THE POLITICAL ECONOMY
OF ENVIRONMENTAL REGULATIONS
IN THE U.S. INTENSIVE LIVESTOCK INDUSTRY

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Graduate Studies and Research
in Partial Fulfillment of the Requirements
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ABSTRACT

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<u>The Political Economy of Environmental Regulations in the U.S. Intensive Livestock</u>
<u>Industry</u>
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When setting the stringency of environmental regulations of the intensive livestock industry, governments make a trade-off between rural economic development and environmental quality. This trade-off represents the weight the government places on social welfare relative to the profitability of the intensive livestock industry. The impact of the weight the government places on rural economic development on the formation of environmental regulations in the US intensive livestock industry is examined in this thesis.

A political economy model explaining the formation of environmental regulations in the presence of a special interest lobby group is developed. The theoretical model finds that the incumbent government sets policy in response to the marginal disutility from pollution, the intensity of pollution damages, and according to the weight the government places on rural economic development.

The theoretical model is tested using a cross-sectional analysis of 1997 intensive livestock industry environmental regulations across US states. Econometric results provide evidence that state governments implement more stringent regulations in response to the concerns of rural citizens and the intensity of pollution damages. The study finds that the pressure to pursue rural economic development has a positive relationship with the stringency of regulations.

ACKNOWLEDGEMENTS

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CHAPTER ONE:

INTRODUCTION

The threat of a "race to the bottom" in environmental standards among US states was among a number of factors that led the federal government to create the Environmental Protection Agency (EPA) in 1968 and "to pass subsequent legislation establishing national standards for air and water quality" (List and Gerking, 2000). Oates and Schwab (1988) describe two opposing views of the consequences of economic competition between jurisdictions. The "distortion inducing" view maintains that the local determination of standards for environmental quality will be subject to interregional competition, resulting in relaxed standards for environmental quality; essentially supporting the "race to the bottom" hypothesis. Conversely, the "efficiency enhancing" view proposes that regional competition provides regions with the opportunity to choose the type and scale of environmental quality they desire.

If the "race to the bottom" hypothesis is indeed true, this indicates that maintaining or improving environmental quality has perceived costs in terms of reduced economic growth; otherwise regions would not compete on the basis of environmental standards. The "race to the bottom" implies that political decision makers place priority on economic growth rather than on maintaining environmental quality (Harrison, 1996). Following the economic efficiency-enhancing proposal, regional decisions reflect regional preferences for maintaining environmental quality versus stimulating economic

growth. "If existing residents care about public outputs (including environmental quality), and presumably they do, then tax or standard competition to attract economic activity imposes real costs on the citizenry" (Oates and Schwab, 1988, p. 388). Thus, regional differences in environmental standards result from differences in the perceived political tradeoffs between economic growth and environmental quality. Regardless of the view of the effects of economic competition between regions, both theories maintain that decisions regarding the provision of environmental quality are political in nature.

Based on the inverted U-shaped relationship between income inequality and income levels proposed by Kuznets (1955), the environmental economics literature has examined a similar relationship between income and pollution (referred to as the environmental Kuznets curve (EKC)), where pollution increases with income at low levels of income and pollution decreases with income at high levels of income (Grossman and Krueger (1992) and Seldon and Song (1994)). Shafik (1994) maintains that it is difficult to make unambiguous theoretical predictions regarding the relationship between environmental quality and per capita income. Empirically, Shafik finds that the relationship between income and pollution is negative when environmental degradation is localized. On the other hand, if the environmental damage is a global problem, then environmental deterioration tends to increase as income increases.[1]

Grossman and Krueger (1995) suggest that the link between income and environmental quality is primarily due to an induced policy response: "As nations or regions experience greater prosperity, their citizens demand that more attention be paid to

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[1] Local air pollution, for example, is found to have a U-shaped relationship with income. At low levels of income, due to the process of industrialization, local air pollution increases with increased income. Beyond a threshold level of income, as the economy develops and new technologies are adopted, higher incomes tend to reduce local air pollution. Carbon emissions, on the other hand, are a global problem and the relationship between carbon emissions and per capita income is positive (Shafik, 1994).

the noneconomic aspects of their living conditions" (p. 372). The EKC has been

interpreted as a long-run relationship implying that improvements in environmental

quality are driven by increased income (Beckerman, 1992). Nonetheless, in the context

of the political economy of environmental regulations, the overall level of income may

not be the relevant measure of the political pressure for environmental quality relative to

economic development. Political decisions are largely driven by the short-term pressures

of the political cycle. Therefore, the recent performance of the economy may better

reflect the incentive incumbent governments have to implement environmental

regulations. This thesis examines the impact of the perceived short-run political tradeoff

between environmental quality and economic development on the formation of

environmental policy in the US intensive livestock sector.

1.1 Background

In early 2003, the US Environmental Protection Agency (EPA) implemented new

federal environmental regulations applying to confined animal feeding operations

(CAFOs).[2] These regulations were implemented in response to the changing nature of

the US intensive livestock sector and to apparent enforcement and compliance problems

with the existing regulations. The EPA's rationale for the development and

implementation of these revised regulations was as follows:

> The continued trend toward fewer but larger operations, coupled with
> greater emphasis on more intensive production methods and
> specialization, is concentrating more manure nutrients and other animal
> waste constituents within some geographic areas. These large operations
> often do not have sufficient land to effectively use the manure as fertilizer.

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[2] Confined animal feeding operation (CAFO) is the EPA term equivalent to intensive livestock operation (ILO). These
two terms and their associated acronyms are used interchangeably throughout this thesis.

Furthermore, there is limited land acreage near the CAFO to effectively use the manure. This trend has coincided with increased reports of large-scale discharges from CAFOs, as well as continued runoff that is contributing to the significant increase in nutrients and resulting impairment of many US water bodies. (EPA, 2003, p. 7180).

Prior to 2003, existing federal policies regulating the US intensive livestock sector had not achieved the uniform environmental results for which they were designed. The revised regulatory rules were developed in order to assure that "strong and consistent national expectations" existed for the intensive livestock industry (EPA, 2003, p. 7182).

Since responsibility for the implementation and enforcement of US intensive livestock environmental regulations rested with state governments, non-uniform environmental results indicated that state governments were potentially competing on the basis of environmental standards. Prior to 2003, implementation of the EPA's base regulations coincided with the imposition of increasingly more stringent state-level environmental regulations (Metcalfe, 2001). Despite the increasing stringency of state-level intensive livestock environmental regulations, differences in both the regulatory stringency and the pollution damages from intensive livestock production among states persisted. The following sections discuss the issues relevant to the regulation of the US intensive livestock industry as they stood in and around the year 1997.

1.1.1 Pollution Problems

Intensive livestock production results in both a point and non-point source of water pollution. Point source pollution is delivered to surface and/or ground water directly from a single or identifiable small number of sources, whereas non-point source pollution enters the water source diffusely from a large number of sources. Point and

non-point source manure nutrient pollution result from "surface runoff and erosion, overflows from lagoons, spills and other dry-weather discharges, leaching into soil and ground water, and volatilization of compounds and subsequent redeposition on the landscape" (EPA, 2003, p. 7181). The pollutants contained in animal manure include nutrients (nitrogen and phosphorus are the primary concern), organic matter, pathogens, and odorous compounds (EPA, 2003). Manure nitrogen enters water systems through runoff and leaching while manure phosphorus is transported to water systems primarily by soil erosion.

Agricultural practices in the US are generally recognized as the largest source of non-point pollution of water bodies (Ribaudo, et al., 1999). In 1998 the EPA reported that agriculture is the largest source of water pollution in rivers and streams in the US. Based on 50 1996 State 305(b) Reports, the EPA estimated that agricultural activity "degrades aquatic life or interferes with public use" of 25% of the river miles surveyed in the reports.[3] Of all water quality problems identified in the rivers and streams surveyed, 70% were contributed to by agriculture. Cook and Stanley (1998) note that animal operations are identified as impacting 20% of impaired river miles in the 22 states providing information about specific types of agriculture in the 1996 State 305(b) Reports. In addition to water quality problems in rivers and streams, agriculture contributes to 41% of impaired water quality in lakes. Animal feedlots were among the top ten contributors to ground water quality problems in 17 states and agriculture was ranked fifth among contributors to water quality impairment of estuaries (EPA, 2000). The EPA (2003) cites runoff from animal manure produced in the Mississippi River

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[3] State 305(b) Reports are required under the *Clean Water Act*.

Basin as a significant contributor to the hypoxic zone in the northern Gulf of Mexico.[4]

The EPA identified over 150 reports of surface water discharges from livestock

operations, including 30 reports in Iowa between 1992 and 1997. Each of the Iowa

reports resulted in between 500 and 500,000 fish kills.

Over one half of the US population gets its drinking water from groundwater

sources. Groundwater accounts for 40% of the water withdrawn by cities and towns and

virtually all of the water used by private users is groundwater (Nolan and Stoner, 2000),

implying that significant portions of rural citizens are affected by groundwater quality.

Excessive nitrates in drinking water can cause potentially fatal low oxygen levels in

infants and high nitrate levels have been associated with spontaneous abortions and

increased risk of non-Hodgkin's lymphoma (Nolan and Stoner, 2000).   A specific

example of groundwater contamination by livestock manure is found in southern

Delaware, where a study found 34% of 200 wells sampled exceeded the EPA drinking

water standard for nitrogen. Land application of poultry wastes was cited as one of the

major contributing factors to the high nitrogen concentrations (Sharpley, et al, 1998).

1.1.2 Manure Nutrient Production

Over the past twenty years production in the US intensive livestock sector has

increasingly intensified. Between 1982 and 1997, the number confined animal farms in

the US decreased by 27% to 529,658 while the number of confined animal units

increased by approximately 7% over the same period (Kellogg, et al., 2000). The USDA

estimates that the largest decrease in confined animal farm numbers occurred in the hog

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[4] A hypoxic zone is one where the dissolved oxygen content of water is below the level needed to sustain animal life.

sector, where the number of confined farms declined by 64% between 1982 and 1997.

The number of farms with confined fattened cattle, confined dairy cattle, and confined

poultry declined by 52%, 47%, and 46% respectively. Over the same period, the

aggregate number of large confined animal operations increased by approximately 21%

(Kellogg, et al., 2000).[5]

Coinciding with the increasingly intensified nature of livestock production has

been an increase in the production of manure nutrients. During the fifteen-year period

between 1982 and 1997 total US manure nutrient production increased by 20% (Kellogg,

et al., 2000). The increase in manure nutrient production was accompanied by a shift in

the spatial concentration of intensive livestock production; in 1997 fewer counties

accounted for the majority of US manure nutrient production for each of the livestock

types as compared to 1982.

> An increase in the concentration of manure nutrient production has had
> impacts on the ability of regions to assimilate all of the manure nutrients
> produced. Kellogg, et al. (2000) estimated that in 1997, 78% of ILOs had
> the potential ability to assimilate all manure nitrogen and 69% had the
> potential ability to assimilate all the manure phosphorus their operations
> produced.[6] Averaged across all size classes, the available cropland and
> pastureland controlled by these intensive livestock operations declined
> from 3.6 acres per animal unit (AU) in 1982 to 2.2 acres per animal unit in
> 1997. Large operations had 0.2 acres of cropland and pastureland per
> animal unit in 1997 (Kellogg, et al., 2000).
> Reductions in the assimilative capacity utilized by intensive livestock producers

have had implications regarding the levels of excess nutrients produced. Kellogg, et al.

(2000) estimated the 1992 and 1997 county-level excess nutrients produced by ILOs

across the US. These estimates find that county level excess nitrogen and phosphorus

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[5] An operation with over 300 AUs is classified as large by Kellogg, et al.
[6] Kellogg, et al. calculated farm-level assimilative capacity based on the ability of the farms cropland and pastureland
to utilize manure nutrients. Excess soil manure nutrients occur when the quantity of manure produced on a given farm
exceeds that farms assimilative capacity. This does not imply that these operations are managing manure in a manner
that does not create excess nutrients, only that they have the assimilative capacity available to utilize all manure
nutrients their operations produce.

increased by 60% between 1982 and 1997. Poultry operations accounted for over 60% of the on-farm excess nitrogen and over half of on-farm excess phosphorus. Assuming export of manure nutrients from the farm, but within the county, 73 counties had excess nitrogen and 160 counties had excess phosphorus. Kellogg, et al. (2000) find that the number of counties with excess nitrogen has increased by 103% between 1982 and 1997 and the number of counties with excess phosphorus has increased by 58% in the same period.

1.1.3 Importance in the Rural Economy

The EPA (2002) estimated that in 1997 the US intensive livestock industry accounted for over 1.6 million full-time equivalent (FTE) jobs in the US, including both farm-level employment and employment in the processing sector.[7] This represents approximately 1% of nationwide US FTE employment. Figure 1.1 provides a graphical summary of the intensive livestock industries contribution to regional FTE employment in the US by livestock type. As expected, aggregate FTE employment by region is greatest in the Midwest, the traditional US livestock production region.

In 1997, the beef sector accounted for 336,700 FTE farm level jobs and 145,617 FTE processor jobs. The majority of regional farm and processing employment in the beef sector was in the Midwest, which accounted for over half of total beef sector employment. Employment totals in the central region followed those in the Midwest, accounting for 40% of beef sector employment. National employment in the dairy sector accounted for approximately 38% of aggregate intensive livestock employment, three quarters of which was farm level. Together, the Midwest, Pacific, and Mid-Atlantic

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[7] 1 FTE = 2,080 hours of labour.

regions accounted for 80% of dairy sector employment. Hog production contributed

280,623 FTE jobs to the US economy, 67% of which were in the traditional hog

production region of the Midwest. The Mid-Atlantic region accounted for 20% of hog

sector FTE employment in 1997. In contrast to the other intensive livestock sectors, the

majority of employment in the poultry sector was in the processing sector. In 1997, 74%

of the 276,000 FTE jobs in the poultry sector were at the processor level. Over 55% of

poultry sector employment was in the South, followed by the Mid-Atlantic, which had

25% of poultry sector employment.
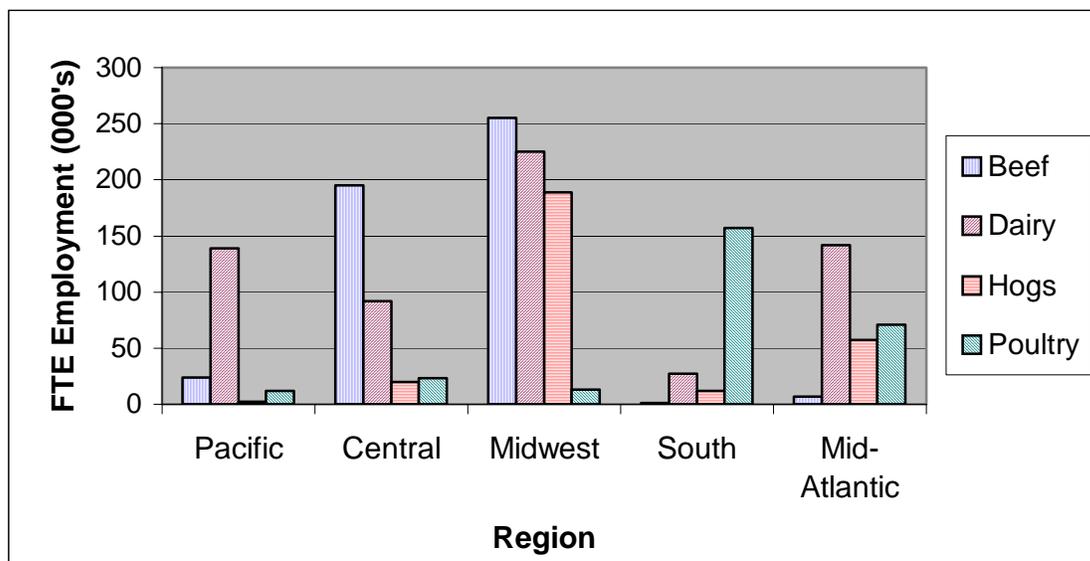
Figure 1.1: 1997 Regional US FTE employment (EPA, 2002)

As stated earlier, the total number of large confined animal operations in the US

increased by 21% between 1982 and 1997. The number of large CAFOs by state, as

estimated by the EPA (2002), provides additional information regarding the relative

importance of the various livestock sectors to the economies of each state in the year

2000. In the beef sector, Nebraska, Kansas and Texas had the largest number of large

beef CAFOs, Nebraska having the most at 591. Large-scale dairy production occurred most in California (763 large operations), New York (346 large operations), and Wisconsin (267 large operations). Between 1982 and 1997, of the four livestock sectors, hog production experienced the greatest increase in the number of large operations (Kellogg, et al., 2000). In 2000, Iowa had 1,236 large hog animal feeding operations, followed by North Carolina, which had 1,076 large operations. Minnesota, Illinois, and Indiana had between 400 and 600 large-scale hog operations each. As mentioned previously, poultry operations contribute to a significant amount of the excess manure nutrients produced by intensive livestock. States with the largest number of large poultry operations were Georgia (512 large operations), Arkansas (372 large operations), and Alabama (338 large operations).

