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Environmental regulation and land use change:
Do local wetlands bylaws slow the conversion of open space to residential uses?

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Abstract

The conversion of open space land to residential, commercial, and industrial uses as cities develop is an issue of significant environmental concern. Local governments play a key role in land use decisions and can use a variety of policy tools to influence the rate of land use change or to permanently protect open space. An important but controversial form of local regulation in Massachusetts is local wetlands protection bylaws, which give towns and cities additional regulatory power over land near wetlands. This paper uses newly compiled information about land use regulations in towns and cities in eastern Massachusetts, in combination with data on land use changes and other community characteristics, to analyze the relationship between local wetlands bylaws and rates of conversion from open space to residential land uses between 1985 and 1999. We use variation in the timing of adoption of wetlands bylaws to examine possible effects on conversion rates, housing permits issued, and the ratio of land converted to residential use per new housing unit. We find that for communities with more than five percent of land area in wetlands, having a wetlands bylaw for the full extent of the 1985 to 1999 period is associated with an estimated 1.1–1.4 percentage point decrease in the rate of conversion of forest and agricultural lands to residential uses, after controlling for other factors. We find some evidence that wetlands bylaws may slow the rate of permitted single- and two-family housing units in cities and towns with more than five percent of land area in wetlands, but do not find that bylaws are associated with lower numbers of permits for all housing types. Finally, we find weak evidence that wetlands bylaws are associated with less land used per new unit of housing. Future research should further explore the question of how local regulation affects the spatial patterns of new housing and preserved open space.

Keywords: environmental regulation, open space, land use, urban policy

JEL classification: Q24, R14, R31, R52

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It is available at http://www.cid.harvard.edu/cidwp/grad/018.htm. Comments are welcome and may be directed to the corresponding author, Katharine R.E. Sims, at kresims@fas.harvard.edu.

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The Sustainability Science Program at Harvard's Center for International Development seeks to advance basic understanding of the dynamics of human-environment systems; to facilitate the design, implementation, and evaluation of practical interventions that promote sustainability in particular places and contexts; and to improve linkages between relevant research and innovation communities on the one hand, and relevant policy and management communities on the other. Further information on the Sustainability Science Program can be found at http://www.cid.harvard.edu/sustsci.

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1. Introduction

The conversion of open space, including agricultural fields, forests, orchards, wetlands and recreation areas, to residential, commercial, and industrial uses across the United States is an environmental issue of significant current concern.[1] The environmental costs of such 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. Several policy options for protecting open space are currently being used, including land use regulations, land development taxes, impact fees, public land purchase, and private land trusts. The evaluation of proposed or implemented strategies to protect open space, however, has been complicated by the fact that much of the decision-making about land use takes place at the local level, where data on regulations and development decisions are limited.

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.[2] Local wetlands protection bylaws, which give towns and cities additional jurisdiction beyond state and federal laws over land near wetlands, have been a potentially important and controversial type of regulation in Massachusetts. The Massachusetts Homebuilders Association 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."[3] The concern is that local land use regulations reduce the supply of new housing by limiting the supply of land and/or increasing the costs of construction, potentially resulting in higher housing costs. On the other hand, the Massachusetts Association of Conservation Commissions (2002) cites the purpose of a model wetlands bylaw as: "to protect the wetlands, water resources, and adjoining land areas…by controlling activities deemed by the Conservation Commission 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, deemed important to the community." This quote articulates the view of advocates that local wetlands bylaws will protect important environmental resources that provide societal benefits.

While we do not directly assess the costs or benefits of wetlands bylaws in this paper, we seek to answer whether such laws have actually affected the rates of conversion of land from undeveloped open space to residential uses. Previous research in Massachusetts suggests that wetlands bylaws do affect where residential units are sited within a developable parcel, conditional on housing permits having been granted (Meyer and Konisky 2005), and that some measures of regulation, including wetlands bylaws, are associated with lower numbers of housing permits (Glaeser and Ward 2006). However, very little is known about whether wetlands bylaws have deterred the aggregate conversion of land from undeveloped to residential uses or influenced the amount or density of new housing. Although focusing on one specific type of local regulation, our findings contribute to the broader literature on the evaluation of local regulatory policies in two ways. First, few previous studies of the determinants of land use change have

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[1] According to the USDA, in the five years between 1992 and 1997 an estimated 11.2 million acres (more than 2 million per year) were developed throughout the U.S. The amount of land that has been converted appears to reflect preferences for low-density development as much as increase in population. Kolankiewicz and Beck (2001) estimate that of 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.

[2] All land in Massachusetts is incorporated within city or town boundaries, so there is no regulation of land by county governments. Local laws adopted by towns are called bylaws, those adopted by cities are called ordinances. In this paper, we will use the term bylaws to mean both bylaws and ordinances.

[3] "Statistics Show Limited Growth in Massachusetts Housing Starts" (June 25, 2004) http://www.hbama.com/content/page.php?id=58&st=Building_Issues.

specifically examined the role of land use regulation at the local level, and few studies in the literature on the effects of land use regulation on housing market outcomes have focused on environmental regulations rather than conventional zoning. Second, our dataset allows us to include a full set of controls, including measures of the broad regulatory environment in each community and local environmental preferences, which are likely to be correlated both with adoption of wetlands bylaws and with rates of development, but which are typically difficult to observe.

In this paper, we take advantage of new data from Massachusetts on local land use regulations, as well as data on land use change and housing permits, to explore whether local wetlands bylaws may have affected the rate of conversion of land from open space to residential uses, the quantity of new construction, or the amount of land used per new housing unit between 1985 and 1999. Specifically, we examine how conversion rates and other measures of development vary with the number of years that wetlands bylaws have been in place, including regression controls for other community-specific factors which might influence both the adoption of wetlands bylaws and the rate of land conversion. These include controls for the prevalence of wetlands, environmental preferences (measured by votes on statewide environmental referenda), other land use regulations, and standard determinants of the relative returns to residential development and conversion costs, including demographics and distance to major city. To control further for possible omitted characteristics, we use data from the preceding period (1971–1985) to confirm the magnitude of our results using a first-differences approach. We will argue qualitatively why the timing of wetlands bylaws in this particular context is likely to be a good source of plausibly exogenous variation, conditional on other control variables, with which to identify policy effects. However, since we could not find strong instrumental variables for the bylaws, we are not able to rule out completely the possibility that town characteristics that changed over time may have affected both the adoption of bylaws and the rates of development or that communities could be passing bylaws in response to rapid land conversion. In case of the first, we think it is most likely that our results represent an upper bound on the absolute value of the magnitude of the effect. With respect to the second, we think this problem is unlikely, as we test for patterns in permitting that we would expect to be present if this were the case and do not find evidence of this type of relationship. Nonetheless, we advocate a cautious interpretation of our results.

We find that having a wetlands bylaw for the full extent of the 1985–1999 period, after controlling for other relevant factors, is associated with an estimated 1.1–1.4 percentage point decrease in the rate of conversion of forest and agricultural lands to residential uses for towns and cities that have substantial land area in wetlands (more than 5 percent). Out of a mean 10.3 percent of land converted, wetlands bylaws are thus associated with a reduction in the share of land converted between 1985 and 1999 of about 10 to 14 percent. Having a larger amount of land area in wetlands is associated with lower rates of conversion, which suggests that state and federal wetlands regulations do pose a constraint on land conversion, although we argue that the magnitude of this effect does not seem large. The estimated magnitudes of the effects of bylaws on conversion rates are robust to a variety of specifications including different sets of controls, regional fixed effects, spatially-weighted standard errors, and a first-differences specification using data from the 1971–1985 period. With respect to the quantity of new housing developed, we find that wetlands bylaws are associated with a reduction in the number of one- and two-family units permitted between 1985 and 1999 for communities that have more than 5 percent land area in wetlands, but not all specifications are statistically significant. We do not find a significant reduction in permits of all housing types associated with wetlands bylaws, consistent with the explanation that higher-density housing is more likely to be built on already developed land. Finally, we present suggestive evidence that wetlands bylaws may be associated with less consumption of land per new unit of housing. This effect on the pattern of development could be additionally beneficial to the environment to the extent that it encourages lower fragmentation of open space, but our results are not conclusive on this point. However, the co-existence of low rates of open space conversion with high rates of permitting in some communities does suggest that solutions that balance land protection and housing development are possible.

The paper proceeds as follows: section 2 briefly reviews the relevant existing literature; section 3 outlines our data sources, the patterns of land use change in our sample, and an overview of wetlands and other land use regulation in Massachusetts; section 4 outlines our conceptual framework and empirical strategy; section 5 presents results; and section 6 concludes.

2. Review of previous literature

Local governments in the United States play a significant role in decisions regarding land use change. The effects of land use regulation on housing prices and new construction have been studied in the theoretical and empirical literature, and a solid foundation of theoretical models of land use change exists. However, relatively little is known empirically about the effects of local land use regulation on land use change, in part because of the difficulty of obtaining local-level data on regulations and land use change.

2.1 The effects of land use regulations on land prices and housing construction

The theoretical question of how regulation may affect land values has been explored in a number of papers that modify the standard monocentric city model of land rents (see, for example, Capozza and Helsley 1989; Fujita 1982; Wheaton 1982). In general, the literature finds that growth controls—such as greenbelts or urban growth boundaries—will drive up the value of existing developed land and housing by constraining the supply of additional land for development. However, Brueckner (1990) argues that the effect of growth controls on the value of undeveloped land is ambiguous. Although controls may delay the receipt of rents or reduce the allowable density of housing and thus profitability, mild controls may also raise total rents by reducing negative population externalities. More traditional types of zoning, such as minimum lot sizes, may reduce land values by lowering allowable density below the profit-maximizing point, but are likely to raise the price of finished housing by requiring high per-unit land consumption (Fischel 1985).

Although the magnitudes of the effects differ across studies, most empirical studies on the effects of regulations on prices and rents find evidence that regulation increases prices and reduces the amount of new construction. Fischel (1990) provides a thorough review of the early empirical evidence. Several papers have found increased prices both across submarkets within a single housing market (for example, Green 1999; Pollakowski and Wachter 1990; Rosen and Katz 1981) and across metropolitan areas (Malpezzi 1996; Glaeser and Gyourko 2001, 2002; Quigley and Raphael 2005). A few studies have specifically tried to estimate the effects of regulations on supply elasticity and have concluded that, as expected, heavily regulated areas have lower levels of new construction and lower supply elasticities than less regulated metropolitan areas (Mayer and Somerville 2000; Green, Malpezzi, and Mayo 1999; Green and Malpezzi 1996; Levine 1999). Landis, Deng, and Reilly (2002) provide a more recent review of the key questions and evidence around growth management and its possible impacts, focusing on California. They conclude that some types of local growth control and management programs do appear to limit population growth where adopted, but most probably have little effect in terms of restricting the amount or pace of new housing or increasing housing costs.

With respect to Massachusetts in particular, two recent studies have examined the effects of land use regulations on prices and permits (also using the newly compiled Local Housing Regulation Database, which we describe in section 3). Glaeser and Ward (2006) assess the relationship between a broad range of regulations and housing permits, prices, and overall density. They find that minimum lot size is negatively associated with number of new housing permits from 1980–2004 and with overall housing density in 2004. Dummy variables indicating the presence of regulations on wetlands, septics, and subdivisions are not individually significant, but an index combining all three measures yields a significant negative association with the number of annual housing permits. Using the Local Housing Regulation Database in a study of rental housing markets, Schuetz (2006) finds that strict regulation of multifamily housing is associated with lower levels of new permitting for both multifamily and single-family housing and higher prices for owner-occupied housing but finds no significant effects on contract rents for rental housing.

2.2 The effects of local land use regulation on land use

The common starting point for most theoretical models of land use conversion in both the environmental and urban economics literatures is a utility maximizing individual landowner who faces a choice of whether, how, and when to convert land from one use to another. The landowner's decision is based on net present value calculations, comparing returns from the current land use with returns to alternative uses and conversion costs. The probability of converting a parcel to a given use increases as the relative returns to that use increase and decreases with higher conversion costs. This general intuition has been applied to model several types of land use outcomes, including the probability of parcel-level conversions (e.g., Carrion-Flores and Irwin 2004; Irwin and Bockstael 2002, 2004; Lubowski, Plantinga, and Stavins 2006; Kline and Alig 1999; McMillen 1989), the aggregate shares of land converted in some larger jurisdiction (e.g., Stavins and Jaffe 1990; Hardie et al. 2000), or the existing shares of land in particular use categories at a single point in time (e.g., Miller and Plantinga 1999). In section 4 we apply a simplified version of the common framework to our analysis.

