effectiveness of bylaws in slowing conversion.

4.2. Empirical specifications

4.2.1. Estimating effects on land conversion and housing development

We estimate a reduced form model where conversion of land to residential use is a function of factors affecting returns to development and conversion costs:

$$\Delta\, residential\ land^{i}_{\Delta t} = \beta_1 (YrsBylaw)^{i}_{\Delta t} + \alpha Z^{i}_{t} + \gamma_{\Delta t} + \gamma_i + \varepsilon^{i}_{\Delta t} \qquad (1)$$

Residential development[22] from time *t-1* to *t* (e.g. Δt) is assumed to be a function of the number of years that bylaws were in effect during that period (YrsBylaw), a vector of other characteristics *(Z)* of the community environment affecting the relative utility of conversion, measured at time *t*, time-period fixed effects ($\gamma_{\Delta t}$), and jurisdiction-level fixed characteristics (γ_i).

We estimate this function using two strategies. The first takes advantage of the panel structure of the data and includes jurisdiction-level fixed-effects. In this case effects are identified from differences within jurisdictions across time (Table 4, columns 1–4). Fixed characteristics across communities which could affect timing of adoption and conversion rates, such as geographic location or government structure, are differenced out. We also control for several potentially confounding time-varying factors: we include the amount of land in wetlands and the remaining land potentially available for development (unprotected open space[23]). These variables are measured at the start of each period (1971, 1985) to avoid endogeneity concerns. To control for local environmental preferences, we include the proportion of "green" voters, based on results from two state environmental referenda near the start of each period and the proportion of the population that has a bachelor's degree or more (also a proxy for permanent income). Other demographics commonly included in housing models to measure housing demand are added as robustness checks, although none are significantly correlated with the timing of adoption after adding the controls above: population size, percent of the population that is white non-Hispanic and percent of population under age 18.

The second estimation strategy (Table 4, columns 5–6) uses pooled cross-sectional regressions.[24] This allows us to estimate coefficients for fixed characteristics that are differenced out by the first set of models, including distance to Boston, transportation access, government structure, and other regulatory measures that are likely to be correlated with both the adoption of wetlands bylaws and conversion of open space.

To estimate the effects of wetlands bylaws on housing development, we use similar models to those described above, with measures of housing prices, new housing production and the amount of land used per new housing unit as dependent variables (Table 5). These provide alternative measures of whether wetlands bylaws have restricted housing supply.

4.2.2. Testing for shifts in location of development

Restrictions on land use in particular locations are likely to result in changes or displacement in the locations of development. There are a number of possible pathways through which such displacement could occur. First, as previously mentioned, restrictions could result in spillovers of development to nearby communities without bylaws. Second, development might shift to different parcels, presumably farther away from wetlands, within the same jurisdiction. Third, developers may build on the same parcel of land, but alter the locations of individual houses on that parcel.

To explore questions of potential spillover effects across jurisdictions, we include a spatial lag for bylaws in neighboring communities in our basic model (Table 6, columns 1–3). This is measured as the average of the YrsBylaw variable for each of the community's five nearest neighbors (defined by distance between centroids). The modified model is shown in Equation 2:

$$\begin{aligned}\Delta\, residential\ land^{i}_{\Delta t} = {} & \beta_1 (YrsBylaw)^{i}_{\Delta t} + \beta_2 (YrsBylawNN)^{i}_{\Delta t} \\ & + \alpha Z^{i}_{t} + \gamma_{\Delta t} + \gamma_i + \varepsilon^{i}_{\Delta t}\end{aligned} \qquad (2)$$

where *YrsBylawNN* measures the behavior of neighbors; other variables are the same as in Eq (1) above.

To test for whether development shifts to new locations farther from wetlands within the same jurisdiction, we use GIS analysis to measure the distance from the centroids of each of the converted patches of land in each of the periods to the nearest wetlands area. We then normalize this measure by dividing by the average distance of land available for development at the start of each period to the nearest wetlands area. If in towns with wetlands bylaws, developers are choosing parcels further away from wetlands out of all the parcels available, then we should expect to see higher values of this ratio where wetlands bylaws have been adopted (Table 6, column 4). Finally, to test for whether there might be changes in housing location within parcels, we measure the distance from the edges of new

[21] We look for a spike in the previous calendar year, since new bylaws are typically adopted in annual town meetings held in May or June, making it difficult for a community to pass a bylaw in the same year.