1.1.4 Excess Manure Nutrients and Large CAFOs

Increases in the production of excess nutrients have been greatest in the Southeast and the mid-Atlantic regions of the US (EPA, 2003). The EPA attributes the increase in excess nutrients in these regions to the expansion of large hog and poultry operations between 1982 and 1997, listing North Carolina, Georgia, Alabama, Mississippi, Arkansas, California, Maryland, Delaware, Pennsylvania, Virginia, and Washington as the states with the greatest excess nutrient concerns. The states with the greatest excess nutrient concerns, as defined by the EPA (2003), are presented in Table 1.1 below, indicating the number of large operations in each sector that are located in that state. The data indicates that large-scale poultry production is a potential concern in the Southern states, along with large-scale hog production in North Carolina and to a lesser degree

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Arkansas and Virginia. Large-scale beef and dairy production appears to be the cause of

excess nutrient problems in California and Washington. Problems in Maryland,

Delaware, and Pennsylvania are the result of large-scale poultry (MD and DE) and dairy

(PA) production.

Table 1.1: Number of Large CAFOs by Selected State and Sector

State	Beef	Dairy	Hogs	Poultry	Total
North Carolina	2	56	1076	263	1397
California	102	763	11	133	1009
Georgia	0	61	54	512	627
Arkansas	0	8	106	372	486
Pennsylvania	6	135	135	186	462
Alabama	0	17	16	338	371
Virginia	2	65	19	117	203
Mississippi	0	17	17	225	259
Washington	53	103	4	38	198
Maryland	0	31	11	84	126
Delaware	2	6	4	58	70

Source: EPA (2002)

1.1.5 Environmental Regulation

EPA federal regulation of US animal feeding operations, under the authority of

the *Clean Water Act*, dates back to the 1970s. The EPA established national effluent

limitation guidelines in 1974 and began the National Pollution Discharge Elimination

System (NPDES) in 1976. The national effluent guidelines established by the EPA

applied to animal feeding operations greater than 1,000 animal units (AUs). These

guidelines, based on the best available technology that was economically achievable in

the 1970s, had the objective of prohibiting the discharge of effluent into water sources

except in the case of a 25 year, 24 hour storm (EPA, 2003). NPDES permits were

assigned to all CAFOs greater than 1,000 AUs. Additionally, any animal feeding operation between 300 and 1,000 AUs was required to obtain a permit if they "discharged pollutants through a man made device or if pollutants were discharged to the waters of the US that ran through the facility or otherwise came into contact with the confined animals" (EPA, 2003, p. 7186).

While EPA regulation of the intensive livestock sector established base national requirements, responsibility for the enforcement of federal regulations was assigned to state governments (Metcalfe, 2001). In addition to the enforcement of federal regulations, state governments developed and implemented their own regulations. Metcalfe (2000) examined the regulatory stringency of the intensive livestock industry in the major hog producing states for the years 1994 and 1998. Metcalfe found that the average stringency of regulations increased between 1994 and 1998. The stringency of regulations was assumed to increase as the number of regulations imposed on the intensive livestock industry increases. For example, public notice requirements and provisions allowing for local control were assumed to increase the stringency of regulations. The presence and the severity of setback requirements, NMPs, and requirements for groundwater monitoring also increased the stringency of regulations. On the other hand, state cost share programs reduced the compliance costs of the ILO industry, therefore reducing the stringency of regulations. Table 1.2 presents the state regulatory stringency index totals as constructed and presented by Metcalfe (2000).

Table 1.2: State environmental regulatory stringency index

State	1994 Index Total	1998 Index Total
Georgia	8	12
Kansas	4	12
South Carolina	-	12
Illinois	3	11
Iowa	5	11
Mississippi	6	11
Arkansas	12	10
Maryland	-	10
Minnesota	9	10
Missouri	8	10
North Carolina	3	10
South Dakota	4	10
Nebraska	3	9
Kentucky	3	8
Oklahoma	9	8
Pennsylvania	5	8
Indiana	4	7
Ohio	10	7
Oregon	-	7
Tennessee	-	7
Virginia	3	7
Colorado	-	6
Michigan	4	2
New York	4	1

Source: Metcalfe (2000).

Comparison of the regulatory stringency indices developed by Metcalfe reveals that a large amount of new regulatory activity was initiated in the intensive livestock sector between 1994 and 1998. A survey conducted by the National Animal Confinement Policy Task Force (NACPTF) in 1998 found evidence of a significant amount of public controversy regarding intensive livestock production (Edelman, et al., 1999). The survey indicated that intensive livestock production was the subject of increased incidences of conflict and attention in the media in 39 of the 46 conterminous states surveyed. Within almost half of the conterminous states surveyed, new legislation

regarding ILOs had been proposed during the past year. The rank order of livestock type

generating the most controversy nationwide is as follows: hogs, dairy, poultry, and beef.

In Connecticut, Delaware, Maryland, Ohio, and Vermont poultry is the largest generator

of controversy. The dairy industry generates the most controversy in Arizona, California,

Florida, Idaho, Maine, Nevada, New York, Washington, and Wisconsin. Of the 46

conterminous states surveyed, 44 indicated that state agencies are responsible for the

administration and enforcement of intensive livestock environmental regulations.

1.1.6 Case Study: Intensive Livestock Production in North Carolina

Development of the pork industry in North Carolina is often cited as an example

of the trade off between rural economic development and the environment. Legislators

view development of the hog industry as "the force that is keeping jobs and money in

counties where tobacco is fading" (*The News and Observer*, 1996, p. 15). Between 1980

and 1993, hog production in North Carolina increased by 109%, involving an investment

estimated at $180 million and the addition of 2,000 jobs (Kenyon, 1994).

Environmentally, the North Carolina hog industry has been scrutinized as a less than

ideal steward of the environment. An oft-cited example of the environmental dangers of

hog production occurred in 1995 when over 40 million gallons of untreated manure

escaped lagoons at seven North Carolina hog operations due to flooding. The spill

resulted in 15 million fish kills off North Carolina's coastal plain due to nutrient over-

enrichment (Nowlin, 1997).

In the early 1990s, ILO compliance with environmental regulations was more

costly in Virginia as compared to North Carolina (Kenyon, 1994). Kenyon attributed the

trend of increasing hog production in North Carolina and decreasing hog production in

Virginia to the relatively less stringent environmental regulations in North Carolina. Hurt

and Zering (1993) examined the environmental and regulatory constraints to hog

expansion in North Carolina and found that they were relatively less restrictive compared

to restrictions on hog expansion in the Midwest states of Illinois, Minnesota, and Indiana.

Hurt and Zering also point to the importance of contract hog production to the expansion

of the hog industry in North Carolina. The expansion of the hog industry in North

Carolina coincided with a declining tobacco industry, once the "King of Agriculture" in

North Carolina. Due to the decline of the tobacco industry, many small tobacco

producers found hog production contracts to be an attractive way to stay on the farm.

Despite high feed-grain costs, the costs of production were favourable in North Carolina,

due to "lower building costs, low labour costs, lower waste disposal costs, perhaps lower

interest rates, and lower transportation costs to move finished pork products to east coast

markets" (Hurt and Zering, 1993, p. 13).

In 1995, *The News and Observer* of Raleigh, North Carolina had a series of

articles titled "Boss Hog: North Carolina's Pork Revolution" (*The News and Observer*,

1996) for which the paper was awarded the 1996 Pulitzer Prize for Public Service. These

articles outlined "the power of pork" in North Carolina, exposing the hog industry's

political connections with state legislators and the apparent link to the weak stringency of

intensive livestock environmental regulations in that state. In particular, the actions of

Wendell Murphy, who is both a legislator and the largest hog producer in the US, are

scrutinized. The implication being that Murphy's decisions on state legislation

concerning the hog industry was biased due to his financial interests in the industry he

was legislating. In an analysis of the political influence of the North Carolina hog industry, former North Carolina Senator Robert Morgan (1998) states:

> The hog industry's growing political power was due not only to the efforts of individual legislators such as Senator Murphy, but to large and continuing contributions to candidates; it takes a great deal of money to get elected these days, and the industry was generous in its support of officials who might be able to help it in the future.

Further, *The News and Observer* (1995) reports that political campaign contributions, totaling $439,719 since 1990, from hog industry interests were influential in determining the outcome of legislative decisions impacting the hog industry. Sales tax exemptions, gas tax exemptions, property tax exemptions, weakened environmental penalties for hog manure discharges into streams, and restrictions on county zoning authority over hog and poultry production were among the legislative decisions that were favourable to North Carolina's hog industry (*The News and Observer*, 1995).

1.2 Specific Problem

A number of studies have addressed the relationship between intensive livestock production and environmental regulations in the US (Metcalfe (2001), Roe, et al. (2002), Park, et al. (2002), and Herath, et al. (2003)). Recognizing differences in regulatory stringency across US states, these studies have examined the impact of environmental regulations on intensive livestock production decisions. These studies have not, however, explicitly modeled the political formation of intensive livestock environmental policy.

The political formation of environmental policy outside of the agricultural sector has been examined in the wider economics literature. The theoretical literature dealing with environmental policy, specifically the work of Fredriksson (1997), Aidt (1998), and

Schleich (1999), propose political economic models adapted from the work of Grossman and Helpman (1994) for trade protection. The political economy approach to the determination of environmental policy finds that the government balances a number of different objectives, including aggregate social welfare, when setting policy. The weight the government places on these different objectives determines the stringency of regulations. For example, in Damania, et al. (2003), Fredriksson, et al. (2003), and Fredriksson and Svensson (2003), a corrupt government is considered to place greater weight on the campaign contributions it receives from industry relative to the weight it assigns to aggregate social welfare, potentially leading to less than optimal environmental regulation.

As outlined earlier, the formation of environmental policy in the intensive livestock sector is partly dependent on the relative weight the incumbent government places on environmental quality relative to the pressure for rural economic development. An incumbent government in a region where recent economic growth has been relatively low may be under greater pressure to foster rural economic development. Conversely, an incumbent government in a region recently experiencing high economic growth may be under less pressure to increase rural economic development and has greater political ability to protect environmental quality. The short-run trade-off between environmental quality and rural economic development in the formation of intensive livestock environmental regulations is the focus of this thesis.

1.3 Hypothesis

The stringency of environmental regulations in the US intensive livestock sector is dependent on the pressure for rural economic development; the greater the pressure for rural economic development, the lower the stringency of environmental regulations, *ceteris paribus*. Formally stated, the hypothesis of this thesis is as follows:

H_o: recent rural economic growth has no effect on the stringency of ILO environmental regulations

H_a: recent rural economic growth has a positive effect on the stringency of ILO environmental regulations

The theoretical model presented in this thesis will lay the foundation for the empirical examination of this hypothesis.

1.4 Objectives

The objective of this thesis is to develop a theoretical economic model explaining the determination of the stringency of environmental policy as it relates to the intensive livestock industry. Specific objectives are as follows:

- Test the relationship between the pressure for rural economic development and ILO environmental regulations
- Examine the above relationship in the context of the power of environmental groups, the potential environmental damages from ILO production, and the size of the ILO industry
- Account for the potentially endogenous relationship between intensive livestock inventory and ILO environmental regulation

1.5 Scope of Thesis

This thesis will provide a state-level empirical examination of the US intensive livestock industry, comprised of the beef cattle, dairy cattle, hog, and chicken sectors.

The determination of 1997 environmental regulatory stringency in the US intensive

livestock industry will be examined. Following previously published literature, this

thesis will account for the potentially endogenous relationship between intensive

livestock inventory and regulatory stringency. The theoretical aspect of this thesis

focuses on the determination of environmental regulatory stringency.

1.6 Organization

This thesis is organized as follows. Following the introduction, Chapter 2 will

present a review of the literature pertinent to ILO environmental regulation. The

literature review describes the economic models to be used in this thesis, followed by an

examination of the literature dealing with intensive livestock inventory and ILO

environmental regulations.

The theoretical framework for this thesis is presented in Chapter 3. A theoretical

model is built, based on the models explaining environmental policy formation and the

characteristics of the US intensive livestock sector as described in the literature review.

A number of predictions are derived from the theoretical model. These predictions form

the base of the testable hypotheses in the empirical research aspect of this thesis. Chapter

4 outlines the methods and procedures used in this thesis. The chapter begins with a

general econometric specification, followed by a description of the data requirements and

more detailed econometric specifications. Alternative specifications are proposed in

order to test the robustness of the preferred specification.

Chapter 5 presents the econometric results of the preferred specification and the

alternative specifications. The chapter concludes with a comparison of the results of this

chapter with the results published in other academic studies. A summary of the research

presented in this thesis is provided in Chapter 6. Study limitations and prospects for

future research are discussed, followed by concluding statements.

CHAPTER TWO:

LITERATURE REVIEW

This chapter begins with an overview of the theoretical literature concerning the political economy of trade protection and environmental policy and the empirical literature examining the determination of environmental policy. The chapter concludes with an examination of the literature dealing with the impact of environmental regulations on the location decisions of polluting firms. Location studies dealing with polluting industries outside of agriculture are considered first, followed by a more detailed examination of the spatial pattern of the US livestock industry.

2.1 Political Economy Model of Trade Protection

The Grossman and Helpman (1994) model (hereafter G-H model) of the political economy of trade protection provides the basis for the theoretical framework used in this thesis. Grossman and Helpman "view politicians as maximizing agents who pursue their own selfish interests rather than as benevolent agents seeking to maximize aggregate welfare" (p. 848). Formally, the G-H model considers the interaction between an incumbent government that cares both about campaign contributions and aggregate welfare and special interest groups solely concerned about the welfare of their members.

The theoretical basis of the G-H model is the first-price menu auction developed by Bernheim and Whinston (1986). Bernheim and Whinston examine competitive

bidding where the object is partially divisible. The bidders make a set of offers to the

auctioneer for various allocations of the divisible object. This situation is classified as a

first price menu auction under the assumption of complete information. Lemma 2 (p. 10)

characterizes the Nash equilibrium, the two conditions of primary importance being as

follows. First, the auctioneer chooses the allocation that maximizes its own welfare.

Second, in the equilibrium allocation each individual bidder maximizes the joint welfare

of the auctioneer and the individual bidder. Bernheim and Whinston further develop the

analysis to find that a truthful Nash equilibrium emerges where each bidder offers

rewards based on the net willingness-to-pay for that action.[8]

Bernheim and Whinston apply their model of first-price menu auctions to a

number of situations, one of which is a situation of economic influence where interested

parties offer contingent bribes to a decision maker. They find that "parties who can

compensate agents at low cost will have more influence, yet the action chosen will

nevertheless remain Pareto efficient" (p. 22). Also, the payoff to the decision maker

increases with the level of conflict between bidders. In terms of political economy, this

model shows that interest groups that are relatively more efficient at lobbying the

government will have more influence.[9] This application finds that the action chosen is

Pareto efficient for the parties involved, but does not model the welfare effects on parties

outside of the menu auction of economic influence. The conclusion that increased

conflict among bidders increases the payoff to the auctioneer makes intuitive sense in

terms of political economy; the greater the competition between interest groups, the

greater the 'market power' of the incumbent government.

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[8] Net willingness-to-pay is equal to the difference between the bidder's gross payoffs from alternative allocations.
[9] Efficient lobbying may be the result of lower coordination costs or of the weight that the government places on the
interest groups welfare relative to other interest groups.

The G-H model extends the first-price menu auction presented in Bernheim and Whinston to an analysis of the formation of trade protection policy. The G-H model explains the equilibrium outcome of a political process wherein interest groups attempt to influence trade policy decisions and incumbent politicians trade off the financial incentives offered by special interest groups with the alienation of the electorate that results from economically inefficient trade policies. The G-H model finds the Nash equilibrium of this political process: the incumbent government trades off the aggregate welfare of society with campaign contributions. The trade off implies that the government weights different members of society differently, with those represented by special interest groups receiving a larger weight than those who are not.

Grossman and Helpman examine the case of a single organized lobby and the resulting determination of equilibrium campaign contributions. A single organized interest group, representing the specific-factor owners in a given industry, will lobby the incumbent government for trade protection. If this lobby makes no contributions, the government will implement the free trade policy. Contributions from the lobby compensate the government proportional to the weight the government places on the deadweight loss resulting from deviations from free trade. The government is therefore indifferent between receiving campaign contributions and implementing the free trade policy. As a result, the special interest group captures the entire surplus resulting from its lobbying activities.

Alternatively, Grossman and Helpman consider the situation where all voters are represented by special interests. In this case each lobby must make positive campaign contributions. Due to the intensity of competition between interest groups, the government is able to capture all surplus. As in Bernheim and Whinston, the outcome is

Pareto efficient; maximization of the joint surplus involves all members of society and the free trade policy is implemented.

