From Deforestation to Reforestation In New England

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1. Introduction

Driven in part by concern about global warming and thus carbon emissions and sequestration, society has expressed increasing interest in actively addressing the fate of forested lands. For example, in regions with tropical forests, concerns about both global warming and biodiversity has motivated land-use policies such as forested bio-reserves or "sustainable" forest management. To evaluate such policies, we need to understand the underlying processes that drive land use.

Theoretical analysis of forest areas often starts with a model of agricultural and/or extractive production. Empirical analysis has tended to focus on population. This paper aims to provide perspectives on such land-use analysis, including on the predominance of the agricultural framework and the population variable. It examines historical reforestation in New England. This historical case permits the use of observations over a long period, which in turn permits relatively informed commentary on long-run policy analysis. Long-run land use analysis is particularly relevant for global warming policy, as if warming occurs at all it may occur quite slowly over time.

It would be ideal if the points made here were relevant to all current and future land use. However, we must acknowledge differences between historical New England and other contexts. Some differences are in property rights regimes, potential erosion, and irreversibilities such as from species loss. Despite this important caveat, though, the points made below seem rather general.

Historical data from the late 19th to the early 20th century are examined for New England. From the attempt to explain the reforestation that occurred, three main land-use claims arise:
1) population clearly does not fully dictate land use (e.g., de- or re-forestation); while population may well have an independent effect on land use, that effect clearly does not dominate all others;
2) factors that affect relative land-use returns, whether "external" to a region or not, clearly do affect land use; two examples are transport costs and productivity of other regions, which affect trade; and finally, 3) long-run analysis must consider shifts even in overall framework, such as from agriculture to migration and industrialization processes involving different economic dynamics.

Support for these claims comes from limited historical data alongside relevant theory concerning optimal allocation of land between the four most relevant land uses: agriculture, manufacturing, forest (for timber or as a result of abandonment), and shelter (or, more generally, land uses other than for production). Supporting the "population" claim, previous New England farm expansion flattened out post-1850 and eventual reversed itself, even as population was increasing. Regarding the "returns" claim, the breakpoint in the 1790-1930 series of within-region measures (based on county-level data) of concentration of population is very clearly at about 1830, precisely the era in which the transportation revolution involving railroads, steamships and canals started to have its effect. Concerning the "long-run" claim, given an interest in land use there are grounds for attention to shifts in regional output, such as towards manufacturing from agriculture, as there is evidence that such shifts involved significant changes, in particular concentration of population within particular counties, along rivers and in particular locations along rivers.

Two additional points are suggested by the returns and long-run claims. First, they suggest the likelihood of significant shifts in relative returns over the long run. Any number of factors may affect these returns, including potentially sudden shifts between multiple equilibria in concentration of people and industry. Significant shifts in relative returns may render policy-induced marginal changes in returns infra-marginal in future land decisions. Thus any given empirical finding on the land-use impact of a land policy may lack future relevance. Second, they suggest seemingly general mechanisms through which forested area might first drop and then rise as development proceeds. However, in New England the sign reversal in the change in forest area depended at least in part upon the ability of other regions of the country to supply food (i.e., New England "exported" its agricultural land clearing). The provision of timber also shifted to other regions of the country. Thus even if elements of the New England story are quite general, the New England experience does not yield a prediction that *all* regions can reforest as they continue along a development path.

The paper proceeds as follows: Section 2 provides historical background on New England; Section 3 sketches relevant theoretical points concerning optimal land use, with a focus on the three main productive land uses during this period: agriculture, forest for timber, and manufacturing; Section 4 presents data and evidence and, in light of the specific historical background and general theory, suggests implications of what is observed; finally, Section 5 summarizes and discusses.

2. Historical Background

When the Pilgrims landed in the early 1600's, at least ninety percent of New England's area was covered with forest (see Figure 1 and Harper (1918), who cites a U.S. Forest Service circular by Kellogg(1909)). Native Americans had long lived in the region, using a mobile, rotating system of hunting, fishing and planting. While this system certainly involved disturbance of the forest, such as from the frequent burning of fields as a method of clearing and of fighting insects, it may have been sustainable at low population density. The arriving colonists imposed a different system of property rights, creating small, fixed areas for individuals (see, for example, Cronon (1983)).

By the early 19th century, permanent colonization and greater population density within a European-style agricultural production system had put New England on a path of at least semi-permanent clearing. This continued until about 1830, when deforestation appears to have slowed. For example, Raup (1966) discusses Petersham, MA, where total clearing appears to have increased slowly in the late 1700's (10% in 1770 to 15% in 1790 overall). On one 600 acre Petersham farm plot, clearing went from 11% clearing in 1770 to 77% in 1830 and 90% in 1850, indicating faster growth in first half of the 1800's, while in the 1960's the town is 85% forested land (see Foster (1992, 1993) for more information on both specific sites and clearing in New England as a whole).

During the first half of the nineteenth century, the United States' boundaries expanded to include enormous and diverse areas such as the Louisiana Purchase, Texas, and the area from Idaho, Utah, and Arizona westward. Incorporation within one country most likely facilitated not only settlement but also the adoption by regions of different roles within an expanded economy. However, simply placing territories under one administration could not by itself have engendered a national economy. For inter-regional economic linkages to arise, transport costs between regions would had to have been drastically reduced. In the 1830's, steamboats, railroads and canals started to proliferate, greatly facilitating the transport of both people and cargo. Steamboats sailed the rivers and coasts, while railroads offered east-west transport. As north-south transport along the coasts had long existed, railroads probably had greater effect on trade (see Williams (1989)). Stimulated principally by the success of the Erie Canal, total canal mileage also grew rapidly, nearly tripling in the two decades from 1830-1850 (Taylor (1951), as cited in Slaughter (1997)). This mode of transport also explicitly aimed to create new paths for commercial exchange.