Several empirical studies to date have confirmed that price changes and national policies do influence the pace of land use change in ways consistent with this theoretical framework. In a study of land use change across the nation using data from the USDA's National Resources Inventory, Lubowski, Plantinga, and Stavins (2003) evaluate determinants of historical land use change across the U.S., looking at conversion between six different land use categories. They find that in all use categories, transition reflects changes in profits to each use (mostly driven by prices of agricultural inputs and outputs), but government policies also have a significant impact. In particular, the Conservation Reserve Program decreased the conversion from pasture, while government crop payments affected conversion rates of agricultural land. A recent paper by Roberts and Lubowski (2006) finds that Conservation Reserve Program payments may also have enduring effects by generating land use change that may extend beyond the contract period. However, where agricultural lands are close to metropolitan areas, programs such as the CRP may 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. Carrion-Flores and Irwin (2004) examine land use conversion from agricultural to residential land in the Cleveland suburbs and find that a mixture of market forces and government policies affect the likelihood of conversion. In particular, high initial population density, large parcel size and large minimum lot sizes (3 acres or more per lot) decrease the probability of conversion, while this probability increases with proximity to infrastructure and higher quality of land. Proximity to the urban core (Cleveland) has a non-linear effect on conversion probabilities. Kline and Alig (1999) examine Oregon's statewide land use planning law, which was intended to reduce conversion of land in designated "farm" and "forest" zones, while encouraging conversion within already developed areas inside the urban growth boundary. They find that land use planning does not reduce conversion of designated farm and forest land. However, they find that population growth, land ownership by entities other than farmers or corporate investors, and being inside urban growth boundaries all significantly increase the likelihood of conversion. Cho, Wu, and Boggess (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 reduced the total developed area by approximately 12.2 percent between 1982 and 1992. With respect to potential spatial effects of regulations, McConnell, Walls, and Kopits (2006) study density within subdivisions built in a suburban Maryland county, asking whether low-density, land-intensive patterns of housing seem to be driven by zoning regulations or by market forces. They conclude that both zoning and economic variables determine density; and calculate that about 10 percent more lots would have been added in the absence of density limits. Lichtenberg et al. (2005) assess whether lot size standards and forest conservation regulations in Maryland affect how much open space developers provide within suburban residential subdivisions; they find some evidence that regulation crowds out voluntarily provided shared open space. Irwin and Bockstael (2004) focus on the timing of conversion from undeveloped to developed uses and estimate a hazard model of conversion using data from suburban Calvert County, Maryland. They find that proximity to employment centers (Washington, D.C. and nearby towns) and the shoreline decrease time until conversion. With respect to policy variables, they 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.

The complexity of zoning regulations and other policies at the local level and the lack of centralized data sources on these has limited the types of policies that have been studied as well as the ability to study effects at the local jurisdiction. While we focus mainly on wetlands bylaws in this paper, we will also report our findings with respect to how land use change varies with minimum lot size and other regulations that have been previously studied.

3. Background on land use change and local regulation in Massachusetts

3.1 Data sources

Our analysis draws on a variety of information sources about local land use regulations, land use patterns, other geographic characteristics, and socio-economic and political variables. The full list of variables and sources are described in detail in Table 1; summary statistics are shown in Table 2. All variables are aggregated to the level of the city or town, which is the unit of observation for the study.

Data on wetlands bylaws and other local land use regulations come from the Local Housing Regulation Database, a new database on land use regulations in eastern and central Massachusetts that was assembled in 2004 by the Pioneer Institute for Public Policy and the Rappaport Institute for Greater Boston. These data were assembled by coding local regulations and interviewing town staff to clarify ambiguities.[4] The resulting database contains detailed information not only on local wetlands bylaws but on various types of zoning practices, including single- and multi-family dimensional requirements, cluster zoning, growth management practices, road design standards for subdivisions, and septic system regulations. More information on these variables and the indices we create to summarize them can be found in Appendix A. The communities included in the database, and thus in our study, are 187 cities and towns that are roughly within a 50-mile radius of Boston (but not including Boston itself). Figure 1 shows the location of the towns and cities in the database. This geographic area spans several types of localities including older, dense inner-ring suburbs, industrial (or formerly industrial) satellite cities, employment centers along a technology corridor, bedroom communities, and relatively undeveloped

[4] More information on the methodology used to construct the database can be found at www.pioneerinstitute.org/municipalregs/.

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 in Massachusetts and other geographic variables comes from the Massachusetts Geographic Information Systems (MassGIS) database.[5] The land use classifications available in this system were interpreted from 1:25,000 aerial photography of the state; complete statewide coverage is available for 1971, 1985, and 1999. In addition, we used data on the amount of wetlands, location of major roads, and amount of protected land obtained from the following datalayers: DEP Wetlands, Towns, Executive Office of Transportation, and the Protected and Recreational OpenSpace Datalayer. By intersecting (overlapping) these layers using GIS software, we are able to identify which parcels of land have converted from open space to residential uses (the main dependent variables), as well as other land characteristics used as control variables (see descriptions in Table 1).

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. To measure the environmental preferences of local citizens, we use the percentage of votes, out of total votes on that issue, in favor of state-wide referenda on environmental issues conducted in 1972, 1982, and 1986.[6]

3.2 Patterns of land use change in Massachusetts

Between 1985 and 1999, the major land use transition in Massachusetts has been the loss of open space land (agriculture, forest, and other land) that is converted to residential uses. While data on land use is not available at the parcel level in Massachusetts, the datalayer by MassGIS does track patches of land over time.[7] It is therefore possible to track how all the land classified with a particular use in 1985—for instance agriculture—had changed by 1999. We used the MassGIS land use layer to calculate transition matrices that track these changes in land use for the 187 towns and cities in the Local Housing Regulation Database. Table 3 shows a transition matrix for 8 major categories of land use (our groupings); Table 4 shows a transition matrix for all 21 of the land uses categorized by MassGIS. Both tables show how land in a given use in 1985 is subsequently allocated in 1999.

In our sample, of the 134,031 acres of land in agricultural uses in 1985, 16,148 acres (or 12.0 percent of that land) had been converted to residential uses by 1999. Of the 1.11 million acres of forest in

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[5] Data is available for download at www.mass.gov/mgis/database.htm. Massachusetts has one of the best state geographic information systems in the country. Further details on the data layers can also be found at this site.

[6] Data on referenda comes from the *Massachusetts Election Statistics* series. The 1972 vote is to approve of 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 Legislature is authorized to adopt necessary legislation and to provide for eminent domain takings where required for the purpose of the amendment." The 1982 vote is on the "Bottle Bill" which required that a refundable deposit be paid for certain beverage containers sold in Massachusetts. The 1986 vote is on a recommendation about proposed acid rain legislation: "Shall the Commonwealth of Massachusetts urge the President of the United States and the United State Congress to enact a national acid rain control program which would require a fifty percent reduction in total national sulfur dioxide emissions by the year 1995 and which would allocate the required reductions in sulfur dioxide emissions, and the costs of achieving those reductions, equitably among the states?"

[7] The term "parcel" refers to a contiguous plot of land owned by a single entity; we have no information on defined parcels. The Mass GIS data allow us to identify "patches" of geographically contiguous land that share the same use; however, these may include multiple parcels held by different owners, so conversion of a patch may represent either a single conversion decision by a single owner or many separate decisions by multiple owners.

our sample, 78,592 acres (or 7.1 percent of that forest) had been converted to residential uses by 1999. Another 11,325 acres (or 6.6 percent) of other open space lands, mainly from the open land and urban open space categories, had been converted to residential uses. A smaller fraction of agricultural, forest, and other lands had been converted to commercial or industrial use: 1.3 percent, 0.7 percent, and 3.4 percent respectively. Land already in residential uses by 1985 was very unlikely to be converted to other uses: 99.7 percent of residential land was still in that use in 1999. In addition, we can see that the state laws to protect wetlands appear to be working in the case of the non-forested wetlands as classified by MassGIS: only 0.3 percent of these lands were converted to residential or commercial use by 1999.

These transition matrices outline how land use changed in total across the 187 towns in the Local Housing Regulation Database. However, there is considerable variation across communities in the amount of open space that is lost during this period, as can be seen in Figure 2, which shows a map indicating the loss of open space in each town between 1985 and 1999. Fifty-two communities converted less than 5 percent of their agriculture and forest lands to residential uses during this period; 57 cities or towns converted more than 10 percent; and 10 communities converted more than 15 percent. Theoretical models of land use change would suggest that differences in conversion rates across municipalities should reflect differences in the returns to developed uses and conversion costs. In the following two sections, we explore how land use regulation in Massachusetts, particularly local wetlands bylaws, could alter returns to residential development and conversion costs and thus affect conversion rates.

3.3 Wetlands bylaws in the Massachusetts regulatory context

Following national trends, municipal governments in Massachusetts began adopting zoning ordinances as early as the 1920s, after the historic Supreme Court Euclid decision in 1926, and subdivision regulations became widespread in the decades after World War II. The 1970s, however, saw a general expansion in local regulations governing development. Altshuler and Gomez-Ibanez (1993) cite several reasons for the emergence of new forms of regulation: municipalities became increasingly concerned about possible negative fiscal impacts of development, the growing environmental movement encouraged citizens to protect open space and natural resources, and local advocacy groups became more effective at intervening in the political process. The Pioneer/Rappaport Initiative on Local Housing Regulation collected data on more than 100 different details of local regulations pertaining to new residential construction, illustrating the complexity of the current process. Wetlands bylaws are just one piece (and a relatively recent one) of the local regulatory framework governing new residential construction in Massachusetts.[8] 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. Many zoning bylaws set additional requirements for development, such as lot shape rules or caps on the number of permits that may be issued in a single year. 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.[9]

[8] All the regulations discussed here are primarily relevant to residential development; localities also regulate development of commercial and industrial uses, but through different mechanisms, such as parking requirements, restrictions on building height and FAR, and limits on noise, traffic, and general nuisance impacts. These regulations are outside the scope of our study.
[9] This is only a partial list of land use regulations commonly used in the state; for more detailed discussion of the content of local bylaws, see Dain (2005), Glaeser, Schuetz, and Ward (2006) or Glaeser and Ward (2006).

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. 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 state's wetlands protection law (Dain 2006). They may impose conditions on the building project in order to protect wetlands resources and they have leeway in terms of details, but the law specifies minimum protection which conservation commissions are bound to uphold (Meyer and Konisky 2005).[11] In addition to the state law, cities and towns may adopt local wetlands regulations that expand jurisdiction beyond the state minimum. 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. By 1999, ninety-four cities and towns in Greater Boston had adopted bylaws or ordinances that extend protection beyond that granted by the state law.[12] The adoption of wetlands bylaws has proceeded at a fairly even rate from the early 1980s to the present, with a small increase in adoptions in the late 1980s and early 1990s, as shown in Figures 3 and 5. Although the contents of local bylaws may vary, there is considerable agreement on a number of provisions, as shown in Table 5. Nearly two-thirds of communities with wetlands bylaws granted buffer zones to vernal pools, almost 90 percent 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.

4. Framework for estimating the effects of wetlands bylaws

4.1 Conceptual framework

The conceptual framework for our analysis draws on a very simple version of the models of land use change described briefly in Section 2. These models posit a dynamic maximization problem in which a utility maximizing risk-neutral individual landowner solves for the best use for each parcel of land, choosing among a set of alternate uses (Stavins and Jaffe 1990; Parks and Murray 1994; Miller and Plantinga 1999; Lubowski, Plantinga, and Stavins 2006). The solution to such models is generally a decision rule that specifies that a landowner will convert a parcel of land if the present value of the expected net benefits from the new land use, minus the costs of converting to that use, are higher than the present value of the expected net benefits of any other use minus the costs of converting to that use. A straightforward characterization of this type of problem (Bockstael 1996) is thus given as a discrete choice and can be framed generally by expressing the choice in utility terms. We focus on a very simple

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

[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 developers would be willing to fill wetlands if that were the only cost. Meyer and Konisky's (2005) review of nearly 600 individual projects found less than 10 percent that involved filling any 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] We are missing data on the adoption year of nine towns in the sample; these are excluded from the analysis.

version of the discrete choice problem: whether or not to convert undeveloped land to residential uses.[13] As our data will show, this is by far the largest land use transition in Massachusetts in our period of study.[14] We also assume the decision is irreversible, because land in developed uses is very unlikely to convert back to open space, and we assume that landowners are basing their expectations of future returns on information available to them at the start of the time period.

We assume that the utility of converting a representative parcel j (currently undeveloped) in town i, at time t to residential uses (VC_{jit}) is a function of the characteristics of the parcel (x_{jit}), including conversion costs, and an error term (ε_{jit}). This is expressed as:

(1) $$VC_{jit} = f(x_{jit}, \varepsilon_{jit})$$

The utility of leaving the representative parcel in its undeveloped state (VU_{jit}) is similarly:

(2) $$VU_{jit} = f(x_{jit}, \varepsilon_{jit})$$

Then the probability of observing the conversion choice ($y_{jit+1} = 1$) between time t and time $t+1$ is just the probability that the utility of converting is higher than the utility of not converting:

(3) $$\Pr(y_{jit+1} = 1) = \Pr(VC_{jit} > VU_{jit})$$

[13] This is similar to the approach used in several other papers, including Bockstael 1996, Irwin and Bockstael 2002, 2004, Carrión-Flores and Irwin 2004.

[14] In practice, a small fraction of land was converted from undeveloped uses to commercial or industrial land. Commercial and industrial uses are also much more restricted by zoning than residential development; on average in our sample communities, 80 percent of land area is zoned to allow residential uses while only 10 percent is zoned to allow commercial or industrial uses.

That is, we expect there will be a higher probability of conversion when the utility of the conversion choice, which includes conversion costs, is higher than the utility of leaving the land in its undeveloped state.[15] Due to data constraints, we will only be able to observe conversion choices at the aggregate town/city level, so we re-write this in terms of the land converted to residential use as a share of total developable parcels:

(4) $$(\text{Share land converted})_{it+1} = \Pr(VC_{it} > VU_{it}) = f(x_{it}, \varepsilon_{it})$$

Thus we expect the share of land converted from undeveloped to residential uses in each town to be a function of observable characteristics and an unobservable error term. The primary drivers of this decision are likely to be the relative returns to residential land use versus undeveloped land uses, and conversion costs.

