THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS AND LEGACY POLLUTION: A GEOHISTORICAL ANALYSIS OF THE ENVIRONMENTAL CONSEQUENCES OF INDUSTRIALIZATION IN WORCESTER, MASSACHUSETTS (USA)

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ABSTRACT

Industrialization is widely recognized as an important mechanism for economic development. Yet, environmental impacts of industrialization are only given selective treatment in the literature examining the relationship between economic development and its effect on the environment. This paper argues that theoretical reconciliation between industrialization and the resulting environmental degradation remains unresolved. The continuing presence of long-term legacy pollution on former industrial properties in industrialized countries challenges the assumption present in the Environmental Kuznets Curve literature that environmental impacts of economic development are minimal and easily reversed using capital and technology. The geohistorical analysis of past industrial development presented here demonstrates that the long-term environmental consequences remain unresolved, expensive, complicated to remediate, and possibly irreversible.

Key Words: brownfield, environmental Kuznets curve, environmental services, environmental history, deindustrialization, legacy pollution, Massachusetts, Worcester

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INTRODUCTION

Industrialization has been traditionally considered one of the most important mechanisms of economic development (Peet 1987). Developed economies experienced rapid growth in industries beginning in the late eighteenth century. Increasing international competition, and stricter environmental, workplace health and safety standards after WWII forced corporations in the United States of America (US) to look for opportunities abroad (Harvey 1989; Leonard 1984). Corporations, keen to keep their investments profitable, migrated to developing countries in search for cheaper labor, lax regulations and cheaper production costs. While this resulted in a 'race to the bottom' to attract and keep capital investment in developing countries, it also led to significant deindustrialization in the US.

The literature on global economic development has, however, paid much less attention to persisting environmental problems resulting from past industrial activities in deindustrialized spaces. Though various federal and state environmental acts have to some degree led to gradual improvement in air (EPA 2009) and drinking water (EPA 2000) quality in the US, contaminated former industrial land remain important elements of economic development agendas in centers of declining industrial production in the US. It is estimated that up to one million of these contaminated properties, commonly referred to as brownfields, exist in the US (EPA 2007), along with almost 50,000 sites where hazardous wastes may have been dumped without steps to ensure that the wastes do not pollute groundwater (Hardoy and Satterthwaite 1995).

There are multiple factors that complicate the brownfield redevelopment process. Deindustrialization in the US began in the period immediately following WWII but federal and state agencies started maintaining systematic databases about releases and spills of suspected pollutants only in the early 1980s and, by then, many of the suspect industries were already shuttered. This resulted in a stark knowledge gap about the contamination profile of these properties that has continued to generate anxieties regarding unknown contaminants on industrial properties and results in the widespread negative perception of brownfields. Later, the 1980 implementation of the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was blamed for increasing instances of owners choosing to 'mothball' or abandon properties for fear of uncertain legal liability. The retroactive, strict, joint and multiple liability scheme, its lack of flexibility in cleanup standards, and the ability of the EPA to intervene in state-supervised cleanup projects under the CERCLA Act, served as major deterrents for potential developers in former industrial sites (Collins 2003). Despite the expenditure of $700 million in grants to states, local governments and nonprofits by the EPA between 1995 and 2003 (Wernstedt et al. 2004), the large number of brownfields has meant that this financial assistance has proven vastly inadequate.

The real or perceived presence of contamination in brownfields has adversely affected the economic, social and, in many cases, environmental health of local communities (Greenberg, Lee, and Powers 1998; WRRB 2005). Moreover, as Western economies have become increasingly reliant on service industries, cities and regions with brownfields are facing an uncertain economic future. Legacy pollution has been difficult to qualify and quantify, and environmental legislation and State-sponsored financial assistance have failed to produce the desired level of investment in redevelopment of brownfields (Collins 2003; Wernstedt et al. 2004). As 'pollution havens' caused by 'regulation flight' from the North are becoming more common in the South, the future of 'sacrifice zones' such as brownfields in the former remain unresolved.

This paper argues that optimistic demonstrations of reduction in environmental pollution with economic growth in the Environmental Kuznets Curve (EKC) literature are misleading. This mainly results from two important and inter-related omissions: the type and medium of pollutants and environmental problems that are considered for the studies, and the time-period included in the analysis. This paper uses geohistorical analysis to challenge the EKC assumption that current and future environmental impacts of industrialization are benign and disappear with economic growth.

