Impact of Massachusetts Health Care Reform on Asthma Mortality

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Abstract

The state of Massachusetts implemented a health care reform in 2006 that induced a number of changes to its health care system. Studies regarding this reform bear a certain degree of predictive power on the national scale because the reform was used as a model for the Affordable Care Act, the highly controversial national health care reform law passed in 2010. Most of the research on health care reform focuses on the costs, not the quality, of health care. I utilized a difference-in-differences statistical design to isolate the impact of the Massachusetts reform on the state's asthma mortality rate, a health care quality indicator. Given certain assumptions, my empirical results indicate that the reform led to a 45.38% reduction in asthma mortality in Massachusetts. Due to the similarity between the Massachusetts and the national health care reform laws, I drew the conclusion that national asthma mortality rates will decrease after 2014 when certain key provisions of the national reform come into play.

Introduction

I conducted an empirical analysis on the effect of Massachusetts health care reform (MHR) on health outcomes. By using a difference-in-differences (DD) statistical design to detect the association between the MHR and asthma mortality rates in Massachusetts, I tested my hypothesis that the MHR improved health care in the state. The state reform law, signed into law in 2006, has many provisions, the most notable being the individual mandate, which requires Massachusetts citizens to purchase health insurance or face a financial penalty. Studies regarding the MHR law are highly relevant because the state reform was used as a model for the Patient Protection and Affordable Care Act (ACA), a federal statute signed into law in 2010 by President Barack Obama. For an overview of the two laws, see the *Appendix*. The Supreme Court judged all of the highly controversial federal reform to be constitutional on June 28, 2012, with the exception of the provision regarding the expansion of Medicaid, which was limited. This passage through the Supreme Court, coupled with President Obama's successful re-election bid, signify that the ACA is here to stay.

The ACA is the largest overhaul of the U.S. health care system since the passage of Medicare and Medicaid in 1965. Its primary objectives are to reduce the number of uninsured Americans and the overall costs of health care. The U.S. spends a greater portion of its gross domestic product (GDP) on health care than any major industrialized country, spending $2.3 trillion on health care in 2008, increasing 4.4% from the previous year (National Center for Health Statistics).

However, the U.S. is not one of the top performers with respect to several significant health indicators. The U.S. has a below average life expectancy in comparison with other developed countries, a much higher prevalence of several conditions such as heart disease and cancer, a very high asthma mortality rate, and has been noted for its overuse of certain risky medical procedures (Docteur and Berenson, 2009). Proponents of the ACA argue that the ACA is the best solution to a broken health care system.

The efficiency of a health care system, from a high level overview, can be evaluated based on two key criteria: quality and costs. Although both the ACA and the MHR were primarily focused on insurance coverage rates and health care costs, monitoring the effects of the reform on quality is equally important. Because the MHR served as a model for the ACA, economists are using the Massachusetts experience as a means of gleaning insight into the future national health care landscape that will result as a consequence of the 2014 implementation of key ACA provisions. By conducting an a posteriori statistical analysis to evaluate the effects of the MHR on key health care quality indicators, I intend to both expand upon the existing body of research and collect evidence to make an a deduction as to how the ACA will affect quality outcomes.

Literature Review

My thesis posits that the MHR was associated with a decrease in the asthma mortality rate. This literature review will be categorized to focus on two key topics that are directly relevant to the thesis. First, literature helping to elucidate why the MHR would or would not be expected to affect health outcomes will be examined.

Second, the body of literature covering how the MHR has affected health outcomes will be reviewed.

Why would the MHR affect health outcomes?

Multiple mechanisms can explain why the MHR would be expected to positively change health outcomes. While the primary goal of the MHR was to increase health insurance coverage rates, the reform also included important quality-oriented initiatives. Starting in the second year of the reform, hospitals were required to meet certain quality benchmarks or pay for performance standards in order to be eligible for MassHealth rate increases ("Massachusetts Health Care Reform Bill Summary."). The MHR also allocated funding to care management demonstration projects, aimed at improving the care provided to those with chronic diseases. Moreover, the MHR created the Health Care Quality and Cost Council (HCQCC), "a public entity responsible for setting quality and cost targets for the Commonwealth" (Health Care Quality and Cost Council.). In its 2009 Cost Containment Report, the HCQCC stated that it "envisions a system where patients have access to safe, high-quality, effective patient-centered care that is affordable and equitable." Under the assumption that the HCQCC is effective and capable of attaining its objectives, it would be expected to positively affect health outcomes.

The MHR also sets prevention as a key objective to reduce health care costs and improve quality. The theory behind prevention is that rather than treating or curing symptoms, it is less costly to stop them from occurring in the first place, and that prophylaxis is logically a more effective way to improve population health.

In addition to allocating $20 million for public health and prevention programs, MHR has acted to make prevention a core component of health coverage (McDonough, John et al.). All Commonwealth Care plans have no copay for preventive services, and have low copays for primary care physician (PCP) office visits, lab work, and diabetes care ("Minimum Creditable Coverage (MCC) Requirements."). Also, prevention is included in Massachusetts' MCC requirements: doctor visits for preventive care must be provided prior to the beneficiary's deductible, removing financial barriers between the beneficiary and preventive care. Assuming that preventive care is a better method of improving population health, and that the easing of financial barriers is enough to entice residents to seek out preventive care, these changes would be expected to positively impact health care quality.

Aside from its effects on preventive care, by shifting financial incentives, MCC requirements may also influence residents in other ways that could affect their health. The requirements limit annual deductibles, out-of-pocket costs, and prescription drug deductibles, and remove yearly caps on prescription drug benefits and the total amount paid for a particular illness or benefit. Depending on how residents' coverage has changed since the reform, and on the sensitivity of residents to changes in coverage, resident behavior could have shifted in a way that could positively or negatively affect their health care utilization.

Another mechanism through which the MHR could affect health outcomes is through changed health insurance coverage rates. Because health insurance decreases the out-of-pocket price of medical services to residents, if health insurance coverage rates increased after the reform, residents could have more access to the proper care, be more informed on their health status, and gain access to beneficial prescription drugs. On the other hand, the MHR could decrease a resident's health care access. For example, if more people utilize the health care system post-reform, it is possible that overcrowding will cause wait times to increase, making it harder for an individual to obtain proper care. Also, if the state sets MassHealth reimbursement rates too low after the reform, hospitals (with the exception of the emergency room) and physicians may exercise their right to reject patients.

To analyze whether this mechanism could have impacted health outcomes in MA, two assumptions must be examined: the MHR improved health insurance coverage, and health insurance coverage improves health outcomes. As described by Cutler and Gruber (1996), there is a potential for a phenomenon known as *crowding out* that comes with an expansion of publicly subsidized health coverage which increases the costs of decreasing the uninsured rate. *Crowding out* of commercial, or private, insurance occurs when such a public expansion causes residents to shift from commercial to public insurance, often because the public insurance is cheaper or has better benefits. In their analysis of MHR, Kolstad and Kowalski (2010) used the Current Population Survey to demonstrate that the MHR did, in fact, increase health insurance coverage among the general MA population. They showed that among the inpatient population, insurance coverage rates increased 36% after the reform. The study also showed some evidence of *crowding out*, with the quantity of privately insured decreasing post-reform.

Having shown that health insurance coverage increased as a result of the MHR, the link between health coverage and health outcomes must be explored. The RAND Health Insurance Experiment is a notable study that randomly assigned people to different health care plans with different cost-sharing arrangements and recorded their behavior. Cost-sharing is when health insurance plans hold beneficiaries accountable for a portion of their medical costs, and may be effected in the form of copayments, coinsurance, and deductibles. Beneficiaries of cost-sharing plans, as opposed to plans without cost-sharing, would be expected to have lower health care utilization. This experiment revealed, "reduced service use under the cost-sharing plans had little or no net adverse effect on health for the average person" (Manning et al 1987). The study did demonstrate, however, that under the same circumstances, the health of the sick and poor, the most disadvantaged portion of the population, was negatively affected. Markedly, "the poor who began the Experiment with elevated blood pressure had their blood pressure lowered more on the free care plan than on the cost-sharing plans." Using epidemiologic data, the study implies "that the magnitude of this reduction would lower mortality about 10 percent each year among this group." This finding directly supports my thesis. Research supports that poverty and a lack of health care access are associated with higher asthma mortality, so it is likely that the MHR would lower asthma mortality by aiding the most disadvantaged portion of the populations ("Asthma").

Even if health insurance increases health care utilization, a conclusion supported by Anderson, Dobkin, and Gross (2010), it might not necessarily improve health outcomes. Kaestner and Sasso (2012) evaluated the effect of outpatient spending on hospital admissions and arrived at a counter-intuitive result: seeing the doctor more often results in more hospital admissions. While the RAND experiment and Kaestner's study seem to indicate that increased health insurance coverage rates and health care utilization do not improve health outcomes among the general population, other studies indicate the opposite. Research indicates that uninsured young children have lower immunization rates than insured children, uninsured adults are less likely than to receive preventive services, and uninsured children are at a greater risk of dying when hospitalized (Bernstein, Chollet, and Peterson, 2010). Despite the challenge of showing the causal effect of health insurance on health outcomes, there are studies evidencing both sides of the debate (Levy Meltzer 2007).