Expanded and varied territory plus easier transport could be expected to engender trade. Slaughter (1997) finds evidence that commodity prices converged across regions as smaller, differentiated regional economies were linked more tightly in a national economy. In addition, agricultural output was seen to have risen in the Midwest and fallen in New England, while New England, relatively well endowed with rivers and thus power, appeared to find a niche in the trade system by moving towards factories and industry. Thus a basic pattern emerged of concentration of agriculture in the Midwest and manufacturing in the northeast. For example, Raup (1966) tells of living in the Midwest and receiving fish products from the northeast in the early 1900's, in wooden barrels and buckets crafted in factories from forests grown up on formerly agricultural lands. From 1820 to 1850, employment in New England per thousand people in the national population grew from 41 to 75; however, regional agricultural employment actually dropped, from 30 to 23, while manufacturing employment rose, from 11 to 28 (see Census (1850), including the Compendium).

Economic activity in New England included more than agriculture and manufacturing. Both households and industries created a growing demand for timber. Household demand for wood for heating tailed off only after 1900 (MacCleery (1992), Cronon(1983)). Industries used wood for fuel, charcoal (for iron), railroad ties, shipbuilding, and eventually for pulp as well. Other forest products were also used, such as pitch for making ships. As a result of all these uses, timber production shot up in the mid-1800's, rising eightfold in the following sixty years, a rate of increase more than double that of the population (MacCleery (1992)).

This demand for wood's services spawned not only greater use of but also two types of substitution for New England timber. First, substitute supplies of timber were generated at an enormous rate from other regions of the country, such as the Lake States and the South. While in 1840 the northeast accounted for over two thirds of timber production, by 1860 this share had been reduced to about one third and was continuing to fall, although the level of output from the region remained more or less constant (Williams (1989), including Figure 7.5). Second, other materials were substituted for timber in a number of tasks. Examples include coal and oil in generation of energy, as well as cement and steel in construction. Although the absolute peak for wood harvested occurred in about 1930, the fraction of total U.S. energy produced by wood fell from ninety percent in 1850 to about ten percent in 1930. In contrast, the percent of energy provided by coal rose from about ten percent in 1850 to seventy percent in 1910, falling to fifty percent by 1930 as oil increased in popularity (Williams (1989), Figure 10.2).

Finally, it is important to recognize that legislation is a potentially significant factor in land use. In the U.S., from the second half of the 19th century on, debate over such legislation was inspired by both economic (see, e.g., Starr (1865) and Pinchot(1919), cited in Williams (1989)) and ecological (see, e.g. Marsh (1864) and Muir (1876), cited in Williams (1989)) rationales for forest conservation. However, much of the debate over public versus private ownership, national parks, other uses of public lands, and tree-planting conditions for homesteads was centered around lands west of the Mississippi. Yet today the citizens of Maine vote on proposed restrictions on clear-cutting on private land. Thus the fate of New England forests rests on political factors too. Finally, summarizing this history: the region shifted into permanent agricultural colonization and then later shifted back out of agriculture as transport linked regions; this non-agricultural role included timber production, although substitutes developed for that as well; finally, manufacturing grew within the region (and eventually land-use legislation came to play a more significant role).

3. Theoretical Background

Deforestation and reforestation are outcomes of decisions about how best to make use of given areas of land. This section first presents a sketch of a basic economic theory of land allocation, and then considers additional points relevant to the land use choices implied by the maximization of returns in each of three land uses relevant in New England: agriculture, timber, and manufacturing.

3.1 Optimal Land Use and Agricultural Land-Use Returns

Land is assumed to be allocated between alternative uses in order to obtain the greatest expected total return. Thus the factors which affect the relative returns from different uses should drive land allocation. For example, Pfaff (1997) finds that factors thought to affect returns from land use in the Brazilian Amazon, such as distance to markets, road access, and quality of the soil, are empirically important explanatory factors for deforestation in the Amazon. Population may be one such factor: greater population might increase demand and thus the price of output, and/or increase labor supply and thus decrease the wage. Both of these prices affect land use returns.

For the case of New England land use, it is important to recognize that one factor likely to drive relative returns is trade, and in particular absolute (or comparative) advantage based on regional factor endowments (see, e.g., Heckscher and Ohlin (1991)). The Midwest has an absolute advantage over New England in agriculture, an absolute disadvantage in ocean products such as fish and at least during this period (when rivers produced manufacturing power) apparently also an absolute disadvantage in manufacturing. Given greater productivity in Midwest agriculture, if transport costs were low we would predict imports of agricultural output by New England because agricultural revenues could not cover high costs, implying low returns and thus little agriculture. Even should forested land use returns be zero, agricultural production could be worse. Thus the observed drop in transport costs is consistent with the ongoing reforestation of New England.

3.2 Timber Land-Use Returns

Timber production is one possible use of a given parcel of land. While returns from timber may also have been bounded by dropping transport costs and competing supplies from other regions, the increasing population of New England represented increasing demand and thus upward pressure on expected timber prices. In addition, increasing consumption (reducing future supply) raised expectations of future scarcity and thus future timber prices (Williams (1989), p.80). Thus not only lower agricultural returns but also higher timber returns could have led to reforestation.