The city of Worcester (Massachusetts, US) was part of the industrial revolution in the northeastern US since the early nineteenth century and is used as a case study in this paper (see Figure 1). After WWII, the city experienced rapid deindustrialization and has been grappling with the socioeconomic repercussions ever since. A detailed industrial history of Worcester was compiled using various secondary sources and particular emphasis was placed on the scale and type of environmental consequences. Emphasis was also placed on documenting the environmental consequences of urbanization, a related process of industrialization in Worcester.

The paper is organized as follows. The next section provides a theoretical context for the study by discussing the EKC hypothesis, a key body of literature that emerged in the 1990s and attempted to empirically study the link between economic growth and the environment. A detailed account of industrialization and the resulting pollution in Worcester is offered next. In the following section, the paper discusses the implication of legacy pollution on the validity of the EKC.

THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS

The EKC hypothesis is based on the inverted U-shaped relationship between income inequality and per capita income proposed by Simon Kuznets (Kuznets 1955). According to Kuznets' analysis, inequality in the distribution of income decreases in the course of a country's

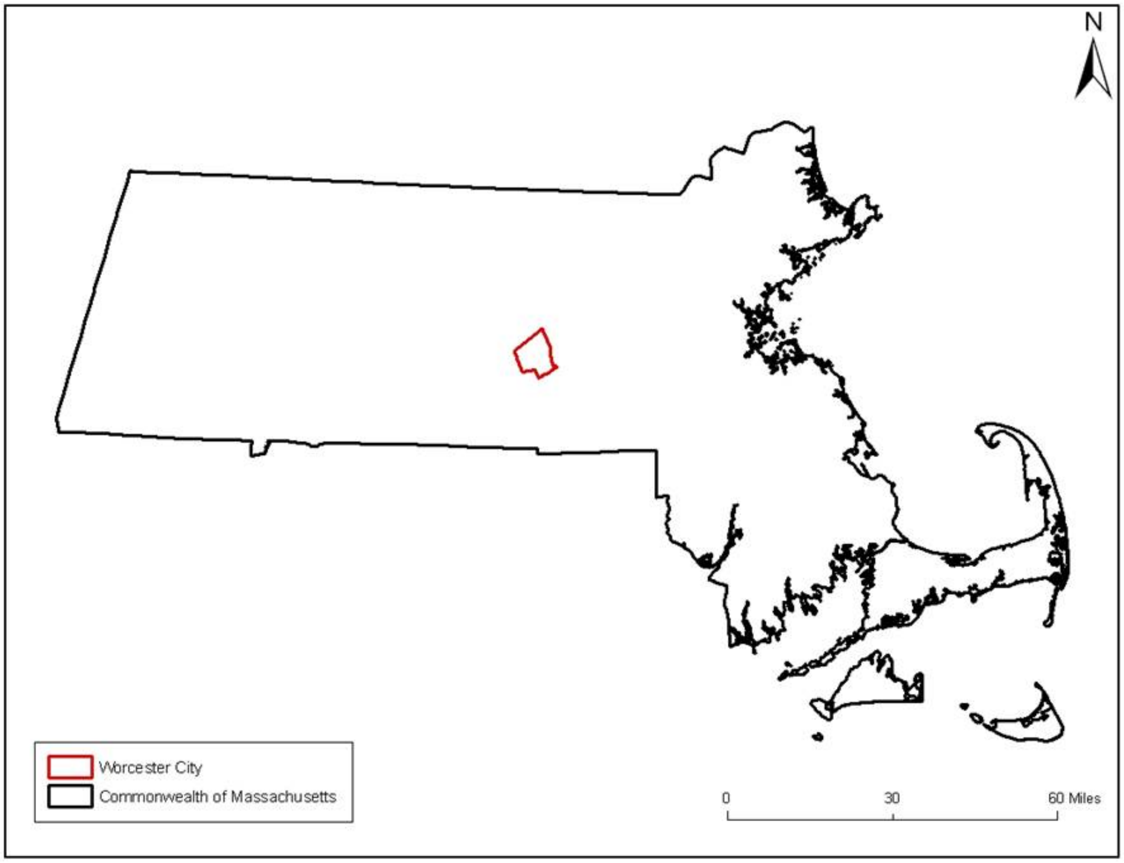

Figure 1: The Worcester, Massachusetts Study Area

economic growth. Kuznets argued during post-WWII industrialization in the newly-independent countries in the South that industrial development would lead to higher standards of living. The early integration of Kuznets' hypothesis into environmental thinking occurred in response to publication of 'The Limits to Growth'. The restrictions to production due to resource constraints envisaged by Meadows et al. (1972) were challenged on both theoretical and empirical grounds. Various authors (e.g. Malenbaum 1977) argued that the intensity of raw materials consumption decreases with increase in GDP due to increased industrial efficiency.

Availability of empirical data on various pollutants in the 1990s allowed researchers to extend their analysis to finding relationships between pollution emissions and increase in GDP (e.g. Grossman and Krueger 1995). Panayotou (1993) labeled this relationship as the EKC which has since gained popularity in studies documenting the effects of industrialization on environmental conditions. According to EKC, decline in environmental quality in the early stages of economic development is followed by structural change towards information-intensive industries and services as development progresses and income increases. This structural change is also coupled with increased environmental awareness, enforcement of