Local wetlands bylaws may affect the probability of converting a given parcel of land to residential uses by increasing conversion costs or potentially decreasing the returns to residential development. If indeed these are significant changes, then we would expect to see communities with local wetlands bylaws converting less land to residential uses, all else equal. Wetlands bylaws likely increase conversion costs by adding complexity to the permitting process, making additional lands subject to conservation commission review, or increasing the risk of seeking a construction permit. Meyer and Konisky (2005) suggest that having a local bylaw makes a strong difference in the transactions costs of the appeals process. When there is no local bylaw, permit applicants or neighbors can appeal the permit to the Massachusetts Department of Environmental Protection and the appeals process goes 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).

With respect to the returns to new residential development, there may be both direct and indirect effects of bylaws. The most likely direct effect is a lowering of returns to residential use if the bylaws prevent developers from building housing units at the maximally profitable density. Or, if developers can simply maintain the same number of units per parcel by altering the micro-level siting of units, then wetlands bylaws will not change returns to residential use except through transactions costs. Two types of indirect, general equilibrium effects may also be possible and could increase the returns to new residential development. If wetlands bylaws restrict supply sufficiently, they could increase the returns to development by driving up underlying land prices. This effect is likely to be small within individual communities, since consumers can substitute across jurisdictions, but may well increase prices for the region as a whole.[16] A more localized impact is that by preserving open space, bylaws could increase the

[15] In addition, unlike many models of land use, we are modeling changes over a period as a function of observed characteristics at the beginning of the period. We are therefore not assuming that land use in each time period has already reached equilibrium, in which case the returns to different land uses would be equal and we would expected only changes in the relative returns to land use to affect the probability of conversion. Land uses will not necessarily be in equilibrium if the option value of future development is important or if land markets are thin; either would require a threshold of excess rents to be crossed, in which case levels will matter. A recent paper which demonstrates that both levels and changes are important empirical determinants of land use change in the context of expiring Conservation Reserve Program contracts is Roberts and Lubowski (2006). A similar strategy is also adopted by Carrión-Flores and Irwin (2004).

[16] An example of the difficulty in finding price effects across locations within MSA due to overall supply restrictions is given by Schuetz (2006), which finds that although local multifamily zoning restrictions significantly decrease construction within the restrictive locality, they do not lead to significant rent differences by town.

amenity values of a community, also making new development more attractive.[17] This effect is also likely to be limited in magnitude because most of the land protected by wetlands bylaws is private and less desirable for recreation, so amenities values are probably small.

4.2 Empirical specification

To test how wetlands bylaws may be related to conversion rates, we use OLS regression to estimate the following linear model of the percent of land in city or town *i* in undeveloped uses at time *t* that was converted to residential uses by time *t+1*:[18]

(5) $$(\text{Pct undeveloped to residential})_{it+1} = \beta_o + \beta_1 YrsBylaw_{it} + \alpha' Z_{it} + \varepsilon_{it}$$

The variable $YrsBylaw_{it}$ is the number of years that community *i* has a wetlands bylaw between *t* and *t+1*. *Z* is a vector of control variables that proxy for other relevant factors potentially affecting the relative utility of converting land versus leaving it in an undeveloped state.

The main dependent variable in our analysis is the percent of forest and agricultural land in 1985—excluding land that was designated as protected open space—that is subsequently converted to residential uses before 1999.[19] For instance, the town of Tewksbury in 1985 had 4849 acres of forests and agriculture that were not classified as protected. Of these acres, 546 were converted to residential uses between 1985 and 1999; the share converted is thus 11.27 percent. There is considerable variation in values of the dependent variable across the state, as can be seen in Figure 2, which shows the shares of not-protected forest and agricultural land in each community that were converted to residential use between 1985 and 1999.

This specification relies on variation in the timing of wetlands bylaws to estimate the effects of wetlands bylaws on land development outcomes; we are implicitly comparing outcomes between communities that had bylaws for the full sample period with those from communities that had more recently adopted bylaws or had not yet adopted them.[20] In the next section we offer a brief explanation for plausible sources of quasi-random variation in the timing of wetlands bylaws, conditional on other community characteristics. We believe we are able to control for many of the characteristics of communities that would be correlated both with wetlands bylaws and rates of conversion, and that the patterns in the data suggest that wetlands bylaws themselves are not caused by the share of land converted. However, ultimately our estimates rest on these two assumptions, and we discuss briefly below how possible failures would affect the interpretation of our results.

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[17] For a full theoretical development of this issue and the potential for open space regulations to create leapfrog development, see Wu and Plantinga (2002).

[18] We choose a linear model for simplicity of interpretation rather than other models that would constrain the predicted values of the dependent variable to be between zero and one. We also estimated a logistic model (share of land converted = exp(xB)/(1+exp(xB))) using quasi maximum likelihood estimation. The fit of the logistic model was slightly better but did not substantially change the results.

[19] We exclude protected land, such as state and federal parks, since this land is only made available for development under unusual circumstances.

[20] We also assume a linear relationship between years of bylaws and outcomes; the true relationship could have a more complex shape, particularly if the length of time a community has had a bylaw matters for enforcement.

4.3 Determinants of variation in the timing of wetlands bylaws

Like all forms of land use regulations, local wetlands bylaws/ordinances are adopted through a community's formal political process, namely by winning a two-thirds vote of approval from either the town meeting or city council. The probability of adopting a bylaw is likely to reflect the community's characteristics and preferences, including the presence of concerned and organized citizens who successfully petition to put the measure on the ballot, residents' preferences over environmental protection and urban growth in general, current housing market conditions, and the broader regulatory framework around development. Adoption may also reflect the saliency of the threat to wetlands, which could be affected by media or interest group attention, the introduction of bylaws in neighboring communities, and particularly controversial completed or proposed developments. As described below, we include a number of variables to control for possible systematic differences in observable characteristics between communities with respect to both likelihood of having a wetlands bylaw and the rate of land conversion. As Figure 4 shows, there is no clear geographic pattern of adoption of wetlands bylaws: neighboring communities adopted bylaws at different times.

Plausibly exogenous sources of variation in the timing of wetlands bylaws come from several sources. One is the occurrence of trigger events, particular development projects that damage or threaten wetlands or other environmentally sensitive land but that are small enough in scale that they do not affect the overall rate of conversion. Several events of this nature are described in contemporaneous articles in *The Boston Globe.* 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, although with the implicit consent of the Conservation Commission (Hart 1990, 1991). Similarly, 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 20–30 acre parcel, but the town had no authority to stop the clearing activities (Boston Globe, 1988). These anecdotes echo the results of von Hoffman's (2006) case study of Arlington, Massachusetts. He found that development restrictions tended to be triggered not by overall levels of new development but by particularly unattractive or otherwise objectionable individual projects.

Other possible sources of variation in timing arise from local politics, media attention, or statewide events. Turnout in local elections, which may be affected by the presence of other ballot measures or specific officials, as well as small variations in the wording of particular provisions, can sway the passage of wetlands bylaws. Reviewing weekly community updates columns in *The Boston Globe*, we found that ballot measures frequently passed or failed by only a few votes, especially in smaller towns. Particularly in communities with a town meeting form of government, which is unique to New England, residents who strongly favor or oppose a particular measure can swing the outcome by recruiting a fairly small group of like-minded neighbors to attend (Fiorina 1999). Adoption of a bylaw might coincide with the appointment of new conservation commission members, which occurs at the end of a fixed term: a new, more active conservation commission might propose a bylaw; or if a new conservation commission is perceived as less aggressive or active than the previous one, residents might propose the bylaw to achieve enhanced protection. 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 instance, 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 1987–1989, quite possibly as a result of statewide organizing and media attention rather than local events.

4.4 Controlling for possible systematic differences between communities

According to our model of land conversion, in the absence of regulation, the probability of conversion depends on factors that affect the returns to undeveloped land, the returns to residential land, and conversion costs. Some of these factors may also affect the likelihood of a community adopting a wetlands bylaw. Within our sample, most of the cross-sectional differences in probability of conversion result from differential returns to residential land.[21] Therefore we control for a number of variables used as common proxies for residential land values: distance to Boston, access to major highways, educational attainment and demographic characteristics of the population, and physical constraints on land supply. In addition to these measures of market determinants of conversion, we include several variables on political characteristics, namely the strength of environmental preferences (measured by votes on statewide environmental referenda) and the type of local government. We also include the initial endowment of wetlands, shares of land in various use types, and the initial density of housing, all of which are likely to affect conversion costs and may be correlated with timing of bylaw adoption. All specifications also include an indicator of whether the community had a very small share of wetlands (less than five percent of total land area) at the start of the period and an interaction between this variable and the years of wetlands bylaw. The coefficient on the years of wetlands bylaw variable is therefore interpreted as the effect of the bylaw for communities that had at least five percent wetlands in 1985. We make this adjustment because a few highly developed communities have passed wetlands bylaws but have extremely small amounts of wetlands remaining, so it is unlikely that the bylaw will affect conversion rates by much. Each regression table shown in the next section specifies the included controls.[22]

Communities that adopt wetlands bylaws might also differ systematically along other important dimensions of the regulatory environment (although we actually find very weak evidence that this is the case). Like wetlands regulations, these regulations have the potential to raise conversion costs of undeveloped land or to alter the relative returns to residential uses. Controlling for the broader regulatory environment is not a simple task, since the overall regulatory environment is composed of hundreds of individual policies and restrictions. We create aggregate index variables that capture the stringency of regulation along several broad categories of policies: wetlands, septics, single-family and multifamily dimensional requirements, cluster zoning, growth management, and other zoning. The methodology for creating the index variables is described in Appendix A. Since measures of these variables are available only for the current period, we run the models both with and without these controls.

While we believe our regression strategies are able to control for the most important community characteristics that could affect both the timing of adoption of wetlands bylaws and development outcomes, we cannot completely rule out the possibility of unobservable characteristics biasing our results. In particular, our estimates may leave out important non-random aspects of local enforcement or non-linear effects in timing. Regulations on the books may differ significantly from regulations as they are enforced. Many bylaws are intentionally written to grant discretionary authority to local officials, while others contain language that is open to multiple interpretations.[23] Communities with or without

[21] The returns to undeveloped land are essentially the quality of land and climate that affect agricultural productivity, and the price of agricultural outputs. Because our sample is within a relatively close geographic area, we assume that there are few major geographical or climatic differences in returns to agriculture or forestry across our sample (we do check robustness with region fixed effects however). Similarly, the physical costs of conversion—construction materials and labor—are likely to be quite similar across communities in the region.

[22] The specifications shown also exclude Worcester, which is an extreme outlier in size of housing market. The results do not change substantially if we include or exclude Worcester, however.

[23] For example, many of the wetlands bylaws grant local conservation commissions authority over land within a designated circumference around vernal pools; based on identical language, some communities enforce 100 feet of

bylaws may choose to enforce unwritten or informal policies, such as informal “no-build” or “no-disturbance” zones around wetlands. If communities who tend to enforce environmental provisions strongly are also those who adopt wetlands bylaws, our results will tend to overestimate the magnitude of the effects of wetlands bylaws.[24] 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; in this case our estimates might understate the effects of the regulations in the longer term if towns make the regulations stricter on the books or through enforcement over time. Unfortunately, our small sample size and the lack of annual land use data or annual data on the specific details of the bylaws limits our traction on these issues.

4.5 Testing for possible reverse causality

A potential source of bias in our analysis is the possibility that communities adopt wetlands bylaws directly in response to high rates of land conversion. If this were true, we might expect to see adoption of bylaws just after a sharp increase or spike in the number of housing permits. 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 granted over several longer periods prior to adoption. 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, so it would be difficult for a community to pass a bylaw in the same year that permits increased. Two-tailed t-tests on the difference in mean permits between each of these periods (Table 6) provide no 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. However, we cannot test the possibility that bylaws are adopted in reaction to a surge in the completion of new housing units, some period of time after permits have been issued, although the lack of a spike in permits makes this unlikely. If higher levels of overall community development are causing the adoption of wetlands bylaws, then our results may understate the magnitude of the effect of wetlands bylaws because we are more likely to observe laws in those towns with relatively high development rates.

5. Results

We find that having a wetlands bylaw for an additional year, after controlling for other factors, is associated with an estimated 0.08–0.10 percentage point decrease in the rate of conversion of forest and agricultural lands to residential uses in communities that have at least five percent of their land area in wetlands. Over the full extent of the period, this corresponds to a 1.1 to 1.4 percentage point decrease. Compared to the mean conversion rate of 10.3 percent in the 1985–1999 period, this is approximately a 10 to 14 percent share of the land converted. These results are statistically significant at the five percent level across most but not all specifications of the regression model. We also find that having more naturally occurring wetlands is associated with lower rates of conversion, which suggests that the statewide wetlands protection act does pose some supply limitations, although the magnitude does not seem large. Our findings are robust to several alternate specifications including different sets of control variables, different measures of the rate of conversion, spatially-weighted standard errors, and a first differences approach that compares rates in the 1985–1999 period with the 1971–1985 period.

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jurisdiction while other enforce 200 feet, and both interpretations could be supported by the wording of the regulations.

[24] Conversely if citizens are passing such laws to force stricter enforcement by local conservation commissions, our estimates may underestimate the magnitude.