Much of forestry economics from Faustmann (1849) on has focused on maximizing timber returns from a stand of trees through the choice rotation period, i.e. the amount of time a stand of trees should be left to grow before being cut (see Johansson and Lofgren (1985) for a number of forestry economics results). Two points concerning this maximization of returns in this particular land use are helpful here: first, the dynamic nature of timber production makes future timber prices a function of current consumption (which reduces future supply); and second, a profit-maximizing owner will act to equate the expected percent increase in scarcity rent with the interest rate, i.e. to equate the marginal return from selling additional timber with that from keeping the tree as an asset. Combining these points, falling expectations of future prices should lead a profit-maximizing owner to cut additional trees up to the point at which these marginal returns are again equated.

Given the historical background, induced innovation and property rights also seem relevant to the returns to timber (see Boserup (1966) on responses induced by population pressures, and Hayami and Ruttan (1971) on innovation in reaction to factor endowments). The development of substitutes timber, such as other stocks or the ability to use coal, appeared to be a reaction to scarcity. For stoves, this is particularly so in urban areas, although fuels' weights and sizes per unit energy mattered as well (Williams (1989), p.334). The effect of substitutes on timber decisions depends on property rights. An open-access, non-marketed forest resource will last longer if a substitute for wood services becomes available. However, as just discussed, if wood is owned and marketed, then a drop in expected future timber prices should lead to faster cutting by profit-maximizing owners. Importantly, New England featured fairly developed property rights and significant private ownership (see, e.g. Williams (1989), pp.58, 407). This is one aspect in which the New England context may well differ in an important way from a number of tropical contexts.

3.3 Manufacturing: Land Intensity, "Agglomeration" and Total Cleared Land

Manufacturing started to replace agriculture in New England during this period. This is itself perhaps an innovation induced by the drop in transport costs and agricultural returns (much as it has been suggested that the enclosure movement contributed to the Industrial Revolution). In any case, as manufacturing did grow, in considering land outcomes it is useful to consider what maximizing returns in manufacturing, including through location, might imply for land use.

A number of general features of manufacturing production may suggest less land clearing in a manufacturing region relative to an agricultural region (while more manufacturing need not imply less agriculture, consider two regions with the same population and employment, one producing agricultural and the other manufacturing outputs). The most prominent may be that manufacturing production simply tends to feature lower ratios of land to labor and capital than does agriculture. This directly lowers the use of cleared land use per employment or output.

Other features, which might loosely be called "agglomerative" features of manufacturing, lead to spatial concentration of manufacturing production. Their link to total cleared land is less direct, as for the same level of production fewer sites need not imply less land use. However, such concentration may well reduce "related" land use, such as for shelter of workers, and thus reduce the total cleared land use implied by the location of production. For example, urban apartment buildings may house a concentration of manufacturing workers on relatively little land. The rest of this section considers a number of such features which affect manufacturing decisions, and notes analogous "agglomerative" features of individual location decisions.

Manufacturing production is often thought to feature increasing returns to scale. For any firm, this argue for fewer locations of production. Concentration of production might also arise from interactions between firms. For example, in Krugman (1991), locational externalities between firms arise from transport costs and the fact that one firm's employees are another firm's customers. These interactions may yield concentration, multiple equilibria in the location of concentration, and the possibility of rapid shifts of concentration between equilibria. Another possible interaction between firms is informational spillovers, which are usually assumed to decrease with distance. This too may yield spatial concentration of manufacturing activity (see, for example, Marshall (1961), Henderson (1974), Rivera-Batiz (1988), Fujita (1993), Krugman (1994), Chincarini (1995), and for empirical work, Ellison & Glaeser (1994) and Hanson (1997)).

Another feature of manufacturing production decisions which may lead to spatial concentration is the fixed, idiosyncratic location of important factors. This case-specific feature may be important for explaining any given example. For instance, along New England's lengthy coast, the non-uniformity of population density is striking, and the big cities are found in the natural harbors. River location is also important. Rivers provide not only transport but, during the period considered here, also water power for production. As it may be of interest to predict relative levels of spatial concentration in manufacturing versus agricultural regions, note that there exist analogous agricultural features including the idiosyncratic location of agriculturally relatively productive areas such as areas of good soil (much as in section 3.1, but instead within-region).

Along these lines, for completeness consider that existing railways too could be significant determinants of location. Certainly by the 1890's and even by as early as the 1850's, many of the significant towns in the New England region such as New Haven, Hartford, Springfield, Worcester, Providence, Boston, Portsmouth, and Portland were already connected by railroads (see, e.g., the maps produced by Boston & Maine (1895), Colton (1878), Mayer (1870), and Hale (1853)). However, accounts appear to suggest that causality was more likely to run from town location to railroad location (see, for example, Tanner (1840), or Harlow (1946), chapters 3 and 5).

Finally, note that processes within manufacturing (and agricultural) production are not the only agglomerative processes. Stories analogous to those concerning industrial location decisions suggest positive externalities in migration (i.e. between individual location decisions) which would yield spatial concentration. As these may be independent of a region's output type, they should factor into expected levels of concentration within agricultural as well as manufacturing regions (although further speculation differentiating such regions is possible; e.g., the spatial concentration of jobs in manufacturing might make it feasible for people to live closer together and thus for this sort of individual locational externality to exert a significant effect on overall concentration).

4. Evidence and Implications

4.1 Data

The data are from decennial U.S. censuses for 1790 to 1930. They are for New England at both the county and the town level. The measures used below are of population and land use on farms. The latter is assumed to be linked to deforestation. Agricultural variables available in these early censuses include measures of particular farm activities (e.g., quantities produced of particular crops). These are not used below, as they represent only part of the economic activity (also, some are dollar-valued and would thus require somewhat arbitrary deflation for comparisons over time).