environmental regulations, better technology, and higher environmental expenditures, and lead to leveling off and gradual decline of environmental degradation (Panayotou 1993). This relationship reproduced in graphic format mirrors the bell-shaped relationship predicted by Kuznets (see Figure 2). Neumayer (2003) argues that countries becoming rich through industrialization-led economic growth would be better placed to meet the higher demands for environment protection (for overviews of EKC, see Stern 2003, 2004).

The literature on EKC has been inconclusive despite claims to the contrary by its proponents (Alstine and Neumayer 2008). There were various limitations to these studies in addition to quality, non-availability and incomparability of data. The studies have generally involved the analysis of pollution data that did not exist for the period prior to the 1970s and, thus, only covers the time-period when industrialized countries had presumably began their EKC 'turn-around' (Vincent 1997). According to Stern (1998), the main arguments against EKC include the demonstration of EKC for only a subset of indicators. For example, most EKC studies focus on air pollutants such as SO_x, CO_x, NO_x and particulates. Studies have mostly included environmental problems that are local, easy and inexpensive to solve, and data for which are well organized and available (Rothman 1998). This result in ignoring environmental problems that are less visible, and more expensive and difficult to clean. The impact of technological change and high income on the environment also remain in doubt (Lopez 1992; Wen and Cao 2009).

According to de Bruyn and Heintz (1999), available evidence seemed to refute the EKC hypothesis that economic growth can actually lead to the benefit of the environment and it was necessary to examine a wider range of environmental issues to verify that EKC was not just a 'stylized fact'. There has been some evidence, especially in developing countries, that emissions reducing technological change can overcome the scale effect of rising income per capita on emissions (Stern 2004). But others have argued that while the EKC may work for traditional pollutants (e.g. SO_x), it does not apply as well to newer pollutants (e.g. carcinogenic chemicals) which remain unregulated almost everywhere other than industrialized countries (Dasgupta et al. 2002). The environmental future of developing countries looks even more disconcerting if one imagines a 'race to the bottom' scenario where dirty production is outsourced from developed countries and pressure of globalization would preclude any additional tightening of environmental regulation to maintain competitiveness. If one considers the problem of environmental degradation, one realizes that EKC needs to be explained and understood in multidimensional ways or in terms of multidimensional issues (Dinda 2004).