Effect of MHR on Health Outcomes

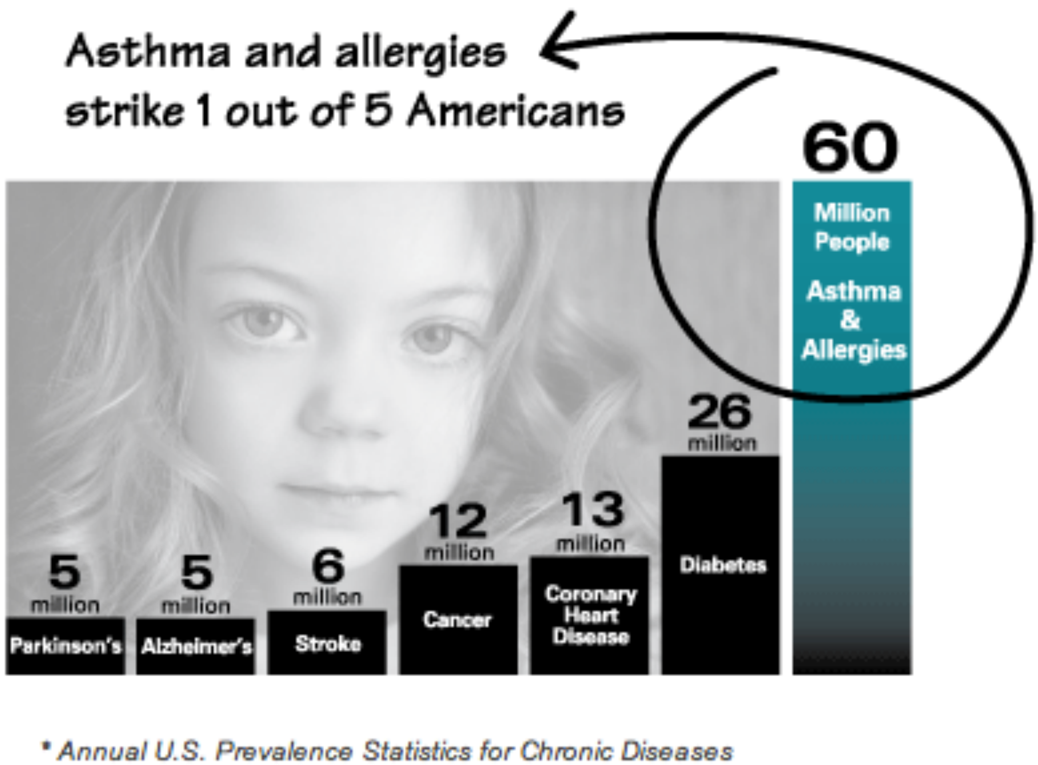
In addition to showing that insurance coverage rates increased as a result of the MHR, Kolstad and Kowalski (2010) made several other important determinations. Their study showed that the MHR caused a decrease in the length and number of inpatient admissions originating from the emergency room (ER) of MA hospitals as well as a decrease in hospitalizations for preventable conditions without causing a growth in hospital costs. Courtemanche and Zapata (2012) also provided positive evidence for the MHR. Using the Center for Disease Control and Prevention (CDC) BRFSS behavioral survey, it was shown that after the reform, residents had better self-assessed health. However, the validity of self-assessed data is debated, and is not one of the strongest health care quality indicators.

Miller and Wang (2011) investigated the impact of MHR on both hospital costs and quality of care. Using Centers for Medicare and Medicaid Services (CMS) acute hospital data, they showed that health care quality improved, while total hospital costs and physician salaries were unaffected. To measure quality, they used "several preventive care measures related to heart attacks, heart failure, pneumonia, and surgery as [their] measure of quality of care."

Miller (2012) also analyzed the effect of the MHR on ER visits. Using acute hospital case mix databases, Miller regressed the number of insured in each county on per capita ER rates. Some theorize that many of the uninsured seek non-urgent care in ERs because, as a result of the Emergency Medical Treatment and Active Labor Act, they can receive care regardless of their ability to pay. This is an issue because usage of the ER for non-urgent care can result in overcrowding and excessive costs. If this is the case, than decreasing the amount of uninsured should reduce the inherent inefficiency caused by this effect. Miller's study is a validation of this theory. The key takeaway from her study was that the MHR significantly reduced ER usage, and that the reduction mostly consisted of non-urgent visits that could be treated in alternative settings.

Asthma Relevance

Asthma is a very relevant disease that significantly affects the lives of Americans. According to the Asthma and Allergy Foundation of America (AAFA), every day in America 44,000 people have an asthma attack. Every day due to asthma, 36,000 kids miss school, 27,000 adults miss work, 4,700 people visit the ER, 1,200 people are admitted to the hospital, and 9 people die ("Asthma"). It is apparent that the disease brings significant costs to the American economy, in the form of lost productivity, decreased quality of life, and heightened medical expenditures. Annual costs are estimated at $18 billion, with $10 billion of direct costs (mostly medical expenditures) and $8 billion of indirect costs (i.e. lost earnings caused by illness or death). Asthma is one of the most prevalent chronic diseases, with close to 25 million Americans suffering from the disease. Since the 1980s, prevalence has been increasing across all age, sex, and racial groups.



Asthma Background

Asthma is a chronic disease that affects the respiratory system ("What Is Asthma?"). Symptoms can include coughing, wheezing, shortness of breath, and chest tightness. The onset of these symptoms is known as an asthma attack, and can be deadly. Although asthma symptoms are very treatable, uncontrolled asthma can lead to emergency room (ER) visits and can affect a person's ability to be active, limiting his quality of life. Over 25 million Americans are affected by the disease, which causes 2 million ER visits every year (one quarter of all yearly ER visits). Asthma is characterized by airway obstruction, bronchial tube inflammation, and airway irritability. Small triggers can exacerbate these issues, causing airways to constrict. The disease can occur at any age, although onset is more common in younger individuals. Allergies are often linked with asthma, and the symptoms of seasonal allergies may trigger the symptoms of asthma.

While there are several tests used to test for asthma, including lung function tests (i.e. spirometry and methacholine challenge tests), the disease can be tricky to diagnose. Because an asthmatic can go weeks to months without displaying symptoms, it is not likely that they would exhibit symptoms while in a doctor's office. Once diagnosed, however, the disease is highly treatable. Certain medications, asthma inhalers, steroids and other anti-inflammatory drugs, bronchodilators, and asthma nebulizers can all be used to control asthma symptoms. The disease is not presently curable, but some asthmatics report "growing out" of their symptoms as they age.

Common asthma attack triggers are dust, molds, pollens, pets, cockroaches, tobacco smoke, and certain airborne chemicals, such as ozone, nitrogen dioxide, and sulfur dioxide. Other triggers include viral infections, like the cold or flu, exercise, sudden stress, and allergies to medications. The Centers for Disease Control and Prevention (CDC) report that acid reflux, bad weather (such as thunderstorms or high humidity), breathing in cold, dry air, some foods, and strong emotions can also act as triggers ("Asthma Basic Information.").

Theory

The MHR would be expected to reduce asthma mortality in the state of Massachusetts for the period after the reform's 2006 implementation. Kolstad and Kowalski (2010) showed that the MHR increased health insurance coverage rates. Because health insurance decreases the out-of-pocket price of medical services to beneficiaries and since health insurance coverage rates increased after the reform, the post-reform Massachusetts population would have more access to the proper care, be more informed on their health status, and gain access to beneficial prescription drugs. This would improve the odds of proper asthma diagnosis and treatment, in turn reducing the probability of asthma mortality.

A proper understanding of other variables that could potentially significantly affect asthma mortality is necessary in order to isolate the effects of the MHR. I have broken these other variables into three categories: prevalence, demographics, and asthma attack triggers. One would logically expect asthma prevalence to be positively correlated with asthma mortality.

Demographics can be more tricky. Current data suggest gender, ethnic, and age disparities ("Asthma."). Women account for 65% of asthma deaths overall, African Americans are three times more likely to die from asthma, and Senior citizens account for roughly 60% of the 4,000 annual asthma mortalities. The AAFA finds that ethnic disparities are highly correlated with poverty, urban air quality, indoor allergens, lack of patient education, and inadequate medical care. Akinbami and Schoendorf (2002) find that asthma mortality is high among children. Lang and Polansky (1994) evidence higher mortality among African Americans, hispanics, the poor, and females.

For the reasons explained above, health insurance is expected to be negatively correlated with asthma mortality. Because the wealthy should have less financial barriers to health insurance, I would expect income to be negatively correlated with mortality, whereas poverty rates should be positively correlated. However, it is possible that the population segment under the poverty level, due to Medicaid eligibility, could be better protected from asthma mortality than the population just over the Medicaid eligibility cutoff. Education would be expected to be positively correlated with mortality because those who are educated should better understand the hazards of asthma and be more prone to take treatment seriously.

All of the triggers described above should be positively correlated with asthma mortality. Pollutant levels, the number of smokers, pollens, pets, dust, viral infections, high humidity, and cold air are all important triggers. Precipitation could reduce asthma mortality by cleansing pollens from the air. Marks et al. find that there is a positive correlation between thunderstorms and asthma mortality, stating:

> These findings are consistent with the hypothesis that some epidemics of exacerbations of asthma are caused by high concentrations of allergenic particles produced by an outflow of colder air, associated with the downdraught from a thunderstorm, sweeping up pollen grains and particles

> and then concentrating them in a shallow band of air at ground level. This is a common cause of exacerbations of asthma during the pollen season.

These triggers may be more influential during certain times of the year. Weiss and Wagener (1990) evidence a certain seasonality to asthma, showing that a disproportionate share of the 5-34 year old population died from asthma from June to August, whereas the 65+ population showed disproportionate asthma mortality from December to February.