The measures of land use on farms that I could consistently find were improved and unimproved land (an exhaustive breakdown of total land on farms). In the 1870, 1910 and 1920 censuses, unimproved is broken down into woodland and other unimproved land. In 1930, three sub-categories of crop land, three of pasture land, plus woodland and other land are provided. For comparison, these were (somewhat speculatively) aggregated into improved and unimproved. It would appear that improved can roughly be thought of as all crop land plus plowable pasture land.

While measures of farm areas are not direct measures of deforested area, they permit an estimate of deforestation. Harper (1918) suggests a method of calculating a measure of forested area. From total county area, subtract five percent (for originally treeless land), subtract one fifth of an acre per inhabitant (which he allows is too much for urban land use), subtract total land in farms, and then add back in the woodland area of unimproved land on farms. The latter two operations are almost the same as subtracting improved land on farms; they differ in that "other unimproved" land on farms is also subtracted. As I could find the breakdown of unimproved land into woodland and other unimproved only for a few censuses, a measure based on improved appears in Table 1.

Demographic variables in the Census include numerous breakdowns of the population by age, gender, ethnicity, and origin. Of these, other than perhaps some form of age-weighted index, perhaps the most natural measure of economic activity and land demand is total population. Of course, concentration of population does not necessarily indicate a concentration of production, as individuals may choose to locate near to each other for reasons unrelated to production. The demographic measure of manufacturing activity used below is total employment in manufacturing.

4.2 Evidence

Table 1 presents trends in population, employment and land use for New England from 1850 to 1930. Total population grew steadily, and employment in manufacturing grew even more quickly. Improved land on farms increases a bit but on net stays fairly flat from 1850 to 1890, and then shrinks steadily from 1890 to 1930. This suggest the potential for reforestation, and even the estimate of forested area which takes into account the growing population turns upward after 1890.

Table 2a and Figure 2 present measures of population concentration at the regional level. The sixty-seven counties in New England are ranked for each census year (both according to density and according to total population). From this ordering, five-, fifteen-, and twenty-five-county concentration ratios are calculated (these are the fraction of the sum of all the population densities (or levels) made up by the sum of, respectively, the highest five, fifteen, and twenty-five total population densities (or levels)). In addition, a "Gini coefficient" is calculated for each census year, which is a single aggregate measure of how skewed the distribution of the densities (or levels) is away from a hypothetical comparison distribution in which all counties have equal densities (or levels). These measures clearly indicate significant intra-region concentration after the beginning of the transportation revolution. No concentration measures falls in any decade after 1830. Table 2b presents analogous measures for improved land on farms and total employment in manufacturing. Agriculture seems to increase a little in concentration over time, although manufacturing does not. The main lesson from this table is that manufacturing appears significantly more concentrated.

Tables 3a and 3b present measures of population concentration along the two major rivers (the availability of town-level data limit the years for which this can be calculated). Table 3a shows that throughout the last half of the nineteenth century just a few towns on the Merrimack River contain quite a large percentage of the total population of the significant towns on the river. Table 3b shows that as the New England region continued to shift towards manufacturing from agriculture, the population share of the few largest towns on the Connecticut rose significantly. Also of interest is the Erie Canal, along whose path across relatively empty land Rochester and Syracuse boomed because of their sudden access to transport. The development of those urban centers was quite distinct from the persistent lower population density along much of the canal.

4.3 Implications

4.3.1 Implications From The Tables

The ideal implication of the evidence in the tables viewed in light of the land-use theory presented above would be a definitive explanation of exactly why reforestation took place in New England during this period. While the information available for this paper is not sufficient for that entire task, in light of the theoretical and historical background even the simple tables here indicate parts of the story. To begin with, the most basic evidence concerning the land-use literature is that the oft-cited positive correlation between changes in population and changes in land use does not hold for historical New England over this time period, as can be seen in Table 1. This implies that it could not be true that population alone effectively drives land-use outcomes.

The result to be taken away from much of the empirical land-use literature, particularly cross-national studies (see, for example, Lugo *et al.* (1981), Allen & Barnes (1985), Palo *et al.* (1987), Rudel (1989), Cropper & Griffiths (1994), and Deacon(1994)), is that population is the most significant explanatory factor in deforestation regressions. If one interprets that earlier work as evidence that population is the sole or dominant driver of land use, then Table 1 presents useful cautionary evidence. However, that work might more appropriately be interpreted as presenting a correlation which requires more context for causal interpretation (it is at times presented in this fashion, e.g. in Palo (1990)). For instance, one might believe that, all else equal, increased population creates a push towards deforestation. Nonetheless, if it were only one of many possible driving factors, then population would not be expected to fully determine land-use outcomes.

Given that population did in fact increase, what other factors might explain reforestation? The simple optimal land-use theory above suggests that lower returns from production on the land could lead to abandonment of production and thus to forest, the default land cover. In this view, two possible land-use drivers would be transport costs and sectoral productivity in other regions, both of which affect trade and thus both input and output prices. Given absolute agricultural advantage in the Midwest, a drop in transport costs could lead to less agricultural use and a decrease in cleared land in New England despite a rise in population which by itself might lead to more clearing. Given the timing of the transport revolution, that sort of story is suggested by Table 2. Thus in light of the historical facts, Tables 1 and 2 together provide evidence that factors which affect the relative returns from land uses affect land-use outcomes. This is true whether those are relevant local factors, such as exactly where the soil is good, or relevant factors "external" to the region in question, such as transport costs and the sectoral productivities of other regions.