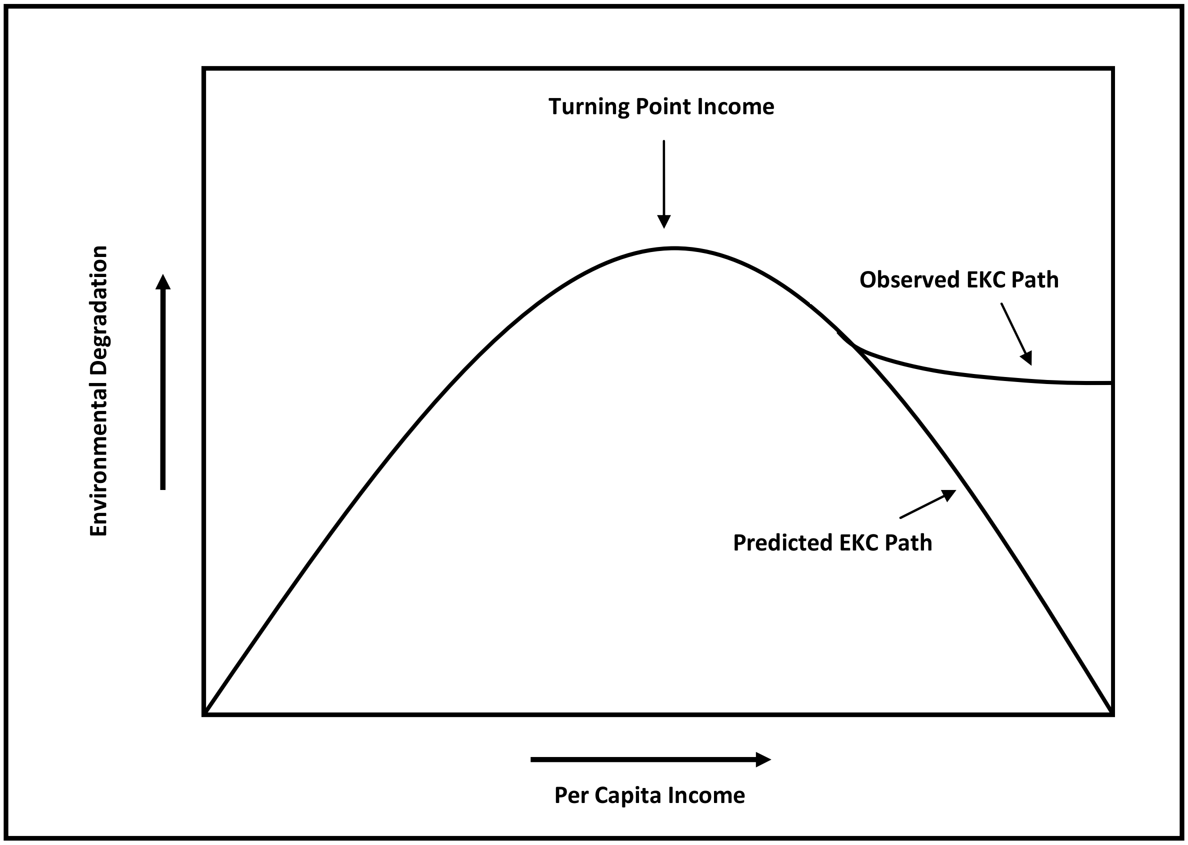

Figure 2: The EKC Relationship in Graphical Form

While there is still no definite agreement on EKC, the subject of the relationship between pollution and economic growth is an open-ended subject and EKC analysis continues to be widely used.

While there has been intense examination and reexamination of available data from both industrializing and industrialized countries over the last two decades, the focus has remained on evaluating recent data and traditional pollutants. This trend remains problematic for two reasons; firstly, it ignores other forms of pollutants present in the industrialized countries that are not equally visible but could potentially be more difficult to resolve and secondly, ignoring these problems in industrialized countries could lead to repetition of the same polluting behaviors in industrializing countries. Thus, the shortcomings of EKC regarding time-period and pollutants considered for analysis, cost and ease of environmental cleanup, and the relative lack of success with brownfield redevelopment despite better technology and high GDP in developed countries necessitates a closer examination. The following geohistorical analysis of Worcester provides a methodology for addressing the above-mentioned weaknesses in current EKC research.

THE ENVIRONMENTAL HISTORY OF INDUSTRIAL WORCESTER

According to Muir (2000), the lack of large amounts of suitable land for farming and a growing population led to development of industries in early Worcester. Though the first mills in Worcester were established in 1685 (Washburn 1917), a permanent settlement materialized only around the 1720s (Erskine 1981). By June 1827 Worcester is said to contain "large paper-mills…five machine shops…one Cotton factory, a Lead aqueduct factory and other works of minor note" (p. 60). The construction of the Blackstone Canal connecting Worcester with Providence (Rhode Island) in 1828, and railway service between Worcester and Boston in 1835 resulted in rapid industrial growth in the following period. Worcester was among the top 30 cities in the US in terms of population size and level of industrialization in 1880 (Jonas 1992). Worcester was ranked first among all US cities for war production in 1918 (Crane 1924). Manufacturing and mechanical industries was noted as occupation for 42,631 city residents in 1920, almost 24 percent of the population.