Data

The DD design of my model has important ramifications: the only variables affecting asthma mortality that need to be included in the model are those with observations varying over both time and location. Variables with observations that are constant over either time or state are already controlled for by the model, and their addition to the model would result in collinearity. For example, new asthma medications or inhaler technology would not affect the model because the new technology would homogenously affect all of the states in the model. Unless otherwise specified, data was obtained for the five states in the model (Massachusetts, Connecticut, New York, New Jersey, and Pennsylvania) from the years 1999 to 2010 for a total of 60 observations. For the independent variable, asthma mortality rates per 100,000 people, data was obtained from the CDC Wonder public health data system. The underlying cause of death data request was made using ICD-10 codes J45-46. Health insurance coverage rates were obtained from both the CDC and the Current Population Survey (CPS), although the CDC's data was used because the CPS did not have 2010 data available.

The CDC's Behavioral Risk Factor Surveillance System (BRFSS) survey data provided adult overall lifetime asthma prevalence, in total and by race, (as determined by a person's positive response to ever being diagnosed for asthma) and the proportion of smokers in the population. 1999 asthma prevalence observations were missing from all of my model's states, with the exception of Pennsylvania. Gender, age, and race data were obtained from the Census Bureau's intercensal population estimates. Seasonally adjusted unemployment rates were obtained from the Bureau of Labor Statistics (BLS), and the Census Bureau's Model-Based Small Area Income & Poverty Estimates (SAIPE) provided data for average income and poverty rates.

Historical average daily temperature, total annual precipitation, average wind speed, and number of days with thunderstorms in a year were obtained from wunderground.com. Because this data is only available for cities and not states, the weather data for the largest city (by population) in each state was used as a proxy for the conditions of the entire state (Philadelphia, PA; Bridgeport, CN; NYC, NY; Newark, NJ; Boston, MA). Because Weiss and Wagener (1990) indicated that asthma mortality was seasonal, I thought it would also be prudent to record the average daily minimum temperature from January 1st to March 31st of every year in a variable called *mintempwinter*. Dropout rates were obtained from the National Center on Education Statistics Common Core of Data system, although too many observations were missing for it to be included in the model.

Nitrogen dioxide, sulfur dioxide, and ozone levels were obtained from the Environmental Protection Agency (EPA). State-wide data was not available, and the

EPA warned that pollutant levels could not be expected to be homogenous across regions. I used data from the largest city (by population) in each state, knowing that those pollutant levels would affect a large portion of the state's population and following the assumption that the asthma is most prevalent among city dwellers, an assumption supported by the AAFA ("Asthma.").

Note that, as an internal control for population size, all variables involving a quantity of people are represented as proportions of a population. The asthma mortality rate is a proportion per 100,000 people, while health insurance coverage rates, asthma prevalence rates, race, gender, and age distributions, unemployment rates, poverty rates, and smoking prevalence are represented as proportions of the total population of each state in its respective year.

Methodology

I utilized a difference-in-differences (DD) design in order to isolate the association between the MHR and health outcomes. This design enabled me to evaluate the causal effect of the MHR on health outcomes while simultaneously netting out common variation caused by other factors. To do this, in addition to the treatment group (MA), the design included control groups, or states very similar to MA without health care reform. The control states were Connecticut, New Jersey, New York, and Pennsylvania. A simplified model looks like the following:

$$Y_{it} = \alpha_0 + \alpha_1 \text{ (MA*Reform)}_{it} + \alpha_2 MA_i + \alpha_3 Reform_t + \beta X_{it} + e_{it}$$

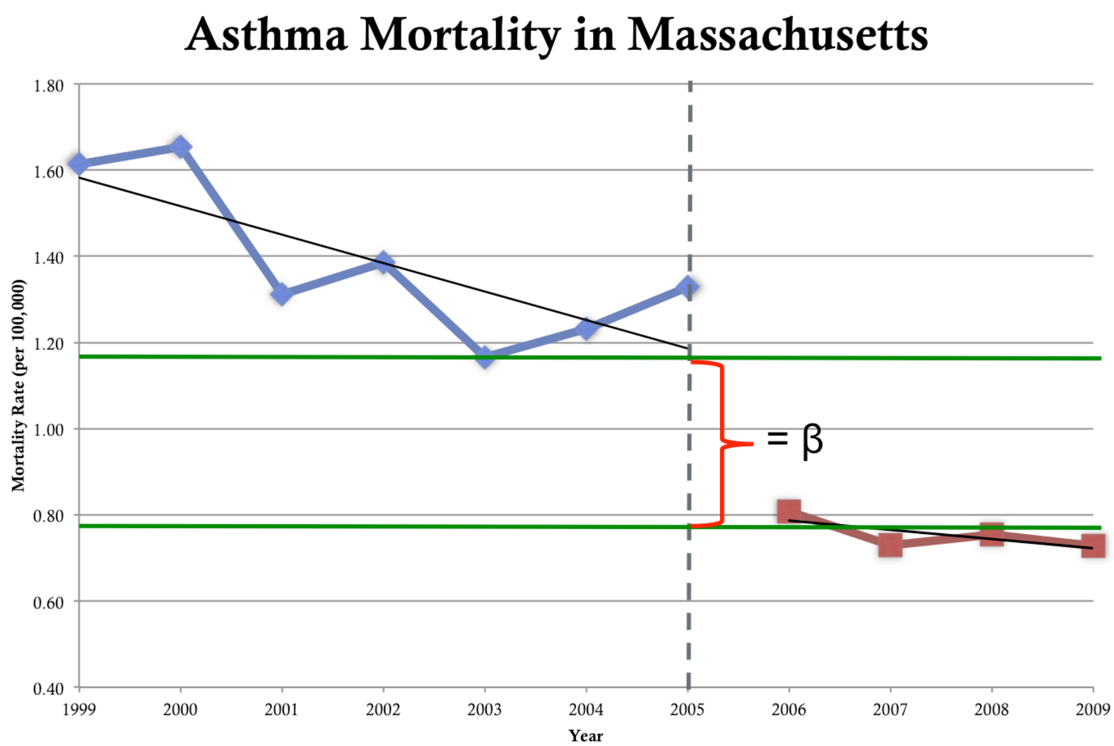
Y is the dependent variable, which could be any health care quality indicator, but is the asthma mortality rate in this instance. Index *i* varies by state, while index *t* varies with time (years). *MA* is a binary, or dummy, variable equal to 1 for data from Massachusetts and 0 for all other states. *Reform* is binary variable equal to 1 for observations after the MHR was enacted 0 for before. *X* represents space in the model for any control variables, and *e* is the error term.

Coefficient α_1 should represent the reform law's causal effect in MA on the dependent variable. However, the biggest difficulty of this design was isolating the MHR effects by controlling for all other exogenous changes that occurred at the same time as the reform, because coefficient α_1 will also capture these uncontrolled changes. Though, the exogenous change would have to occur in MA and not in the control group for it to be picked up by α_1. For example, Medicare Part D, the Medicare prescription drug benefit, was implemented federally in 2006, shortly before the MHR. Because it is a federal law, its effects also occurred in the control states, and were therefore netted out.

$$\alpha_1 = \Delta\text{Reform} = (Y^{\text{After}}{}_{\text{Treatment}} - Y^{\text{Before}}{}_{\text{Treatment}}) - (Y^{\text{After}}{}_{\text{Control}} - Y^{\text{Before}}{}_{\text{Control}})$$

With a plethora of possible health care quality indicators to use as the dependent variable, I decided to start by analyzing the effect of the MHR on asthma mortality rates. As discussed earlier, even though asthma mortality should be easily prevented by a successful diagnosis and the prescription of an emergency inhaler, America has a very high asthma mortality rate compared to other developed countries. The uninsured, without affordable access to health care, face a much greater risk of facing a potentially deadly asthma attack without knowing how to handle it.

One can see from the above chart of asthma mortality in Massachusetts that there was a considerable decrease in asthma mortality, represented by the vertical distance (β) of the discontinuity in the trend lines, at the time of the MHR's implementation. The chart has no controls and is composed of raw data, but it was a positive sign that the DD model would be able to ascertain meaningful insight from the data.



My general econometric approach was to start with a very basic model and slowly build upon it, testing new variables and different functional forms. I judged the inclusion of a variable on four criteria: it made sense in the model, it had the expected sign, the adjusted R^2 increased, and the variable was statistically significant. I tested different functional forms for each variable (i.e. geometric, logarithmic), lagged effects, variable interactions, and different time trends. My most basic model regressed the asthma mortality rate on *ma2006*, a binary variable equal to 1 for all observations in Massachusetts after and including 2006, *ma*, a binary equal to one for all observations in Massachusetts, *ct*, a binary for Connecticut, *nj*, a binary for New Jersey, and *ny*, a binary for New York. A fifth binary for Pennsylvania was omitted to avoid collinearity. These four control states were chosen based on data availability and geographic location. Later, I will discuss the benefits of keeping the control states in the same region as Massachusetts. Also, the coefficient on *ma2006* represents the change in asthma mortality caused by an exogenous change in 2006. My model will favor this coefficient as the most important. Later I will make an argument to support that the MHR was this exogenous change.