[22] This variable is measured as the number of acres converted to residential land use in each period. We also constructed a version that subtracts any land that was previously in commercial or industrial uses (relevant only for a few communities). The results are very similar; we present here the more conservative estimates given by using all land converted. The results are also robust to using the percent change in residential land use or the log of acres as dependent variables.

[23] We exclude protected land, such as state and federal parks, since this land is only made available for development under unusual circumstances (by intersecting the MassGIS "Open Space" layer, accounting for dates of protection with the "Landuse" layer.)

[24] Random effect models produce similar results (available from authors).

residential development to wetlands areas. We construct variables measuring the proportion of newly converted parcels that overlap with wetlands (Table 6, column 5) or are within 100 feet of a wetland.

5. Results

5.1. Wetlands bylaws, land conversion and housing development

Regression results show that wetlands bylaws have slowed the conversion of open space to residential land, although the size of the effect is relatively modest. Each additional year of having a wetlands bylaw is associated with a 10.0–10.1 acre decrease in the amount of open space converted to residential land, controlling for community and time fixed effects and a number of community-level characteristics (columns 1–2 of Table 4). This is approximately 2% of the average acreage converted by communities in each 14 year period. These results suggest a moderate impact of wetlands bylaws on the conversion of land to residential uses. Taking into account the number of years that community bylaws were in effect across the two time periods (for the 158 communities), this equals approximately 10,710 acres protected, compared to 168,039 acres converted in those communities (about 6% of the total).

Table 4
Conversion to residential use and bylaws.

Dependent variable:	Residential development (acres)					
	(1)	(2)	(3)	(4)	(5)	(6)
Years bylaw	−10.11**	−10.05**	−13.45*	−11.19**	−5.19	−7.92**
	(4.55)	(4.52)	(7.54)	(4.64)	(3.63)	(3.52)
Wetlands	0.717	0.734	0.713	0.770	−0.068***	−0.073***
	(1.078)	(1.070)	(1.076)	(1.076)	(0.025)	(0.025)
Land available	−0.101	−0.101	−0.100	−0.100	0.033**	0.034***
	(0.075)	(0.075)	(0.076)	(0.076)	(0.013)	(0.013)
Green vote	−21.56	−20.57	−20.48	−21.34	−54.84***	−56.62***
	(21.61)	(20.87)	(20.94)	(21.08)	(19.72)	(20.08)
Percent has BA degree		−0.850	−1.26	−0.763	3.75*	3.43
		(6.23)	(6.35)	(6.27)	(2.24)	(2.39)
Years bylaw * stringency			0.381			
			(0.700)			
Years bylaw * wetlands				0.002		
				(0.003)		
Distance to Boston					52.72***	51.17***
					(9.64)	(9.72)
Distance to Boston sq.					−1.072***	−1.045***
					(0.186)	(0.190)
Distance to satellite city					10.86	3.57
					(15.99)	(2.79)
# Major routes					−2.67	10.45
					(9.49)	(16.32)
# Road exits					218.3**	−1.08
					(90.8)	(11.49)
Log total land area					−12.29	177.5*
					(20.64)	(98.53)
Commuter rail stops					2.742	−17.87
					(2.70)	(21.28)
Rep. town meeting					−12.02	7.45
					(53.26)	(56.97)
Council					−60.82	−22.64
					(99.95)	(100.59)
Cluster zoning index						−10.31**
						(4.57)
Community fixed effects	Yes	Yes	Yes	Yes	No	No
Time period dummy	Yes	Yes	Yes	Yes	Yes	Yes
Other land use regs?	–	–	–	–	No	Yes
N	316	316	316	316	287	287
Communities	158	158	158	158	144	144
Adj. R^2	0.707	0.705	0.703	0.703	0.592	0.598

*** $p<.01$ ** $p<.05$ * $p<.10$. Parentheses show robust standard errors.
Levels variables (wetlands, land available for development, green vote, percent BA) are measured at the start of each period. Green vote is normalized to a standard normal distribution. The sample is the 158 communities (out of the 187 communities in the Local Housing Regulation database) that had more than 50 acres of wetlands in 1971 and reported the adoption date of wetlands bylaws. Additional demographic controls in columns 5 and 6 are log of the population size, percent white, and percent kids.