When we measure development in terms of number of housing permits issued, we find that wetlands bylaws are associated with a decrease in single family permits but not with total permits. This corresponds to the intuition that wetlands bylaws would be expected to affect only the types of development that are occurring on previously undeveloped land; this is most likely to be the construction of new single family units. These results are significant only at the ten percent level in our theoretically preferred specification. With regard to the amount of land used per new unit developed, we find that wetlands bylaws are associated with a decrease in the amount of land used. However, the magnitude is small and not statistically significant for our preferred specification. Below we discuss our results in greater detail.

5.1 Wetlands bylaws and conversion rates

Table 7 shows the results from a regression of the percent of land converted from not-protected agriculture and forest lands to residential uses between 1985 and 1999 on the number of years that wetlands bylaws were in place during that period and relevant controls. The magnitude of the result is relatively robust across several different specifications (Tables 8, 9, 10), although not all coefficients estimated are significant at the five percent level. We find that each additional year of having a bylaw in place between 1985 and 1999—for communities with more than five percent of land area in wetlands—is associated with an estimated 0.08 to 0.10 percentage point decrease in the share of land converted, holding other factors constant.

The amount of existing wetlands in a community is an important control variable.[25] Communities with larger amounts of naturally occurring wetlands are slightly more likely to have wetlands bylaws, and we would expect wetlands bylaws to have a larger effect where there is a large area of wetlands. All specifications include a dummy for jurisdictions that have less than five percent of land area in wetlands and an interaction between this dummy and the number of years that wetlands bylaws are in effect. The estimated coefficients on the interaction between the "no wetlands" dummy and years of wetlands bylaws are positive and of a larger magnitude than on the bylaw years alone; however, since the coefficients are not statistically significant, we cannot draw any conclusions about the relationship between bylaws and conversion rates for communities with very little wetlands. These communities include cities and towns that are closer to Boston and already very developed.[26]

The percentage of a community's land in wetlands is also statistically significantly related to the rates of conversion from open space to residential uses. Each additional percentage point of land in wetlands is associated with approximately 0.17 percent less land converted. This suggests that the state law that prohibits building on wetlands does possibly pose a constraint to development. If builders were simply substituting to other available land when wetlands are encountered, then we would not expect this coefficient to be negative and significant. However, the magnitude does not seem very large. The mean percent of wetlands across our communities is about 13 percent; a doubling of the mean, or an increase to 26 percent wetlands, would still correspond to only a 2.2 percentage point decrease in conversion rates over the full period. Including the density of four different types of wetlands (marsh, wooded swamp,

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[25]While we do not have a perfect measure of all types of wetlands as they existed at the beginning of the period, the transition matrices indicate that very small amounts of wetlands have been developed during the relevant period, so we can use the current density of wetlands in communities as a measure of the density at the beginning of the period without major concern. The estimated coefficient of wetlands bylaws is 0.12 without this control.

[26] Specifically, the jurisdictions that have wetlands bylaws by 1999 but do not have more than five percent land area in wetlands are: Winthrop, Arlington, Plymouth, Lowell, Marblehead, Winchester, Watertown, and Newton.

cranberry bog, and salt marsh) has no effect on other coefficients and the magnitudes of all wetlands types are negative (Table 7, column 6). [27]

Controls for environmental voting preferences and other regulations are important inclusions in terms of possible omitted variables, although adding or dropping these variables does not change the magnitudes greatly. Including measures of the stringency of other regulations, as described in Appendix A, increases the magnitude of the estimated association slightly.[28] Dropping the measures of environmental voting preferences (Column 5) increases the magnitude of the wetlands bylaw variable (as we would expect if green voters are more likely to pass wetlands bylaws and also to use other measures to slow development) but the change is small. [29] Other controls perform as might be expected.[30] The percent of non-protected forest and agricultural land that is converted to residential use between 1985 and 1999 increases non-linearly with distance to Boston, increases with the number of major routes in the community, and decreases with initial residential density.

5.2 Wetlands bylaws and conversion rates: robustness checks

The negative association between years of wetlands bylaws (in communities with more than five percent wetlands) and rates of conversion from undeveloped land to residential use is robust to several other specifications, as shown in Tables 8, 9, and 10. We re-calculate the dependent variable subtracting out from the denominator land that is developed as commercial or industrial use (Table 8, column 1). While the majority of land in undeveloped uses is converted to residential uses, a small portion goes to commercial/industrial; this specification checks that this alternate option for land conversion does not bias our results. Our preferred measure of the dependent variable is the share of not-protected land that was in agriculture or forestry uses in 1985 that is converted. However, our results are very similar when the dependent variable includes all types of "open" land, such as urban open space and recreational land (see Table 3 for definitions and Table 8, column 3), and when we do not exclude protected land areas from the

[27] However the coefficient estimates on percent wooded swamp and percent salt marsh increase in absolute value and significance when we do not control for environmental referenda votes; to the extent that environmentally-minded residents chose to live in communities with more open space and wetlands, and that environmental preferences do matter for conversion, omitting these preferences from the regression is likely to give biased estimates on the effects of amount of wetlands.
[28] None of the other regulatory measures were estimated to have significant impacts on conversion in these specifications.
[29] Signs on the measures of environmental voting preferences in 1972 (environmental amendment) and 1982 (bottle bill) are generally negatively related to conversion, though not statistically significant in this specification. The sign on the 1986 vote is positively related to conversion rates, which is counterintuitive. We think that this is due to income differences across the votes: the 1972 and 1982 votes are highly correlated with wealth but the 1986 vote received high vote levels in several less affluent communities which are more developed. The strong correlations between the green vote variables and income make it difficult to interpret them independently.
[30] Additional control variables tried which did not change the results included: high school graduation rates, expenditures per pupil, number of exits off highways, presence of commuter rail lines, number of subway stations, county-level fixed effects, tax rates, non-school fiscal expenditures, and the year communities first adopted any zoning regulations.

calculations (Table 8, column 2).[31] Including region fixed effects and controlling for the stringency of wetlands bylaws[32] also do not substantially change the magnitude of results (Table 8, columns 5 and 6).

While we control for a wide set of variables, there may still be community-specific unobservable characteristics that could create bias. As an additional check of our results we take advantage of the data available from a previous period (1971 to 1985)[33] to run a first-differences specification. This essentially removes any fixed characteristics of communities, thereby controlling for time-invariant community characteristics. The estimates of the effect of wetlands bylaws are identified in this case from changes in the variables between the two periods. The magnitude of the estimated effect across these specifications is only slightly smaller, ranging from a 0.07 to 0.09 percentage point decrease in rates of conversion associated with having a wetlands bylaw for an additional year (Table 9). Finally, we test for spatial autocorrelation in the error terms (Table 10). Including the spatial weights changes the standard errors very little; some coefficients become marginally more significant, but the results are essentially the same as clustering standard errors by region, as in the other models.

5.3 Wetlands bylaws and new housing construction

Although our primary research question is what effect wetlands bylaws have on the amount of open space converted to residential land, we also examine two alternate measures of development: the number of new housing units permitted and the amount of land converted per new housing unit. We use these measures as dependent variables because development can be quantified in somewhat different ways. In particular, the amount of land required to build a given number of new housing units will vary depending on the density of development; it is possible that wetlands bylaws change either the density or pattern of development, or the total number of units built, but not the overall amount of land converted.

Overall, we find mixed evidence on the likely effects of wetlands bylaws on new housing units permitted; the correlation between years of bylaws and total units permitted is not statistically significant, however bylaws are significantly negatively associated with development of one- and two-family units in towns that have more than five percent of land in wetlands (Table 11). The difference in estimated effects on total permits and single-family or one- and two-family permits (Table 11, columns 1, 2, 3) is not surprising, because one- and two-family homes are more likely than multifamily housing to be constructed on newly developed land and therefore might be expected to be most affected by wetlands bylaws.

However, when we consider only those communities that were adding net single family housing during this period by including an additional dummy and interaction for the other communities (Table 12, column 4) we actually find a smaller association that is significant only at the ten percent level in some specifications. Roughly twenty communities in our sample have a net loss of single-family units between 1985 and 1999; these communities are very likely to have redeveloped from low-density to high-density

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[31]As the distribution of open space land is not correlated with wetlands bylaws this essentially introduces measurement error into the right hand side. The estimated coefficient on wetlands bylaws is somewhat smaller in absolute magnitude and is not statistically significant, which is consistent with attenuation bias. However, we include this robustness check since our measures of protected land may not perfectly measure what is protected due to some uncertainties in the purchase dates.

[32] Unfortunately we do not have information on when specific clauses in the bylaw were adopted, so the measure of stringency assumes that the bylaw has been of constant stringency over time. Data on the details of bylaw contents are available only for 2004.

[33] Calculating conversion rates for the earlier period, however, is somewhat problematic as we are less sure that we have accurate data on which lands were protected open space in 1971.

residential housing.[34] The estimated magnitude suggests that each additional year of having a wetlands bylaw between 1985 and 1999 is associated with a 0.62 percent decrease in the number of single- and two-family permits. This corresponds to roughly six fewer permits per year on average, or approximately 80 fewer permits total for communities that had wetlands bylaws in effect during the entire period. For communities that had more than five percent of wetlands and added single family housing, having a wetlands bylaw for the full period is associated with an estimated decrease of 8.7 percent in permits, but this coefficient is only statistically significant at the ten percent level (Table 11, column 4). If we drop the measures of environmental preferences from the control set (Table 11, column 5), wetlands bylaws appear to be more strongly associated with a decrease in permits. This suggests that without controls for environmental preferences we might slightly overestimate the effect of the regulations on housing permits. The results are not robust to dropping the variables measuring other types of regulation (Table 11, column 6)—the magnitude decreases and the estimate is not statistically significant, suggesting relevant correlation between other regulations and number of permits. We find similar results of wetlands bylaws using an alternate measure of development, which normalizes the number of permits granted by existing housing stock, giving a rate of growth in housing stock (Table 11, column 7). The magnitude of the coefficient suggests that each additional year of the bylaw is associated with about a 0.57 percent decrease in permits as a share of stock, but the p-value of the estimate is only 0.06.

5.4 Wetlands bylaws and land used per new unit

A final question of interest is whether wetlands bylaws have any effect on the total amount of land used for a given number of new housing units. From an environmental perspective, preserving open space is an important goal. However, limiting the supply of housing may increase housing prices. The goals of adding new housing and preserving open space can theoretically both be accomplished if the new units are built at relatively high densities. We create two measures of the density of new development by dividing the amount of undeveloped land that converted to residential use between 1985 and 1999 by the number of permits for new housing units issued between 1983 and 1997.[35] The first measure (Table 12, columns 1–5) divides land converted to single family structures by the number of new single- and two-family units permitted. The second measure (Table 12, column 6) divides land converted to all types of residential uses by total new permits issued. A low value for either of these ratios indicates that cities and towns used less open space for each additional new permitted housing unit.

We find that the estimated relationship between land converted per new housing unit and wetlands bylaws is negative across all specifications but is not consistently statistically significant. If we consider all communities with more than five percent of land in wetlands (Table 12, column 1), the estimated relationship between more years of wetlands bylaws on the books and land converted per new unit is negative and marginally significant ($p = 0.09$), but if we consider only those communities that (in net) gained single family units during this period (Table 12, columns 2–5), the relationship is not statistically significant and the estimated magnitude decreases. As shown by the coefficient on the dummy variable for lost single family units, communities that lost single-family units converted significantly fewer acres per unit permitted, and the coefficient on the interaction between lost single family and years of wetlands bylaw is actually positive, although not significant. Including an indicator for rapidly growing communities, as measured by the number of single- and two-family permits in the

[34] This group includes close-in and highly built-out communities, including Arlington, Brookline, Cambridge, Chelsea, Malden, Quincy, Somerville and Waltham.
[35] We use permits lagged by two years to account for the time between permit issuance and construction completion.

period increases the magnitude of the coefficient slightly but is still not statistically significant at the 5 percent level (Table 12, column 5).[36]

When we measure the ratio of all land converted from open space to residential to all new permits issued, there is a strong negative association between years of wetlands bylaws and land converted per new unit (Table 12, column 6). Given the other results, however, we are skeptical that this represents a causal relationship between wetlands bylaws and land converted per new unit. It is plausible that wetlands bylaws are increasing the density of new housing, by in effect "squeezing together" houses on plots of land that border wetlands. However, high numbers of permits may also tend to be issued in places that are already relatively dense and also have wetlands bylaws. While we have attempted to control for existing density of housing, our current measurement may obscure considerable variation in underlying pre-existing densities.

In fact, the true relationship between wetlands bylaws and density of new construction may be ambiguous. 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. Exploring the question of how regulations, including wetlands regulations, may affect density of new housing is an interesting question for future research, particularly as more information is learned about how different patterns of housing affect both environmental and price outcomes (Lenth et al. 2006, Pejchar et al. 2007).

6. Conclusions and future research

The effects of land use regulation on housing prices and new construction have been previously studied in the theoretical and empirical literature, however, relatively little is known about whether and how land use regulation has actually affected land use itself. Moreover, most of the literature on regulations has focused on conventional zoning, despite the growing prevalence of non-zoning regulations. In this paper, we seek to contribute to the literature on regulations and land use change, as well as to shed some light on an important policy issue in Massachusetts.