The first decision I had to make was how to add the element of time to the model. One option was to include a variable *time* with values 0-11 corresponding to 1999-2012. The second option I evaluated was to include a dummy variable corresponding to each year (with one year omitted to avoid collinearity). Although the first option had a higher adjusted R^2, I decided the second option was better because it allows the model to have more flexibility towards yearly differences. Next, based on adjusted R^2, I decided that the logarithmic functional form for the dependent variable (*logamorate*) was a better fit.

If the reform's effects were not instantaneous, instead reaching its full power over the course of several years, *ma2006* might not be the best variable to detect the reform's effects. I tested six other options. The first was from the Kolstad Kowalski model: set a *maduring* binary equal to one for observations in Massachusetts from 2006-2007 and an *maafter* binary equal to one for the following period (2012). The second was to have a binary variable for each post-reform MA observation. The third and fourth were linear time trends, with the latter reaching a maximum in 2008. The fifth was a time trend that equaled [ln(year-2005) + 1] for all years after 2005. This trend would be appropriate if the reform's effects were rapid initially and diminishing every year thereafter. The sixth was the same as the third except that the time trend stopped growing after 2008. As you can see from the table below, *ma2006* was the best fit, indicating that the reform's effects reached full power very quickly.

*regress logamorate **ma2006** ma ct ny nj i.time*

Option	Adjusted R^2
keep **ma2006**	**0.7457**
1	0.7396
2	0.7214
3	0.7080
4	0.7212
5	0.7275
6	0.7313

Because several observations were missing from the asthma prevalence variable and I did not want to simply drop the observations from the model, I devised three ways of filling in the missing data. I used Excel to extrapolate each state's missing data point, I filled in each missing data point with the lowest asthma prevalence value in the data set, and I filled in each missing data point with the highest asthma prevalence value in the data set. While the first method offered the highest adjusted R^2, the percent difference between the favored coefficient (the coefficient on *ma2006*) of the first method and that of the other two methods did not exceed 2.72%, and so I can infer the missing data points did not significantly affect the model.

Race has been shown to be a significant factor in asthma prevalence and mortality and the CDC's total asthma prevalence rates are not weighted by race distribution. For this reason, the total asthma prevalence rates could be biased based on the racial distribution of those surveyed. In order to create a more accurate control, I created two new variables by multiplying the African American asthma prevalence rates by the proportion of African Americans in the population, and the white asthma prevalence rates by the proportion of white citizens in the population. The effect is to create a variable controlling for the proportion of African American asthmatics in the population and another controlling for the proportion of white asthmatics in the population. Instead of adding these variables together to get an estimate for the total number of asthmatics in the population, I kept them separate under the assumption that African American asthmatics face a greater mortality risk.

On the basis of adjusted R^2 and variable significance, I added variables controlling for the logarithmic functional form of wind, the proportion of the population aged 18-64, unemployment, the geometric functional form of sulfur dioxide concentration, and the geometric functional form of the CDC's health uninsured rates. On the same grounds, the estimates for the proportion of African American asthmatics in the population and the geometric functional form of the proportion of white asthmatics in the population was added to the model. Although the *mintempwinter* variable described above increased adjusted R^2, it did not have the correct correlation with asthma mortality so it was rejected. A lagged effect for health insurance coverage rates was tested and rejected.

Interactions were tested between variables that would be rationally expected to have an effect on each other's coefficients. If the interaction term was significant and the addition of the term improved the adjusted R^2 of the model, it was added to the model. Trial and error led to the addition of two interaction terms. The first represented an interaction between the square of the airborne sulfur dioxide concentration and the proportion of white asthmatics in the population. The second represented an interaction between the square of the health uninsured rates and the proportion of African American asthmatics in the population.

Empirical Results

Shown below, the final model is:

$$logamorate_{st} = \alpha + \beta_1 * ma2006_{st} + \beta_2 * squninsuredcdc_{st} + \beta_3 * unemploy_{st} + \beta_4 * sqso2_{st} + \beta_5 * logwind_{st} + \beta_6 * baprevfitxblack_{st} + \beta_7 * sqwaprevfitxwhite_{st} + \beta_8 * sqso2\_sqwaprevfitxwhite_{st} + \beta_9 * adult_{st} + \beta_{10} * squninsuredcdc\_baprevfitxblack_{st}$$

logamorate is the outcome variable for asthma mortalities per 100,000 people in state *s* during year *t*. The favored coefficient of interest, β_1, gives the impact of the reform: the change in asthma mortality after the reform relative to before the reform in Massachusetts relative to the control states. A table with variable descriptions is below.

Variable	**Description**
logamorate	=LN(asthma mortality per 100,000 people)
s	State index (MA, NY, NJ, PA, CT)
t	Time index (1999-2010)
ma2006	= 1 for all obs in MA after 2005
squninsuredcdc	= (health uninsured rate)^2
unemploy	= unemployment rate
sqso2	= (aerial sulfur dioxide concentration, 1-hour parts per billion)^2
logwind	= LN (average wind speed)

baprevfitxblack	= black asthma prevalence * proportion of blacks
sqwaprevfitxwhite	= (white asthma prevalence*proportion of whites)^2
sqso2_sqwaprevfitxwhite	Interaction between *sqso2* and *sqwaprevfitxwhite*
adult	= proportion population aged 18-64
squninsuredcdc_baprevfitxblack	Interaction between *squninsuredcdc* and *baprevfitxblack*

Source	SS	df	MS
Model	2.9636406	25	.118545624
Residual	.339251327	34	.00997798
Total	3.30289193	59	.055981219

Number of obs =	60
F(25, 34) =	11.88
Prob > F =	0.0000
R-squared =	0.8973
Adj R-squared =	0.8218
Root MSE =	.09989

logamorate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ma2006	-.4538462	.1034493	-4.39	0.000	-.6640806	-.2436119
ma	.8252949	.3497524	2.36	0.024	.1145124	1.536077
ct	.2135321	.1318439	1.62	0.115	-.0544068	.4814711
ny	.5343425	.3153296	1.69	0.099	-.1064844	1.175169
nj	.134456	.2046104	0.66	0.516	-.2813624	.5502743
time						
1	-.0334809	.0826136	-0.41	0.688	-.2013719	.1344101
2	-.0360668	.0994408	-0.36	0.719	-.2381547	.1660212
3	.076705	.1256061	0.61	0.545	-.1785573	.3319673
4	.1240518	.1551415	0.80	0.429	-.1912336	.4393372
5	-.0275776	.1816176	-0.15	0.880	-.3966689	.3415137
6	.0322235	.1702801	0.19	0.851	-.3138272	.3782742
7	.0038979	.1905553	0.02	0.984	-.3833572	.391153
8	-.1031199	.210326	-0.49	0.627	-.5305538	.3243141
9	.0374449	.2273668	0.16	0.870	-.42462	.4995098
10	.359973	.305217	1.18	0.246	-.2603026	.9802486
11	.4132994	.3192	1.29	0.204	-.235393	1.061992
squninsuredcdc	.0035703	.0020507	1.74	0.091	-.0005972	.0077378
unemploy	-.1070521	.0377242	-2.84	0.008	-.1837169	-.0303874
sqso2	.0000989	.0000336	2.94	0.006	.0000306	.0001672
logwind	-.7050012	.4331175	-1.63	0.113	-1.585202	.1751995
baprevfitxblack	.3754426	.1409327	2.66	0.012	.0890329	.6618524
sqwaprevfitxwhite	.0033615	.0019118	1.76	0.088	-.0005236	.0072467
sqso2_sqwaprevfitxwhite	-7.84e-07	3.39e-07	-2.32	0.027	-1.47e-06	-9.59e-08
adult	-15.16205	10.6198	-1.43	0.162	-36.74408	6.419978
squninsuredcdc_baprevfitxblack	-.0013253	.0008113	-1.63	0.112	-.0029741	.0003235
_cons	10.26298	6.645457	1.54	0.132	-3.242213	23.76817

Because the dependent variable is in the logarithmic form, it has a convenient interpretation. "We prefer natural logs (that is, logarithms base e) because, as described above, coefficients on the natural-log scale are directly interpretable as approximate proportional differences: with a coefficient of 0.06, a difference of 1 in x corresponds to an approximate 6% difference in y, and so forth"

(Gelman 2007). Therefore, assuming that the initiation of the MHR was the only significant exogenous change that occurred in Massachusetts in 2006, we can interpret coefficient β_1 on *ma2006* to indicate that **the reform led to a 45.38% reduction in asthma mortality in Massachusetts.**

Robustness

In order to show the model's robustness, I have prepared several alternate models for comparison with the final model shown above. Below, notice Stata's regression output for an alternate model in which all of my final model's geometric functional forms were replaced with linear functional forms. The geometric functional forms were used in the final model because they led to a higher adjusted R^2 value. In this first alternate model, the adjusted R^2 value is slightly lower, but the coefficient β_1 on *ma2006* is still highly significant. This first alternate model estimates that the reform led to a 42.52% decrease in asthma mortality in Massachusetts, which is only 2.86% lower than the estimate for the favored coefficient in the final model.