Table 5
Housing development measures and bylaws.

Dependent variable:	Change in housing values	# Permits issued	Change in housing units	Land used per new unit
	(1)	(2)	(3)	(4)
Years bylaw	−111.6	−17.84	−27.44	−0.002
	(316.3)	(16.03)	(23.40)	(0.006)
Wetlands	−123.0	2.680	8.270	−0.001
	(104.1)	(3.801)	(5.542)	(0.002)
Land available	13.56***	0.002	−0.107	0.000
	(3.61)	(0.240)	(0.177)	(0.000)
Green vote	−607.7	71.72	102.72	−0.031
	(1304.3)	(93.96)	(71.70)	(0.038)
Percent has BA degree	1252.4***	13.80	−14.38	0.007
	(373.7)	(19.36)	(14.95)	(0.009)
Community fixed effects	Yes	Yes	Yes	Yes
Time period dummy	Yes	Yes	Yes	Yes
N	314	274	316	309
Communities	157	137	158	155
Adj. R^2	0.890	0.753	0.530	0.686

*** $p<.01$ ** $p<.05$ * $p<.10$. Parentheses show robust standard errors.
Levels variables (wetlands, land available for development, green vote, percent BA) are measured at the start of each period. Green vote is normalized to a standard normal distribution.

Results of pooled specifications without community fixed effects but including direct measures of geographic characteristics and the regulatory environment are shown in columns 5–6 of Table 4. These confirm the importance of controlling for the broader land-use regulatory framework, as the results are similar to the fixed effects models but give a slightly more conservative estimate of a 7.9 acre decrease. Of the regulation measures added, the only significant determinant of decrease in residential land use is more generous cluster zoning regulations (Table 4, column 6). Cluster zoning provisions allow higher density development in exchange for setting aside a portion of the land as protected open space. The change in the coefficient on bylaws with the inclusion of this variable suggests that cluster zoning may have been used by communities as a substitute form of regulation to protect open space.

We do not find statistically significant impacts of wetlands bylaws on several measures of housing supply and density (Table 5): the change in housing prices, the number of new permits issued, the change in the overall number of housing units, or the average land converted per new housing unit. If wetlands bylaws were constraining housing supply, we would expect to see smaller numbers of permits and new housing units, as well as perhaps greater density of new housing or greater increases in housing prices. The coefficients on permits, change in housing units and land converted per new unit all show the expected signs (columns 2–4, respectively), but none are statistically significant. The sign on change in housing prices (column 1) is unexpected but also not significant, and the size of the standard errors suggests that this is a very imprecise estimate. The lack of significant results with respect to housing supply may be partly a function of the large amounts of variation in the density of new housing developed in communities with wetlands bylaws.[25] For instance, between 1985 and 1999, Revere, MA added more than 2000 housing units while converting 65 total acres of open space; Plympton, MA added less than 200 new housing units while losing 330 acres of

[25] Correlation coefficient = 0.328 for amount of land used for new residential housing vs. change in housing units.

Table 6
Displacement effects of wetlands bylaws.

Dependent variable:	Residential development (acres)	Change in housing values	# Permits issued	Patch distance	Intersects wetlands
	(1)	(2)	(3)	(4)	(5)
Years bylaw	−9.95**	−135.1	−18.24	0.592*	−0.387**
	(4.53)	(310.3)	(16.14)	(0.301)	(0.168)
Years bylaw of nearest neighbors	−6.50	1286.4**	21.43		
	(8.48)	(589.0)	(27.01)		
Wetlands	0.748	−126.2	2.41	0.021	0.037
	(1.084)	(98.4)	(3.81)	(0.103)	(0.042)
Land available	−0.098	13.00***	−0.005	−0.000	0.003
	(0.076)	(3.66)	(0.237)	(0.003)	(0.002)
Green vote	−20.61	−567.0	76.27	3.18***	0.582
	(21.05)	(1250.9)	(95.29)	(1.08)	(0.703)
Percent has BA degree	−0.820	1241.4***	13.23	0.288	−0.636***
	(6.198)	(375.5)	(19.32)	(0.340)	(0.207)
Community fixed effects	Yes	Yes	Yes	Yes	Yes
Time period dummy	Yes	Yes	Yes	Yes	Yes
N	316	314	274	316	316
Communities	158	157	137	158	158
Adj. R^2	0.704	0.893	0.752	0.370	0.643