However, only if New England land had been abandoned would this evidence of falling agricultural returns be a sufficient explanation for its reforestation. A drop in agricultural returns does explain a drop in agricultural land use, but that would not lead to reforestation if the subsequent optimal land use were not abandonment but rather a land use which, like agriculture, featured cleared land. Thus the set of determinants of the returns to alternative land uses, and the forest-relevant features of those land uses, must also be considered as determinants of reforestation.

One obvious alternative land use is forest itself, which may arise not only through abandonment and the natural accident that forest may be the default land cover in New England but also through conscious land-use choice. Unfortunately, the effects of factors in returns to forest are not studied here, for lack of organized evidence on the determinants of returns to timber (including substitutes) or on the property rights regime (which affects owners' incentives). However, we should note that the nature of forest returns may change over time. For instance, since the relatively early 1900's northeastern cities have acted to preserve forests' watershed services, and today New England remains significantly forested and forest returns appear to include aesthetic or other values offered to tourists or those with vacation retreats (see, e.g., discussion in Stroud (1997)).

Manufacturing also followed agriculture, though, as suggested in Table 1. If this was indeed an induced innovation, then the returns to manufacturing may not have been extremely clear while those from agriculture may have been sufficiently low to convince people unwilling to move to try new things. However, here the focus is not the determinants of manufacturing production but rather the forest-relevant features of manufacturing: if manufacturing production implies less use of cleared land than agricultural production (e.g., for an equivalent level of population or output), then a shift to manufacturing would provide another explanation for reforestation. Two ways in which this might be the case were given above: one, lower land intensity within production; and two, greater concentration, or "agglomeration", lowering non-production land use such as for shelter.

This leads to the final pieces of evidence, which suggest that some "agglomerative process" (see the list of quite varied "agglomerative" features of production in section 3.3) was driving the location and thus the land-use impacts of individuals and economic activity in New England after 1830. This is first suggested in Table 2, by the increasing concentration of population (and by inference, perhaps also of economic activity). In densities or levels, all three concentration ratios plus the Gini coefficient (all based on county measures) increase significantly from 1830 to 1930.

Given multiple candidate explanations, further examination is required to determine whether this evidence of population concentration is evidence of any single agglomerative process. Perhaps the agricultural agglomerative feature (idiosyncratically located areas of higher agricultural productivity) could explain the observed concentration into fewer counties over time, obviating the need for other stories. Depending on the within-region distribution of most productive land both between and within counties, either an increase or the expected decrease in regional agricultural employment after 1830 could yield such concentration. The top half of Table 2b suggests that in fact the retreat of agriculture (and the distribution of favored areas) did contribute somewhat to regional concentration. The concentration ratios all increase a little bit from 1850 to 1930.

However, given that this is a small effect and that manufacturing was becoming increasingly dominant (as suggested in Table 1), that could not be the only explanation for the concentration of population seen in Table 2a. The bottom half of Table 2b suggests that manufacturing did not in fact become more concentrated over this period. However, the comparison of the agricultural with the manufacturing results suggest an explanation. The manufacturing concentration is simply much higher than that in agriculture; in fact, for any given measure, the ratios in Table 2a are in between those in the agricultural and manufacturing halves of Table 2b. Thus the increasing concentration in Table 2a could be explained by a significant regional replacement of relatively dispersed agriculture by concentrated manufacturing production.

Thus we might look for evidence of effects of agglomerative features of manufacturing production. The historical background motivates consideration of rivers, one example of important idiosyncratically located inputs. More generally, access to water transport may be important. Although this does not appear in the tables, of the total population of the five-largest towns in all counties, about forty percent was on the coast. For the non-coastal part of this population, about forty percent was on "large" rivers, and three quarters was on some river. Perhaps this feature of the landscape explains most of the concentration, obviating the need to consider the effects of other agglomerative processes such as externalities in firm and individual location decisions.

However, Tables 3a and 3b show concentration even within the set of such relatively advantageous locations, i.e. concentration in only a few sites along the length of major rivers. Just a few towns on the Merrimack River contain quite a large percentage of the total population on the river, and the population share of the few largest towns on the Connecticut rose significantly. This may suggest that not just the idiosyncratic location of services but also other agglomerative processes such as externalities or economies of scale affected concentration. However, it may not suggest anything of the kind. More information on the heterogeneity of services along the river's length, such as on infrequent natural falls, might show that concentration exists where services are highest. This paper lacks the additional information necessary for differentiating these effects.

4.3.2 From Advantage and Agglomeration: Future Policy Impacts? Kuznets Curve?

The evidence above suggests that the factors which drove population concentration and thus perhaps also reforestation in New England include both a drop in transport costs and features of agriculture, migration and manufacturing location which yield spatial concentration. Here two particular possible implications of the significance of these factors are examined.

The importance of the drop in transport costs lay in the change in the effective regional output prices. In a dynamic global economy, significant shifts in both the input and output prices for any given region are a relatively common occurrence, in particular over the long term. Processes involving multiple equilibria, in which masses of productive capacity or output may shift location or price relatively quickly, make such significant shifts more likely, again in particular over time. Such shifts must be acknowledged in forecasting the effects of future land-use policies.