Source	SS	df	MS
Model	2.95852259	25	.118340904
Residual	.344369334	34	.01012851
Total	3.30289193	59	.055981219

Number of obs =	60
F(25, 34) =	11.68
Prob > F =	0.0000
R-squared =	0.8957
Adj R-squared =	0.8191
Root MSE =	.10064

logamorate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ma2006	-.4252496	.1097625	-3.87	0.000	-.6483139	-.2021853
ma	.9048016	.3651412	2.48	0.018	.1627454	1.646858
ct	.2479963	.1454187	1.71	0.097	-.04753	.5435227
ny	.6073315	.3169378	1.92	0.064	-.0367636	1.251427
nj	.1789227	.2017876	0.89	0.381	-.231159	.5890044
time						
1	-.0302012	.0832961	-0.36	0.719	-.1994791	.1390768
2	-.03266	.0997508	-0.33	0.745	-.2353781	.1700581
3	.1167457	.1339963	0.87	0.390	-.1555674	.3890589
4	.1622522	.1646691	0.99	0.331	-.1723956	.4969001
5	.0327458	.1967591	0.17	0.869	-.3671167	.4326084
6	.0864291	.1815889	0.48	0.637	-.2826039	.4554621
7	.0554327	.2041286	0.27	0.788	-.3594064	.4702719
8	-.0363944	.2308865	-0.16	0.876	-.5056122	.4328234
9	.1130656	.2514217	0.45	0.656	-.3978849	.6240161
10	.4567017	.3364003	1.36	0.184	-.226946	1.140349
11	.5197247	.3538597	1.47	0.151	-.1994046	1.238854
uninsuredcdc	.0687892	.0386207	1.78	0.084	-.0096974	.1472758
unemploy	-.1117826	.0390273	-2.86	0.007	-.1910955	-.0324696
so2	.0221288	.0073677	3.00	0.005	.0071558	.0371018
logwind	-.748029	.4300738	-1.74	0.091	-1.622044	.1259861
baprevfitxblack	.5067295	.2290618	2.21	0.034	.0412198	.9722392
waprevfitxwhite	.116863	.0563624	2.07	0.046	.0023208	.2314051
so2_waprevfitxwhite	-.0019344	.0007625	-2.54	0.016	-.0034841	-.0003847
adult	-17.62273	11.00573	-1.60	0.119	-39.98906	4.743607
uninsuredcdc_baprevfitxblack	-.0270457	.0174371	-1.55	0.130	-.0624822	.0083908
_cons	10.60176	6.708083	1.58	0.123	-3.030705	24.23422

The second alternate model, shown below, is the same as the final model, save the omission of the state and time dummies that form the DD model. The adjusted R^2 dropped by 0.1795, but the statistical significance of the favored coefficient did not change, and its magnitude only increased 1.96%.

Source	SS	df	MS
Model	2.32169201	10	.232169201
Residual	.981199919	49	.020024488
Total	3.30289193	59	.055981219

Number of obs =	60
F(10, 49) =	11.59
Prob > F =	0.0000
R-squared =	0.7029
Adj R-squared =	0.6423
Root MSE =	.14151

logamorate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ma2006	-.4730524	.1107457	-4.27	0.000	-.6956043	-.2505005
squninsuredcdc	-.0023222	.0015927	-1.46	0.151	-.0055229	.0008784
unemploy	-.0237175	.0153068	-1.55	0.128	-.0544776	.0070426
sqso2	.0000872	.0000348	2.50	0.016	.0000172	.0001571
logwind	.2957718	.191671	1.54	0.129	-.0894054	.6809491
baprevfitxblack	-.0075724	.1110524	-0.07	0.946	-.2307406	.2155958
sqwaprevfitxwhite	.0026488	.0015554	1.70	0.095	-.0004769	.0057745
sqso2_sqwaprevfitxwhite	-4.93e-07	3.38e-07	-1.46	0.152	-1.17e-06	1.87e-07
adult	-6.637214	4.374153	-1.52	0.136	-15.4274	2.152975
squninsuredcdc_baprevfitxblack	.0009423	.0006903	1.37	0.178	-.0004449	.0023295
_cons	3.524097	2.401374	1.47	0.149	-1.301645	8.349838

The third alternate model, shown below, is the same as the final model except for the addition of new variables. The variable that controlled for the uninsured rate in the final model was replaced with five variables controlling for the uninsured rate: functional forms ranging from the first to the fifth power of the uninsured rates. Similarly, the single interaction term containing the uninsured rate variable was replaced by variables interacting these five functional forms, ranging from the first to the fifth power of the uninsured rates, with the *baprevfitxblack* variable. The purpose of the addition of this multitude of functional forms of the same variable was to, in effect, completely control for the effect of the uninsured rates in the model. This enables us to see what effect the MHR had over and above the insurance coverage rate effect. The adjusted R^2 decreased, although only slightly, and the p-value of the favored coefficient rose from 0.000 to 0.015, which is still highly statistically significant. The magnitude of the favored coefficient dropped 5.72%, likely because the insurance coverage rate effect on asthma mortality was heavily controlled for and removed almost entirely from the coefficient on *ma2006*.

Source	SS	df	MS
Model	3.00252337	33	.090985557
Residual	.300368557	26	.011552637
Total	3.30289193	59	.055981219

Number of obs =	60
F(33, 26) =	7.88
Prob > F =	0.0000
R-squared =	0.9091
Adj R-squared =	0.7936
Root MSE =	.10748

logamorate	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ma2006	-.3963756	.1523017	-2.60	0.015	-.7094362	-.083315
ma	.7322959	.4259222	1.72	0.097	-.1431998	1.607792
ny	.5029534	.414485	1.21	0.236	-.3490327	1.354939
nj	.1310363	.2729419	0.48	0.635	-.4300038	.6920765
ct	.1367088	.1742173	0.78	0.440	-.2213999	.4948175
time						
1	.0070249	.1091281	0.06	0.949	-.217291	.2313409
2	-.0220503	.1220357	-0.18	0.858	-.2728983	.2287977
3	.0909704	.1565887	0.58	0.566	-.2309022	.412843
4	.1290511	.1862065	0.69	0.494	-.2537019	.5118041
5	-.0271517	.2175528	-0.12	0.902	-.4743379	.4200344
6	.0335813	.2075757	0.16	0.873	-.3930966	.4602592
7	-.0096635	.2304508	-0.04	0.967	-.4833619	.4640349
8	-.0982544	.2548647	-0.39	0.703	-.6221363	.4256274
9	.0329703	.284642	0.12	0.909	-.5521198	.6180604
10	.3709352	.3820573	0.97	0.341	-.4143949	1.156265
11	.3554622	.4145417	0.86	0.399	-.4966406	1.207565
unemploy	-.1079133	.0497899	-2.17	0.040	-.2102579	-.0055686
sqso2	.0000857	.0000459	1.87	0.073	-8.72e-06	.0001801
logwind	-.5061764	.5461128	-0.93	0.363	-1.628727	.6163746
baprevfitxblack	8.293258	36.76158	0.23	0.823	-67.27126	83.85777
sqwaprevfitxwhite	.0034364	.0021867	1.57	0.128	-.0010583	.0079312
sqso2_sqwaprevfitxwhite	-7.21e-07	4.33e-07	-1.66	0.108	-1.61e-06	1.70e-07
adult	-15.24255	12.72299	-1.20	0.242	-41.39503	10.90992
uninsuredcdc_baprevfitxblack	-5.134156	17.9782	-0.29	0.777	-42.08887	31.82056
squninsuredcdc_baprevfitxblack	1.147535	3.405844	0.34	0.739	-5.853276	8.148347
cubeuninsuredcdc_baprevfitxblack	-.1175857	.3131639	-0.38	0.710	-.7613033	.526132
sqsquninsuredcdc_baprevfitxblack	.0056579	.0139995	0.40	0.689	-.0231184	.0344342
fifthuninsuredcdc_baprev	-.0001041	.0002438	-0.43	0.673	-.0006053	.0003972
uninsuredcdc	5.048289	21.09779	0.24	0.813	-38.31883	48.41541
squninsuredcdc	-1.175279	4.03766	-0.29	0.773	-9.474808	7.124251
cubeuninsuredcdc	.1251486	.3797497	0.33	0.744	-.655438	.9057352
sqsquninsuredcdc	-.0062439	.0176529	-0.35	0.726	-.04253	.0300421
fifthuninsuredcdc	.0001194	.0003267	0.37	0.718	-.0005522	.000791
_cons	2.641114	42.85357	0.06	0.951	-85.44566	90.72789