While we find that wetlands bylaws may have some effects in terms of slowing the rate of land conversion, the magnitude is perhaps smaller than expected given the amount of political controversy surrounding these regulations. Our analysis suggests that having a wetlands bylaw for the full extent of the 1985–1999 period, after controlling for other relevant factors, is associated with an estimated 1.1–1.4 percentage point decrease in the rate of conversion of forest and agricultural lands to residential uses. In addition, the results on housing permits and density, while not conclusive, highlight the fact that wetlands bylaws may well be interacting in complicated ways with overall permitting and the density of new housing. Wetlands bylaws are associated with a reduction in the number of one- and two-family housing units permitted, although these estimates are only marginally statistically significant. Bylaws may also increase the density of new housing, but these estimates are also not robust in all specifications. We do find significant evidence that having a larger amount of naturally occurring wetlands is associated with

[36] As expected, single-family minimum lot size is positively associated with density. The estimates suggest that a one percent increase in average minimum lot size is associated with roughly a one-half percent increase in acres converted per unit. The average minimum lot size is about 40,000 square feet (just under one acre), so this implies an increase in lot size of about 400 square feet translates to an increase in land converted of 150 square feet. Since minimum lot sizes are both the most common form of zoning and the most direct way to regulate density, this effect is not surprising, but it is useful confirmation of widely held beliefs that zoning does affect development patterns. The actual sizes of lots tend to exceed minimum lot standards, because of the influence of other regulations, so we would not expect a one-to-one relationship. These results are similar to those found by Glaeser, Schuetz, and Ward (2006) and Glaeser and Ward (2006) using the same Mass GIS data on lot sizes.

lower rates of conversion, which suggests that the statewide Wetlands Protection Act has had an appreciable effect on development, as was intended by the law. Meyer and Konisky (2005) find that the actual filling of wetlands does not occur at significantly different rates in towns with or without bylaws and that the overall amount being filled is small. They speculate that the Massachusetts Wetlands Protection Act has created a “powerful norm against wetlands destruction that is widely observed.” If this is true, local wetlands bylaws are likely to have relatively small effects as they are primarily providing environmental protection on the margins rather than core protection of wetlands.

This study has focused on the likely magnitude of the effects of wetlands bylaws on conversion of land from open space to residential uses in Massachusetts; we do not attempt to compare the costs and benefits of local environmental regulations. Local wetlands bylaws that ensure larger buffer zones around wetlands areas are likely to have positive social impacts if water supply or scarce wildlife habitat is protected. Amenity values to existing homeowners who are near wetlands may increase due to their proximity to protected land. On the other hand, local wetland bylaws potentially raise costs for developers and these may be passed on to new homebuyers. Our study indicates some reduction in conversion rates, but these costs do not seem to be so high as to greatly limit greenfields development in communities with wetlands bylaws. In addition, 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. Over the period from 1985–1999, the 187 towns in our overall sample gave 218,710 permits for new housing units. High numbers of permits were granted in several towns and cities that were already quite developed, indicating that some redevelopment at higher densities was both financially profitable and feasible under existing regulations. From an environmental perspective, redeveloping areas and building close to existing infrastructure may bring additional secondary benefits. Future research should seek to understand the complicated set of possible costs and benefits that result from real regulatory policies in order to inform more fully future local efforts to influence land use change.

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Table 1: Variable names and descriptions

Variable name	Description (Year)	Data source
Dependent variables		
Pct not protected forest/ag converted to residential	Percent land in forest and ag uses in 1985—excluding protected open space—that was converted to residential uses by 1999	Calculated from Mass GIS (Landuse_Poly and Protected/OS layer[37])
Pct not protected, not C/I, forest/ag, to residential	Percent land in forest and ag uses in 1985—excluding protected open space and land converted to commercial/industrial—converted to res uses by 1999	
Pct forest/ag to residential	Percent land in forest and ag uses in 1985 converted to residential uses by 1999	
Pct not protected undev to residential	Percent land in all undeveloped uses in 1985—excluding protected open space--converted to residential use by 1999	
Log (permits)	Log of new housing units permitted, all types, 1985-99	New residential construction statistics (U.S. Census)
Log (sf permits)	Log new single-family housing permitted, 1985-99	
Log (1-2 family permits)	Log of new single-family and two-family housing units permitted, 1985-99	
Log (1-2 family/hsg stock)	Log of new single- and two-family housing units permitted 1985-99, divided by housing stock 1985	
Log (land converted/ new units)	Log of land converted to all types residential use 1985-99 per all new housing units permitted 83-96	Calculated from above
Log (land converted/ new 1-2 family units)	Log of land (acres) converted to residential use, excluding multi-family use, per SF + duplex housing units permitted 1983-96	
Measures of wetlands regulations		
Yrs. wetlands bylaw	Number of years during which wetlands bylaw was in effect (1985-99)	Local Housing Regulation Database
Wetlands bylaw index	Index of wetlands bylaw stringency (see Appendix A) (2004)	
Prevalence of wetlands		
Pct wetlands	Pct of land area in wetlands (excluding beaches, dunes, rocky shore; including all other types)	Calculated from Mass GIS (DEP Wetlands datalayer)
Pct marsh	Pct of land area in marsh	
Pct swamp	Pct of land area in wooded swamp	
Pct bog	Pct of land area in bog	
Pct salt marsh	Pct of land area in salt marsh	
No wetlands	Dummy = 1 if pct wetlands < 5 %	
Environmental preferences		
Green vote 1972 Green vote 1982 Green vote 1986	Pct of ballots voting "yes" on environmental referenda; see text for full wording (1972, 1982, 1986)	Secretary of the Commonwealth, *Mass. Election Statistics*

[37] Data in the Protected and Recreational Open Space Layer is from 2006. We excluded all parcels which had a recorded deed date after 1985 and which listed the level of protection as "none" or the owners as private.

Land use regulation measures		
Log (sf size)	Log of average single-family minimum lot size, weighted by district size across zoning districts (2000)	Mass GIS Zoning datalayer
Predicted MF lots	Predicted number of lots on which multifamily housing could be developed (2004)	Local Housing Regulation Database, Schuetz 2006
Cluster index	Index of stringency of cluster zoning provision (2004)	Calculated from Local Housing Regulation Database, see also Appendix A
Growth mgt index	Index of stringency of growth management provisions (2004)	
Exclude wetlands	Dummy = 1 if wetlands excluded from minimum lot size calculation (2004)	
Shape rule	Dummy = 1 if zoning imposes regular lot shape rule (2004)	
Septic systems index	Index of stringency of septic system regulations (2004)	
Subdivision index	Index of stringency of subdivision rules (2004)	
Pct sewer	Pct of houses served by public sewer (2004)	
Other control variables		
Log (Pct BA, post-grad)	Natural log of percent of population with BA, graduate or professional degree (1980)	U.S. Census
Pct < 18 yrs	Pct of population under 18 (1980)	
Log (pct non-Hispanic white)	Pct of population white, non-Hispanic (1980)	
Log (total area)	Log of total area	
Distance to Boston	Distance to Boston in miles from center of town	
# major routes	Number of major routes through town	Calculated from Mass GIS (Eotmajroads)
Pct forest not protected	Pct of land area in non-protected forest land (85)	Calculated from Mass GIS (Landuse_Poly and Protected/OS layer)
Pct ag land not protected	Pct of land in non-protected agricultural land (85)	
Pct other land not protected	Pct of land in non-protected forest land (85)	
Log (hsg 85)	Log of total housing units 1985 (housing units 1985 calculated from census hsg units 1980 plus permitted hsg units 1980-1983)	Mass GIS, Census
Res land per hsg unit	Acres of residential land/total housing units (85)	
Council	Dummy = 1 if governed by city council (2005)	MA Dept. of Housing and Community Development, Community Profiles
Rep. town meeting	Dummy = 1 if governed by representative town meeting (2005)	
Region	Set of dummies: inside Route 128 (Inner Ring); west of Boston between 128 and Interstate 495 (MetroWest); west of 495 (Far West); north of 128 (North Shore); south of 128 and east of 95 (South Shore); southwest of 128/95 (Far South)	Schuetz 2006
Net loss of SF units	Dummy = 1 if number of SF housing units declined from 1985 to 1999	U.S. Census

Table 2: Summary statistics for selected variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Pct not protected forest/ag to residential	184	10.3	5.2	0	31.8
Pct not protected forest to residential	184	7.3	3.9	0	19.3
Pct not protected ag to residential	174	13.6	11.5	0	77.9
Pct not protected other land to residential	187	6.4	4.6	0	23.5
Total permits	187	1170	1069	45	8846
SF permits	187	873	768	40	5819
1-2 family permits	187	921	807	45	5922
1-2 family permits/hsg stock	187	.288	.214	.011	1.125
Land converted to res uses/new 1-2 family unit	187	.679	.470	0	2.254
Yrs. wetlands bylaw	178	5.51	5.94	0	14
Wetlands bylaw index	178	5.108	5.026	0	16.02
Pct wetlands	187	12.9	7.9	.009	39.4
Pct marsh	187	2.2	1.4	.009	7.8
Pct swamp	187	9.4	5.9	0	26.6
Pct bog	187	0.2	1.2	0	13.9
Pct salt marsh	187	1.1	4.1	0	28.4
Green vote 1972	187	81.51	3.46	69.53	87.78
Green vote 1982	187	60.55	8.24	33.69	79.73
Green vote 1986	187	81.72	2.79	57.03	89.24
SF size	186	40,031	21,887	4200	106,329
Predicted MF lots	186	314	6266	-8291	66,631
Cluster index	177	4.45	3.80	0	11.17
Growth mgt index	187	1.27	2.58	0	8.56
Exclude wetlands	187	.93	.82	0	2
Shape rule	187	.433	.498	0	1
Septic systems index	186	2.03	2.15	0	9
Subdivision index	183	13.39	5.24	0	18.82
Pct sewer	186	2.33	1.86	0	5
Pct BA, post-grad	187	23.32	12.53	5.4	61.7
Pct < 18 yrs	187	28.87	4.04	15.6	37
Pct non-Hispanic white	186	97.19	3.08	80.8	99.8
Total area	187	11,631	7498	676	65,669
Distance to Boston	187	22.54	9.94	2.36	42.47
# major routes	187	1.50	1.25	0	5
Pct forest not protected	187	34.9	18.0	0	71.8
Pct agricultural land not protected	187	4.8	4.3	0	18.4
Pct other land not protected	187	6.6	3.0	.010	19.1
Residential land per housing unit	187	.617	.365	.043	1.76
Rep town meeting	187	.171	.378	0	1
Council	187	.166	.373	0	1

Table 3: Changes in land use from 1985-1999 for communities in the Local Regulation Database (8 categories)

Land Use in 1999 by Land Use in 1985 (Acres)									
Land Use 1985	agriculture	forest/wp	other land	wetlands	residential	comm/ind	Transport	water	1985 Total
agriculture	99,079	5,008	11,769	90	16,148	1,753	150	34	134,031
forest/wp	3,246	1,000,540	19,151	1,298	78,592	7,647	780	254	1,111,508
other land	1,768	17,879	134,574	195	11,325	5,800	568	340	172,449
wetlands	31	1,975	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 1999 by Land Use in 1985 (Percent)									
Land Use 1985	agriculture	forest/wp	other land	wetlands	residential	comm/ind	transport	water	1985 Total
agriculture	73.9%	3.7%	8.8%	0.1%	12.0%	1.3%	0.1%	0.0%	100%
forest/wp	0.3%	90.0%	1.7%	0.1%	7.1%	0.7%	0.1%	0.0%	100%
other land	1.0%	10.4%	78.0%	0.1%	6.6%	3.4%	0.3%	0.2%	100%
wetlands	0.0%	2.3%	0.2%	97.0%	0.2%	0.1%	0.0%	0.2%	100%
residential	0.0%	0.0%	0.1%	0.0%	99.7%	0.2%	0.0%	0.0%	100%
comm/ind	0.0%	0.0%	1.0%	0.0%	0.3%	98.6%	0.1%	0.0%	100%
transp	0.0%	0.2%	1.0%	0.0%	0.1%	0.3%	98.4%	0.0%	100%
water	0.0%	0.0%	0.1%	0.4%	0.0%	0.0%	0.0%	99.4%	100%
1999 Total	5%	47%	8%	4%	28%	4%	2%	3%	100%

The table shows how land that was in a given land use in 1985 was allocated in 1999. The diagonals (highlighted) represent no change. Percentages are for the 1985 totals, given in the far right column. 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)

Table 4: Changes in land use from 1985-1999 for cities and towns in the Local Regulation Database (21 categories)