If significant shifts are likely, current estimates of the marginal land-use impacts of policies may not be good predictors of future policy impacts. To see this, first note that the land-use impact of a policy-driven marginal change in relative returns depends on how much land is `marginal', i.e. has roughly the same returns in either of two land uses. If returns from one use are much greater than returns from other uses, marginal changes in relative returns will not affect land allocation at all. Then consider a policy with land-use impacts, such as the construction of a road. Empirical work might reveal a significant land-use impact of additional roads at one point in time, e.g. a new road might have led to a lot of forest clearing pre-1830. However, if after 1830 agricultural prices were low enough, a new road might barely affect land allocation. Even if the road raised agricultural returns quite a bit, they might still be significantly below forest returns (or even zero).

Another interesting implication is that such factors could cause regional forests to fall and then rise during development. A number of recent aggregate cross-country statistical analyses suggest an "environmental Kuznets curve", i.e. that environmental quality might first decline and then later increase with economic growth (see, among others, Grossman and Krueger (1995), Selden and Song (1994), and Shafik (1994)). However, such work rarely distinguishes a particular mechanism through which such a result might come about (see Chaudhuri and Pfaff (1997) for an analysis of some household-level mechanisms). As New England forests appear to have declined and then later increased in area (see Table 1) during a period in which per capita income surely increased, it is natural to ask whether closer examination of this case could shed theoretical light on and empirical evidence for any generalizable mechanisms behind a "forest Kuznets curve".

Sections 3.1 and 3.3 and the evidence above provide one possible mechanism: transport rises with growth, which makes trade feasible; thus previously rising demand for a region's agriculture declines and manufacturing replaces agriculture; given the land-use features of manufacturing, the trend in optimal land allocation shifts from clearing to reforestation. This story is in principle a general one which could be replicated in other regions. However, it is important to realize that this dynamic could not occur in *all* regions, as it relies upon the use of another region's resources. Thus while somewhat generalizable, this mechanism could not be universally observed.

Section 3.2 provides another possible mechanism, which is that increased timber scarcity should eventually increase the returns to timber production, making it a more competitive land use option even in the face of rising agricultural demand. However, as a general proposition this might be expected to slow clearing to some stationary or more slowly decreasing level, as opposed to increasing forest area while population continues to rise. Timber scarcity might also be expected to induce innovation such as coal-burning stoves (or more generally, fuel shifting), another possible mechanism suggested by the New England experience. However, in considering whether that might explain forest regeneration in any given case, recall that with land ownership and marketed timber, development of substitutes for timber may lead to faster liquidation of the forest asset.

5. Discussion

This paper argued from suggestive data that in evaluating land-use policies and trends analysts must go beyond a focus on population to consider a broad range of land-use drivers including transport costs, trade and "agglomerative" features of agriculture, manufacturing and migration. The paper examined the reforestation of New England, making use of observations over 140 years. Evidence from a long period permitted relatively informed commentary on long-run land use policy analysis.

Historical data were examined for New England during the late 19th to the early 20th century. From the attempt to offer explanations for the reforestation that occurred during this period, three main land-use claims were generated: 1) population clearly does not fully dictate land use (e.g., de/reforestation); while population may well have an independent effect on land use, that effect clearly does not dominate all others; 2) factors that affect relative land-use returns, whether "external" to a region or not, clearly do affect land use; two particularly important ones are the levels of transport costs and productivity of other regions, which lead to trade and specialization; and finally, 3) long-run analysis must consider shifts even in overall framework, such as from agriculture to migration and industrialization processes involving different economic dynamics. Support came from theory combined with historical data permitting limited documentation of: a post-1850 flattening and eventual reversal of previous New England deforestation as population was increasing; increasing within-region concentration of population and activity after 1830 (the start of the transportation revolution); the concentration of population in cities along rivers.

While evidence for 2) would not surprise an economist, evidence over a long time period is of some interest. Given concern about carbon sequestration, questions such as "Will international coffee prices affect Costa Rican forests?" are being asked, and such "external" factors may be difficult to consider within empirical analyses of recent land use. For example, while as discussed above Pfaff (1997) considers a number of land use drivers, at least two temporal stories are not easily empirically addressed: first, the non-Amazon Brazilian economy is thought to be a factor in land clearing in the Amazon; and second, a rising international timber price is widely held to be at least partially responsible for the increased presence of logging firms in the South America. Both of these credible stories about external drivers are hard to test without more evidence over time, as these variables change only over time. Thus the long-run evidence provided here is of interest.

The "returns" and "long-run" claims also suggested two additional points: first, they suggested the likelihood of significant shifts in relative returns over the long run, raising the possibility that current land-use analysis may lack future policy relevance; second, they suggested mechanisms through which forested area might first drop and then rise as development proceeds. However, in New England this reversal in the direction of change in forest area appears to have depended at least in part upon the ability of other regions of the country to supply food (i.e., New England "exported" its agricultural land clearing) as well as timber. To the extent that this is so, even if elements of the New England dynamic appear quite general, the New England experience can not provide the basis for a prediction that *all* regions can become reforested as they develop.

The analysis here could be strengthened through more formal modeling and/or additional data. More data might help to isolate the sign and significance of the effect of population, while both more formal modeling and a great deal more data might help to identify evidence of particular "agglomerative" processes, for instance those involving externalities within manufacturing and urbanization. While it is unlikely that additional land-use observations will become available for this time period, extending the New England example beyond 1930 may help, and of course other locations may offer the opportunity for more in-depth empirical analysis of these and related points.