The final alternate model, shown below, omitted all variables involving the uninsured rate altogether. By omitting this control, I expected the magnitude of the favored coefficient to increase because the *ma2006* variable would pick up the effect of the change in health insurance coverage rates in Massachusetts caused by the MHR. This model had a slightly lower adjusted R^2, but the favored coefficient was still highly statistically significant, and, as expected, the magnitude of the coefficient rose from 45.38% to 52.55%, a change of 7.17%.

```
      Source |       SS       df       MS              Number of obs =      60
-------------+------------------------------           F( 23,    36) =   12.43
       Model |  2.93339286    23  .12753882            Prob > F      =  0.0000
    Residual |  .369499066    36  .010263863           R-squared     =  0.8881
-------------+------------------------------           Adj R-squared =  0.8167
       Total |  3.30289193    59  .055981219           Root MSE      =  .10131

------------------------------------------------------------------------------------
             logamorate |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
------------------------+-----------------------------------------------------------
                 ma2006 |  -.5255161   .0919711    -5.71   0.000    -.7120422   -.3389901
                     ma |   .6560649   .3060632     2.14   0.039     .0353399     1.27679
                     ny |    .572009   .2862008     2.00   0.053     -.008433    1.152451
                     nj |   .1987787   .1845056     1.08   0.288     -.175416    .5729735
                     ct |   .1575303   .1243727     1.27   0.213    -.0947094    .4097699
                        |
                   time |
                      1 |  -.0381101    .083304    -0.46   0.650    -.2070586    .1308383
                      2 |  -.0993506   .0931397    -1.07   0.293    -.2882467    .0895455
                      3 |   .0817926     .12215     0.67   0.507    -.1659392    .3295243
                      4 |   .1095779   .1495816     0.73   0.469    -.1937877    .4129436
                      5 |  -.0538216   .1774086    -0.30   0.763     -.413623    .3059797
                      6 |   .0229933   .1654528     0.14   0.890    -.3125604     .358547
                      7 |   -.024057   .1843567    -0.13   0.897    -.3979498    .3498357
                      8 |  -.1767744   .2015183    -0.88   0.386    -.5854725    .2319238
                      9 |  -.0474499   .2186802    -0.22   0.829    -.4909539    .3960541
                     10 |   .2672651   .2976791     0.90   0.375    -.3364562    .8709863
                     11 |   .3288733   .3140447     1.05   0.302    -.3080389    .9657854
                        |
               unemploy |  -.1056823   .0380199    -2.78   0.009    -.1827902   -.0285745
                  sqso2 |   .0000989   .0000334     2.96   0.005     .0000311    .0001667
                logwind |  -.7961411   .4138993    -1.92   0.062    -1.635568    .0432855
         baprevfitxblack |   .1799307   .0552963     3.25   0.002     .0677846    .2920767
       sqwaprevfitxwhite |   .0040687   .0018932     2.15   0.038     .0002291    .0079082
 sqso2_sqwaprevfitxwhite |  -8.44e-07   3.35e-07    -2.52   0.016    -1.52e-06   -1.64e-07
                  adult |  -11.75607   9.995887    -1.18   0.247    -32.02867    8.516527
                  _cons |   8.809197   6.264228     1.41   0.168    -3.895247    21.51364
------------------------------------------------------------------------------------
```

I believe these four alternate models demonstrate the robustness of my final model. Despite making several substantial changes to the model, the favored coefficient was always highly statistically significant, and its magnitude did not increase or decrease by more than 7.17%. In all instances, the coefficient showed that the reform had a strong negative impact on asthma mortality rates.

Diagnostics

<u>Goodness of Fit?</u>

As shown in the above regression output, the p-value associated with the above F-statistic is zero. This allows us to reject the null hypothesis that all of the model coefficients are zero. At 0.8973, the R^2 goodness of fit value could be considered quite high. The number of variables included in the regression augments this value. The adjusted R^2, which adjusts for the addition of variables, is considerably smaller at 0.8218, although this still represents a strong goodness of fit for the model.

<u>Statistical Significance of Variables?</u>

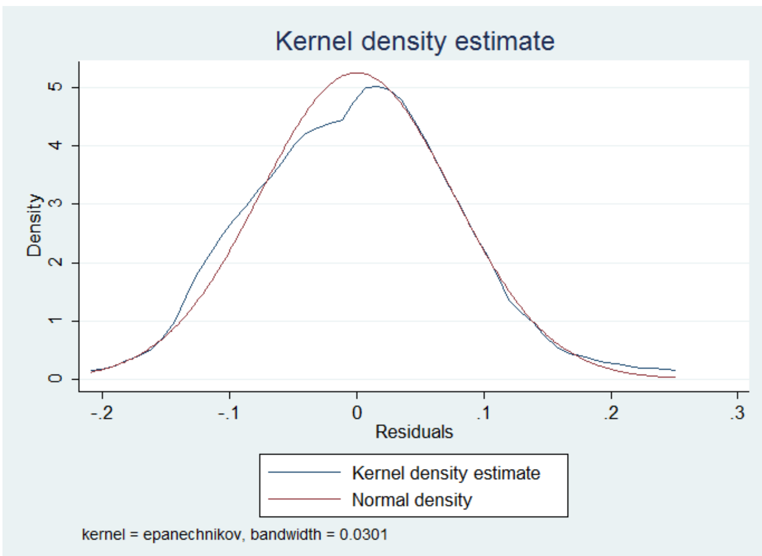
The favored coefficient, β_1, is highly statistically significant with a p-value of 0.000 and a t-statistic of -4.39. The statistical significance of the other variables is less important to the thesis. However, of the nine control variables, four are statistically significant at the 5% level, and eight are statistically significant at the 15% level.

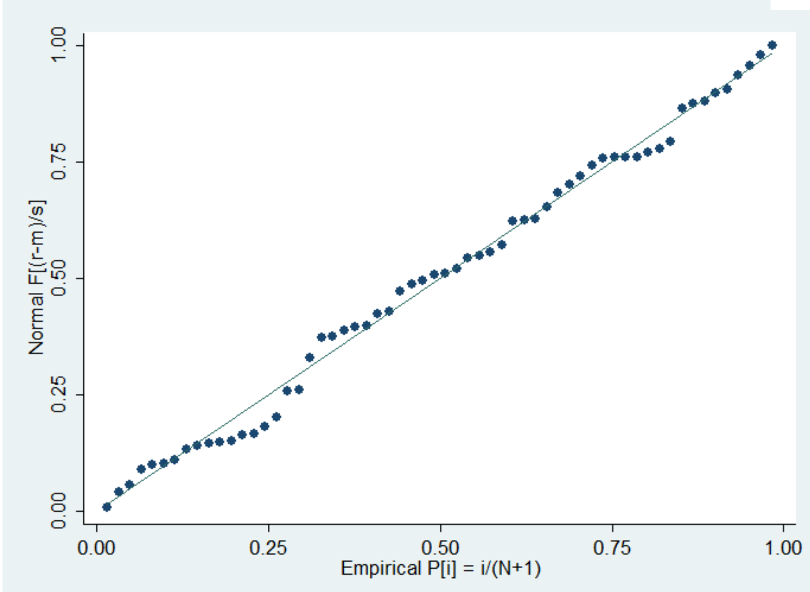
<u>Variables Make Sense in the Model and Have Correct Sign?</u>

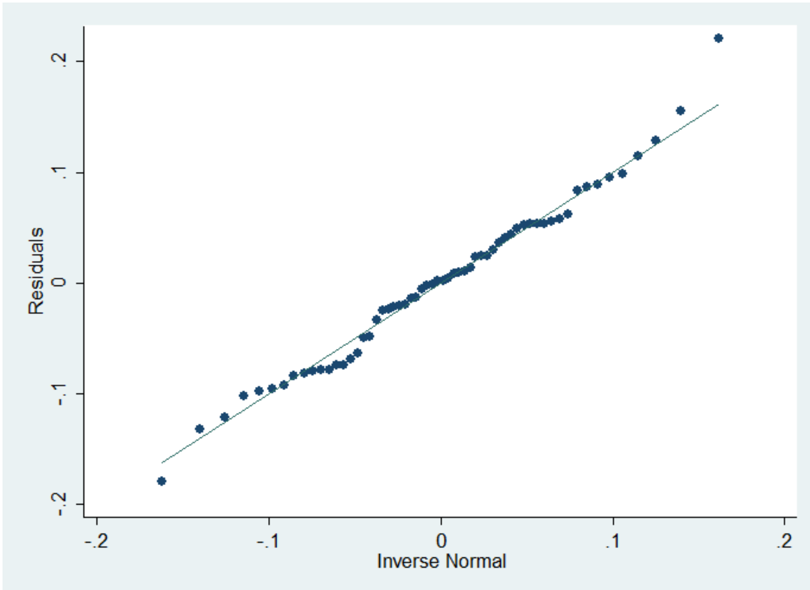
All of the included variables were chosen because they are theoretically expected to impact asthma mortality. Also, the sign of the variables could be defended as being correct in accordance with theory. While I expected that the sign on *unemploy* would be positive because the unemployed have less access to financial resources and do not have access to employer-sponsored health insurance, the sign ended up being negative. However, this sign could be theoretically defended. For example, the unemployed may tend to be less active, making the activation of asthma triggers less likely.

<u>Checking Normality of Residuals</u>

Three plots compare my residuals with the normal probability plot. Below, see a Kernel density plot with an overlaid normal plot, a standardized normal probability plot, and a plot of the quantiles of the residuals against the quantiles of a normal distribution ("Stata Regression Diagnostics.").







Qualitatively, one can see that the residuals are very close to being normally distributed, and that deviations could be considered trivial. Quantitatively, the Shapiro Wilk W test generated a p-value of 0.82677, indicating that we cannot reject that the residuals are normally distributed.

Checking Homoscedasticity

Both the White's test and the Breusch-Pagan test the null hypothesis that the variance of the residuals is homogenous ("Stata Regression Diagnostics."). With p-values of 0.4392 and 0.3788, respectively, we cannot reject the null hypothesis and we can confirm homoscedasticity.

```
. estat imtest

Cameron & Trivedi's decomposition of IM-test

---------------------------------------------------
              Source |       chi2     df      p
---------------------+-----------------------------
  Heteroskedasticity |      60.00     59    0.4392
            Skewness |      29.14     25    0.2579
            Kurtosis |       0.09      1    0.7588
---------------------+-----------------------------
               Total |      89.24     85    0.3554
---------------------------------------------------

. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of logamorate

         chi2(1)      =     0.77
         Prob > chi2  =   0.3788
```

Checking for Multicollinearity

The primary issue with multicollinearity is that "as the degree of multicollinearity increases, the regression model estimates of the coefficients become unstable and the standard errors for the coefficients can get wildly inflated" ("Stata Regression Diagnostics."). I used a VIF, or variance inflation factor, test in order to check for multicollinearity. A VIF greater than 10 could present a problem. As you can see from the output below, almost all of the variables had VIF values greater than 10. However, the favored coefficient, β_1, had a VIF of 4.92. This indicates that, although the standard errors for many of the coefficients have been greatly inflated, the standard error of the favored coefficient has not been significantly affected by multicollinearity.