Unlike other cities in the New England region that were limited almost entirely to a single industry Worcester was amazingly diversified. There were over 1,000 industries and businesses in the city by 1865 (Southwick 1998). By 1898 the very diverse community of industry produced over 3,000 different goods (Nelson 1934). Metal trades and machinery usually accounted for about 40 percent of the city's industrial output by the late nineteenth and early twentieth century (Rosenzweig 1983). Unfortunately the city's prior diverse industrial base marked the beginning of a future with myriad types of contaminants now found in its soil, and surface and ground water. The hundreds of machine shops, foundries, tanneries along with wire, and paper and shoe factories concentrated in large numbers in Worcester were notorious sources of pollutants during these times.

Industrialization led to extensive pollution of Worcester's surface and groundwater sources. Worcester, as most cities in those times, did not have a sewage system. Outlets from cesspools and drains were directed to brooks and streams in the city (Crane 1924). In 1867 it was estimated that 44 sewers were discharging 11,000 cubic meters of raw waste into the Mill Brook (Shanahan 1994). Since its completion in 1828, the Blackstone Canal has been used by the city's residents to dump all sorts of trash – "from ashes to dead horses" (Erskine 1981 p. 117). As a result the Blackstone Canal has been transformed into a 'toxic soup' (Dunham 1992). The stench from sewage and industrial waste was unbearable, and has been held responsible for tuberculosis and other 'miasmic' diseases in neighborhoods adjoining the Canal in the 1870's. When industries in Worcester were encouraged to bury toxic wastes instead of dumping them into the canal, the buried wastes contaminated groundwater (Crane 1924). Due to intensive industrial use of local water sources Worcester was forced early to depend on neighboring communities for a source of clean water. Several reservoirs were built between 1883 and 1911 in towns west of Worcester to supply the city's growing water needs (Crane 1924).

The covering of the Blackstone Canal in 1887 did not stop the dumping of toxic wastes (Krueger 2007). Instead the problem was passed downstream into the Blackstone River (Crane 1924). The river was declared to be the most polluted in the nation in 1882 (Shanahan 1994). The State Legislature responded in 1886 to complaints from downstream communities and ordered Worcester to clean its sewage before discharging it into the Blackstone River. Reporting to the city committee on his research then City Engineer Charles Allen reported "the sewage is extremely acid, owing to the fact that large quantities of sulphuric acid and muriatic acids are discharged into the sewers from iron manufacturing establishments" (Anonymous 1891 p. 88). It was estimated in 1940 that 33 million gallons of wastewater per day comprised virtually all of the upper Blackstone River's low flow (Shanahan 1994). In addition to Worcester's sanitary wastes, the wastewater included a large volume of industrial wastes virtually untreated in its entirety. The Audubon Society declared the Blackstone one of most polluted rivers in the US in 1971 (Kerr 1990).

The heavy contamination of the Blackstone River resulting from intensive industrial activity is still detectable today. Shanahan (1994) and Spliethoff and Hemond (1996) reported that the effects of the industrial period from the late 1700s to the early 1900s have been shown in the Blackstone's sediment cores. High concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc were found in sediment cores at depths corresponding to the intense industrial activity of the early 1900s. The numerous dams constructed on the Blackstone, at its peak an average of one dam every mile, accumulated contaminants in fine sediments behind impoundments in the study area and remain in place today. A study by Chalmers (2002) found that 75 percent of the selected trace elements in the Blackstone River sediment were above the EPA Sediment Quality Guidelines. The river exceeded the National Academy of Sciences and the National Academy of Engineering guidelines for concentrations of total polychlorinated biphenyls (PCBs) in fish tissue. High concentrations, as high as 55 percent, of volatile solids indicated the presence of extensive sludge deposits on the riverbed. Both Mill Brook and Blackstone River continue to have high concentrations of metals (Shanahan 1994).