2.2 Political Economy of Environmental Policy

2.2.1 Theoretical Models of Environmental Policy Formation

Fredriksson (1997), Aidt (1998), and Schleich (1999) extend the G-H model to examine the political economy of environmental policy. These models examine the impacts of special interest lobbying on endogenous pollution taxes in small open economy settings. The Fredriksson model specifically examines the effects of lobby group membership, the importance of lobbying activities, and the tax elasticity of pollution. Aidt specifically examines the impact of competition between lobby groups on the internalization of economic externalities. In the model proposed by Aidt, lobby groups are concerned both with economic efficiency and the distribution of income, which leads to deviations from the Pigouvian tax. Schleich examines the political determination of environmental policy in the cases of decreasing, constant, and increasing marginal environmental damages. Lopez and Mitra (2000) and Damania (2001) present interesting theoretical extensions of the political economy models of environmental policy. Lopez and Mitra consider the formation of environmental policy in the presence of corruption, while Damania examines the political economy of investment in pollution abatement technology.

Fredriksson (1997) models special interest competition between industry and environmental special interest groups in the presence of abatement technology. As in the G-H model, an incumbent government cares only about re-election and the probability of

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re-election depends on aggregate social welfare and aggregate campaign contributions. Whereas the G-H model examined an incumbent government making choices regarding the trade policies affecting a number of different industries, Fredriksson examines the formation of the environmental policy governing a single industry with competition between industry and environmental special interest. Environmentalists' utility is adversely affected by the pollution damages associated with the production of the good produced by the industrialist. The industrialist, on the other hand, derives no disutility from consumption of the polluting good. The incumbent government has the power to implement pollution taxes on the production of the polluting good. Aggregate social utility is maximized when the pollution tax equals the marginal disutility from pollution.[10] The environmental and the industrial interest groups form lobbies and offer campaign contributions to the government commensurate with the benefits they expect to receive from the incumbent government. The incumbent government then makes a trade-off between the campaign contributions offered by the special interest groups and the aggregate welfare of society. This trade-off is based on the exogenously determined weight the government places on aggregate social welfare relative to campaign contributions.

Under the assumption of constant marginal damages, Fredriksson finds that environmental quality is reduced in the presence of a polluting industry lobby. Fredriksson finds that the pollution tax is decreasing in the world market price and increasing in lobby group membership. The pollution tax increases in industry lobby group membership if total tax revenue is increasing in the tax rate. As industry lobby

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[10] The marginal disutility from pollution is equal to the proportion of the population that derives disutility from pollution (the marginal disutility to society).

group membership increases a greater portion of the tax revenue passes back to the industry lobby group members. In the extreme, if all citizens are members of the industry lobby group, then the tax rate is not a concern because all revenue is distributed back to the members. In situations where the tax rate is less than socially optimal, Fredriksson finds that the pollution tax is increasing in the weight the government places on aggregate social welfare.

Fredriksson further extends the model to allow for abatement technology and for a subsidy on pollution abatement. Pollution damage is a function of the level of abatement expenditures, therefore treating pollution damages as endogenous. Pollution abatement subsidies are potentially offered by the government in order to reduce the aggregate level of pollution. Fredriksson claims that previous literature shows that the introduction of an abatement subsidy may induce increased entry resulting in increased total pollution damage. Fredriksson finds that there may be an additional political effect of the abatement subsidy, namely that the pollution tax rate decreases in the abatement subsidy rate. This implies that the "subsidy stimulates pollution both by an increase in supply through lower marginal abatement cost and by a reduction of the tax cost per unit of pollution" (p. 57). The model presented by Fredriksson was the first to extend the G-H model to the political determination of environmental policy. The majority of recent empirical work in the political economy of environmental policy is based on the model developed by Fredriksson.

Aidt (1998) proposes that the political internalization of environmental externalities bridges the Coasian and Pigouvian approaches to environmental policy. In the Coasian approach groups protect their respective interests via transfers. In the model proposed by Aidt transfers occur within political markets as opposed to the private

transfers described by Coase. Following the Pigouvian approach, a coercive government implements environmental policy with the maximization of aggregate social welfare in its objective function.

Since the joint welfare of the interest groups and the government are maximized (as in Bernheim and Whinston, 1986) as opposed to aggregate social welfare, Aidt concludes that the environmental policy chosen may not reflect the socially optimal policy. In addition, Aidt makes an interesting point regarding taxes versus direct regulation. Aidt proposes that direct regulation prevails because small producer groups are more efficient in influencing policymakers than are ordinary citizens, who would prefer taxation due to the generation of tax revenue.

Schleich (1999) allows for decreasing, constant and increasing marginal damages from pollution and models both production and consumption externalities, as well as domestic and trade policy options. Schleich models an economy where all consumers suffer disutility from the consumption of a polluting good. Industry lobby groups form and offer the incumbent government campaign contributions in order to influence government policy. When making campaign contributions, each lobby group takes into account the effect government policies have on their members, including the disutility from consumption of the polluting good. The model proposed by Schleich differs from the Fredriksson (1997) model in two important ways. First, in the Schleich model, all individuals suffer disutility from pollution, implying that pollution is a global problem. Fredriksson models an economy where the industry lobby group suffers no disutility from pollution, implying that pollution is a local problem. Second, Fredriksson considers the case of constant marginal damages, whereas Schleich extends the model of Fredriksson to include increasing and decreasing marginal damages. The difference between the two

modeling approaches results in different conclusions regarding the presence of polluting industry lobbies on the equilibrium tax rate.

Schleich introduces the concept of marginal political benefits and marginal political cost curves to help explain the determination of environmental policy in the presence of a polluting industry lobby. Initial marginal political costs and marginal political benefits occur when no special interest groups are organized. The initial equilibrium is the Pigouvian tax rate. In the presence of a polluting industry lobby, marginal political benefits increase as the output price increases (the pollution tax decreases) due to increased industry lobby profitability. Increased industry lobby profitability is transferred to the government in the form of campaign contributions. On the margin, an increase in industry lobby profitability of one dollar corresponds with an increase in campaign contributions to the incumbent government of one dollar. Marginal political costs also increase in the presence of a polluting industry lobby. The industry lobby considers the impact the environmental policy will have on the welfare of its members.[11] If the marginal pollution damages are constant or increasing, and the proportion of the industry lobby is less than one, the marginal benefit curve shifts up more than the marginal cost curve, and the equilibrium pollution tax is less than the Pigouvian rate. If marginal pollution damages are decreasing, then the marginal political cost curve slopes downward. If the marginal cost curve is decreasing at a faster rate than the decrease in marginal benefits, the presence of a polluting industry lobby causes the equilibrium pollution tax to be higher than the Pigouvian tax rate.

Lopez and Mitra (2000) examine the relationship between economic growth and the environment. The Kuznets environment curve states that environmental degradation

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[11] Schleich assumes that every individual in society suffers disutility from pollution.

occurs at low levels of income but that this relationship changes once a threshold of income is passed. This gives rise to an inverted U-shaped relationship between environmental quality and income. Empirical evidence provides support for this relationship regarding certain pollutants. Nonetheless, empirical evidence regarding natural resources suggests the relationship between resource degradation and income is positive (Lopez and Mitra, 2000).

Lopez and Mitra model both cooperative and non-cooperative interactions between governments and firms in the presence of government corruption and rent seeking behavior regarding the level of pollution and changes in these levels as income grows. Results are consistent between the two types of interactions modeled: corruption and rent seeking always lead to pollution greater than the socially optimal level, corruption does not prevent the existence of a Kuznets relationship, and the turning point in the Kuznets relationship occurs at higher per capita incomes and pollution levels. In conclusion, Lopez and Mitra suggest the following. Compared to developed countries, developing countries, such as China, Indonesia, and India, are experiencing high corruption levels. Therefore, pollution will remain higher in these countries than it was in developed countries when they were at comparable levels of per capita incomes. They note that this conclusion is dependent on the assumption that corruption will not fall as incomes rise.

Damania (2001) finds that choice of technology and lobbying are substitutes in the profit function of firms. The model demonstrates that older, dirtier industries will lobby the government for weaker environmental regulation rather than adopt newer, cleaner technology. Older, dirtier industries are better positioned to lobby the government because they can demonstrate relatively high abatement costs, therefore

raising the welfare costs of stricter environmental policy. This gives these firms an

incentive to under-invest in pollution abatement technology. The ability of firms to

demonstrate a credible commitment to investment decisions is critical to Damania's

conclusions.

2.2.2 Empirical Studies of Environmental Policy Formation

Recent empirical examinations of environmental policy formation have been

based on the theoretical model as presented by Fredriksson (1997). Eliste and

Fredriksson (2002) examine the relationship between environmental regulatory

stringency and government subsidies to agriculture. Damania, et al. (2003) adapt the

Fredriksson model to a examine the relationship between trade policy, corruption, and

environmental policy. Government corruption determines the exogenous weight the

incumbent government places on campaign contributions relative to aggregate social

welfare. Fredriksson, et al. (2003) inspect the pollution haven hypothesis by examining

the relationship between bureaucratic corruption, environmental policy, and foreign

direct investment. Fredriksson and Svensson (2003) look at the relationship between

political instability, government corruption, and environmental policy. Further,

Fredriksson, et al. (2004) examine the determination of environmental policy and its

relationship to policy maker corruption and the relative incentives of worker and

capitalist groups.

The theoretical model developed by Eliste and Fredriksson (2002) predicts that

increases in the stringency of environmental policy leads to increased transfers to the

polluting industry. Eliste and Fredriksson perform a cross-country empirical analysis of

the agricultural sector, examining this "compensation" hypothesis. An index of the stringency of agricultural environmental regulations is developed and transfers to the agricultural sector are based on Producer Subsidy Equivalents (PSE) as developed by the Organisation for Economic Cooperation and Development (OECD). The authors employ two-stage least squares in order to account for the potential endogeneity of transfer payments to producers and environmental stringency.

The stringency of agricultural environmental regulations is found to have a positive and statistically significant impact on government transfer payments to agriculture. The share of agricultural land in the total land base provides a measure of the environmental pressures due to agricultural production. Eliste and Fredriksson found a positive relationship between the stringency of environmental regulations and the share of agricultural land in the total land base. Per capita income was used as a proxy for the demand for environmental quality. The relationship between per capita income and regulatory stringency was found to be positive. Agricultures share of the national economy, measured by the share of agricultural labour as a percent of total labour, has a negative impact on the stringency of environmental regulations applied to agriculture. Econometric results find that PSE is an insignificant variable in the determination of agricultural environmental policy.

The compensation hypothesis is tested by the PSE equation. PSE is a function of environmental stringency, the importance of agriculture in the national economy, the value added per hectare of agricultural land (a reflection of the elasticity of production supply across countries), and the influence of democracy on the level of protection granted to the agricultural sector. The empirical analysis of the PSE equation finds that the stringency of agricultural environmental regulations has a positive impact on transfers

to the agriculture sector, supporting the compensation hypothesis. The share of agriculture in the labour force is insignificant as are the democracy variables. The proxy for supply elasticity is positive and significant, indicating that the cost of redistribution falls as supply elasticity falls.

Damania, et al. (2003) model the interactions between trade policy, corruption and environmental policy. Their empirical analysis is based on allowable lead content in gasoline measured across both developed and developing countries. Greater lead content in gasoline is assumed to represent less stringent environmental regulation. In general, greater openness to trade, measured as the share of exports and imports as a proportion of GDP, leads to stricter environmental regulations. The proxy for corruption is a government honesty index; government honesty and corruption are inversely related. The study finds that greater government corruption reduces environmental stringency and that the level of corruption tends to amplify the impacts of trade openness on environmental stringency. For example, in relatively closed economies the negative impact of corruption on environmental policy is magnified. Protectionism and corruption are found to be complements in the determination of environmental regulations.

In related work, Fredriksson, et al. (2003) examine the relationship between bureaucratic corruption, environmental policy and foreign direct investment (FDI) in the United States. They analyze state-level panel data for the years 1977 to 1987. The first objective of the research is to examine the determination of FDI inflows across the U.S. states, and the influence of environmental standards and public expenditures on those inflows. The second objective is to evaluate the role of corruption in environmental policy determination and public spending. Levinson's (2001) index of state environmental compliance costs is used as the proxy for environmental standards and

non-military government gross state product (GSP) and highway mileage serve as the proxies for public spending. The number of bureaucratic convictions per 1000 bureaucrats in a state is used to measure corruption within states. Instrumental variables control for the potential endogeneity of environmental standards and government GSP. Corruption, per capita state GSP, the share of legal services in GSP, non-military government employment, and tax effort are used as instruments for both environmental standards and government GSP.

The pollution haven hypothesis proposes that FDI will be negatively affected by more stringent environmental standards. The analysis by Fredriksson, et al. (2003) finds a U-shaped relationship between FDI and environmental stringency. This may be explained in part by the findings of Eliste and Fredriksson (2002) outlined above. States with more stringent regulations may attract FDI with transfer payments, thereby overcompensating polluting firms, and contributing to the positive sloped part of the U-shaped relationship. Highway infrastructure has positive impacts on the FDI in a state, while the relationship for government GSP is insignificant. The study further examines new firm location data using a negative binomial specification for discrete plant births.[12] When accounting for the endogeneity of environmental policy and public spending, this specification finds a negative relationship between environmental stringency and foreign-owned new plant births. It also finds that highway mileage and government GSP are statistically significant determinants of new plant births.

Fredriksson and Svensson (2003) examine the relationship between political instability, corruption, and environmental policy formation. Political instability and corruption are found to interact with each other in the determination of environmental

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[12] Fredriksson, et al. (2003) use the term 'births' to refer to the event of a new manufacturing plant locating in a region.

policy. For example, increased corruption reduces the stringency of environmental regulations conditional on the degree of political instability. As political instability increases, the impact of corruption on environmental policy is reduced. Also, the impact of instability on environmental policy depends on corruptibility. Greater instability in the political system makes the producer lobby less likely to bribe because the government has less chance to implement the desired policy. The government, on the other hand, sees bribes as relatively more attractive as instability increases because they are less likely to have the opportunity to implement the policy. The impact of instability increases as corruptibility decreases.

In the Fredriksson and Svensson empirical analysis an equation explaining environmental policy is specified, independent variables including controls, political instability, corruption and an interaction term between instability and corruption. This is a cross sectional analysis of 60 countries for the year 1990. The stringency of environmental policy is measured by the index of agricultural sector environmental policies used in the Eliste and Fredriksson (2002) study mentioned above. Corruption measures are based on an index roughly measuring the extent to which government members expect illegal payments. Instability is measured as 'governmental crises,' defined as rapidly developing situations likely to cause the present government to topple. The set of controls includes per capita income as a proxy for the demand for environmental quality, the lobbying strength of agriculture measured by the share of employment in agriculture, and dummy variables for industrial countries and democracies. Econometric results indicate that per capita income and the dummy for industrialized countries are significant and positively related to environmental stringency. The relationship between the share of employment in agriculture and stringency is

ambiguous and lacks statistical significance. The democracy dummy also lacks

significance and is negative. Corruption and political instability are negatively related to

environmental stringency, their interaction term having a positive impact on stringency.

Fredriksson, et al. (2004) examine the relationship between policy maker

corruption, the incentives of worker and capitalist interest groups, and the determination

of environmental policy. A number of theoretical predictions are tested: one, greater

corruptibility reduces environmental stringency, two, greater lobby group coordination

costs cause more stringent environmental policy, and three, if the wage effects of a policy

are large, then the impact of worker coordination costs compared to capital owner

coordination costs on environmental policy is relatively larger (the converse is also true).

Environmental policy stringency is the dependent variable in this study, measured as

sector energy efficiency over 11 sectors in 12 OECD countries between 1982 and 1996.

A transparency index is used to measure corruptibility. Capital owner and worker

coordination costs are measured as the industry sectors contribution to total value added

and the share of workers employed in a particular sector respectively. The model

predicts that an interest groups stake in the policy outcome will determine the bribery

effort of the sectors interest groups. As the share of total energy used by a sector

increases, that sectors stake in policy increases. Interaction variables between the share

of total energy used by a sector and the value added and employment shares therefore

account for the stakes of interest groups in energy policy. Per capita GDP controls for

the demand for environmental quality while oil prices, electricity prices, production

worker wages, and the cost of capital control for different structures of energy production

across countries. The demand for environmental quality is expected to have a negative

impact on energy intensity. Oil and electricity costs should be negatively related to

energy intensity while labour and capital costs should have a positive impact on energy intensity.

Corruptibility is found to have positive impacts on energy intensity and is significant at the 1% level. Capital owner interest groups are found to experience increasing coordination costs as the size of the sector increases. Workers in relatively large sectors are found to benefit from less stringent energy policy, but this effect is decreasing in sector employment size. The analysis suggests that the coordination costs of worker interest groups increase with greater corruptibility. The coordination costs of capital owners become less important if the sector has a greater stake in energy policy and the opposite is true for worker interest groups. In summary, corruption and energy share differences between sectors reduce capital owner coordination costs and increase the coordination costs of workers. The authors also provide empirical support for the hypothesis that the relative impacts of worker lobby groups versus capital owner groups are negatively related.

2.3 Environmental Policy and Industry Location

The relationship between industry location and environmental regulations has been the subject of a number of studies. This relationship is important to this thesis because of the potential endogeneity between regulatory stringency and ILO production. Of particular interest is the impact of heterogeneous environmental regulations on the location choices of polluting industries. The following section will briefly outline studies of the relationship between polluting industry location decisions and the stringency of

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environmental regulations. The second section will look at location studies specific to the ILO sector.