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
      ma2006 |      4.92    0.203426
          ma |    117.69    0.008497
          ct |     16.72    0.059793
          ny |     95.67    0.010453
          nj |     40.28    0.024827
        time |
         1   |      3.14    0.318976
         2   |      4.54    0.220157
         3   |      7.25    0.137987
         4   |     11.06    0.090449
         5   |     15.15    0.066000
         6   |     13.32    0.075082
         7   |     16.68    0.059954
         8   |     20.32    0.049212
         9   |     23.75    0.042112
        10   |     42.79    0.023369
        11   |     46.80    0.021367
squninsure~c |     80.84    0.012370
    unemploy |     23.30    0.042916
       sqso2 |     38.21    0.026169
     logwind |     30.20    0.033108
baprevfitx~k |     48.90    0.020449
sqwaprevfi~e |     24.73    0.040434
sqso2_sqwa~e |     35.28    0.028347
       adult |     64.84    0.015422
squninsure~k |    138.13    0.007240
-------------+----------------------
    Mean VIF |     38.58
```

To test the hypothesis that the state and year binary variables accounted for a large degree of the multicollinearity, I removed these variables from the regression and ran another VIF test. As you can see in the output below, the VIFs of all of the remaining variables decreased considerably, providing strong evidence for this hypothesis.

```
. vif

    Variable |       VIF       1/VIF
-------------+----------------------
squninsure~k |     49.83    0.020069
squninsure~c |     24.30    0.041155
       sqso2 |     20.41    0.049000
sqso2_sqwa~e |     17.53    0.057038
baprevfitx~k |     15.13    0.066092
sqwaprevfi~e |      8.16    0.122587
       adult |      5.48    0.182433
     logwind |      2.95    0.339276
      ma2006 |      2.81    0.356226
    unemploy |      1.91    0.523127
-------------+----------------------
    Mean VIF |     14.85
```

Model Specification

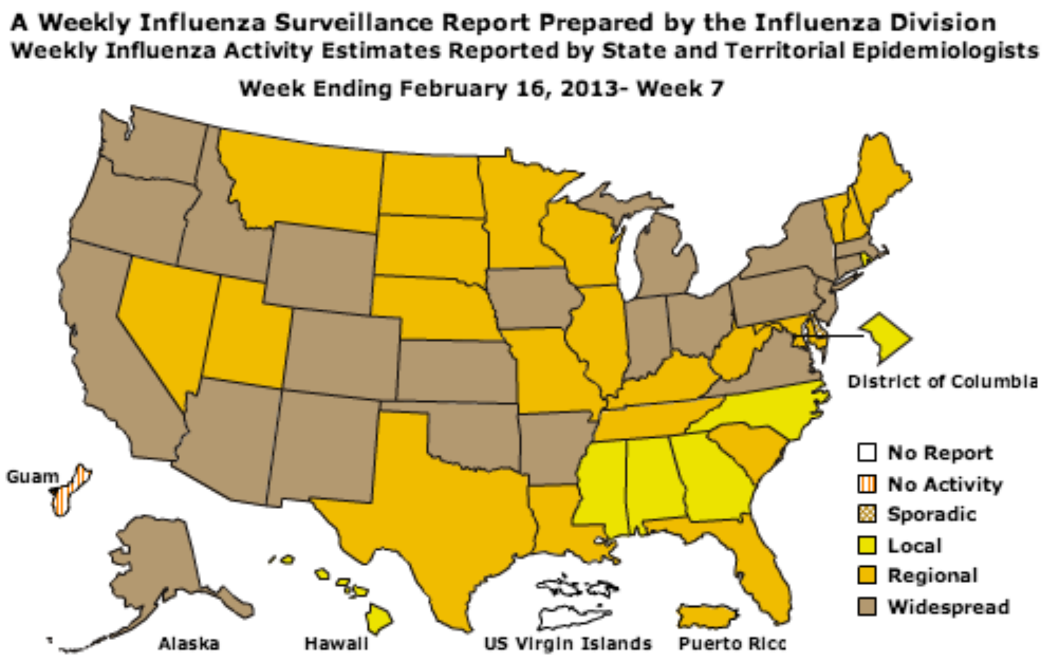
" A model specification error can occur when one or more relevant variables are omitted from the model or one or more irrelevant variables are included in the model" ("Stata Regression Diagnostics."). The linktest and ovtest commands in Stata can be used to evaluate model specification. Shown below, both tests have failed to reject the assumption that the model is specified correctly, and the ovtest confirms that there are no omitted variables.

```
. linktest

      Source |       SS       df       MS              Number of obs =      60
-------------+------------------------------           F(  2,    57) =  249.44
       Model |  2.96421032     2  1.48210516           Prob > F      =  0.0000
    Residual |  .338681602    57  .005941782           R-squared     =  0.8975
-------------+------------------------------           Adj R-squared =  0.8939
       Total |  3.30289193    59  .055981219           Root MSE      =  .07708

------------------------------------------------------------------------------
  logamorate |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        _hat |   1.013545   .0625952    16.19   0.000     .8881999    1.138889
      _hatsq |  -.0435047   .1404932    -0.31   0.758    -.3248375     .237828
       _cons |   .0013176   .0148555     0.09   0.930      -.02843    .0310652
------------------------------------------------------------------------------