The consideration of other locations raises again the issue of what about New England can be transferred to other contexts. Perhaps the mechanisms which caused forest area to fall and then rise would not hold elsewhere. However, even if they did, and even if such a fall and rise had been optimal for New England, the same path might not be optimal elsewhere. Questions of exactly what is valued must be raised. For instance, the current forest in New England contains different species and may be more fragmented than that in the early 1800's. Further, the fall and rise in New England may not have involved potentially irreversible losses, for instance losses of valued species.

Finally, the need to go beyond the typical agricultural or extractive framework to include migration and industrialization in considering relatively long-run land use has been suggested by work on the Brazilian Amazon. Extending the line of research in Reis and Margulis (1991) and Reis and Guzman (1992), Pfaff (1995) examined major driving factors behind deforestation in the Brazilian Amazon. Two main results are that roads appear to have a significant effect in channeling development and deforestation, and that the marginal impact on land clearing of additional people in a county falls with the amount of population already in the county. If Brazil wished a certain level of output and employment from that region with the least possible deforestation, it might appear from those results that building good roads to existing cities and putting subsidies into the cities instead of into previously uncleared areas would be a good approach to regional development.

That policy speculation is based on analysis of past land-use within the context of mainly agricultural processes. The nature of the policies suggested, however, demands that we develop a vision of how a quite different set of processes such as migration to cities and industrialization of cities would unfold over time in this region. Reis' (1997) work has acknowledged this need. In his chapter on carbon emissions scenarios in this volume, a crucial component in the long-run simulations is how migration reacts to policy stimuli in a sub-region. If a stimulus draws people in from other sub-regions and concentrates them, this indirect effect may counter to some extent the direct effects of the stimulus upon the pace of land clearing. The analysis of New England presented here also starts to address this need, but considers only one historical case and must be seen as relatively suggestive. More generally, both Reis' and this chapter can be seen as calls for both more theoretical and more empirical analysis which addresses this question.

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Table 1

TRENDS OVER TIME IN NEW ENGLAND, FROM 1850-1930

Year	Density of Total Population (people / acre)	Density of Mfg. Employment (people / acre)	Density of Improved Land[1] (acre / acre)	Density of Forested Area[2] (acre / acre)
1850	.07	.008	.28	.66
1860	.08	.010	.31	.63
1870	.09	.013	.30	.63
1880	.10	.016	.33	.60
1890	.12	---	.27	.66
1900	.14	.024	.21	.72
1910	.17	---	.18	.73
1920	.19	.034	.15	.76
1930	.21	.028	.13	.78

[1]: The Census divides total land on farms into improved and unimproved. The latter includes both woodland and other unimproved land. At least roughly, improved land would appear to include all crop land plus plowable pasture land.

[2]: This version of Harper's (1918) estimate is: (county area * .95) - (population * .2 acres) - (improved land on farms).

Table 2a
DISTRIBUTION OF COUNTY POPULATION DENSITIES & LEVELS IN NEW ENGLAND
Decennial Concentration Ratios and Gini Coefficients

Year	Dens. CR-5[1]	Dens. CR-15[1]	Dens. CR-25[1]	Dens. Gini[2]	Level CR-5[1]	Level CR-15[1]	Level CR-25[1]	Level Gini[2]
1790	0.18	0.45	0.73	0.24	0.26	0.60	0.84	0.30
1800	0.15	0.38	0.64	0.21	0.23	0.54	0.78	0.27
1810	0.09	0.39	0.61	0.18	0.22	0.50	0.73	0.25
1820	0.09	0.37	0.58	0.16	0.19	0.47	0.69	0.22
1830	0.12	0.34	0.57	0.13	0.19	0.45	0.65	0.20
1840	0.12	0.37	0.58	0.13	0.21	0.46	0.65	0.20
1850	0.20	0.40	0.59	0.14	0.24	0.49	0.67	0.21
1860	0.22	0.46	0.60	0.15	0.27	0.53	0.68	0.21
1870	0.26	0.52	0.63	0.18	0.31	0.57	0.71	0.23
1880	0.29	0.56	0.69	0.20	0.34	0.60	0.74	0.25
1890	0.32	0.60	0.73	0.23	0.37	0.65	0.77	0.27
1900	0.34	0.65	0.77	0.26	0.40	0.69	0.80	0.29
1910	0.35	0.68	0.79	0.27	0.41	0.72	0.83	0.31
1920	0.35	0.71	0.81	0.28	0.41	0.74	0.84	0.32
1930	0.35	0.72	0.82	0.29	0.41	0.76	0.85	0.32

[1]: The "CR-*x*" variables are the sum of the *x* highest county population densities over the sum of all densities.

[2]: This measures the difference between the actual distribution of densities (or levels) over counties and a hypothetical distribution in which all counties have equal densities (or levels). It is an inequality measure of the whole distribution.

FIGURE 2 (from Table 2a): Increasing Concentration of Population Densities post-1830