2.3.1 Environmental Policy and the Manufacturing Industry

McConnell and Schwab (1990) provide an examination of the impact of the regional variation in environmental regulations on firm location decisions. The empirical model examines the impact of county characteristics on the location of 50 new branch plants in the motor vehicle industry between 1973 and 1982. Conducting the study at the county-level allows the authors to capture the distinction between regions that were in attainment of ozone standards in the 1970's.[13] Firms located in non-attainment areas were assumed to be subject to more stringent air quality regulation. Results of the analysis are mixed. In most cases, environmental regulations are found to have no effect on location decisions in the motor vehicle industry. The authors do find evidence that firms are deterred from locating in regions where pollution problems are quite severe leading to high compliance costs.

Henderson (1996) examines the impact of air quality regulation on industrial location. The regulation of ground level ozone is examined, specifically addressing, among other issues, the extent to which polluting plants tend to move towards regions with weaker air quality regulations. The author performs a panel data examination of the effect of attainment status on the location decisions of the major polluting industries in 742 urban counties between 1978 and 1987. The empirical analysis finds that polluting industries move towards areas with records of staying in attainment. Henderson suggests

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[13] A region that has 'stayed in attainment' has a relatively cleaner record than one that has not stayed in attainment. Polluting firms in 'in attainment' regions are likely subjected to less regulatory scrutiny.

that polluting firms move to regions that have a clean record in order to reduce the regulatory scrutiny they are subjected to. The effect of this practice is to relocate source emissions rather than eliminate them.

List and Co. (2000) examine the relationship between foreign direct investment (FDI) and environmental regulation across states in the US between 1986 and 1993. Four proxies for environmental regulations are proposed, including state government spending on pollution regulation, firm-level pollution abatement operating expenditures, and an environmental protection index. Control variables include population density, a proxy for agglomeration economies, manufacturing wages, percentage of unionized workers, energy costs, the number of heating and cooling degree days per year, state tax effort, and state promotional expenditures. All models estimated find that environmental regulations have a negative and statistically significant impact on inbound FDI.

2.3.2 Environmental Policy and the Intensive Livestock Industry

Metcalfe (2001) provides an analysis of US hog production and the influence of water quality regulation. Two proxies are proposed for the stringency of water quality regulations. The first is state spending on water quality and the second is an index derived from the survey conducted by the Animal Confinement Policy National Task Force (ACPNTF) (Edelman, et al. 1999).[14] State hog supply is dependent on the price of inputs, transportation costs, and output prices. Endogeneity of hog prices and the environmental input price (stringency of regulation) is accounted for with the following

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[14] Formed in 1998, the ACPNTF consisted of a group of extension agricultural economists from a dozen land grant universities chaired by Mark Edelman from Iowa State University. The ACPNTF surveyed individuals from land grant universities and state agencies with expertise in the area of animal waste and related animal feeding operation regulations. The survey is referred to as the National Survey of Animal Confinement Policies (NSACP).

instruments. Chicken and cattle prices are the exogenous instruments for hog price. Population density, income level, and the amount of water pollution intensive industry serve as instruments for environmental input price. Metcalfe also controls for differences in the regional effects of environmental regulations and for differences in the ability of hog operations of different size to adapt to environmental regulations. The results indicate that environmental regulations have a negative impact on the hog inventory levels of smaller operations. Large operations, on the other hand, do not show evidence of decreasing inventories in response to more stringent regulations. Rather, Metcalfe finds that proximity to export points and agglomeration economies are driving changes in hog inventory.

Roe, et al. (2002) perform an analysis of the spatial structure of hog production in the US using county level data. This study focuses on the intraregional distribution of hog production, proposing a reduced form model that estimates the impact of firm specific, locality specific, and spatial agglomeration factors. The authors consider several categories of variables, sector and industry agglomeration proxies, urban encroachment indicators, local economic variables, input availability variables, firm productivity and specialization indicators, market access measures, and regulatory variables.

Roe, et al. (2002) formulate three models, explaining three dependent variables (the natural logarithm of total county hog inventory, the change in the natural logarithm of total county hog inventory between 1992 and 1997, and the natural logarithm of the average number of hogs per farm). Metcalfe's regulatory stringency index for both 1994 and 1998 are used as proxies for the state level cost of environmental inputs. The econometric model finds that 1997 county-level hog inventory is negatively affected by increased environmental regulation. This effect is statistically significant and the

elasticity of the inventory response ranges between –0.4 in eastern counties to –0.78 in western counties. The authors also conclude that escalating regulatory stringency was not an "overwhelming barrier to retention or attraction of hogs." Roe, et al. find that hog sector specific and livestock industry infrastructure are important production location variables across all counties. They suggest that property tax rates and environmental regulations are local policy instruments that are effective in altering the location of hog facilities in the counties of the western states examined.[15] In the counties of the eastern states examined, urban encroachment and total population have a negative impact on the location of hog production.[16]

Park, et al. (2002) examine the relationship between environmental policy and industry location in the US livestock industry. Specifically, they attempt to determine whether the livestock environmental regulations constitute proactive or reactive public policy. Proactive public policy is implemented in anticipation of social costs, whereas reactive public policy arises due to consumption and production externalities. The analysis involves examination at the state level (including 48 states) of the location of livestock inventory, dependent on environmental regulations, natural endowments, economic factors, and business climate.

Park, et al. develop an index of environmental stringency based on the ACPNTF survey results. Variables representing monitoring and enforcement of regulations, legislation restricting corporate ownership of livestock, the tendency to fine operations for noncompliance, and the number of staff regulating compliance are constructed from the ACPNTF survey. The econometric model finds that the written regulations have a

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[15] Western counties from the states of Nebraska, Kansas, Oklahoma, Colorado, and Utah.
[16] Eastern counties from the states of Ohio, Indiana, Michigan, Illinois, Wisconsin, Missouri, Minnesota, and Iowa.

positive impact on livestock inventory, as do corporation and zoning restrictions. Staff levels and the willingness to fine noncompliant operations have a negative impact on livestock inventory. The positive relationship between environmental regulation and livestock inventory is interpreted as support for the 'industry drives policy' hypothesis. The authors conclude that the negative sign on the tendency to fine noncompliant operations indicates that the written stringency of regulations is less important than the willingness to enforce regulations.

Herath, et al. (2003) examine the relationship between environmental regulations and the spatial dynamics of the US livestock sector. The authors examine three sectors of the US livestock separately, hogs, dairy, and beef cattle. The environmental regulatory stringency measure is expanded to include 48 states for the years 1975 to 2000. This study seeks to examine the pollution haven hypothesis and the possibility of a race to the bottom in terms of state environmental regulations in US livestock industry.

Annual growth rates in livestock inventories are used as aggregate measures of spatial production. Independent variables include regulatory stringency, relative prices, general business climate, livestock infrastructure, and climatic factors. Regulatory stringency is measured based on a number of sources including the Conservation Foundation Index (1984), the Renew America Index (1987/1989), the Green Index (1991/1992), and Metcalfe's index as described earlier. The authors adjust the index as calculated by Metcalfe and extend it to include 2000 data. Indices are normalized by dividing through by the mean of each index, providing comparable values over time. The validity of this approach is questionable, however, as the Conservation Foundation Index, the Renew America Index, and the Green Index do not specifically apply to agriculture. Control variables include output prices, input prices such as corn, farm labour, and

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electricity, farmland values, and property taxes. Market access and agglomeration economies are considered as livestock infrastructure support. Average annual precipitation and temperature are used to capture differences in the physical features of regions.

Relative regulatory stringency is found to be positively related to changes in hog and dairy inventories, and negatively related to changes in fed-cattle inventories. These results are significant at least at the 10% level. In the hog and dairy sectors, the authors describe these results as counter to the pollution haven hypothesis and conclude that inventory level increases first, followed by increases in regulation. The authors find evidence to support the pollution haven hypothesis in the beef sector and provide an intuitive explanation for the different results among livestock types. Production increases in the hog and dairy sectors have occurred in non-traditional regions where environmental regulations have followed the establishment of significant livestock inventories. Increases in fed cattle production have occurred primarily in the traditional non-populated regions, so expansion may have been influenced by environmental regulations. The authors conclude that relative prices and business climate are the primary drivers of location choice.

2.4 Chapter Summary

This chapter provided an overview of the political economy literature pertaining to trade protection and environmental policy. This literature provides the basis for the theoretical model developed in the next chapter. While not reviewed in this study, tests of the G-H model of trade protection (see Gawande and Bandyopadhyay (2000),

Goldberg and Maggi (1999)) have verified the G-H model empirically. Gawande and

Bandyopadhyay note that the G-H predictions emerge from a fully specified model,

making them superior to traditional models whose predictions are open to interpretation.

Variations of the theoretical model of environmental policy determination of

Fredriksson (1997) have been empirically tested in a number of recent studies. Common

among these empirical tests is the focus on the role of corruption in environmental policy

formation. In all cases, corruption is found to reduce the stringency of environmental

regulations, whether the analysis is at the US state level or is comprised of a cross section

of countries.

This chapter reviews a number of industry location studies that are often cited in

the literature. Typically, empirical examinations of the relationship between industry

location and the stringency of environmental regulations have yielded contradictory

results. Some studies, such as McConnell and Schwab (1990), find that regulations have

no impact on the location decisions of firms because other factors are more important.

The Henderson (1996) and List and Co (2000) studies find that industry location

decisions are negatively affected by environmental regulatory stringency. This chapter

provided a brief summary of the literature dealing with environmental regulations and

industry location, providing a more detailed examination of similar studies dealing

specifically with the US intensive livestock industry.

CHAPTER THREE:

THEORETICAL

FRAMEWORK

This chapter will present a theoretical model of the determination of intensive

livestock environmental regulations. The economic theory follows adaptations of the G-

H model to environmental policy as developed by Fredriksson (1997), Aidt (1998), and

Schleich (1999). The style of presentation used in this chapter follows the style

developed by Fredriksson (1997). The chapter begins with a detailed exposition of the

theoretical model followed by an outline of three predictions as derived from the

theoretical model. These predictions will form the basis of the *a priori* expectations

when the theoretical model is tested empirically.

3.1 Theoretical Model

Following Fredriksson (1997), this theoretical framework models an economy

comprised of the ILO sector, workers with and without environmental concerns related to

ILO production, and an incumbent government. The incumbent government maximizes

an objective function consisting of the aggregate social welfare of society and the profits

of the ILO sector.

The economy is divided into two sectors, one producing a non-polluting

numeraire good c and the ILO sector producing locally polluting non-numeraire good x.

The population is divided into three groups, the ILO sector (denoted I), workers with environmental concerns (R), and workers without environmental concerns (U).[17] All individuals have labour income (l) and population is normalized to one. In addition to labour income, workers with environmental concerns are assumed to derive disutility from the local pollution that may be caused by ILO production.

The ILO sector is able to organize and has an incentive to lobby the government for weaker environmental regulations. As a part of its lobbying effort, the ILO sector makes campaign contributions to the incumbent government. The incumbent government values campaign contributions because campaign spending is positively related to the probability of being re-elected. The interests of the rest of the workers are too diverse to organize a lobby to counter the lobbying efforts of the ILO sector. Of particular importance, the group of workers with environmental concerns is unable to form a lobby that can effectively counteract the political power of the ILO sector. The environmentalists are assumed to either suffer from free-riding problems or to have insufficient resources to offer campaign contributions to the government.

3.1.1 Consumption

The utility of workers without environmental concerns is represented by the function,

$$U^U = c + u(x),$$ (3.1)

and workers with environmental concerns have the following utility function,

$$U^R = c + u(x) - X\theta,$$ (3.2)

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[17] ILO pollution is assumed to be primarily a local problem. In this case, rural citizens are those most affected by ILO pollution, and workers with environmental concerns are denoted R (for rural).

where c represents consumption of the numeraire good and $u(x)$ is the utility derived from consumption of good x. The total quantity of the polluting non-numeraire good produced is X and θ represents the per-unit damages as incurred by individuals suffering disutility from ILO production. The fraction of the population with environmental concerns is denoted α^R. Aggregate disutility from pollution is the sum of all individuals disutility from pollution, $\alpha^R X \theta$.[18]

The per-unit damages are a function of the assimilative capacity of the environment, denoted γ. The assimilative capacity of the environment represents a threshold: when there is surplus assimilative capacity, $\gamma = 0$ and when the assimilative capacity has been surpassed, $\gamma = 1$. If the assimilative capacity of the environment has not been reached, per-unit damages take the value of zero. Once the assimilative capacity has been surpassed the damage coefficient is positive.

3.1.2 Production

Good c is produced using constant returns to scale (CRS) technology and an input-output coefficient equal to one. The wage rate is equal to one. Production of good x requires capital, labour, and land; the technology exhibits CRS. ILO operators receive a net price equal to,

$$p = p^* - r\theta, \tag{3.3}$$

where p^* represents market price and $r \geq 0$ is the stringency of environmental regulation. Profits are a quadratic function of net price,

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[18] Population is normalized to one, $0 \leq \alpha^R \leq 1$

$$\pi(p) = 1/2 \, g p^2 - hp \tag{3.4}$$

where g and h are parameters.

Using Hotelling's Lemma, the supply function is:

$$X(p) = gp - h. \tag{3.5}$$

The derivative of supply with respect to price (inverse of marginal cost) is g, denoted as

X_p hereafter.

3.1.3 Environmental Regulation

In the absence of environmental regulation, $r = 0$ and the ILO sector produces at

private marginal cost. Profits are assumed to decrease as r increases. The compliance

costs due to environmental regulation can also be thought of as a form of revenue for

those providing the 'services' associated with the regulation.[19] The economic

revenue/cost of the environmental regulation is expressed as follows:

$$\omega(r) = X(p)r\theta = (gp - h)r\theta \tag{3.6}$$

The regulation is analogous to a pollution tax, but in the case of the regulation, the

government is not involved in the actual transfer.[20] Distribution of the transfer is

assumed to be equal among all individuals.

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[19] The following are examples of the 'services' associated with environmental regulations. NMP requirements provide expanded markets for firms that conduct soil samples. Set back restrictions may require the producer to purchase more land, therefore bidding up the price of land. Restricting manure nutrient applications may require that manure be shipped greater distances prior to field application, therefore providing revenue to firms involved in the transport of manure.

[20] In the case of a tax, equation (3.6) describes the tax revenue to society and the tax costs to the producers of X.

3.1.4 Welfare Functions

The ILO sector is assumed able to organize. As in Damania, et al. (2003), the number of individuals in the ILO sector is sufficiently small that its utility function is given as, [21]

$$V^I(r) = \pi(p) \tag{3.7}$$

Gross aggregate social welfare is defined as,

$$W^A(r) = \pi(p) + \omega(r) + l - \alpha^R X(p)\theta \tag{3.8}$$

The government utility function is a weighted sum of political contributions from the ILO lobby and aggregate social welfare:

$$V^G = B(r) + \lambda W^A(r) \tag{3.9}$$

where $B(r)$ represents campaign contributions from the ILO sector and $\lambda \geq 0$ is the perceived exogenous weight the government attaches to aggregate social welfare. The incumbent governments objective is to improve its re-election chances. The probability of being re-elected is increased by campaign contributions and the aggregate welfare of society. The lower the value of λ the greater the government's willingness to sell policies to the ILO sector in return for campaign contributions.

3.1.5 The Political Equilibrium

This is a two-stage game between an incumbent local government and the ILO sector. In stage one the ILO sector offers the incumbent government a contribution schedule based on the range of policies that may be implemented by the government. In

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[21] The consumer surplus and revenue due to compliance costs attributable to the ILO lobby are minor compared to the economy as a whole. As is revealed later, this assumption eliminates the impact of the size of the ILO lobby (the percent of the total population represented by the ILO lobby) on the equilibrium regulatory stringency.

the second stage, the incumbent government maximizes its utility considering the campaign contribution offers from the lobby and the aggregate welfare of society. This model involves a bargaining game between a single lobby and the incumbent government, whereas the Fredriksson (1997) model derived the bargaining outcome between the government and two competing lobbies.

Based on Lemma 2 of Bernheim and Whinston (1986), Proposition 1 of Grossman and Helpman (1994) presents four necessary conditions for a subgame perfect Nash equilibrium. Following the Grossman and Helpman presentation, Fredriksson (1997) presents the necessary conditions for the Nash equilibrium pollution tax (T is the government's choice set) in the presence of two or more lobby groups (L is the set of all lobby groups) as follows (p. 49):

Proposition 1. $\left(\left\{B^{i^*}\right\}_{i \in L}, t^*\right)$ is a Subgame Perfect Nash Equilibrium iff
(i) $B^{i^*}(t)$ is feasible for all $i \in L$;
(ii) t^* maximizes $\sum_{i \in L} B^{i^*}(t) + \lambda W^A(t)$ on T;
(iii) t^* maximizes $\left[V^j(t) - B^{j^*}(t)\right] + \left[\sum_{i \in L} B^{i^*}(t) + \lambda W^A(t)\right]$ on T for every $j \in L$;
(iv) for every $j \in L$ there exists a $t^{-j} \in T$ that maximizes $\sum_{i \in L} B^{i^*}(t) + \lambda W^A(t)$ on T such that $B^{j^*}(t^{-j}) = 0$.