									Land Use in 1999 by Land Use in 1985 (Acres)													1985
	LU 1985	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**21**	**Total**
1	cropland	73481	419	1459	33	60	4608	670	.	.	299	45	2780	7729	.	513	506	788	112	21	898	94433
2	pasture	127	25052	2411	53	35	4953	310	.	.	172	67	1551	3505	3	328	406	290	39	35	240	39598
3	forest	864	1824	975799	1128	3170	4600	3136	85	3	3022	1432	23341	49665	.	2473	5073	6825	760	459	2693	1086579
4	nf wetlnd	9	21	1855	59132	34	41	15	.	.	8	16	64	92	.	54	41	48	5	4	119	61711
5	mining	76	235	1029	32	7509	4145	96	10	14	126	104	639	620	.	229	547	376	60	23	332	16299
6	open land	247	418	14676	62	220	39114	428	23	17	394	132	1759	3085	.	711	1099	604	188	70	174	63477
7	part. rec	12	41	56	.	10	153	31478	3	.	45	0	143	119	32	88	41	250	17	1	5	32495
8	spect rec	.	.	4	.	.	53	147	1130	.	33	.	35	16	.	211	103	87	11	.	.	1832
9	water rec	.	.	.	.	.	.	3	.	2631	10	.	9	.	.	4	3	.	2	.	.	2738
10	res MF	.	.	4	.	.	.	9	.	.	18448	.	5	.	.	4	11	.	.	.	.	18481
11	res < .25	1	.	6	.	.	18	1	.	1	21	87879	1	.	.	82	27	18	22	.	.	88076
12	res .25-.5	2	.	3	.	.	6	9	.	1	70	31	205631	10	.	210	44	45	3	.	5	206074
13	res > .5	9	4	18	.	2	66	21	.	.	100	50	2328	180529	.	351	147	84	18	2	25	183753
14	salt wetlnd	.	2	1	.	.	26	1	.	.	2	.	1	0	25774	4	10	.	.	5	.	25832
15	commerical	.	4	3	.	.	34	15	7	.	33	5	30	19	.	35309	64	149	28	4	3	35706
16	industrial	7	9	26	2	10	179	3	9	6	64	6	6	32	.	136	33239	286	22	.	2	34043
17	urban open	264	395	1212	58	166	3305	434	108	13	718	139	1412	1623	6	831	1629	36190	263	77	286	49233
18	transp	.	5	47	4	.	108	23	.	.	4	18	1	21	.	16	74	176	33413	22	7	33940
19	waste disp	15	65	100	5	35	1873	25	.	13	9	10	28	118	.	69	236	71	27	3671	4	6376
21	woody per.	293	265	916	170	11	639	24	.	.	27	15	385	705	.	38	63	199	20	1	21132	24930
	1999 Total	75408	28760	999627	60981	11260	63937	36846	1375	2747	23604	89948	240150	247889	25818	41662	43369	46498	35008	4397	25956	2174987
									Land Use in 1999 by Land Use in 1985 (Percent)													**1985**
	LU 1985	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**21**	**Total**
1	cropland	77.8%	0.4%	1.5%	0.0%	0.1%	4.9%	0.7%	.	.	0.3%	0.0%	2.9%	8.2%	.	0.5%	0.5%	0.8%	0.1%	0.0%	1.0%	100.0%
2	pasture	0.3%	63.3%	6.1%	0.1%	0.1%	12.5%	0.8%	.	.	0.4%	0.2%	3.9%	8.9%	0.0%	0.8%	1.0%	0.7%	0.1%	0.1%	0.6%	100.0%
3	forest	0.1%	0.2%	89.8%	0.1%	0.3%	0.4%	0.3%	0.0%	0.0%	0.3%	0.1%	2.1%	4.6%	.	0.2%	0.5%	0.6%	0.1%	0.0%	0.2%	100.0%
4	nf wetlnd	0.0%	0.0%	3.0%	95.8%	0.1%	0.1%	0.0%	.	.	0.0%	0.0%	0.1%	0.1%	.	0.1%	0.1%	0.1%	0.0%	0.0%	0.2%	100.0%
5	mining	0.5%	1.4%	6.3%	0.2%	46.1%	25.4%	0.6%	0.1%	0.1%	0.8%	0.6%	3.9%	3.8%	.	1.4%	3.4%	2.3%	0.4%	0.1%	2.0%	100.0%
6	open land	0.4%	0.7%	23.1%	0.1%	0.3%	61.6%	0.7%	0.0%	0.0%	0.6%	0.2%	2.8%	4.9%	.	1.1%	1.7%	1.0%	0.3%	0.1%	0.3%	100.0%
7	part. rec	0.0%	0.1%	0.2%	.	0.0%	0.5%	96.9%	0.0%	.	0.1%	0.0%	0.4%	0.4%	0.1%	0.3%	0.1%	0.8%	0.1%	0.0%	0.0%	100.0%
8	spect rec	.	.	0.2%	.	.	2.9%	8.0%	61.7%	.	1.8%	.	1.9%	0.9%	.	11.5%	5.6%	4.7%	0.6%	.	.	100.0%
9	water rec	.	.	.	.	.	.	0.1%	.	96.1%	0.4%	.	0.3%	.	.	0.1%	0.1%	.	0.1%	.	.	100.0%
10	res MF	.	.	0.0%	.	.	.	0.0%	.	.	99.8%	.	0.0%	.	.	0.0%	0.1%	.	.	.	.	.
11	res < .25	0.0%	.	0.0%	.	.	0.0%	0.0%	.	0.0%	0.0%	99.8%	0.0%	.	.	0.1%	0.0%	0.0%	0.0%	.	.	.
12	res .25-.5	0.0%	.	0.0%	.	.	0.0%	0.0%	.	0.0%	0.0%	0.0%	99.8%	0.0%	.	0.1%	0.0%	0.0%	0.0%	.	0.0%	100.0%
13	res > .5	0.0%	0.0%	0.0%	.	0.0%	0.0%	0.0%	.	.	0.1%	0.0%	1.3%	98.2%	.	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	100.0%
14	salt wetlnd	.	0.0%	0.0%	.	.	0.1%	0.0%	.	.	0.0%	.	0.0%	0.0%	99.8%	0.0%	0.0%	.	.	0.0%	.	100.0%
15	commerical	.	0.0%	0.0%	.	.	0.1%	0.0%	0.0%	.	0.1%	0.0%	0.1%	0.1%	.	98.9%	0.2%	0.4%	0.1%	0.0%	0.0%	.
16	industrial	0.0%	0.0%	0.1%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.1%	.	0.4%	97.6%	0.8%	0.1%	.	0.0%	100.0%
17	urban open	0.5%	0.8%	2.5%	0.1%	0.3%	6.7%	0.9%	0.2%	0.0%	1.5%	0.3%	2.9%	3.3%	0.0%	1.7%	3.3%	73.5%	0.5%	0.2%	0.6%	100.0%
18	transp	.	0.0%	0.1%	0.0%	.	0.3%	0.1%	.	.	0.0%	0.1%	0.0%	0.1%	.	0.0%	0.2%	0.5%	98.4%	0.1%	0.0%	100.0%
19	waste disp	0.2%	1.0%	1.6%	0.1%	0.5%	29.4%	0.4%	.	0.2%	0.1%	0.2%	0.4%	1.8%	.	1.1%	3.7%	1.1%	0.4%	57.6%	0.1%	100.0%
21	woody per.	1.2%	1.1%	3.7%	0.7%	0.0%	2.6%	0.1%	.	.	0.1%	0.1%	1.5%	2.8%	.	0.2%	0.3%	0.8%	0.1%	0.0%	84.8%	100.0%
	1999 Total	3.5%	1.3%	46.0%	2.8%	0.5%	2.9%	1.7%	0.1%	0.1%	1.1%	4.1%	11.0%	11.4%	1.2%	1.9%	2.0%	2.1%	1.6%	0.2%	1.2%	100.0%

The table shows how land that was in a given land use state in 1985 is allocated in 1999. The diagonals (highlighted) represent no change.

Percentages are of the 1985 totals, given in the far right column. Category 20 (water) is not shown, but is included in totals.

Table 5: Types of protections in local wetlands bylaws adopted by 1999

Provision	Status		Number of communities	
Has wetlands bylaw				
	Yes		99	
	No		88	
Vernal pools granted buffer zones				
	Yes		62	
		100 ft		50
		125 ft		2
		200 ft		8
		250 ft		1
		Missing		1
	No		37	
Isolated vegetated wetlands granted buffer zone				
	Yes		89	
		25 ft		1
		100 ft		86
		125 ft		1
		150 ft		1
	No		10	
Land subject to flooding expanded				
	Yes		78	
	No		21	
Creates "no build" zones around wetlands				
	Yes		80	
		< 25 ft		19
		26-50 ft		49
		51-100 ft		12
	No		19	
Delay certification of wetlands				
	Yes		84	
	No		15	

Note: These tabulations do not reflect provisions in the 32 wetlands bylaws adopted after 1999.

Source: Local Housing Regulation Database

Table 6: Is there a spike in permits immediately prior to bylaw adoption?

Years prior to bylaw adopted	Total permits, year before bylaw adopted	Avg. annual permits period before bylaw adopted	Difference	Obs.
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

* significant at 10%; ** significant at 5%; *** significant at 1%

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 observations for which permit data are not available for the full period (permit data are available from 1980 onwards).

Table 7: Selected regression results for conversion of forest/agriculture to residential use

Dependent variable: Pct not protected forest/ag converted to residential (85-99)

	(1)	(2)	(3)	(4)	(5)	(6)
Yrs wetlands bylaw, 85-99	-0.060		-0.090**	-0.100**	-0.101**	-0.090**
	(0.033)		(0.032)	(0.038)	(0.026)	(0.034)
Pct wetlands		-0.188**	-0.176*	-0.169**	-0.189**	
		(0.069)	(0.069)	(0.050)	(0.061)	
Log (SF lot size)		1.392	1.417	1.578	1.275	1.363
		(1.468)	(1.480)	(1.435)	(1.235)	(1.470)
No wetlands		4.460	3.681	3.586	2.618	3.705
		(4.151)	(4.139)	(4.246)	(4.162)	(4.233)
No wetlands*Yrs bylaw			0.208	0.203	0.269	0.208
			(0.145)	(0.196)	(0.171)	(0.148)
Green vote 1972		-0.109	-0.087	-0.080		-0.077
		(0.117)	(0.111)	(0.087)		(0.112)
Green vote 1982		-0.088	-0.092	-0.086		-0.095
		(0.070)	(0.067)	(0.048)		(0.066)
Green vote 1986		0.494**	0.456*	0.449*		0.454*
		(0.192)	(0.190)	(0.184)		(0.199)
Distance to Boston (mi)		0.701***	0.638***	0.675***	0.695***	0.637***
		(0.140)	(0.144)	(0.135)	(0.086)	(0.143)
Distance to Boston squared		-0.017***	-0.016***	-0.017***	-0.017***	-0.016***
		(0.003)	(0.003)	(0.003)	(0.002)	(0.003)
# major routes		0.494*	0.475*	0.538*	0.622**	0.475*
		(0.214)	(0.229)	(0.249)	(0.198)	(0.235)
Residential land per hsg unit		-5.489***	-5.686***	-4.159**	-6.274***	-5.616**
		(1.290)	(1.400)	(1.039)	(1.356)	(1.477)
Pct marsh						-0.248*
						(0.099)
Pct wooded swamp						-0.173
						(0.096)
Pct bog						-0.280
						(0.176)
Pct salt marsh						-0.136**
						(0.052)
Other regulations	No	No	No	Yes	No	No
Other controls	No	Yes	Yes	Yes	Yes	Yes
R-squared	0.005	0.456	0.466	0.489	0.439	0.468
Observations	157	157	157	157	157	157

Robust standard errors clustered by region in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Models are as follows: (1) raw coefficient without controls, (2) includes controls but excludes yrs wetlands bylaw, (3) includes controls and years wetlands bylaw but does not include other regulations, (4) includes measures for stringency of other regulations, (5) drops the environmental preference measures, (6) breaks wetlands category down into percent marsh, wooded swamp, cranberry bog, and salt marsh. Additional controls for all models include: structure of town government (dummies), log pct BA post grad, pct population < 18 yrs old, log total land area, log pct white, pct land are in not-protected forest 1985, pct land in not-protected agriculture 1985, pct land in not-protected other land 1985, greater than 75 % developed (dummy). The other regulations (column 3) include predicted MF lots, cluster zoning index, growth mgt index, exclude wetlands, shape rule, septic systems index, pct sewer, and subdivision index.

Table 8: Selected robustness checks for conversion of land

Dependent variable	Pct not protected, not C/I, forest/ag, to residential	Pct forest/ag to residential	Pct not protected undev to residential	Pct not protected forest/ag converted to residential (85-99)		
	(1)	(2)	(3)	(4)	(5)	(6)
Yrs wetlands bylaw, 85-99	-0.101*	-0.100***	-0.098**	-0.084**	-0.091	-0.112
	(0.040)	(0.022)	(0.034)	(0.026)	(0.049)	(0.125)
Pct wetlands	-0.173**	-0.124***	-0.139**	-0.181**	-0.150*	-0.160**
	(0.052)	(0.021)	(0.040)	(0.069)	(0.071)	(0.050)
Stringency wetlands bylaw						0.181
						(0.117)
Stringency*Yrs bylaw						-0.011
						(0.019)
Region FE	no	no	no	no	yes	no
Other regulations	yes	yes	yes	no	yes	yes
Other controls	yes	yes	yes	yes	yes	yes
R-squared	0.498	0.550	0.524	0.445	0.523	0.498
Observations	157	157	157	172	157	157

Robust standard errors clustered by region in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Models are as follows: (1) dependent variable subtracts land that goes to commercial/industrial use in calculation of rates of conversion, (2) dependent variable does not subtract protected open space from calculation of conversion rates, (3) dependent variable includes forestry, agriculture, and other land uses in calculation of conversion rates, (4) includes all observations without missing data (n=172), (5) includes region fixed effects, (6) includes a measure for the stringency of the wetlands bylaw and interaction with the # of years of bylaw.

Additional controls for all models include: log sf lot size, less than 5% wetlands (dummy), nowetlands*yrs bylaw, greenvote 1972, 1982, 1986, distance to Boston, distance to Boston squared, # major routes, residential land per unit, structure of town government (dummies), log pct BA post grad, pct population < 18 yrs old, log total land area, log pct white, pct land in not-protected forest 1985, pct land in not-protected agriculture 1985, pct land in not-protected other land 1985, greater than 75 % developed (dummy). The other regulations include predicted MF lots, cluster zoning index, growth mgt index, exclude wetlands, shape rule, septic systems index, pct sewer, and subdivision index.