'Miasma' or 'sewer gas' resulting from industrial and sanitary waste was thought to be the principal source of many diseases in the nineteenth century. Following prevalent norms coal smoke was prescribed as a solution, and local industries and railroad depots were encouraged to release prodigious amounts in the air (Meyer and Brown 1989). Following numerous siting conflicts regarding air quality, many of Worcester's slaughterhouses, 'rendering' factories, rag shops, tanneries, refuse dumps, stables, kennels, gasoline storage and dye works were forced to relocate through litigation to the thinly-settled urban fringe (Meyer 1995). Officials of the Worcester Board of Health hoped that "what may be an intolerable nuisance in the center of the city may not be noticed on the outskirts" (p. 305). This action of relocating some of the most offensive and polluting industries to the city outskirts led to dispersal of pollution to previously unaffected areas and long-term environmental impacts on local water-bodies and groundwater (Erskine 1981; Shatkin 2002).

Indiscriminate land use prior to the introduction of zoning ordinances in 1925 and large area rezoning later aggravated the distribution of industrial pollutants within the city. The promulgation of zoning laws significantly increased the amount of developed land within city limits, and large area rezoning was championed by Worcester's business firms, real-estate developers, manufacturing firms and by city planning agencies (Natoli 1967). Large area zoning often resulted in conversion of industrial land to residential (Natoli 1971), thus exacerbating potential exposure of city residents to industrial pollution. With deindustrialization and resulting depopulation, vacant lots provided opportune sites for the dumping of toxic waste that further exacerbated the environmental degradation of the city (Landrum et al. 2004).

It may never be possible to fully estimate the health effects of industrial activities on the city's residents. Historical patterns of industrialization and the resulting urbanization have increased the complexity of locating, containment and removal of pollutants from Worcester's soil and groundwater. Metal industries dumped their waste, slag, ashes and scrap metals indiscriminately on land, as did slaughter houses, meat packers, tanneries, glue factories, and fat and bone boiling industries. The huge diversity of Worcester's industries ensured that the legacy pollution in soil and groundwater is equally varied. According to surveys done by state and private agencies, various carcinogenic and toxic compounds including volatile organic compounds, heavy metals, cyanide, PCBs, and volatile and extractable petroleum hydrocarbons have been detected in Worcester's groundwater and soil (e.g. GZA 1996). Lead and asbestos, toxic and carcinogenic respectively, are invariably present in old industrial structures as well as residential buildings. Bailey et al. (1998) noted that current lead exposure in city children is linked to the historical patterns of urbanization and industrial activity in Worcester.

Beginning in the 1950s, Worcester's major industries began to leave or close, and the brownfield era began. The old industrial centers in the city's valleys along railroad tracks today contain most of the city's known brownfields, and most of them continue to be abandoned or vacant. Many more unknown brownfields exist under residential structures that were erected on rezoned industrial properties. Very little is known about soil and groundwater contamination even in recognized brownfield properties. Federal and state agencies started maintaining systematic databases about releases and spills of suspected pollutants only in the early 1980s and many of the suspect industries were already shuttered by then. Deindustrialization resulted in large-scale unemployment and out-migration, and crippled the city's tax base. Huge falls in city revenue has prevented necessary environmental remediation and redevelopment of brownfields.

DOES THE EKC HYPOTHESIS HOLD?

The lack of environmental records from the period of industrialization in the developed countries has allowed EKC analyses to ignore the egregious pollution that created the millions of brownfields that dot the former industrial spaces. By focusing on the time-period when developed countries have presumably began their deindustrialization-led EKC 'turn-around', EKC has sought to promote the idea that the impact of industrial pollution are reversible and environmental quality improves with economic growth. EKC's penchant for environmental indicators that are easy and inexpensive to solve has led it to focus on selected air pollutants and surface water quality. It has ignored various carcinogenic and toxic compounds originating from past industrial activities found in soil, groundwater and surface water sediments in brownfield communities. Given these omissions, I would argue that the EKC relationship for industrialized countries actually resemble the alternate curve where the environmental improvements associated with economic growth is minimal. The EKC curve, instead of a perfect inverted-U shape, actually never reaches the bottom; the long-term and possibly irreversible industrial pollution in soil, groundwater and surface water sediments ensures that the curve transforms into a plateau (Figure 2).