Fredriksson provides the following intuition regarding the necessary conditions for the Nash equilibrium pollution tax. Condition (i) requires that the contribution schedule of each lobby group is feasible, implying contributions are non-negative and are not greater than the aggregate income of the lobby group members. Condition (ii) requires that the government maximize its own welfare as defined by its objective function, which is the sum of campaign contributions and weighted aggregate social welfare.

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Condition (iii) states that the equilibrium pollution tax maximizes the joint welfare of each lobby group and the welfare of the incumbent government, given the other lobby group's equilibrium contribution schedule. If this is not the case, then lobby group j could alter its contributions to stimulate a favourable change in government policy. Since the contributions of the other lobby groups are given, lobby group j would capture the surplus resulting from the favourable change in government policy. Therefore, if lobby group j can benefit from a new contribution schedule, the original pollution tax could not have represented an equilibrium.

Condition (iv) establishes the base level of net welfare that the lobby group j uses as its anchor level. The anchor level is the point where the least favourable pollution tax for lobby group j involves a contribution equal to zero. Condition (iv) states that "each lobby group j increases its net welfare by lowering its contribution schedule until the government is indifferent between t^* and some other policy t^{-j} that gives lobby group j a lower net welfare level" (Fredriksson, 1997, p. 50). Lobby group j does not want the government to substitute t^{-j} for t^* so the contribution it offers is at the point where the government is at least indifferent between the two policies.

The model developed for this theoretical framework involves a single lobby and the incumbent government. The presence of a single lobby implies that the subscript i can be dropped and condition (iv) does not involve competition between lobby groups. The four necessary conditions for regulatory stringency in the presence of a single lobby group are written as follows:

Proposition 1: $\left(\{B^*\}, r^* \right)$ is a Subgame Perfect Nash Equilibrium iff

(i) $B^*(r)$ is feasible;

(ii) r^* maximizes $B^*(r) + \lambda W^A(r)$ on R;

(iii) r^* maximizes $\left[V^I(r) - B^*(r) \right] + \left[B^*(r) + \lambda W^A(r) \right]$ on R;

(iv) there exists a $r^{-I} \in R$ that maximizes $B^*(r) + \lambda W^A(r)$ on R such that $B^*(r^{-I}) = 0$.

Condition (i) states that the contribution offered by the ILO lobby is non-negative and not greater than the total income of the ILO sector. Condition (ii) states that the government maximizes its own welfare: the sum of campaign contributions from the ILO sector and the aggregate welfare of society. Condition (iii) states that the joint welfare of the ILO sector and the government is maximized. Condition (iv) establishes that the ILO sector offers a contribution schedule that leaves the government indifferent between r^* and r^{-I}.

The equilibrium in this model is solved by backwards induction. In the second stage of the game, the government sets regulatory stringency according to the schedule of campaign contributions offered by the ILO sector lobby. According to condition (ii), the government maximizes its utility by choosing the regulatory stringency along its indifference curve that corresponds to the campaign contributions offered by the ILO sector. In the first stage, based on its indifference curve, the ILO sector chooses the set of campaign contributions it is willing to offer the government. This is a full information model, implying that the ILO sector knows the policy choices of the incumbent government given any set of campaign contribution offers. Following condition (iii), the equilibrium regulatory stringency chosen by the government maximizes the joint welfare of the government and the ILO sector. Condition (iv) requires that there be a level of regulatory stringency that the government may implement for which the ILO sector is

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willing to make zero campaign contributions. The government is indifferent between this regulatory stringency and the equilibrium regulatory stringency. In the absence of the ILO sector lobby efforts, the government would implement the socially optimal regulatory stringency. In the presence of the single ILO sector lobby group, the government is indifferent between the equilibrium regulatory stringency and the socially optimal regulatory stringency. In this case, the socially optimal regulatory stringency corresponds with r^{-1} as referred to in condition (iv) in Proposition 1 above.

In order to avoid implementation of the socially optimal regulation, the ILO sector increases its contribution level from zero to the point where the government is indifferent between the socially optimal regulatory stringency and the equilibrium stringency. This offer "is proportional to the excess burden that the equilibrium (environmental) policy impose(s) on society. The factor of proportionality is the weight that the government attaches to aggregate gross welfare (relative to campaign contributions) in its own objective function" (Grossman and Helpman, 1994, p. 846). This implies that the ILO sector captures the entire surplus from the bargaining process between itself and the incumbent government. In the political equilibrium, less than optimal environmental quality is provided, implying that aggregate social welfare has decreased.

3.1.6 The Equilibrium Characterization

From Bernheim and Whinston (1986) and Grossman and Helpman (1994), and following Damania, et al. (2003) the Nash equilibrium is achieved when necessary conditions (ii) and (iii) of Proposition 1 are met:

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$$r* = \arg\max_{t} B*(r) + \lambda W^A(r) \text{ on } R$$

$$r* = \arg\max_{t} [V^I(r) - B*(r)] + [B*(r) + \lambda W^A(r)] \text{ on } R$$

Taking the first order conditions of the above two necessary conditions yields the following:

$$\frac{\partial B(r*)}{\partial r} + \lambda \frac{\partial W^A(r*)}{\partial r} = 0 \qquad (3.10)$$

$$\frac{\partial V^I(r*)}{\partial r} - \frac{\partial B(r*)}{\partial r} + \frac{\partial B(r*)}{\partial r} + \lambda \frac{\partial W^A(r*)}{\partial r} = 0 \qquad (3.11)$$

By substitution of equation (3.10) into equation (3.11),

$$\frac{\partial V^I(r*)}{\partial r} = \frac{\partial B(r*)}{\partial r} \qquad (3.12)$$

This implies that the ILO sector makes marginal campaign contribution offers for small changes in regulatory stringency according to the impact the regulatory stringency change will have on the ILO sectors welfare. This corresponds with the equality between the contribution schedule and the ILO sector indifference curve in Figure 3.1. Further substitution of (3.12) into (3.10) reveals the equilibrium characterization:

$$\frac{\partial V^I(r*)}{\partial r} + \lambda \frac{\partial W^A(r*)}{\partial r} = 0 \qquad (3.13)$$

Following Damania, et al. (2003), the following expansion of the equilibrium characterization presented in (3.13) reveals that the government trades off the profitability of the ILO sector and aggregate social welfare at a rate of λ:

$$\frac{\partial \pi(p)}{\partial r} = -\lambda \left[\frac{\partial}{\partial r} \{ \pi(p) + \omega(r) + l - \alpha^R X(p)\theta \} \right] \qquad (3.14)$$

Examination of (3.14) reveals that for any increase in ILO sector profitability (due to changes in regulatory stringency) the decrease in social welfare due to total pollution

must be greater than the increase in ILO sector profitability. In the context of ILO policy, the pressure for increased rural economic development determines the rate of tradeoff exogenously.[22] When the incumbent government is under greater pressure to generate rural economic development, the weight the government places on aggregate social welfare decreases because of the perception among the electorate that the ILO sector can provide rural employment and increase investment in the rural economy. Governments that are under relatively greater pressure to generate rural economic development are more susceptible to campaign contributions from the ILO sector because they place less weight on aggregate social welfare.

3.1.7 Equilibrium Regulatory Stringency

The equilibrium characterization presented in (3.13) is the sum of the partial derivative of ILO sector utility with respect to regulatory stringency and the partial derivative of the aggregate welfare of society with respect to regulatory stringency weighted by the pressure for rural economic development. The equilibrium characterization is alternatively written as:[23]

$$V_r^I + \lambda W_r^A = 0. \tag{3.15}$$

The partial derivatives of these two welfare functions are calculated based on (3.3) through (3.6) and (3.7) and (3.8). The partial derivatives for ILO sector utility and aggregate social welfare are as follows:

$$V_r^I = -X(p)\theta \tag{3.16}$$

$$W_r^A = X_p \theta^2 \left[\alpha^R - r \right] \tag{3.17}$$

The equilibrium solution is interpreted through the following assumption and three propositions. The assumption ensures that the equilibrium characterization is maximized. The three propositions examine the equilibrium solution under alternative circumstances.

> ***Assumption 1:*** The weight the government places on aggregate social welfare is greater than one ($\lambda > 1$).

Proof: Maximization of the equilibrium characterization requires the following second order condition to hold:

$$\frac{\partial \left(V^I \right)^2}{\partial r^2} + \lambda \frac{\partial \left(W^A \right)^2}{\partial r^2} < 0 \tag{3.18}$$

Solving for the second order condition yields the following result:

$$X_p \theta^2 + \lambda \left(-X_p \theta^2 \right) < 0 \Rightarrow \lambda > 1 \tag{3.19}$$

This implies that maximization of the equilibrium characterization requires that the weight the incumbent government places on aggregate social welfare is greater than unity ($\lambda > 1$).[24]

> ***Proposition 2:*** In the absence of the ILO sector lobby, the equilibrium regulatory stringency is equal to the marginal disutility from total pollution (the proportion of the population that suffers disutility from ILO pollution).[25]

Proof: Setting (3.17) equal to zero and solving for r yields the following:

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[24] An interior solution is assumed. If $\lambda < 1$, ILO sector profitability receives more weight than aggregate social welfare in the government's objective function, implying a corner solution.

[25] From the aggregate social welfare function, $\dfrac{\partial W^A}{\partial X \theta} = -\alpha^R$. This corresponds to the tangency between the governments indifference curve and the horizontal axis (which implies zero campaign contributions from the ILO sector) in Figure 3.1.

$$W_r^A = 0 \Rightarrow r = \alpha^R \tag{3.20}$$

Proposition 3: In the presence of an ILO sector lobby, the political equilibrium regulatory stringency is less than the socially optimal regulatory stringency.

Proof: In the presence of the ILO sector lobby, the incumbent government maximizes the equilibrium characterization presented in (3.15). Substituting (3.16) and (3.17) into (3.15) and solving for r reveals the political equilibrium regulatory stringency:

$$V_r^I + \lambda W_r^A = 0$$

$$-X(p)\theta + \lambda X_p \theta^2 (\alpha^R - r) = 0 \tag{3.21}$$

$$r = \frac{\lambda X_p \theta \alpha^R - X}{\lambda X_p \theta}$$

$$r = \alpha^R - \frac{X}{\lambda X_p \theta} \tag{3.22}$$

Since Assumption 1 states that $1 < \lambda < \infty$ and X, X_p, and θ are unambiguously positive, the second term in the RHS of (3.22) must be positive. This implies that $r < \alpha^R$ in the political equilibrium.

Proposition 4: If the assimilative capacity of the environment has not been reached, the political equilibrium regulatory stringency is zero.

Proof: As stated earlier, if the assimilative capacity of the environment has not been reached, $\gamma = 0$ which implies the damage coefficient equals zero. Further analysis of the equilibrium regulatory stringency reveals that $r = 0$ when $\theta = 0$ since $-\frac{X}{\lambda X_p \theta} \to \infty$. This implies that in the absence of pollution damages, the political equilibrium regulatory stringency is zero.

Graphical representation of the equilibrium is presented in Figure 3.2 below. The vertical axis represents price (P) while the horizontal axis represents the supply of intensive livestock (X(p)). Intensive livestock market price is denoted $p*$. Private marginal costs (PMC) correspond with the supply function ignoring the costs due to regulation. The social marginal cost (SMC) curve is the vertical summation of private marginal costs and the marginal externality cost due to pollution resulting from intensive livestock production. The marginal externality cost is zero at all points to the left of $\gamma = 0$ and equals $\theta\alpha^R$ at all production levels to the right of $\gamma = 0$.

If the government chooses not to regulate the ILO industry, production corresponds to $r=0$ (the intersection of $p*$ and PMC) and the deadweight loss is area abc. The optimal regulatory stringency as described in Proposition 2 corresponds with production at $r=\alpha^R$ as shown in Figure 3.2. At this point, the regulatory compliance costs imposed on the ILO industry force full internalization of the marginal externality costs, thereby eliminating the deadweight loss. As stated in Proposition 3, the political equilibrium regulatory stringency lies somewhere between the production levels corresponding with $r=0$ and $r=\alpha^R$. According to Proposition 4, if the intensive livestock market price is less than or equal to p_1 as shown in Figure 3.2, then the political equilibrium regulatory stringency is zero.

P

SMC

b

$\theta\alpha_R$

PMC

a

p*

c

p=p*-rθ

p₁ ... (p_1)

$\gamma=0$ $r=\alpha_R$ $r=0$

X(p)
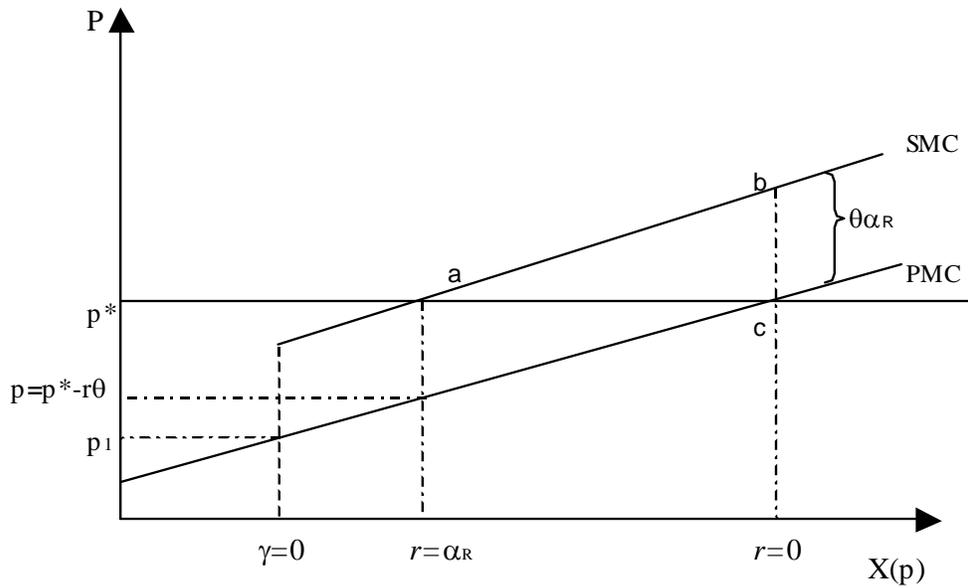
Figure 3.2: Market equilibrium

3.2 Comparative Static Analysis

A comparative static analysis of the regulatory stringency equation provides a number of predictions regarding the relationship between regulatory stringency and key exogenous variables in the model. The comparative static analysis will examine the response of regulatory stringency to the variables λ, α^R, and θ. The predictions derived from this comparative static analysis will form the basis of the testable hypotheses in the empirical component of this thesis.

In order to perform comparative static analysis of regulatory stringency, the equation explaining regulatory stringency should be derived as follows.[26] Substituting (3.3) and (3.5) into (3.21) yields the following:

$$-\left(gp^* - gr\theta - h\right)\theta + \lambda X_p \theta^2\left(\alpha^R - r\right) = 0 \tag{3.23}$$

---

[26] This presentation of regulatory stringency simplifies the interpretation of the results of the comparative static analysis.

Rearranging (3.23) and solving for r results in the following equation for the political equilibrium regulatory stringency:

$$X_p\theta(1-\lambda)r = (gp^* - h) - \lambda X_p\theta\alpha^R$$

$$r = \frac{X + X_p\theta(r - \lambda\alpha^R)}{X_p\theta(1-\lambda)} \qquad (3.24)$$

Notice that, according to Assumption 1, the denominator in (3.24) is strictly negative. Since $r \geq 0$, this further implies that the numerator is negative or equal to zero, and as a consequence $\lambda\alpha^R$ must be greater than or equal to r.

Prediction 1: The relationship between regulatory stringency and the weight the government places on aggregate social welfare is unambiguously positive.

Proof: Total differentiation of (3.24) with respect to λ yields:[27]

$$\frac{dr}{d\lambda} = \frac{-\alpha^R X_p\theta[X_p\theta(1-\lambda)] + X_p\theta[X + X_p\theta(r - \lambda\alpha^R)]}{[X_p\theta(1-\lambda)]^2}$$

$$\frac{dr}{d\lambda} = \frac{-\alpha^R X_p\theta + rX_p\theta}{X_p\theta(1-\lambda)}$$

$$\frac{dr}{d\lambda} = \frac{r - \alpha^R}{1 - \lambda} > 0 \qquad (3.25)$$

Since $\lambda > 1$, the denominator of (3.25) is strictly negative. According to Proposition 3, in the presence of the ILO sector lobby, r is less than α^R, implying that the numerator is also negative. The change in r with respect to λ is therefore unambiguously positive.

Prediction 2: The relationship between regulatory stringency and the marginal disutility from total pollution is unambiguously positive.

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[27] The quotient rule is used for all total differentiations performed in this section.