Table 9: First differences regressions for conversion of land

Dependent variable	Δ Pct not protected forest/ag converted to residential 71-85 to 85-99				
	(1)	(2)	(3)	(4)	(5)
Δ Yrs wetlands bylaw	-0.082* (0.038)	-0.087 (0.062)	-0.066 (0.054)	-0.088 (0.064)	-0.087 (0.061)
# of major routes				0.378* (0.162)	0.347* (0.150)
Δ Green vote[a]					-0.134** (0.044)
Other controls	no	yes	yes	yes	yes
R-squared	0.007	0.135	0.121	0.142	0.179
Observations	157	157	173	157	157

* significant at 10%; ** significant at 5%; *** significant at 1%

All right-hand side variables are also in differences. Other controls include differences in log(pct BA/post grad), pct population < 18 yrs old, log(pct white), pct land in not-protected forest, pct land in not-protected agriculture, pct land in not-protected other land, greater than 75% developed (dummy).

[a] Difference in green vote is measured as the difference between the 1982 and 1972 votes.

Table 10: Robustness check for spatial autocorrelation

Dependent variable	Pct not protected forest/ag converted to residential (85-99)	
	(1)	(2)
Yrs wetlands bylaw, 85-99	-0.109	-0.109*
	(0.068)	(0.052)
Pct wetlands	-0.169***	-0.169***
	(0.062)	(0.048)
Log (SF lot size)	1.578	1.5780
	(1.101)	(0.998)
No wetlands	3.586	3.5860
	(2.239)	(2.807)
No wetlands*Yrs bylaw	0.204	0.2040
	(0.202)	(0.151)
Green vote 1972	-0.080	-0.0800
	(0.132)	(0.102)
Green vote 1982	-0.086	-0.0860
	(0.071)	(0.049)
Green vote 1986	0.449**	0.449***
	(0.197)	(0.147)
Distance to Boston (mi)	0.675**	0.675***
	(0.259)	(0.205)
Distance to Boston squared	-0.017***	-0.017***
	(0.005)	(0.004)
# major routes	0.538	0.538*
	(0.370)	(0.311)
Residential land per housing unit	-4.159	-4.159**
	(2.567)	(1.914)
Other regulations	Yes	Yes
Other controls	Yes	Yes
Observations	157	157

* significant at 10%; ** significant at 5%; *** significant at 1%

Column 5 is an OLS model with robust (non-clustered) standard errors. Column 6 is an OLS model with standard errors adjusted for spatial autocorrelation, using a spatial weights matrix derived from Moran's I (Conley 1999).

Additional controls for both models include: structure of town government (dummies), log pct BA post grad, pct population < 18 yrs old, log total land area, log pct white, pct land are in not-protected forest 1985, pct land in not-protected agriculture 1985, pct land in not-protected other land 1985, greater than 75 % developed (dummy). The other regulations include predicted MF lots, cluster zoning index, growth mgt index, exclude wetlands, shape rule, septic systems index, pct sewer, and subdivision index.

Table 11: Selected regression results for permitted housing units, 1985-1999

Dependent var.	Log (Permits)	Log (sf permits)	Log (1-2 family permits)				Log (1-2 family/ hsg stock)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Yrs wetlands bylaw, 85-99	-0.0010	-0.0101**	-0.0092**	-0.0062*	-0.0079**	-0.0052	-0.0057*
	(0.0039)	(0.0036)	(0.0033)	(0.0028)	(0.0031)	(0.0041)	(0.0024)
Pct wetlands	-0.0121	-0.0085	-0.0079	-0.0106	-0.0111*	-0.0128	-0.0133
	(0.0085)	(0.0070)	(0.0071)	(0.0064)	(0.0055)	(0.0075)	(0.0072)
No wetlands	-0.4352**	-0.3712	-0.2793	-0.2082	-0.3301	-0.1594	-0.0498
	(0.1572)	(0.2138)	(0.1736)	(0.2124)	(0.1690)	(0.1680)	(0.2790)
No wetlands * Yrs bylaw	0.0092	0.0150	0.0185*	0.0268**	0.0394***	0.0213*	0.0048
	(0.0114)	(0.0089)	(0.0087)	(0.0086)	(0.0068)	(0.0092)	(0.0107)
Lost single-family units				-0.4541**	-0.3377**	-0.4954**	-0.6050*
				(0.1184)	(0.1161)	(0.1247)	(0.2571)
Yrs bylaw * Lost SF units				-0.0157	-0.0260**	-0.0126	-0.0141
				(0.0091)	(0.0095)	(0.0094)	(0.0146)
Environ. prefs.	Yes	Yes	Yes	Yes	No	Yes	Yes
Other regulations	Yes	Yes	Yes	Yes	Yes	No	Yes
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.7686	0.7805	0.7902	0.8100	0.8018	0.7900	0.8334
Observations	157	157	157	157	157	157	157

Robust standard errors clustered by region in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Models are as follows: (1) permits for all types of housing, (2) permits only for single family housing, (3) permits for 1-2 family housing, (4) includes dummy for towns that were losing single family units, (5) drops environmental preferences, (6) drops other regulations, (7) dependent variable is the log of the share of 1-2 family permits divided by the estimated existing housing stock at the start of the period.

Additional controls for all models include: dist to Boston, dist to Boston squared, # major routes, res land per hsg unit, structure of town government (dummies), log pct BA/post grad, pct population < 18 yrs old, log total land area, log pct white, percent land in not-protected forest 1985, percent land in not-protected agriculture 1985, percent land in not-protected other land 1985. The other regulations (column 3) include log (SF lot size), predicted MF lots, cluster zoning index, growth mgt index, exclude wetlands, shape rule, septic systems index, pct sewer, and subdivision index. Environmental prefs include green vote 1972, 1982, 1986.

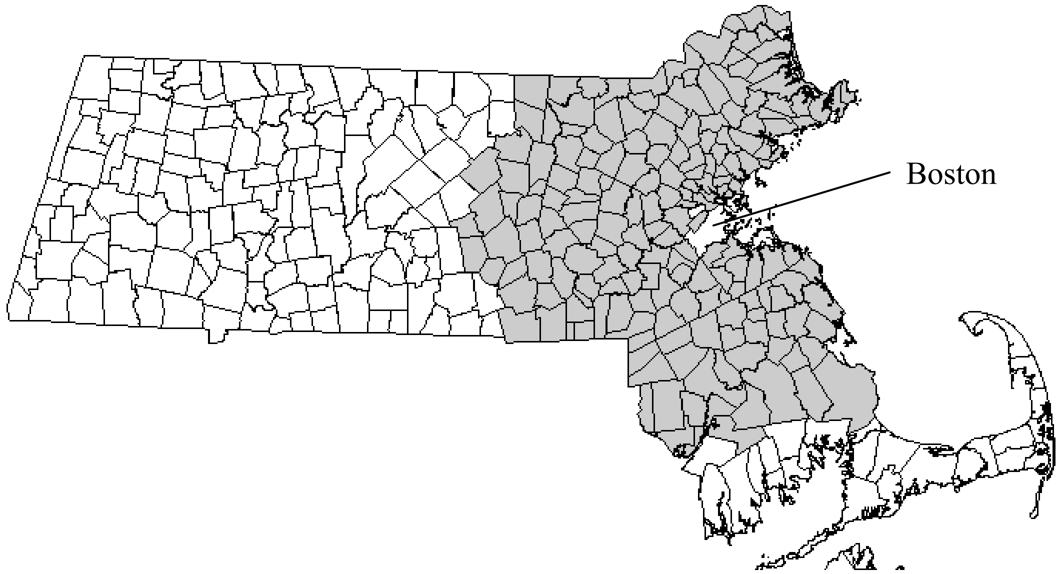
Table 12: Selected regression results for land used per new housing unit

Dependent variable:	Log (land converted/new 1-2 family unit permitted)					Log (land converted/ new units permitted)
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Yrs wetlands bylaw, 85-99	-0.0072*	-0.0050	-0.0046	-0.0051	-0.0064*	-0.0096***
	(0.0035)	(0.0038)	(0.0045)	(0.0037)	(0.0031)	(0.0023)
Pct wetlands	-0.0042	-0.0055	-0.0008	-0.0051	-0.0082	-0.0046
	(0.0066)	(0.0071)	(0.0045)	(0.0057)	(0.0064)	(0.0064)
Log (SF lot size)	0.4633	0.4354*	0.4253*	0.4102*	0.4670*	0.5751*
	(0.2484)	(0.1992)	(0.1916)	(0.1943)	(0.2142)	(0.2363)
No wetlands	-0.5947	-0.3216	-0.2467	-0.3542	-0.2934	-0.2058
	(0.4609)	(0.4147)	(0.2620)	(0.4188)	(0.4196)	(0.3929)
No wetlands * Yrs bylaw	-0.0251	-0.0456	-0.0498	-0.0465	-0.0457	-0.0148
	(0.0475)	(0.0455)	(0.0352)	(0.0489)	(0.0419)	(0.0247)
Lost single family units		-0.7818**	-0.8216**	-0.8120**	-0.8783**	-0.9622**
		(0.2554)	(0.2476)	(0.2920)	(0.2520)	(0.3277)
Yrs bylaw * lost SF units		0.0256	0.0422	0.0312	0.0195	0.0252
		(0.0286)	(0.0441)	(0.0240)	(0.0299)	(0.0330)
Environ prefs	yes	yes	yes	no	yes	yes
Other regs	yes	yes	no	yes	yes	yes
1-2 family permits 83-96	no	no	no	no	yes	yes
Other controls	yes	yes	yes	yes	yes	yes
R-squared	0.8530	0.8621	0.8571	0.8605	0.8735	0.8723
Observations	156	156	171	156	156	157

Robust standard errors clustered by region in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Additional controls for all models include: dist to Boston, dist to Boston squared, # major routes, res land per unit 1985, structure of town government (dummies), log pct BA post grad, pct population < 18 yrs old, log total land area, log pct white, pct land are in not-protected forest 1985, pct land in not-protected agriculture 1985, pct land in not-protected other land 1985. The other regulations (column 3) include log (SF lot size), predicted MF lots, cluster zoning index, growth mgt index, exclude wetlands, shape rule, septic systems index, pct sewer, and subdivision index. Environmental preferences include green vote 1972, 1982, 1986.

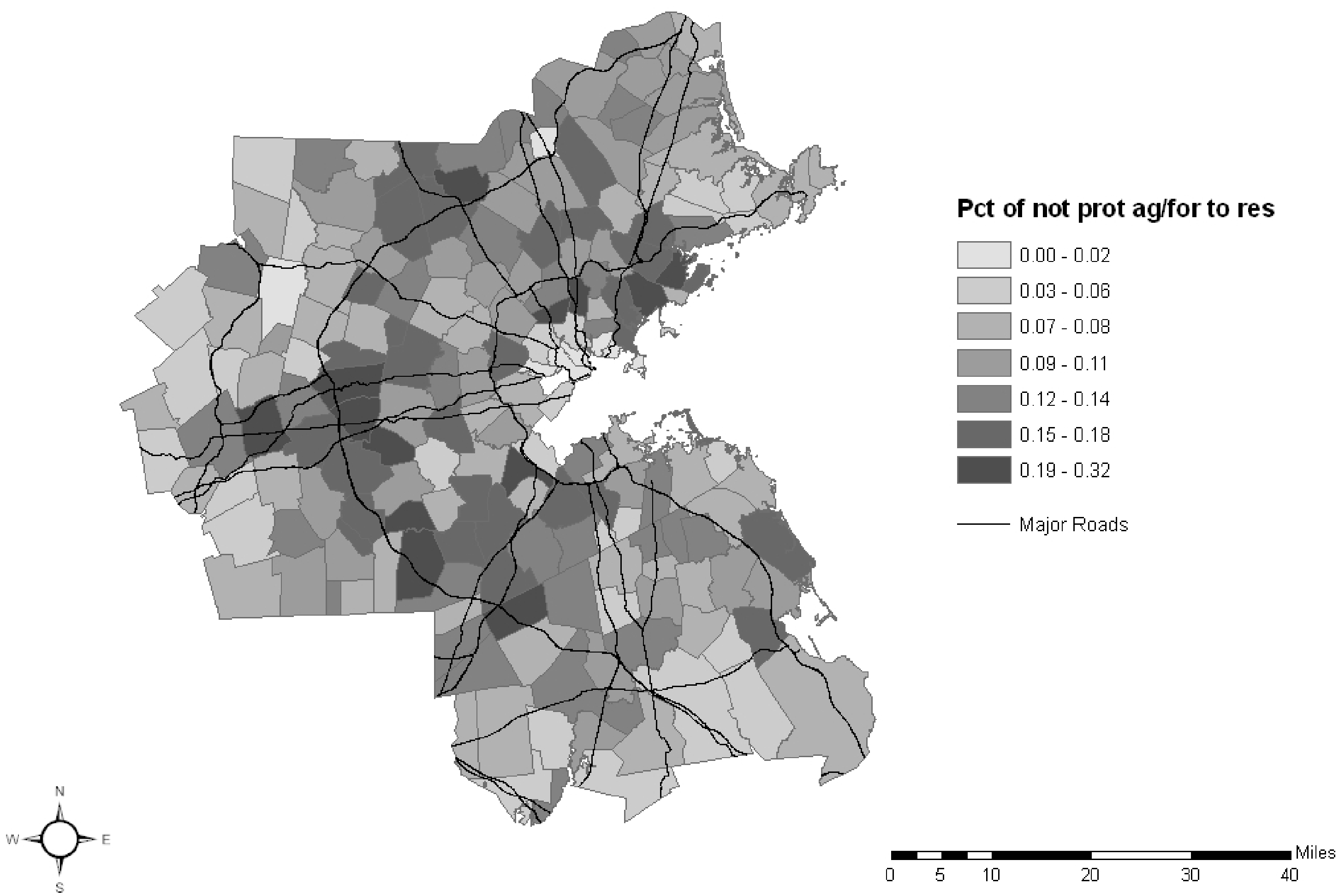
Figure 1: Communities in Local Housing Regulation Database (study area)