*** $p<.01$ ** $p<.05$ * $p<.10$. Parentheses show robust standard errors.
Levels variables (wetlands, land available for development, green vote, percent BA) are measured at the start of each period. Green vote is normalized to a standard normal distribution. Patch distance is the average distance from converted land patches to wetlands/average distance from available land parcels to wetlands (and expressed as a percent). Development intersects wetlands is the percent of newly converted parcels converted that overlap with wetlands.

open space. Such variation reminds us that there is not necessarily a close association between land-use change and production of housing units because of strong differences in density determined by zoning.[26]

We might expect systematic sources of heterogeneity in the effects of bylaws, and include corresponding specification checks. Communities with larger amounts of wetlands might have stronger preferences for protection (or conversely, less concern about losing a more abundant resource). However, the interaction between years of bylaws and land in wetlands is not significant (Table 4; Column 4) or large in magnitude. We also might expect stronger effects in communities with more stringent wetlands regulations. To test this we use an index based on detailed information about various provisions in the bylaws (see Appendix A).[27] Again, we do not find significant differences for communities with stricter bylaws (column 3). Non-linear effects of timing may occur if there is a learning curve for new types of regulation or if the specific details of bylaws have changed greatly over the time period. Anecdotal evidence from von Hoffman (2006) suggests that local officials may become more effective at applying the regulations over time. However, the results do not change substantially if we allow for non-linear effects by adding higher order terms (results available from authors). There may be other sources of heterogeneity in the enforcement and implementation of wetlands bylaws that are difficult to measure. Many bylaws are intentionally written to grant discretionary authority to local officials and others contain language that is open to multiple interpretations. Future work could look qualitatively at how regulations on the books may differ from regulations as they are enforced.

5.2. Changes in the location of development

As discussed in Section 3, wetlands bylaws may have altered the location of residential development, either across or within jurisdictions. In Table 6, we show the results of several tests for different types of displacement. In the models shown in columns 1–3, we include a measure of the number of years neighboring jurisdictions have had wetlands bylaws, as well as the timing of the jurisdiction's own bylaw. If bylaws are pushing development from communities with bylaws into communities without them, we would expect to see greater conversion to residential land and more new development in jurisdictions whose surrounding neighbors have bylaws. The results do not show evidence for a strong displacement across jurisdictions in terms of land conversion or permits (Table 6, columns 1–2), or land used per new unit of housing (not shown). More years of neighboring towns' bylaws are associated with higher housing prices, however (Table 6, column 3). If several neighboring communities have bylaws, the combined restricted supply in that housing submarket may have pushed housing prices up in the home community.

The final models shown in Table 6 test for possible evidence of shifts in location within rather than across jurisdictions. There is a positive, marginally significant relationship between wetlands bylaws and the normalized distance from the centers of newly converted patches of land to nearest wetlands (Table 6, column 4). This suggests that wetlands bylaws result in conversion of land that tends to be further away from wetlands. This is consistent with (although not conclusive proof of), some displacement of development to parcels where development would not be hindered by wetlands bylaws. In addition, we find (Table 6, column 5) that there is a significant decrease in the proportion of new conversion that has edges that overlap with wetlands.[28] This is also consistent with small shifts in development away from wetlands areas, possibly within the same parcels. These results are consistent with the case study findings from Meyer and Konisky (2005, 2007), suggesting that wetlands bylaws alter the location of new development within parcels.

6. Conclusion

The evaluation of local strategies to protect open space has been limited because of the difficulty of obtaining data on both policy tools and land-use patterns at the community level. Our results indicate that wetlands bylaws in Massachusetts have led to a statistically significant but modest reduction in the amount of open space converted to residential land. Bylaws likely altered the location of housing development within jurisdictions, but did not have significant impacts on housing prices, new housing permits rates or the density of new development.