Proof: Total differentiation of (3.24) with respect to α^R yields the following result:

$$\frac{dr}{d\alpha^R} = \frac{-\lambda X_p \theta (1 - \lambda) X_p \theta}{\left[(1 - \lambda) X_p \theta\right]^2}$$

$$\frac{dr}{d\alpha^R} = \frac{-\lambda}{(1 - \lambda)} = \frac{\lambda}{\lambda - 1} > 0 \tag{3.26}$$

Both the numerator and denominator are the same sign, implying that the change in regulatory stringency with respect to α^R is unambiguously positive.[28] In the political equilibrium, marginal changes in regulatory stringency according to small changes in the disutility from pollution are set according to the weight the government places on aggregate social welfare. If the incumbent government maximizes aggregate social welfare ($\lambda \to \infty$), then a given change in the marginal disutility from pollution results in an equivalent change in regulatory stringency.

Prediction 3: The relationship between regulatory stringency and per-unit pollution damages is unambiguously positive.

Proof: Total differentiation of (3.24) with respect to θ yields:

$$\frac{dr}{d\theta} = \frac{\partial r}{\partial \theta} + \frac{dX}{d\theta} \frac{\partial r}{\partial X}$$

$$\frac{dr}{d\theta} = \frac{X_p \left(r - \lambda \alpha^R\right) - X_p (1 - \lambda) r}{X_p \theta (1 - \lambda)} + \left(-X_p r\right)\frac{1}{X_p \theta (1 - \lambda)}$$

$$\frac{dr}{d\theta} = \underbrace{\frac{\lambda \left(r - \alpha^R\right)}{\theta (1 - \lambda)}}_{(+)} + \underbrace{\frac{-r}{\theta (1 - \lambda)}}_{(+)} > 0 \tag{3.27}$$

The first term in the RHS of (3.27) represents the direct effect of a change in the damage coefficient on regulatory stringency. Due to Proposition 3 and Assumption 1, the first

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[28] Recall that maximization of the equilibrium characterization requires that $\lambda > 1$.

term is unambiguously positive. The second term in the RHS of (3.27) represents the indirect effect of the damage coefficient acting through intensive livestock supply. As stated in equations (3.3) and (3.5), the damage coefficient has a negative impact on intensive livestock supply. Similarly, according to equation (3.24) the relationship between intensive livestock supply and regulatory stringency is negative. The indirect relationship between the damage coefficient and regulatory stringency is therefore unambiguously positive.

The direct effect of the damage coefficient on regulatory stringency captures the impact of pollution damages on aggregate social welfare. Holding all else constant, an increase in pollution damages reduces aggregate social welfare, giving the government an incentive to increase regulatory stringency. The indirect effect of the damage coefficient is due to changes in output that result from a change in the pollution intensity of intensive livestock production. All else equal, an increase in the pollution intensity of intensive livestock production increases compliance costs and results in lower production levels. Lower production levels correspond with lower aggregate ILO sector profits. In the political equilibrium, the government is trading ILO sector profitability in exchange for aggregate social welfare. Since ILO sector profitability decreases with an increase in the damage coefficient, the government has an incentive to increase regulatory stringency.

3.3 Chapter Summary

The theoretical model presented in this chapter will provide the framework for the empirical analysis component of this thesis. A general equilibrium model was presented, allowing for interaction among a regional incumbent government, the ILO sector, and

rural citizens. The incumbent government determines the stringency of environmental regulations. When setting environmental policy, the government maximizes its objective function, which consists of campaign contributions from the ILO sector and aggregate social welfare. The weight the incumbent government places on aggregate social welfare is determined by the perceived political trade-off between environmental quality and rural economic development. The weight therefore increases as the pressure to pursue rural economic development decreases. Comparative static analysis indicated that the relationship between the weight the government places on aggregate social welfare and regulatory stringency is positive.

While the trade-off between environmental quality and rural economic development is of primary interest in this thesis, the theoretical model finds that a number of other factors will impact the formation of ILO environmental policy. The marginal disutility from pollution has a positive relationship with regulatory stringency. Essentially, this variable controls for the political power of individuals with environmental concerns, assumed to be rural citizens in this case. Per-unit pollution damages control for the vulnerability of regional environments to water contamination by manure nutrients. If the pollution damage intensity of ILO production is high, then the government has an incentive to increase the stringency of regulations.

The predictions outlined in the last section of this chapter form the testable hypotheses of the empirical research component of this thesis. The following chapter presents the methods and procedures used to test these hypotheses. Specification of the econometric model is presented along with a detailed discussion of the data utilized in this analysis.

CHAPTER FOUR:

METHODS AND

PROCEDURES

This chapter will set out the methods and procedures used to conduct the

empirical analysis of the theoretical model presented in Chapter 3. This chapter begins

with a general outline of the econometric specification, based on the theoretical

framework and past research into the spatial pattern of livestock production in the US.

The second section provides a discussion of the data requirements. The final section

begins with the econometric specification of the preferred model, followed by a number

of alternative econometric specifications that are used to substantiate the results of the

preferred model.

4.1 Empirical Model

The primary purpose of the empirical analysis conducted in this thesis is to test

the predictions derived from the theoretical model presented in the preceding chapter. As

derived in the theoretical model, state regulatory stringency is explained by the marginal

disutility from pollution, the extent of pollution damages, and the pressure on the

incumbent government to pursue rural economic development initiatives. As has been

recognized in past studies of the US intensive livestock industry (Park, et al., 2002) and

the US hog industry (Metcalfe, 2001), intensive livestock production is potentially

endogenously determined with regulatory stringency. The potential endogeneity between

intensive livestock production and regulatory stringency requires that an equation

explaining intensive livestock inventory be specified. The econometric model of

intensive livestock inventory used in this study follows the work of Metcalf (2001), Park,

et al. (2002), Roe, et al. (2002), and Herath, et al. (2003). Following the notation used in

the theoretical model, the regulatory stringency and the intensive livestock inventory

functions are specified as follows:

$$r = f\left(X, \alpha^R, \theta, \lambda\right)$$

$$X = f\left(r, X_p\right).$$

Proxies are used for a number of the variables in this analysis, requiring the use of a

number of different econometric specifications. The following section provides a

detailed discussion of the data requirements.

4.2 Data Requirements

Secondary data was collected from a variety of sources in order to estimate the

econometric model. Where possible, data for the years 1995, 1996, and 1997 was

gathered. As in (Eliste and Fredriksson, 2001), three-year data was averaged in order to

smooth out the impacts of economic cycles. Also, following Metcalfe (2001), intensive

livestock producers are assumed to be forward looking so intensive livestock inventory

decisions in 1995, 1996, and 1997 are a function of expected regulations in 1997.

Similarly, the determination of government policy is partly based on the past history of

the industry, so inventory levels in 1995, 1996, and 1997 are relevant to the analysis.

Table 4.1 provides variable abbreviations, a brief description of the data collected, and

the source of the data. Table 4.3, presented at the conclusion of this section, provides

descriptive statistics of the variables used in the econometric analysis.

Table 4.1: Description of Variables

VARIABLE	DESCRIPTION	SOURCE
STRING	ILO environmental regulatory stringency index (0,1,…,19)	1998 National Survey of Animal Confinement Policies (NSACP) – Questions 7 - 25 http://cherokee.agecon.clemson.edu/confine.htm
SETBACK	Setback regulation (1=yes)	1998 NSACP – Question 7
NUTSTDS	Nutrient standards (1=yes)	1998 NSACP– Question 15
RANKSTDS	Nut. Std. (0=no std, 1=N, 2=N+P)	1998 NSACP– Question 15
AU1997[a]	Hog, beef, dairy, poultry animal units (1997 AU)	Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States http://www.nrcs.usda.gov/technical/land/pubs/manntr.html
PERCENTRURAL[a]	Non-metropolitan share of total population (%)	BEA. Regional Economic Accounts – CA1-3 Population http://www.BEA.gov/bea/regional/reis/
DENSITY[a]	Non-metropolitan population/Total rural land (number of persons/1,000 acres)	BEA. Regional Economic Accounts – CA1-3 Population http://www.BEA.gov/bea/regional/reis/ NRCS, USDA. Summary Report, 1997 NRI. http://www.nrcs.usda.gov/technical/NRI/1997/summary_report/table2.html
ENVFACTORS	Index of environmental factors indicating potential vulnerability of watersheds (1,2,…,9)	NRCS, USDA. Potential Priority Watersheds for Protection of Water Quality from Contamination by Manure Nutrients http://www.nrcs.usda.gov/technical/land/pubs/wshedpap_w.html (Maps 6-8)
RESNCHANGE	Change in residual nitrogen between 1992 and 1997 (%)	Manure Nutrients Relative to the Capacity of Cropland and Pastureland to Assimilate Nutrients: Spatial and Temporal Trends for the United States http://www.nrcs.usda.gov/technical/land/pubs/manntr.html
NATAMENITY	Natural amenity rank (1,2,…,7)	ERS, USDA. Natural Amenities Drive Rural Population Change. http://www.ers.usda.gov/Data/NaturalAmenities/
DEMOCRAT	Popular vote cast for US president – Democratic (%)	Statistical Abstract of the United States http://www.census.gov/prod/3/97pubs/97statab/election.pdf
PCI(year)	Percent change in non-metropolitan per capita income (%)	BEA. Regional Economic Accounts – CA1-3 Per capita personal income http://www.BEA.gov/bea/regional/reis/
TOTPOP[a]	Total state population (number of persons)	BEA. Regional Economic Accounts – SA1-3 Population http://www.bea.gov/bea/regional/spi/
CORNPRICE[a]	Corn Price ($/bu)	USDA – NASS Agricultural Prices—Annual http://jan.mannlib.cornell.edu/reports/nassr/price/zap-bb/
LANDVALUE[a]	Value of farm real estate ($/acre)	ERS, USDA. Agricultural Resources and Environmental Indicators: Farm Real Estate Values, Rents, and Taxes http://www.ers.usda.gov/publications/arei/ah722/arei1_2/arei1_2farmrealestatevalues.pdf
MFGWAGE[a]	Average manufacturing wage ($/hr)	U.S Dept. of Comm. U.S. Census Bureau. General Summary 1997 Economic Census Manufacturing Subject Series http://www.census.gov/prod/ec97/97m31s-gs.pdf
PROPTAX[b]	Taxes levied on agricultural real estate (Taxes per $100 of full market value)	ERS, USDA. Agricultural Resources and Environmental Indicators: Farm Real Estate Values, Rents, and Taxes http://www.ers.usda.gov/publications/arei/ah722/arei1_2/arei1_2farmrealestatevalues.pdf

Note: all variables are at the state level
[a] Three-year average (1995, 1996, 1997)
[b] Three-year average (1993, 1994, 1995)

4.2.1 Regulatory Stringency

4.2.1.1 Examples from a Review of the Literature

The stringency of intensive livestock environmental regulations has been used as an independent variable in a number of ILO industry location decision studies (Metcalfe (2001), Park, et al. (2002), Roe, et al. (2002), Herath, et al. (2003), and Isik (2003)). Metcalfe (2001) ranks the stringency of ILO regulations both quantitatively and qualitatively. The quantitative variable uses regional spending on water quality programs as a measure of stringency. This measurement may account for the attitude of the state towards water quality protection, but it does not reflect the compliance costs borne by the ILO sector.[29] As an alternative to the quantitative measure, Metcalfe derives qualitative stringency measures for the years 1994 and 1998 based on an examination of the extent of state manure management regulations. The 1994 measure is based on research conducted by Copeland (1994) and the 1998 measure is based on the1998 National Survey of Animal Confinement Policies (NSACP) (Edelman, et. al., 1999). The number of state regulations imposed on ILOs is summed using a weight based on the relative severity of the regulation. Each state is then rated on a scale between one and three, one being low stringency. The index totals for both years are reported in Metcalfe (2000) and were reproduced in Table 1.2 in the introductory chapter of this thesis.

In their study of the US livestock industry, Park, et al. (2002) use data from the 1998 NSACP to create a number of measures of regulatory stringency. The general stringency of environmental regulations was measured as an unweighted sum of affirmative responses to 29 of the survey questions. Each of the 48 participating states

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[29] Metcalfe recognizes that state government water quality spending may reflect the extent of state government assistance to the ILO sector.

(Louisiana and West Virginia did not participate) received a score ranging between zero and nineteen. Dummies for anti-corporate farming laws and local agricultural zoning were also created from the survey. Park, et al. create variables to represent the monitoring and enforcement efforts of the individual states. Enforcement is seen as a better measure of regulatory stringency because enacting environmental legislation is only the first step in the regulatory process; monitoring and enforcement are needed to ensure the regulations are followed

In an analysis of the U.S. steel industry, Gray and Deily (1996) examine the link between enforcement of air quality regulations and compliance decisions. Although not explicitly tested, Gray and Deily suggest that enforcement may be a function of firms' political power. Park, et al. generate "imperfect substitute" variables for enforcement levels among states using information from the 1998 NSACP. A dummy variable representing whether or not fines can be levied and a count variable for the number of staff employed in monitoring roles were constructed. Park et al. found that the proxies for monitoring and enforcement were significant determinants of the location decisions of the ILO industry. Nonetheless, the reliability of the staff enforcement variable is questionable as it fails to adjust for both the size of the industry and the size of the geographic area being monitored. Also, two thirds of states did not respond to the staffing level question, indicating that they assign zero hours to enforcement. The proxy for enforcement is based on the response to a question regarding the imposition of fines. Answers to this question reflect the fines that the regulator is able to impose in the event of illegal discharges into streams or waterways. Answers to this question do not reflect whether or not these fines have been imposed. Similar to the regulatory stringency

variable, the enforcement variable measures the written stringency of regulations, rather than the actual enforcement of the regulation.

In his study of the location decision of dairy farms across the U.S., Isik (2003) creates a measure of the stringency of environmental regulations using the 1998 NSACP using the same methodology as in Park, et al. This proxy is based on affirmative answers to 29 questions relating to regulations from the survey. Each of the 48 participating states (including Alaska and Hawaii) was ranked according to relative regulatory stringency.

4.2.1.2 Regulatory Stringency

Similar to the studies mentioned in the previous section, the proxy for regulatory stringency constructed for this analysis is based on the ACPNTF survey conducted in 1998. Since this survey was conducted throughout 1998, the survey is assumed to represent regulations as they stood in 1997. Louisiana and West Virginia did not participate in the ACPNTF survey and are therefore not included in the sample used in this thesis. The responses for Alaska and Hawaii are excluded from the sample as they do not have significant intensive livestock inventories. New Jersey is excluded since it has no non-metropolitan counties. For the purposes of this study, Alabama is dropped from the sample due to the large proportion of blank responses reported in the survey.[30] Alabama did not respond to any of the environmental questions, yet gave an affirmative answer to the question regarding cost sharing and incentive programs used to encourage compliance. This contradiction casts doubt on the validity of the Alabama survey. After these exclusions the sample size consists of 44 states.

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[30] All 19 questions from section two are blank.

Following the method used in Park, et al. (2002) and Isik (2003), construction of

the regulatory stringency index is based on responses to 19 questions related to

environmental regulation from section two and 9 questions related to industry regulation

from section three of the 1998 ACPNTF survey. These questions are presented in

Appendix A. As an example, Question 7 from the survey is as follows: "Are minimum

set-back distances required by state government for site approval? Describe any required

set-backs." An affirmative answer to this question implies the state has implemented

setback requirements, thereby increasing the stringency of environmental regulations in

that state. Question 15 asks "Does your state government impose nutrient standards or

other limits which restrict amounts of manure applications, timing of land application, set

backs for application, irrigation, or other forms of manure disposal from confined

livestock operations? If "yes", please describe." An affirmative answer to this question

implies that the state government has implemented nutrient management plan (NMP)

requirements on the intensive livestock sector, which also increases the stringency of

environmental regulations. The total number of affirmative answers to the 28 questions

evaluated generated an index score for each state. The highest index score recorded was

in Iowa, which answered a total of 19 of the survey questions affirmatively. Illinois,

Maryland, and Oklahoma each received index scores of 18. Delaware, Massachusetts,

and New Hampshire received index scores of zero, making them the least stringent of the

states included in the sample.[31] New York answered one question affirmatively, giving

that state a score of 1. The regulatory stringency index (STRING) ranges from 0 to 19,

zero indicating low stringency and 19 indicating high stringency. The index scores for

each of the 44 states evaluated in this analysis are presented in Table 4.2 below. The

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[31] Based on the number of affirmative answers to the 28 questions, Alabama would also receive a score of zero.

correlation between the regulatory stringency index developed and reported by Metcalfe (2000) (based on 25 states) and the regulatory stringency index calculated for this study (based on the same 25 states) is 0.79.