Data source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts

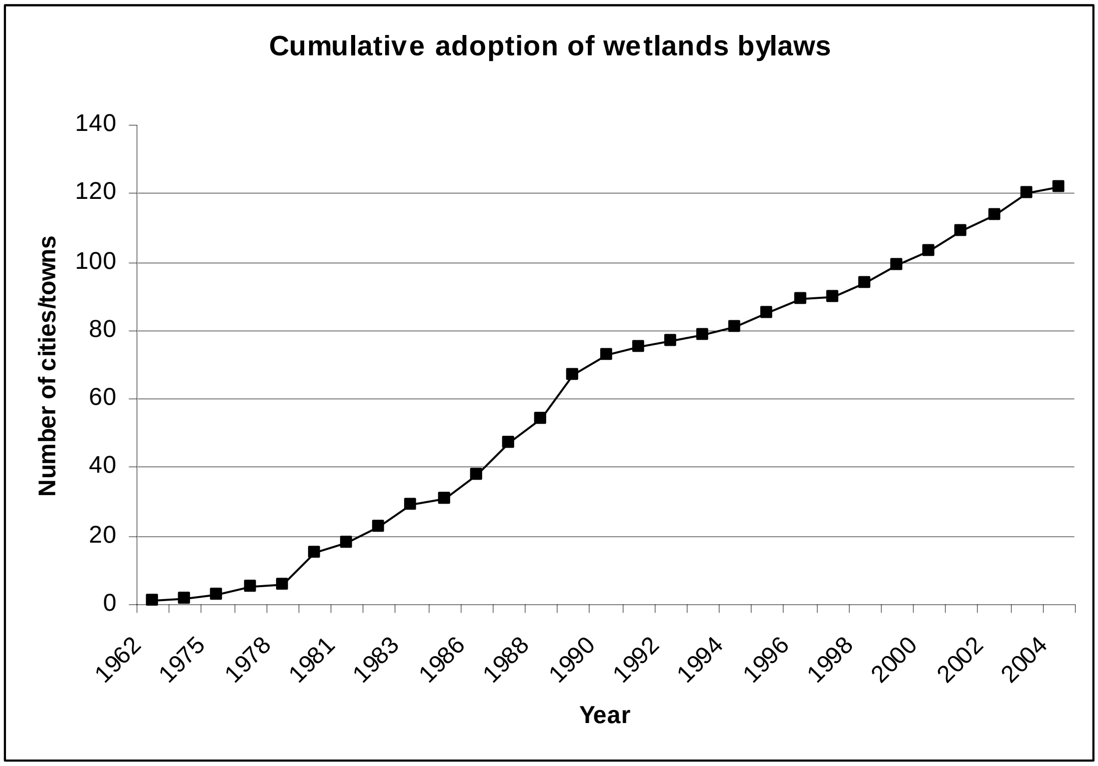
Figure 2:

Percent of not-protected forests/agriculture converted to residential use, 1985-1999



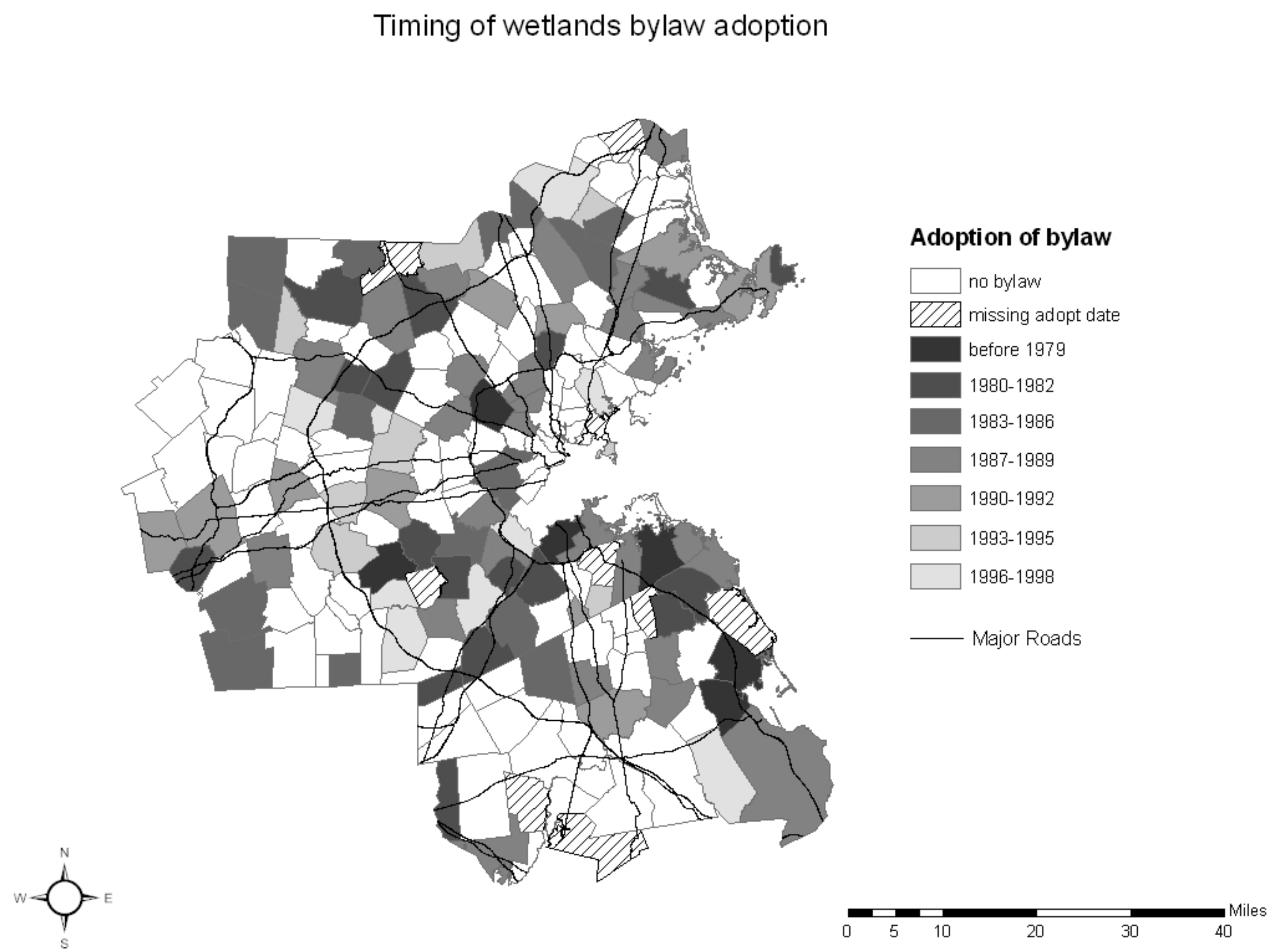
Data source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts

Figure 3: Cumulative adoption of wetlands bylaws, 1985-99



Source: Local Housing Regulation Database

Figure 4:



Data source: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts

Appendix A: Methodology for creating regulatory index variables

A.1 Overview

The Local Housing Regulation Database contains over 130 variables on specific regulations, which can be broadly grouped into four categories: zoning, subdivision rules, wetlands bylaws/regulations, and septic regulations. The zoning section contains multiple variables on the regulation of multifamily housing, cluster zoning, inclusionary zoning, and growth management practices. Often the database will contain one broad variable that identifies whether a city/town has a particular type of program (such as provisions for cluster zoning) and several related variables that describe the characteristics of the program (such as the minimum parcel size or amount of open space required) for any jurisdiction in which the umbrella variable is coded as "Yes." Including all of the variables that describe one particular characteristic of one program in regressions on housing market outcomes is unlikely to yield statistically or substantively meaningful results. Therefore we create a small number of aggregate variables to compare the overall stringency of regulation within each category or subcategory.

To determine whether the individual variables should be weighted before summing them into an index, we ran principal components analysis on each set of variables within the appropriate category or subcategory. The results of the analysis for all sets of variables suggested that only one component was necessary to capture a significant majority of the variation across the variables, and the weights derived from that component were roughly equal to one another. Therefore, for simplicity of interpretation we created unweighted indices, standardizing individual variables (set to mean zero and variance one) before summing them. Also to simplify interpretation, we adjusted the final values of the index so that the minimum value of each index (indicating lowest possible level of stringency) equals zero; the adjustment does not alter the distribution of values.

A.2 Zoning

<u>Single-family minimum lot size</u>
SFSIZE is the average minimum lot size required for single-family houses. The average minimum lot size for the town is calculated by multiplying the minimum lot size in each district allowing single-family housing by the area of that district, summing across all districts, and dividing by the total land area of all districts allowing single-family. Data on minimum lot size and size of the district are taken from the Mass GIS zoning survey in 1999-2000.

$$SFSIZE = \frac{\sum_{i=1}^{n} MinLotSize_i \cdot Area_i}{\sum_{i=1}^{n} Area_i}$$

<u>Multifamily zoning</u>
MFLOTS is the maximum number of multifamily lots that could be developed in a municipality. This is calculated by dividing the land area in each district allowing multifamily by the minimum lot size in that district to calculate the number of potential lots per district, then summing the

number of lots across all districts. Data on minimum lot sizes and district areas are taken from the Mass GIS survey. See Schuetz (2006) for more discussion of MFLOTS.

$$MFLOTS = \sum_{i=1}^{n} \frac{Area_i}{MinLotSize_i}$$

Cluster zoning

CLINDEX = NOBONUS + TYPE + PARCEL + NEWOPEN

NOBONUS is an ordinal variable indicating whether more units can be built under cluster development provisions than would be allowed by conventional zoning, in ascending order of stringency. TYPE is an ordinal variable in ascending order of stringency, indicating whether cluster provisions allow development of structures other than single-family detached houses. PARCEL is an ordinal variable indicating minimum parcel size required for cluster development, in ascending order of stringency. NEWOPEN is an ordinal variable indicating minimum open space required to be set aside under cluster development, in ascending order of stringency. Each variable is assigned the maximum value if cluster development is not allowed.

Inclusionary zoning

INCINDEX = INCLUDE + LIEU + IBONUS

INCLUDE is an ordinal variable in increasing order or stringency indicating whether inclusionary zoning provisions exist, and whether they are optional or mandatory. LIEU is an ordinal variable in increasing order of stringency, indicating whether the developer has alternatives to building affordable units on site. IBONUS is an ordinal variable in increasing order of stringency indicating whether bonus units offered as part of inclusionary provisions, and whether the bonus is discretionary or mandatory.

Growth management

GROWINDX = GROWMGT + MGTNUM + EXEMPT

GROWMGT is an ordinal variable in increasing order of stringency, identifying the presence of targeted growth rates or subdivision phasing. MGTNUM is an ordinal variable in increasing order of stringency, measuring the amount of new construction allowed under growth management (total units allowed under growth cap and units per subdivision per year under phasing). EXEMPT is the sum of the number of exemptions not granted (out of 6 possible) under growth management.

Other zoning: EXCLUDE and ANYSHAPE

EXCLUDE is an ordinal variable indicating whether the bylaw excludes wetlands, easements etc. from minimum land area calculations, and if so, whether buildable area is required to be contiguous. ANYSHAPE is a binary variable indicating whether the zoning bylaw imposes any shape rule enforcing lot regularity.

A.3 Subdivision

SUBINDEX = PAVEWIDE+ RTWAY + CURB + SIDE

PAVEWIDE is the minimum width of pavement (in feet) required for "typical" subdivision road. RTWAY is the minimum width of right of way (in feet) required for "typical" subdivision road. CURB is an ordinal variable in increasing order of stringency indicating type of curbing materials required for "typical" subdivision road: none, bituminous or granite. SIDEWALK is an ordinal variable in increasing order of stringency indicating number of sidewalks required for "typical" subdivision road.

A.4 Wetlands

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.

A.5 Septics

SEPTINDX is an unweighted index created by summing the binary measures of whether communities exceed the state's Title V regulations on several different criteria. The index is assigned a value of zero if the community does not its own regulations for septic systems, and a value of one if it has regulations but does not exceed state standards on any components measured here. The specific components measured are: (1) whether the highest "depth to groundwater" minimum requirement exceeds 5 feet; (2) the requirement for design flow for a three-bedroom house exceeds 330 gallons per bedroom per day; (3) the maximum allowable percolation rate is less 60 minutes per inch; (4) bylaw establishes a minimum size for leaching fields; (5) requires a setback over more than 10 feet between the property line and the soil absorption system; (6) requires a setback of more than 50 feet between bordering vegetated wetlands and the soil absorption system; (7) requires a setback greater than 100 feet between private wells and the soil absorption system; (8) limits the time of year when percolation tests can be observed; (9) limits the months when septic systems can be installed or constructed; or (10) prohibits shared septic systems.