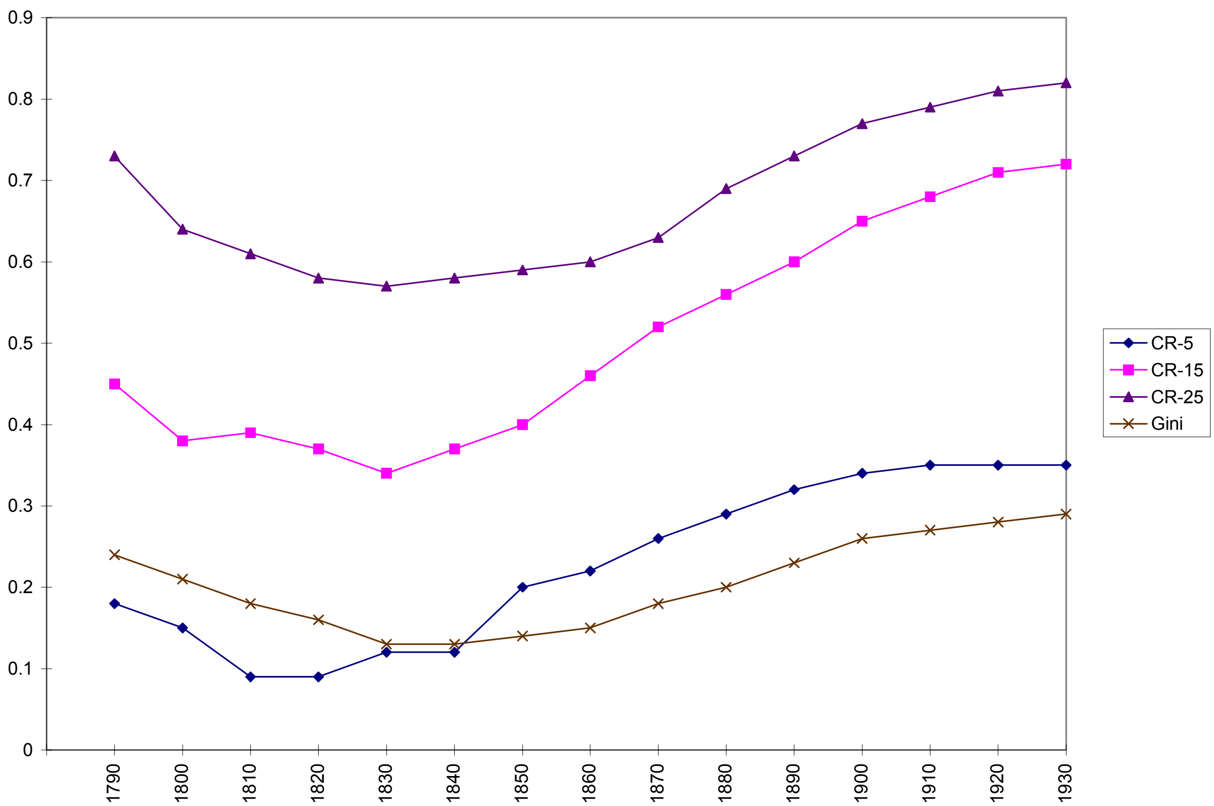

Table 2b
DISTRIBUTION OF IMPROVED LAND AND MANUFACTURING EMPLOYMENT
Decennial Concentration Ratios

Year		Dens. CR-1	Dens. CR-5	Dens. CR-15	Dens. CR-25	Level CR-1	Level CR-5	Level CR-15	Level CR-25
	Improved Land								
1850		0.03	0.13	0.36	0.56	0.05	0.18	0.42	0.61
1860		0.03	0.12	0.34	0.53	0.04	0.16	0.39	0.59
1870		0.03	0.12	0.35	0.55	0.04	0.16	0.40	0.60
1880		0.03	0.12	0.33	0.52	0.04	0.16	0.39	0.59
1890		0.03	0.13	0.34	0.53	0.03	0.15	0.40	0.59
1900		0.04	0.15	0.37	0.55	0.05	0.18	0.43	0.62
1910		0.04	0.15	0.37	0.55	0.06	0.20	0.43	0.62
1920		0.05	0.17	0.41	0.58	0.07	0.20	0.45	0.64
1930		0.05	0.18	0.42	0.59	0.09	0.22	0.47	0.65
	Manufac. Employ.								
1850		0.50	0.70	0.86	0.94	0.12	0.44	0.74	0.87
1860		0.36	0.59	0.82	0.91	0.12	0.42	0.74	0.86
1870		0.49	0.69	0.86	0.94	0.09	0.43	0.73	0.86
1880		0.53	0.72	0.88	0.95	0.09	0.44	0.76	0.88
1890		---	---	---	---	---	---	---	---
1900		0.49	0.69	0.88	0.94	0.09	0.42	0.78	0.88
1910		---	---	---	---	---	---	---	---
1920		0.45	0.69	0.90	0.96	0.09	0.41	0.82	0.90
1930		0.46	0.69	0.90	0.96	0.10	0.41	0.82	0.90

Table 3a

CONCENTRATION OF POPULATION ALONG THE MERRIMACK

Merrimack[1]	1850	1860	1870	1880	1890
CR-1[2]	0.32	0.26	0.24	0.27	0.28
CR-3[2]	0.54	0.53	0.56	0.60	0.59
CR-5[2]	0.70	0.70	0.71	0.74	0.76

[1]: The total number of towns counted as "on the Merrimack" for this table is 26.

[2]: The "CR-*x*" variables are the sum of the populations of the *x* largest towns on the Merrimack divided by the sum of the populations of all the towns on the Merrimack (i.e., the 26 counted).

Table 3b

CONCENTRATION OF POPULATION ALONG THE CONNECTICUT

Connecticut[1]	1850	1860	1870	1880	1890
CR-1[2]	0.09	0.09	0.17	0.17	0.17
CR-3[2]	0.22	0.22	0.35	0.38	0.43
CR-5[2]	0.28	0.30	0.44	0.48	0.53

[1]: The total number of towns counted as "on the Connecticut" for this table is 111.

[2]: The "CR-*x*" variables are the sum of the populations of the *x* largest towns on the Connecticut divided by the sum of the populations of all the towns on the Connecticut (i.e., the 111 counted).