Table 4.2: 1997 State Regulatory Stringency Index Scores

State	Index Score	State	Index Score
Iowa	19	Tennessee	12
Illinois	18	New Mexico	11
Maryland	18	North Dakota	11
Oklahoma	18	Pennsylvania	11
Nebraska	17	Utah	11
South Carolina	17	Wisconsin	11
South Dakota	17	Montana	10
Kansas	16	Virginia	10
Arkansas	15	California	9
North Carolina	15	Connecticut	9
Texas	14	Idaho	9
Florida	13	Indiana	9
Kentucky	13	Nevada	9
Mississippi	13	Colorado	6
Ohio	13	Rhode Island	6
Vermont	13	Washington	5
Wyoming	13	Maine	4
Arizona	12	Michigan	3
Georgia	12	New York	1
Minnesota	12	Delaware	0
Missouri	12	Massachusetts	0
Oregon	12	New Hampshire	0

Source: Authors calculations, data retrieved from Edelman, et al. (1999)

4.2.1.3 Alternative Regulatory Stringency Measures

In addition to the basic measure of regulatory stringency, a number of binary variables were constructed based on individual questions from the ACPNTF survey. These alternative measures are based on individual regulations that are used in a number of the states. The regulations chosen impose costs on ILO producers and are designed to protect the air and water quality of rural citizens. The first alternative measure was based on the presence of setback provisions and was used by Herath, et al. (2003) to

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differentiate the regulatory stringency across US states.[32] The second alternative measure

was based on the imposition of nutrient management plans (NMPs). This regulation was

chosen because it addresses the application of excess manure nutrients, potentially

causing the greatest concern regarding water quality problems associated with intensive

livestock production.

The first variable, from Question 7 of the ACPNTF survey, recognized the

presence of legislated setback provisions (SETBACK). Setback restrictions place

minimum distance requirements on the distance between water sources or human

dwellings and the application of manure nutrients. Essentially, these restrictions limit the

availability of land for intensive livestock production, thereby increasing the stringency

of ILO environmental regulations. Setbacks are intended to protect against water

pollution and to preserve the air quality of rural citizens. The presence of setback

legislation (SETBACK=1) increases the stringency of regulations.

The second variable, from Question 15 of the ACPNTF survey, examined the

presence of nutrient management plan (NMP) legislation (NUTSTDS). NMPs place

restrictions on the timing of application, the method of application, and on the quantity of

manure nutrients that may be applied to agricultural land. These restrictions limit

producer flexibility when disposing of manure nutrients, increasing the compliance costs

of ILO environmental regulations. NMPs are imposed in the interest of protecting water

sources from manure nutrient contamination. If manure nutrients are applied in excess of

the assimilative capacity of the agricultural land, the potential for water contamination by

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[32] The distance of the setback provision, adjusted by the cost of agricultural land, was used in the aggregate measure of regulatory stringency for the year 2000.

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manure nutrients increases. If a NMP is required (NUTSTDS=1), the compliance costs of the producer are expected to increase.

The third variable, also based on answers to Question 15 of the survey, provides an expanded measure of NMP legislation (RANKSTDS). NMP legislation can be ranked according to the stringency of the requirements. NMPs that restrict applications of both nitrogen and phosphorus may be more stringent than regulations that place restrictions on nitrogen only. It follows that NMPs that restrict nitrogen applications are more stringent than the absence of a NMP. This variable was constructed as an ordered rank variable taking values of 0, 1, and 2, ranked according to the expected compliance costs of the NMP.[33] As in the NUTSTDS variable mentioned above, the absence of a NMP resulted in a score of 0. A NMP that restricts applications of nitrogen was given a score of 1 while NMPs that restricts both nitrogen and phosphorus applications were given a score of 2.

4.2.2 Livestock Inventory

State livestock industry (AU1997) was calculated using the animal unit totals as reported in Kellogg, et al. (2000). Kellogg, et al. adjusted 1997 state livestock inventories, as reported in the 1997 Census of Agriculture, by an animal unit conversion factor based on the manure nitrogen characteristics of each animal class. Four animal classes are included in this calculation: hogs, beef cattle, dairy cattle, and poultry. This measure provides an estimate of the total livestock inventory in a state in 1997, adjusted by the contribution of each species to the quantity of manure produced. An adjustment

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[33] The difference between 0 and 1 is not the same as the difference between 1 and 2. The code 0,1,2 simply indicates the ascending rank of regulatory stringency (Greene, 2000, p. 875).

for potential manure nutrient production is used in order to control for the aggregate production of manure nutrients in a state over the course of a year. Therefore, the animal unit calculations used in this study provide an aggregate indication of the potential stock of manure nitrogen but nitrogen flows from previous years are not captured.

4.2.3 Marginal Disutility from ILO Pollution

4.2.3.1 Percent Rural and Rural Population Density

Population data was obtained from the Bureau of Economic Analysis (BEA) Regional Economic Accounts. The percent of the population that is rural (PERCENTRURAL) is the ratio of non-metropolitan population to total population.[34] Rural population density (DENSITY) was defined as the ratio of non-metropolitan population to rural land area. Rural land area data was collected from the Natural Resource Conservation Service (NRCS) (1997) and included all cropland, CRP land, pasture, rangeland, and forestland.

The proportion of the population that has environmental concerns impacts the stringency of environmental regulations. In the context of ILO environmental regulations, the percent of the population that is considered rural represents those with environmental concerns. All else equal, an increase in the number of rural citizens as a percent of the total population gives rural citizens greater political power, and results in higher regulatory stringency. The interaction between rural population density and the percent of the population rural is a proxy for the availability of land suitable for ILO production. A region that has a large number of rural citizens who densely populate the

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[34] Throughout this study, non-metropolitan is equivalent to rural.

rural land base is assumed to be less suitable for ILO production. Conflicts between rural

citizens and the ILO industry are more likely to arise if open, unpopulated space is

scarce. This interaction term therefore provides an additional control for the importance

of rural citizens with environmental concerns.

4.2.3.2 Natural Amenity

The Natural Amenity Scale, as developed by the ERS (1999), provides a

measurement of the attractiveness of a location as a retirement or vacation destination.

This scale includes measures of warm winter, winter sunlight, temperate summer, low

summer humidity, topographic variation, and water area, all thought to be attractive

natural amenities. The ERS data provides a scale and rank for each county in the lower

48 states. State natural amenity ranks (NATAMENITY) were calculated as an average of

the county ranks for each individual state. California, Arizona, Colorado, Nevada, New

Mexico, Oregon, and Utah were the top ranked states on the natural amenity scale. At

the bottom of the list were states such as Indiana, Iowa, Minnesota, and North Dakota.

The natural amenity scale is only a measure of the natural features of the states

environment. The impact of human activities on the aesthetic quality of the landscape is

not considered. This variable merely captures the initial natural amenities endowment,

not investments in the natural amenities of an area.

In the context of intensive livestock environmental regulations, states that are

relatively more abundant in natural amenities likely have greater incentive to protect

environmental quality from intensive livestock pollution.[35] This variable was found to

have a positive relationship with rural county population changes over the past 25 years

(ERS, 1999). This variable therefore has two effects: first, it provides a measure of the

potential for a region to further develop as a retirement or vacation destination and

second, the natural amenity scale may capture the effect of recent migration on the

stringency of ILO environmental regulations.[36]

4.2.4 Pollution Damages

4.2.4.1 Environmental Factors

The vulnerability of watersheds to manure nutrients was measured using a set of

three environmental factors developed by the NRCS (Kellogg, 2002): a percolation

factor, a runoff factor, and a soil erosion factor. The percolation factor estimates the

annual precipitation that percolates through the root zone. The calculation was based on

annual precipitation, a weight for precipitation in the non-growing season, and soil

hydrologic groups. Hydrologic groups sort soils according to the potential for water

infiltration. The run-off factor estimated the annual precipitation that is run-off,

evaporation and percolation into the soil being the alternatives. Annual precipitation

combined with soil hydrologic group, tillage, conservation practice, and land cover

determine the potential for run-off. The soil erosion factor estimated the potential for soil

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[35] The intent of the natural amenity variable is to capture the marginal disutility from pollution. The inclusion of water area in the calculation of this variable also captures the potential for pollution damages from ILO production. The correlation between STRING and NATAMENITY is –0.184.

[36] Recent migrants to an area may not have an interest in the economic well being of the existing intensive livestock sector and may lobby for more stringent regulations. While correlated with population growth, calculation of the natural amenity scale controls for the potential for pollution damages from intensive livestock production. A better proxy for the impact of recent migration may be recent population growth. January temperature and days of sunlight may also serve as a proxy for past and future ability to attract retirees and vacationers.

to move due to sheet and rill erosion. Calculations for the soil erosion factor were based on the Universal Soil Loss Equation.

The environmental factors were combined with the residual manure nutrients produced in each region analyzed.[37] Excess nitrogen and phosphorus nutrients represent the difference between the pounds of recoverable manure nutrients produced and the assimilative capacity of available cropland and pastureland. Nitrogen is highly dissolvable in water and losses of nitrogen occur primarily due to leaching and run-off. Phosphorus is less soluble in water and tends to adsorb to soil particles. Therefore, the percolation and run-off vulnerability factors estimate the potential for manure nitrogen to move from agricultural land and the soil erosion vulnerability factor provides an estimate of the potential for phosphorus to move from agricultural land.

Since the data underlying the maps provided by the NRCS was not available, a visual inspection of the maps was performed in order to assign a vulnerability rank to each state. Each factor was displayed on a map, with each degree of vulnerability represented by a different shade, five shades in total. Each state was assigned a value ranging from 1 to 9, with even values assigned to combinations of adjacent shades. Vulnerability increases with an increase in the environmental factor. The vulnerability index (ENVFACTORS) is the average of the three environmental factors, with vulnerability increasing in the index.

Overall, the Southeastern states are the most vulnerable to manure nutrient contamination of water resources. Mississippi, Georgia, and North Carolina were ranked as the most vulnerable, followed closely by Tennessee and South Carolina. High scores in these states are attributed to high percolation and runoff scores, indicating high

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[37] Residual manure nutrients calculated assuming no export from the farm (from Kellogg, et al. (2000)).

vulnerability to nitrogen contamination. Virginia, Kentucky, and North Carolina had the highest soil erosion scores, making them the most vulnerable to phosphorus contamination. Among the lowest overall scores were Nevada, Utah, Wyoming, New Mexico, and Arizona. High soil erosion scores in Montana, North Dakota, and Idaho differentiated these states from states with the lowest overall scores.

4.2.4.2 Changes in Residual Nitrogen

Residual nitrogen ratios were obtained from Kellogg, et al. (2000). Kellogg, et al. measure county residual nitrogen as the ratio of recoverable manure nitrogen to the potential for cropland and pastureland to assimilate manure nitrogen.[38] Individual county residual nitrogen ratios were converted to state residual nitrogen ratios by calculating a weighted average of all counties within a state. Weighting was based on the counties proportion of total state cropland and pastureland. The percent change in residual nitrogen (RESNCHANGE) was based on the difference between state residual nitrogen ratios in 1992 and 1997. An increase in the percent change represents an increase in the potential for problems associated with manure nitrogen. This does not account for additions to the stock of residual manure nitrogen for a particular year, nor does it account for potential accumulations in the stock due to residual nitrogen in previous years. The RESNCHANGE variable provides a rough measure of the change in potential environmental damages associated with manure nitrogen, however, this variable does not

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[38] This residual manure nitrogen calculation assumed export from the farm and no export from the county. Naturally, residual manure nitrogen is lower when export from the farm is assumed. This measure does not account for export to adjacent counties, therefore distorting the results.

account for the location of potential manure nitrogen applications, whereas the ENVFACTORS variable described above is calculated spatially.

Correlation between the ENVFACTORS variable described in the previous section and RESNCHANGE is 0.51. Across all states, the average change in residual nitrogen between 1992 and 1997 was approximately an 11% increase. States such as Arkansas, Mississippi, South Carolina, Missouri, and Georgia had the highest percent increases between 1992 and 1997. Montana and Rhode Island experienced the largest percentage decreases in residual nitrogen over the same period.

4.2.5 Environmental/Rural Development Preferences

4.2.5.1 Democratic Support

Durden, et al. (1991) examined the formation of US coal strip-mining legislation in the 1970's. The formation of legislation was analyzed in the framework of a trade-off between the environmental degradation due to coal strip-mining and the economic development resulting from coal strip-mining. The authors proposed that congressional voting on a 1974 surface-mining control bill was dependent on the relative political power of environmental versus coal industry groups, the importance of coal mine employees in the local economy, political ideology, and political leadership preferences. Political leadership preferences were classified as either Democratic or Republican. The Democratic Party was expected to demand stronger environmental regulations while the Republican Party demands weaker legislation. Empirical results confirmed expectations; the Republican Party variable was strongly significant, having a negative impact on the tendency to vote for the more stringent coal strip-mining environmental legislation.

In an analysis of the public choice determinants of EPA penalties for carbon emission violations, Mixon (1995) proposed that states represented by Republican governors between 1988 and 1990 may have lobbied for less severe penalties. The presidency of George Bush was thought to potentially increase the influence of the Republican governors, enabling them to lower the penalties for noncompliance within their respective states. The empirical results found that the number of days a state is in violation of EPA carbon emission standards increased if a Republican governor represented the state. Also, although insignificant, the likelihood of violating EPA emission standards increased if a Republican governor represented the state. In general, Mixon found that interest groups do have an impact on the penalties assessed by the EPA. Mixon concluded that the EPA was influenced by the lobbying efforts of the businesses that it was mandated to regulate.

The two studies mentioned above both highlighted the importance of political preferences in the determination of environmental policy. Democratic voters were thought to demand stricter environmental legislation than their Republican counterparts. State voting tendency may provide an indication of the weight that states place on environmental quality versus economic development. Thus, the percent of state voters that voted for the Democratic Party in the 1996 Presidential Election (DEMOCRAT) was used as a proxy for the environmental preferences of the state (US Census Bureau, 1997).[39] Massachusetts, New York, and Rhode Island showed the highest levels of Democratic support in 1996, whereas Idaho, Utah, and Wyoming showed the highest levels of Republican support.

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[39] A dummy variable (GOVERNOR) was also constructed, taking the value of 1 if the state had a Democratic governor in 1997 and 0 if the state had a Republican governor in 1997. Among the states, Maine was the only to have an Independent governor and was assigned a zero since the previous governor was Republican.

4.2.5.2 Percent Changes in Per Capita Income

In the context of the G-H model, the weight the incumbent government places on aggregate social welfare is a measure of the willingness of the government to sell policies in return for campaign contributions (Damania, et al., 2003). Fredriksson and Svensson (2003) argued that the weighting factor is a measure of the level of corruption in the political system. In the G-H presentation, the incumbent government weights aggregate social welfare and campaign contributions in its objective function. "Social welfare will be of concern to the incumbent government if voters are more likely to re-elect a government that has delivered a high standard of living" (Grossman and Helpman, 1994, p. 838). In this analysis, the weight the government places on aggregate social welfare is a measure of the willingness to set policies that will favour rural economic development over environmental quality. In relation to the G-H model, social welfare (environmental quality in this analysis) is more important to the incumbent government when the recent performance of the rural economy has been relatively good. The following section argues that the recent performance of the rural economy represents the pressure on the incumbent government to pursue rural economic development initiatives. Stated another way, the recent performance of the rural economy exogenously determines the preference for economic development relative to environmental quality as perceived by the incumbent government.

An examination of the history of economic development policy in Wyoming by Gerking and Morgan (1998) provides an example of the importance of recent economic performance on the formation of environmental policy. The review of economic

development policy in Wyoming notes that prior to escalations in energy prices the promotion of economic development was a political priority in the early 1970s.[40] However, during the energy boom years of the 1970s and 1980s economic development become less of a political priority. High economic growth rates shifted the focus of public policy away from economic development and towards the protection of environmental quality. Commenting from the perspective that high economic growth rates were costly to the existing residents of Wyoming, Gerking and Morgan (1998) state the following:

> Rapid growth fueled by the booming mineral industries often was viewed as a cause for concern and state policy makers during that period directed efforts largely at reducing economic growth rates and mitigating its adverse consequences. Environmental standards were made more stringent and the Department of Environmental Quality was created. Processes were institutionalized to govern the location of new mines and processing plants when the Industrial Siting Commission was established (p. 137).

When energy prices declined in the mid-1980s the focus of public policy on economic development was renewed. In 1984 the Economic Development and Stabilization Board was created, and among other initiatives promoted the use of state funds for low-interest loans to manufacturers.

As described by Gerking and Morgan, the history of economic development policy in Wyoming supports the concept that governments pursue economic development in times of low economic growth. However, in periods of high economic growth the perceived political importance of economic development initiatives falls. When Wyoming experienced high economic growth rates the public policy focus shifted from economic development to the protection of environmental quality. As the economic

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[40] "Wyoming ranks first among US states in coal production, fifth in natural gas production, and sixth in oil production" (Gerking and Morgan, 1998, p. 134).

fortunes of Wyoming shifted, the public policy focus on economic development relative to environmental quality also shifted.

Three common indicators of rates of economic growth are (i) changes in per capita personal income, (ii) changes in total employment, and (iii) changes in population. In this analysis, recent economic growth rates were measured by percent changes in rural per capita personal incomes.[41] In a discussion of the political decision-making process regarding the tradeoff between economic growth and environmental quality, Harrison (1996) states the following:

> [The] electoral cycle is decidedly short term relative to the ultimate economic consequences of environmental degradation. As a result, near-term economic costs can be expected to loom larger than distant economic benefits in politicians' eyes (p. 471).