Although it is perhaps not surprising that wetlands bylaws have reduced the rate of open space conversion, the estimated impacts are fairly small, at least when compared to the heated political rhetoric of opponents of such bylaws. There are several possible explanations. First, wetlands are already protected by federal and state law, so that the local bylaws give only some marginal additional protection. Second, wetlands bylaws are one element of the complicated network of land-use regulations that affect residential development in most communities in Massachusetts. The marginal effect of any one regulation is thus likely to be small, a finding that is consistent with other recent research on the effects of policies such as inclusionary zoning (Schuetz et al., 2008; Knaap et al., 2008). Finally, our results suggest that some of the potential constraints of land-use restrictions may have been deferred by shifting development to other available parcels within communities. As demand for housing continues to grow, undeveloped land, even near wetlands areas, may come under new pressure for development. This highlights the need for additional research on the long term impacts of local options for protecting open space.

Future research should also consider the potential effects of environmental regulations on the supply of affordable housing. Wetlands regulations are one of the few types of regulation that

[26] The 20 communities that were excluded from the study because they were already substantially developed in terms of land use issued more than 35,000 permits for new construction between 1971 and 1999.

[27] Unfortunately data on the details of bylaw contents are available only for 2004.

[28] We find a smaller and marginally significant decrease (not shown) in the proportion of new conversion that is within 100 feet of wetlands.

cannot be bypassed or altered in the course of applying for permission to develop affordable housing under the state's Chapter 40B law. Anecdotal evidence of early attempts to develop affordable housing under 40B in several Suburban Boston communities indicate that some proposed developments were effectively blocked by environmental regulations, but systematic quantitative impacts are not known.[29]

Our results also emphasize the potential divergence between development as measured by the amount of land used for new housing and development as measured by the production of new housing units. Some communities with wetlands bylaws may encourage building at high densities and preserve large parcels of open space with wetlands, while others force higher per-unit land consumption by excluding wetlands from minimum lot size calculations. Future research should work to understand the local processes and policies that determine these divergent density outcomes.

Finally, while limiting the ability to develop greenfields may mean higher housing costs for new consumers, it also may increase the relative returns to redeveloping already dense urban areas. From an environmental perspective, redeveloping areas and building close to existing infrastructure likely means net gains in environmental benefits. If there are clear gains from developing more densely in some areas while preserving contiguous areas of open space in another, there may be scope for a tradable development rights system that would work across communities. Such policy solutions will depend in part on increased future attention to how ecological benefits vary with different patterns of housing (e.g. Lenth et al., 2006; Pejchar et al., 2007) across site and community level landscape scales.

Appendix A: Methodology for creating wetlands bylaw stringency index

Communities have a number of different tools by which they can expand the regulation of wetlands beyond protections offered by the state law; the more tools used in a bylaw, the more restrictive that bylaw will be. Thus to capture the overall stringency of each bylaw, we create an index that sums the number of components by which the bylaw exceeds state regulations. Results of principal components analysis suggest that each component should be given roughly equal weight in this index, so for simplicity of interpretation we created unweighted indices, standardizing individual variables (set to mean zero and variance one) before summing them. The index ranges from zero to sixteen, with zero indicating the lowest possible level of stringency.

$$WETINDEX = VERNAL + VERNWIDE + NEWBUFF + LSF + NOBUILD + DELAY$$

VERNAL is a measure of local regulation of vernal pools. Values range from 0 to 3, indicating the number of ways in which the bylaw expands the regulated jurisdiction around vernal pools beyond the state's standards: (1) listing vernal pools as a resource area, (2) regulating a buffer zone around vernal pools, or (3) defining the pool's “habitat” as part of the resource area. VERNWIDE is the width (in feet) of buffer zones around vernal pools. NEWBUFF is a categorical variable increasing in stringency, indicating whether the bylaw regulates buffer zones around isolated vegetated wetlands. LSF is a measure counting the number of ways in which the bylaw expands regulation over land subject to flooding: (1) adding terms to “land subject to flooding”; (2) extending a buffer zone around land subject to flooding; or (3) expanding the definition of land subject to flooding beyond state's definition (i.e. shallower depth or smaller volume). NOBUILD is a continuous variable indicating whether the jurisdiction creates “no building” or “no disturbance” zones that limits the type or amount development activities near wetlands, and if so, the width (in feet) of the no-build zone. DELAY is a dummy variable that indicates whether the bylaw gives the Conservation Commission the right to delay certification of wetlands during certain times of the year or weather conditions.

[29] Case studies of some of the early 40B challenges are described in Haar and Iatridis (1974); a more recent summary of the interaction between 40B and wetlands regulations is offered in Courchesne (2003).

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