. ovtest

Ramsey RESET test using powers of the fitted values of logamorate
       Ho:  model has no omitted variables
                  F(3, 31) =      0.75
                  Prob > F =      0.5302
```

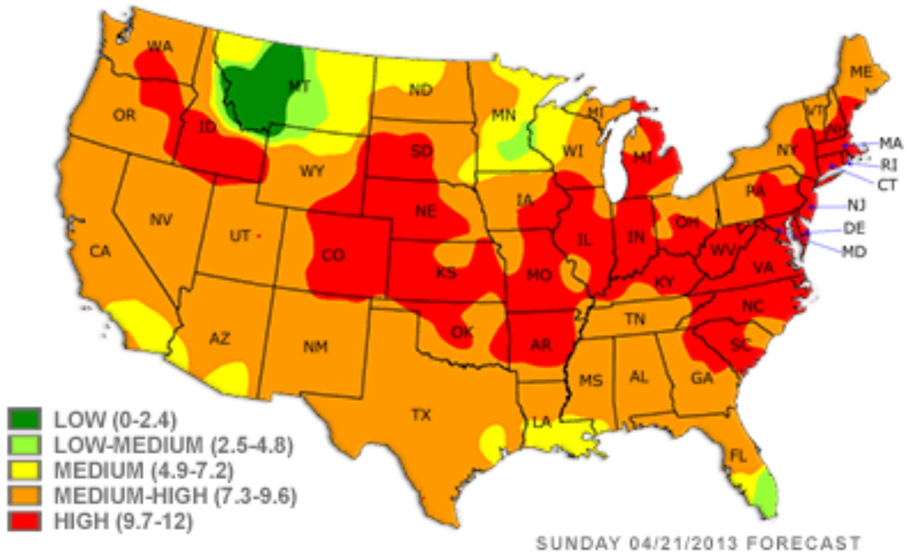
<u>Heckman-Hotz Pre-program Test</u>

In order to evaluate the validity of non-experimental estimates, Heckman and Hotz (1989) developed several specification tests. The pre-program test checks the validity of the control groups. To conduct the pre-program test of my control states, I used Stata to run a regression on the pre-reform data (all observations before 2006). I used the same final model, only I omitted the *ma2006* variable. For the pre-program test, the treatment group should not be significantly different from the control groups in the period before the reform. After running the pre-program test regression, the coefficient on *ma* was not significant at the 10% level. This indicates that prior to the reform, with the controls in place, there was no significant difference between the treatment and control states.

This test verifies that Pennsylvania, Connecticut, New York, and New Jersey are appropriate control states. I chose these states to be controls due to the availability of relevant data and due to their geographic proximity. The DD model is innately able to control for effects that occur to all states equivalently. By keeping the control states geographically close, the model is able to control for effects that my control variables could not. For example, flu season severity and pollen counts could be expected to affect asthma mortality, but I was not able to obtain historical data to control for these two issues. Because flu season severity and pollen counts tend to be homogenous across regions, and all of the states in my model are in the Northeast, the DD model will control for these two effects. The two graphics below evidence the regional homogeneity of these two effects.



Source: http://www.cdc.gov/flu/weekly/usmap.htm



Source: http://www.pollen.com/images/usa_map.gif?d=4212013

Discussion of Results

My results indicated that there was a strong, negative, highly statistically significant effect on asthma mortality rates associated with Massachusetts in the post-MHR time period. I support that this strong exogenous effect was caused by the MHR, and that the favored coefficient reflects the change to asthma mortality rates brought about by the MHR. Medicare Part D was also implemented in 2006, although this is a national implementation, so the control states would have netted out its effects. The control states also would have netted out any technological advances that could have had a strong negative impact on asthma mortality rates. I believe this exogenous effect can be attributed solely to the MHR because no other exogenous changes occurred only in Massachusetts in 2006 that could reasonably be expected to have had such a notable impact on asthma mortality rates.

I believe that the strong results of my study warrant further research into the effects of the MHR on health care quality. The effect of the MHR on the mortality rates for other potentially deadly chronic diseases, such as diabetes and coronary heart disease, should also be explored. Additionally, having shown that the MHR had a large impact on asthma mortality rates, it is exceedingly important to understand the mechanisms through which the MHR created this effect, and which components of the MHR had the greatest impact on quality outcomes.

One would expect that the increased insurance coverage rates brought about by the reform caused the lion's share of the MHR's effect on asthma mortality rates. However, as shown above in the robustness analysis, the favored coefficient had a large magnitude even when health insurance coverage rates were heavily controlled. I will propose several possible mechanisms, although further research is necessary to test my hypotheses.

Although the increase in health insurance coverage rates did not account for all of the MHR's effect, this was only one part of the MHR's effect on health insurance in the state. As discussed in the *Appendix* and in the literature review, in addition to limiting deductibles and out-of-pocket costs, the MHR established a minimum for acceptable health insurance coverage in the state, known as Minimum Creditable Coverage (MCC). By regulating the health insurance market more heavily and increasing the minimum coverage of health plans, both for those who were insured before the reform and those who gained insurance after, it is likely that health plan beneficiaries were allowed greater access to health care with less financial constraints.

The MHR set aside $20 million for public health initiatives and developed the Health Care Quality and Cost Council (HQCC). It is possible that these public health initiatives included asthma education and screening. Also, the HQCC may be placing pressure on the Massachusetts health care system to cut costs and increase quality by cutting ER admissions related to asthma.

One final potential mechanism I'd like to discuss is the reaction of health insurance plans to the reform. Health insurance plans can boost their bottom line in one of the following ways: increasing membership, raising premiums, cutting administrative costs, or cutting medical expenditures. Because of heightened competition on the new health insurance exchange created by the MHR, insurers are most likely facing downward pressure on their premiums. If they tried to increase profit by raising premiums, they would likely lose membership. Assuming that each health insurer has relatively similar premiums and plan offerings, each insurer's market share will likely remain fairly constant over time, so the firms are most likely more interested in maintaining membership than trying to gain new membership. I would also like to assume that administrative costs are already fairly minimal. For these reasons, I believe the MHR may have increased health insurer's emphasis on cutting medical expenditures as a means of improving their bottom line. It is possible that, in order to cut medical expenditures, insurers have taken a more active role in the disease management of their membership bases. For example, insurers may have calculated that it is cheaper to ensure that its members have sufficient access to inhalers for asthma than to pay for an ER visit once a member has an asthma attack.

Regardless of the mechanism through which the MHR reduced asthma mortality, my results display a positive sign for health care reform. The passage of the ACA was highly controversial, with Governor Romney, the Republican presidential candidate in the 2012 elections, stating, “If I’m the president at a time when the Supreme Court has left Obamacare in place, I will repeal it on Day One by sending out a waiver for all 50 states" (Summers). President Obama, who fought to pass the ACA, has a different opinion, stating:

> It’s reform that finally extends the opportunity to purchase coverage to the millions who currently don’t have it -- and includes tough new consumer protections to guarantee greater stability, security and control for the millions who do have health insurance. ("President Barack Obama on Patient Protection and Affordable Care Act.")

As described in the *Appendix*, the MHR was a model for the ACA, and there are many similarities between the two laws. For this reason, I believe that the ACA will decrease national asthma mortality rates once certain key provisions come into play in 2014, just as the MHR reduced asthma mortality rates, and has the potential to improve other health outcomes. My empirical results support that President Obama's Affordable Care Act inherently possesses the capacity and the propensity to craft a higher quality health care system for the United States.

Special Thanks

I would like to sincerely thank my thesis advisor, Professor Marvin Kraus, for all of the hours he spent discussing, theorizing, and debating the different aspects of my thesis with me. Professor Kraus challenged me to think freely, and gave me the courage to undertake a unique project rather than replicating the work of another study. I would also like to thank Professor Chris Maxwell and Professor Matt Rutledge for being invaluable resources, spending a considerable amount of time and energy guiding me through my thesis process. I was very fortunate to have so much support from BC's faculty, and I wouldn't have been able to accomplish my thesis without it.

Appendix: ACA and MHR Overview

As should be expected from a law that is over 2000 pages long, the ACA has a very large number of provisions. For the sake of brevity, only the major changes brought about by the ACA will be covered. Some argue that the ACA represents a health insurance reform, not a health care reform, because it does not directly change the delivery of care. However, even if this is the case, it is still a distinct possibility that reform health insurance will also cause a change in the health care system and impact health outcomes.

Presently, the ACA has implemented a number of important changes, including the removal of pre-existing conditions as a basis for price discrimination, prohibiting insurance companies from charging beneficiaries a deductible, copayment, or coinsurance for certain preventive benefits on all new insurance plans, and allowing young adults to stay on their parents' health plan until the age of 26 ("Read the Law."). Another important provision is a floor to health plans' medical loss ratio (MLR): a ratio of claims paid to medical premiums received. If a firm's MLR falls below the 80-85% limit, the excess must be rebated back to its beneficiaries. This, along with other components of the reform, has fueled a massive wave of consolidation among health plans this past year. As the MLR floor limits health insurance companies' capacity to raise premiums as a means of creating profit, they seek economies of scale and larger membership bases in order to reduce their administrative costs and improve their bottom line.

In early 2014, the most significant implementations will occur. The Medicaid program in certain states will be greatly expanded, with eligibility extended to all individuals with income below 133% of the federal poverty level. Originally, this expansion was mandated, but the Supreme Court ruled this summer that each state would have the right to individually reject the expansion, making it effectively optional. However, given the substantial federal subsidization of the expansion, a state's decision not to expand its Medicaid program would bear considerable opportunity costs.

The trio of the individual mandate, guaranteed issue, and community rating also will come into play in early 2014. The individual mandate declares that all citizens must have minimum required health insurance benefits or be liable for a tax penalty. Guaranteed issue is "a requirement that health plans must permit you to enroll regardless of health status, age, or other factors that might predict the use of health services" ("Guaranteed Issue."). Lastly, community rating is a policy that doesn't allow insurers to price discriminate based on health status, limiting their price discrimination power to a few factors such as age and geographic area ("Community Rating and Guaranteed Issue in the Individual Health Insurance Market.").

It also standardizes the health insurance offerings available to exchange-eligible individuals, including setting a minimum level of coverage to be considered part of the exchange. It therefore has a substantive impact on the number and quality of plans available on the individual market, more than just making the search for such a plan easier.

The last key 2014 implementation is the mandatory establishment of online state health insurance exchanges (HIE). An HIE is an online tool which streamlines citizens' enrollment in health plans, allowing them to find plans that best suit their needs in the small group and individual markets, and the large group markets. In addition to making the search for a plan easier, the HIE standardizes the plans available, setting a minimum level of coverage and controlling both the number and quality of plans available on the market. The HIE will enable Americans to avoid the costs of using a broker to select a health plan and ease the barriers to purchasing health insurance. The HIE will also offer income-scaled subsidies to citizens within certain income ranges in order to facilitate their enrollment in a health plan.

Being a model for the ACA, the MHR is similar in many ways. The MHR also has the trio of the individual mandate, guaranteed issue, and community rating, with taxes imposed on citizens who don't possess the minimum creditable coverage (MCC) and on businesses that don't offer a minimum required contribution to their employees' health coverage ("The Massachusetts Health Care Landscape."). The MHR also expanded Medicaid and the Children's Health Insurance Program (CHIP), which are operated as one public-assistance program called MassHealth. The program, jointly funded by the state and federal government, is intended for certain subsets of the low to medium income population of MA, including children, the unemployed, pregnant women, the elderly, the disabled, clients of the MA Department of Mental Health, people in need of long term care, and HIV positive individuals.

The MHR also has a HIE, branded the Massachusetts Health Connector, with resources for individuals, employers, and brokers. In addition to helping connect employees to employer-sponsored insurance, the Connector offers many commercial products through eight health insurance plans that operate in the state. Five of these plans have contracted with MA as a part of the MHR's Commonwealth Care program, which offers subsidized health insurance on the Connector for low-income adults who are not covered by MassHealth (Medicaid) and do not have an employer that sponsors health insurance. The MHR has also established a program on the Connector to provide affordable, unsubsidized coverage for individuals, families, and small business called Commonwealth Choice.

While the bulk of the MHR is very similar to the ACA, many of the components of the ACA, such as the MLR floor, were not implemented in MA. Also, many provisions are similar in design, but implemented differently. For example, in MA, young adults aged 19 to 25 can remain on their parents' plan for two years after losing their dependent status, which less generous than the ACA's provision, discussed above. The Medicaid expansion resulting from the ACA will also be more dramatic than that enacted by the MHR.

The penalties of the individual mandate, designed to be the driver of increasing health insurance coverage rates in both pieces of legislation, are also a point of disparity. The MHR's yearly penalty is scaled to income, and ranges from $228 per year to $1,026 per year ("What are the penalties?"). In 2009, only 1% of residents faced this penalty ("In Mass., individual mandate sparks little outcry."). On the other hand, the ACA's yearly penalty, after being completely phased in by 2016, will be the greater of inflation-adjusted $695 or 2.5% of family income ("Federal Healthcare Reform.").

The disparities between the MHR and the ACA represent challenges that economists face when attempting to project effects of the ACA based off of the results of the MHR. However, because the two have a similar framework, the results of MHR will paint a prophetic picture, albeit a rough one. As one can see from the overview of the two laws, although the provisions are not commensurate, the theory and objectives behind the laws correspond closely.

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