Worcester officials estimated in 2001 that it could cost as much as $100 million to clean up the confirmed 240 contaminated industrial sites totaling 327 acres – these estimates only contain 25 percent of the all industrial sites in the city and it is possible that the real number of contaminated sites could be as high as 600 (Kotsopoulos 2001a, 2001b). These numbers provided by the city administration are, however, highly conservative. For example, environmental investigation and remediation on the 7.8 acre site of the recently completed Boys and Girls Club project in Worcester cost more than $10 million. If one takes into consideration that the environmental cleanup was only partial in exchange for future use restrictions, the cost estimate is a small fraction of what would be required if more comprehensive measures were used instead. Most environmental remediation in Massachusetts' brownfields currently opt for partial cleanup to minimize expenditure and leave significant amount of the legacy pollution in the soil and groundwater.

Since 1972 over $75 million in combined state and federal funds has been spent to upgrade the Blackstone River from Class D to Class C in Massachusetts alone (Kihn et al. 1986). For Blackstone Valley to be suitable for boating and swimming it must be upgraded to Class B status, a task estimated to cost at least an additional $75 million in the form of sewage-treatment facilities. Measures recommended in a 1981 sediment control plan for the Blackstone River entailed an estimated $35.6 million to address sediments contaminated by metals. Substantial additional funds and external capabilities would be required to assure safe disposal of solid waste, and to locate and clean up hazardous waste sources. By 1994, expenditures for pollution abatement in the Blackstone River appeared to have approached $150 million in actual dollars (Shanahan 1994). A 1996 report also found Worcester County to have above average percentages of acidified streams and lakes (Godfrey et al. 1996). The Executive Office of Environmental Affairs of Massachusetts listed 11 water bodies within the city limits that have unresolved presence of pollutants (EOEA 1998).

One must add to this list the cost incurred due to a degraded environment resulting from almost three centuries of industrialization and urbanization. The pollution of surface and groundwater resources has resulted in Worcester becoming completely dependent on external sources for its drinking water supplies. The extensive dumping of industrial waste in the soil has resulted in extensive groundwater contamination – all of Worcester's aquifers are classified as Non-Potential Drinking Water Source Areas (MassGIS 2006). While technically these aquifers are portions of what would otherwise be Potentially Productive Aquifers, the continued presence of legacy pollution ensures that these aquifers would remain unusable in the near future. While it is understandable that this may not be a concern at present, availability of drinking water would become increasingly significant in case of a prolonged drought in the region in the future. Hill and Polsky (2005) note that the central Massachusetts region experienced two significant drought periods in the second half of the twentieth century – the first an extreme multi-year drought during 1963-1966, and the other in 1999 was of lesser duration and intensity. Worcester survived these droughts by buying water at considerable expense from distant reservoirs (e.g. the Quabbin).

Even after the completion of environmental remediation at a brownfield site, the pollutants themselves do not just disappear. The cleanup of brownfield contaminants creates new environmental threats by relocating hazardous waste to landfills, processors and incinerators. Remediation wastes from processors and incinerators ultimately end up in landfills as the facilities only remove some of the hazard and require burial of the incinerated ash. Thus, while the word 'cleanup' may give the impression that all the harmful contaminants are neutralized, in reality the environmental costs from these pollutants are just externalized. Most of Worcester's remediation waste is transported by railroads to landfills located in the Midwest and Northeast US. In 1983 the federal Office of Technology Assessment estimated that no more than

10 to 20 percent of all hazardous wastes were treated according to the official guidelines (Szasz 1986). The remaining 90 to 80 percent of hazardous waste was either put in municipal landfills or disposed of illegally.

The concentration of historically blue-collar residential neighborhoods around former industrial properties makes this particular demographic particularly vulnerable to health consequences of legacy pollution. The massive depopulation following deindustrialization after WWII and the more recent influx of immigrants has resulted in a loss of local knowledge about past industrial activities in neighborhood properties. This concentration of the economically and socially vulnerable population close to brownfields increases their susceptibility to risks resulting from legacy pollution. A 2005 study on environmental injustice in Massachusetts put Worcester at the top of the table (Faber and Krieg 2005). By conducting assessments mostly at the country level, EKC 'smoothes out' local and regional distortions like Worcester that continue to carry a disproportionate burden of legacy pollution.

BEYOND POLLUTION

It can be argued that the impact of the industrial mode of economic development has environmental impacts beyond air, soil and water pollution, even though it is obvious that even these are not considered comprehensively by EKC analysis. Industrialization and attendant urbanization in Worcester were responsible for myriad environmental effects, most of them possibly irreversible. Worcester's extensive forests were decimated by the early 1800s and provided timber for industrial and domestic use, charcoal for industries, and potash and pearl ash for export (Erskine 1981; Washburn 1917). The disappearance of the forests led to local extinctions of many plant and animal species (e.g. cedars, wild turkey) and altered species distribution and numbers (Herwitz 2001). Worcester's early horticulturists introduced numerous foreign and non-local species, and an 1892 survey found 105 out of 161 plant species in Worcester to be foreign or non-local. Altered distribution and numbers, and introduction of foreign species caused increased plant vulnerability to pest and diseases like chestnut blight, elm leaf beetles, leopard moths, Dutch elm disease (Herwitz 2001), and more recently the Asian long-horn beetle (Nuss 2008). The lack of forest cover caused increase in local temperature, lowering of water table, and increased soil erosion, precipitation runoff and flooding. The erection of numerous mills on the Blackstone River stopped anadromous fish migration as early as 1790 (Shanahan 1994).

These environmental effects of industrialization in Worcester, many possibly irreversible, have important implications for the ecological future of the region. The loss of biodiversity and forest cover due to industrialization has certainly impacted the quality of environmental services. Environmental services, as argued by Myers (1996), include indirect values such as "generating and maintaining soils, converting solar energy into plant tissue, sustaining hydrological cycles, storing and cycling essential nutrients…, supplying clean air and water, absorbing and detoxifying pollutants, decomposing wastes, pollinating crops and other plants, controlling pests, running biogeochemical cycles…, controlling the gaseous mixture of the atmosphere (which helps to determine climate), and regulating weather and climate at both macro and micro levels" (Meyers 1996: 2764). The focus on short-term impacts and easy-to-solve environmental problems with EKC has obfuscated the long-term degradation of environmental services, and decline in the integrity of ecosystem processes and resilience as a result of industrial activities.

CONCLUSION

It is clear from the preceding discussion that environmental impacts of industrial pollution are complicated, long-term, expensive to remedy, and probably impossible to reverse. EKC proponents continue to imply that any limitations related to natural resources or environmental degradation can be solved and outgrown using better technology, institutional systems such as the open market, and investing a larger share of the budget (buoyed by economic growth) for environmental protection. The US Government Accountability Office estimated that between 1993 and 2004 the federal government has spent more than $20 billion (in 2004 dollars) on brownfields-related expenditure (GAO 2005). It can be safely assumed that associated federal agencies (e.g. HUD), state governments, local municipalities have spent several billions more on brownfield redevelopment around the country. Yet by EPA's own admission, there still exist more than one million contaminated properties waiting to be remediated. The successful examples of brownfield remediation like the Boys and Girls Club project in Worcester took more than 11 years to complete, required financial help from numerous sources and, despite the availability of appropriate technology, still chose only to partially remove contaminants from the site's soil and groundwater. While relocation of polluting industries from the US to other parts of the world led to visible reduction in air and surface water quality, economic prosperity has not been successful in removing or reversing some of the most serious environmental impacts of industrial activity.

A bigger concern with the above limitations of EKC lies with the environmental implications for industrializing countries in the developing world. As numerous authors in a recent edited publication (Gallagher 2008) point out, most developing countries are aping the 'grow now, clean up later' logic encouraged by the EKC literature. The fact that the EKC proponents have formed their conclusions from a highly limited understanding of the development paths of today's industrialized nations is of great concern. It will take decades and large sums of money for these industrializing countries just to reverse the limited environmental parameters that are the focus of EKC research. The inclusion of legacy pollution contained in the soil, surface and groundwater, and irreversible loss of environmental services and resilience would certainly add significant multigenerational socioeconomic burden for these developing communities. Given the challenges posed by brownfields in developed economies like the US, it would be fair to argue that dealing with industrial legacy pollution is easier said than done.

Geohistorical techniques, as applied in this paper, contribute an important and critical context to discussions on the environmental impact of industrial mode of economic development. Policy-makers is industrializing nations serious about environmental conservation should pay serious attention to not only the visible forms of pollution documented by the EKC literature but also the concealed forms of pollution and environmental degradation. Unless environmental policies to protect the soil, surface water, groundwater and environmental services are instituted concurrently with industrialization, serious possibilities exist for long-term, irreversible and prohibitively expensive environmental problems.

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