Since the electoral cycle is four years long and governments are generally perceived as short-term decision makers, the time span for the percent change in per capita income should range between two and four years.[42] For the purposes of this analysis, three variables were constructed, one for each of two year, three year, and four year changes (%) in state non-metropolitan per capita personal income (PCI*year*) based on statistics provided by the Bureau for Economic Analysis (BEA). The change in state non-metropolitan per capita income over four years (PCI*four*) was designated as the preferred proxy for the pressure for rural economic development. This variable coincides with the length of the electoral cycle and is long enough to smooth out the impacts of the economic cycle. Iowa, Rhode Island, and Minnesota had the highest increases in per

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[41] The percent change in total rural employment was also constructed and tested in place of the change in rural per capita income.

[42] In an update of Fair (1996), Fair uses the growth rate of real per capita GDP in the three quarters prior to the election (GROWTH) as well as the number of quarters in the first 15 quarters of the administration in which the GDP growth rate was greater than 3.2% (GOODNEWS) to predict the incumbent share of the two-party US Presidential vote. Both GROWTH and GOODNEWS are positive and significant, indicating that recent economic growth factors are important to incumbent US Presidential candidates. Update retrieved June 15 from World Wide Web: http://fairmodel.econ.yale.edu/RAYFAIR/PDF/2002DHTM.HTM

capita income over four years, followed by Massachusetts, Mississippi, and Missouri. California, Idaho, and Montana had the lowest percent changes in per capita income over four years.

4.2.6 Livestock Production Costs

Instrumental variables for livestock inventory are the livestock production costs, including total state population (TOTPOP), corn prices (CP), agricultural land values (LANDVALUE), manufacturing wages (MFGWAGE), and agricultural real estate taxes (PROPTAX). Higher total state population is expected to attract a higher livestock inventory because livestock producers benefit from being closer to market. This is especially true for a dairy state like California. Fluid milk is costly to transport so production will move towards the final market. This is less the case in the poultry, pork, and beef industries, where other factors, such as the availability of grazing land for beef production may become more important. Corn represents an important input into intensive livestock production. Corn prices are expected to have a negative impact on intensive livestock inventories. High land values are expected to have a negative impact on inventory. Manufacturing wages are used as a proxy for the cost of labour in the intensive livestock industry. Higher manufacturing wages are expected to decrease livestock inventory. Property taxes (data available for the years 1993, 1994, and 1995) give an indication of the business climate; higher taxes are expected to decrease inventory.

Table 4.3: Descriptive Statistics

Variable	Mean	Std. Dev.	Max	Min
STRING	10.886	5.054	19	0
NUTSTDS	0.591	0.497	1	0
SETBACK	0.750	0.438	1	0
RANKSTDS	1.023	0.731	2	0
LOG(AU1997)	12.944	1.442	15.019	8.147
PERCENTRURAL	32.143	20.401	70.065	1.504
PERCENTRURAL*DENSITY	1539.536	1282.034	5260.54	41.226
ENVFACTORS	4.295	1.798	7.667	1
RESNCHANGE	11.785	40.506	172.768	-55.376
NATAMENITY	3.731	0.988	6.259	2.172
DEMOCRAT	47.039	6.571	61.5	33.3
PCI*four*	17.181	3.793	28.856	8.649
LOG(TOTPOP)	15.063	1.025	17.283	13.097
CP	3.07	0.294	3.66	2.527
LANDVALUE	1041.371	926.881	4393.667	137.667
MFGWAGE	13.683	1.449	18	10.790
PROPTAX	0.835	0.693	4.12	0.087

Source: Author's calculations

4.3 Econometric Specifications

In this section a number of alternative econometric models are proposed to examine the empirical validity of the theoretical model. The econometric results of these specifications will be presented in the next chapter. The preferred specification is presented first (section 4.3.1) accompanied by a discussion of the variations on the preferred specification. Alternative specifications using the binary proxies for regulatory stringency are presented in section 4.3.2. A brief outline of the econometric models tested in this thesis is presented in Appendix B.

4.3.1 Preferred Specification

The preferred specification is presented below. This specification will first be estimated using OLS. Reduced form estimations of the two equations follow, allowing the validity of the instrumental variables to be examined. Two-stage least squares (TSLS) estimations will be performed in order to account for the potential endogeneity between regulatory stringency and intensive livestock inventory.[43]

$$
\begin{aligned}
STRING = \beta_1 &+ \delta_1 LOG(AU1997) + \beta_{12} PERCENTRUR\ AL \\
&+ \beta_{13} PERCENTRUR\ AL * DENSITY + \beta_{14} ENVFACTORS \\
&+ \beta_{15} NATAMENITY + \beta_{16} DEMOCRAT + \beta_{17} PCIfour + \varepsilon_1
\end{aligned}
\tag{4.1}
$$

$$
\begin{aligned}
LOG(AU1997) = \beta_2 &+ \delta_2 STRING + \beta_{22} LOG(TOTPOP) + \beta_{23} CP \\
&+ \beta_{24} LANDVALUE + \beta_{25} MFGWAGE + \beta_{26} PROPTAX + \varepsilon_2
\end{aligned}
\tag{4.2}
$$

The validity of the PCI*four* variable is tested using PCI*three* and PCI*two* variables as substitutes for the pressure for rural development. These two specifications are tested using TSLS. The overidentifying restrictions are tested for all TSLS specifications.

The preferred specification is run as a two-stage tobit (TSTOBIT) model due to the potential that the censored nature of the regulatory stringency variable has materially affected the results. The TSTOBIT results are presented for the stringency equation only. Also, an alternative proxy for the marginal damages from intensive livestock production is tested: the RESNCHANGE variable is used in place of the ENVFACTORS variable due to the potential for measurement error in ENVFACTORS.

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[43] Coefficients on endogenous variables are represented by δ_i and coefficients on exogenous variables are represented by β_{ij} in equations (4.1) and (4.2).

4.3.2 Alternative Specifications

The final group of models tested in this analysis use a number of alternative discrete choice proxies for the regulatory stringency dependent variable. The structural equations for each of these alternative specifications are estimated. The first two models within this group use binary logit (to account for the discrete nature of the dependent variable) to estimate the stringency function. In the first alternative specification, SETBACK is used as a proxy for the stringency of ILO environmental regulations. The second specification uses NUTSTDS as the measure for regulatory stringency. The third of the alternative specifications is an ordered logit analysis of RANKSTDS. The specification of these three models is as follows.

$$
\begin{aligned}
SETBACK \ (orNUTSTDS \ ) = \ \beta_1 + \ \beta_2 LOG \ (AU \ 1997 \ ) + \ \beta_3 PERCENTRUR \ AL \\
+ \ \beta_4 PERCENTRUR \ AL * DENSITY \ + \ \beta_5 ENVFACTORS \\
+ \ \beta_6 NATAMENITY \ + \ \beta_7 DEMOCRAT \ + \ \beta_8 PCIfour \ + \ \varepsilon_1
\end{aligned}
$$

$$
\begin{aligned}
RANKSTDS \ = \ \beta_1 + \ \beta_2 LOG \ (AU \ 1997 \ ) + \ \beta_3 PERCENTRUR \ AL \\
+ \ \beta_4 PERCENTRUR \ AL * DENSITY \ + \ \beta_5 NFACTOR \ + \ \beta_6 PFACTOR \\
+ \ \beta_7 NATAMENITY \ + \ \beta_8 DEMOCRAT \ + \ \beta_9 PCIfour \ + \ \varepsilon_1
\end{aligned}
$$

4.4 Chapter Summary

This chapter stated the general specification to be estimated in the empirical component of this research. Two equations were specified; the first is the regulatory stringency equation as derived in the theoretical model and the second is the livestock inventory equation as has been estimated in previous empirical studies of the US livestock industry. These models will be estimated as a system in order to account for

potential endogeneity between regulatory stringency and livestock inventory. The data

requirements were discussed in detail, outlining the type of data that best represents the

model and providing a summary of the characteristics of the actual data collected. The

chapter concludes with an explicit specification of the system of equations to be

estimated. Two groups of specifications are suggested: first, the preferred specification

and second, the alternative specifications based on the alternative measures of regulatory

stringency.

The following chapter will present the econometric results of the preferred and the

alternative specifications. Interpretation of the results will involve an analysis of the

preferred specification as well as comparisons between the preferred model and the

alternative specifications.

CHAPTER FIVE:

RESULTS AND

DISCUSSION

The results of the econometric analysis are presented in this chapter. The results of the preferred model are presented first, followed by the alternative specifications for regulatory stringency. Parameter estimates are presented in table format, accompanied by a discussion of the results and where appropriate a comparison of the results among different specifications.

5.1 Preferred Specification

We first present the results for the preferred group of models. This section is divided into five subsections as follows. OLS results for the regulatory stringency and intensive livestock inventory equations are presented first (section 5.1.1). Second, the reduced form estimates are provided, allowing for examination of the validity of the instrumental variables (section 5.1.2). The third subsection presents the results from the two-stage least squares (TSLS) estimations (section 5.1.3). In the fourth subsection a two-stage analysis of the regulatory stringency equation using TOBIT in the second stage is performed (section 5.1.4). The final subsection presents a TSLS estimation using the alternative proxy for marginal damages (section 5.1.5).

5.1.1 OLS Results

5.1.1.1 Regulatory Stringency

The OLS results for both equations, using PCI*four* as the proxy for rural economic development pressure are presented in Table 5.1 below. The stringency equation has an R^2 of 0.499. According to the theoretical model, expectations regarding the sign on LOG(AU1997) are ambiguous. The highly significant positive sign in the OLS regression reveals that intensive livestock inventory has a positive impact on regulatory stringency. Environmental regulation of the ILO industry therefore reacts to production levels, a result suggested by other studies (Park, et al. (2002) and Herath, et al. (2003)). Given results from the theoretical model, a positive relationship between livestock inventory and stringency indicates that marginal damages are likely increasing in livestock inventory. Additionally, since the measurement of livestock inventory is in animal units, this variable captures the relative quantity of manure nutrients produced across states. The positive sign is consistent with the expectation that regulatory stringency increases as potential pollution damages increase.

The PERCENTRURAL variable has a significant positive impact on regulatory stringency, consistent with the theoretical predictions. The higher the percent of the population that is rural, and therefore the higher the proportion of the population that may be negatively affected by ILO pollution, the higher the regulatory stringency. This indicates that the greater the potential disutility from ILO pollution, the more likely the government is to implement more stringent environmental regulations. Contrary to expectations, the interaction term between PERCENTRURAL and DENSITY is negative. Since the pollution from intensive livestock production is distributed spatially,

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it is expected that high rural population densities in regions where rural citizens comprise a large portion of the population will increase the number of citizens who are potentially adversely affected by intensive livestock pollution. The interaction term captures the spatial density of rural citizens, providing a proxy for the marginal damages of ILO production due to air quality concerns. The negative sign on this interaction term indicates that air quality concerns may not be significant determinants of the stringency of ILO environmental regulations.

Table 5.1: Regulatory Stringency OLS Results

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: STRING				
INTERCEPT	-14.84360	-	-1.667761	0.1040
LOG(AU1997)	1.316709	0.12095	3.644786	0.0008
PERCENTRURAL	0.120495	0.355777	3.154935	0.0032
PERCENTRURAL*DENSITY	-0.001469	-0.207744	-1.704172	0.0970
ENVFACTORS	1.264742	0.499032	2.435497	0.0200
NATAMENITY	1.247615	0.42759	1.630662	0.1117
DEMOCRAT	-0.213879	-0.924145	-1.807551	0.0790
PCI*four*	0.410194	0.647386	3.009108	0.0048
$R^2 = 0.499$				

Source: Author's calculations

As expected, ENVFACTORS is positively related to regulatory stringency. The coefficient on ENVFACTORS is positive and statistically different from zero at the 2% level. This variable controls for both residual nitrogen levels (dependent on cropping practices) and the environmental characteristics (climate, soil type, etc.) of a state.

Combined with the animal units variable (AU1997), the positive sign on ENVFACTORS indicates that ILO environmental regulations are highly responsive to the potential for pollution from intensive livestock production. Aggregate manure nutrients, the ability of the environment to assimilate those manure nutrients, and the vulnerability of watersheds to potential pollution have a positive impact on the stringency of regulations.

States relatively abundant in natural amenities are expected to have more stringent ILO environmental regulations. The econometric results find that NATAMENITY has a positive although statistically insignificant impact on the stringency of regulations. Since the natural amenity scale is positively related to rural population change, this variable may also be capturing the impact of changing demographics on the stringency of environmental regulations. For example, if rural population growth is due to the influx of retirees from metropolitan centers, then there is likely greater pressure for increased ILO environmental regulations. Compared with existing rural residents who may benefit economically from the ILO industry, retirees from metropolitan centers likely have less interest in the economic health of the intensive livestock sector and lobby for more stringent regulations.[44]

The percent of votes received by the Democratic presidential candidate in 1996 was used as a proxy for the political preference of the state.[45] Contrary to expectations, the DEMOCRAT variable had a negative impact on the stringency of regulations. The

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[44] Two alternative proxies were tested in place of NATAMENITY. First, five-year changes (1988-1993) in non-metropolitan population (%) (POPCHANGEFIVE). The correlation between POPCHANGEFIVE and NATAMENITY is 0.640. The sign on POPCHANGEFIVE was positive but statistically insignificant. Second, based on two components of the natural amenity index as provided by the ERS (1999), an alternative natural amenity index was constructed using the average temperature in January and the average number of days of winter sunlight (JANINDEX). The correlation between JANINDEX and NATAMENITY is 0.471. Consistent with expectations, the sign on JANINDEX was positive and statistically significant at least at 1%.

[45] Regional dummies (for the Southeast, Northeast, Midwest, and West) were constructed to account for different regional preferences for environmental regulation. The South was found to have a positive impact on the stringency of regulations, while the Midwest and Northeast had negative impacts on regulatory stringency. All results for the regional dummies were highly insignificant.

incorrect sign on this variable may be due to aggregation over the entire state. If

primarily rural forces drive ILO environmental policy, then the percent of the non-

metropolitan population that voted Democrat may be a better proxy for the state political

preference for environmental protection.[46]

The PCI*four* variable had a positive and significant impact on the stringency of

ILO regulations, conforming to *a priori* expectations regarding the pressure for rural

economic development.[47] States that are experiencing relatively higher per capita income

growth rates implement relatively more stringent ILO environmental regulations.[48] This

result is statistically significant: the null hypothesis that PCI*four* has no effect on the

stringency of ILO environmental regulations is rejected at the 1% level.

5.1.1.2 Livestock Inventory

The overall fit of the livestock inventory equation is good, having an R^2 of 0.737.

The OLS results of the intensive livestock inventory equation are presented in Table 5.2

below. Livestock inventory is positive and significant in regulatory stringency, contrary

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[46] A dummy variable was constructed for the presence of a Democratic governor (GOVERNOR). DEMOCRAT, GOVERNOR, and DEMOCRAT*GOVERNOR were run in the preferred specification. DEMOCRAT and GOVERNOR had negative signs while the interaction term was positive. Both GOVERNOR and DEMOCRAT*GOVERNOR were statistically insignificant at the 20% level. Using GOVERNOR in place of DEMOCRAT in the preferred specification revealed a positive although highly statistically insignificant impact on STRING.

[47] The average (1995, 1996, 1997) non-metropolitan per capita personal income (RURALPCI) was used in place of PCI*four*. RURALPCI was positive but highly statistically insignificant. Following the discussion of Shafik (1994) in the introduction to Chapter 1, the statistical insignificance of this variable may reflect the broad potential externalities from ILO production. For example, agricultural pollution problems in the Gulf of Mexico extend beyond individual state boundaries, potentially weakening the relationship between state per capita incomes and state regulatory stringency.

[48] Due to the potential that government subsidies to the agricultural sector are driving the PCI*four* results, an alternative proxy for the pressure for rural economic development was tested. The change in non-metropolitan total employment (%) was calculated for each of four, three, and two year intervals (EMP*year*). The correlation between EMP*four* and PCI*four* is –0.161. All three variables were highly insignificant in the preferred specification. Consistent with expectations, the sign on EMP*two* and EMP*three* was positive, while the sign on EMP*four* was negative, contrary to expectations. The correlation between EMP*four* and NATAMENITY is 0.514. When NATAMENITY was dropped from the regressions, the sign on all EMP*year* variables was positive but highly statistically insignificant.

to expectations, although consistent with the results in Park, et al. (2002) and Herath, et al. (2003).[49] Livestock inventory increases with the total population of a state, indicating that production tends to locate near to market, potentially due to cost efficiency in transportation and marketing. Corn price is negative and statistically significant at the 10% level. As expected, land values have a negative impact on livestock inventory. In previous studies, the relationship between land values and livestock inventory has been ambiguous. Park, et al. find a positive and insignificant relationship between land value and livestock inventory. Herath, et al. find a negative relationship between fed cattle inventories and land values, likely due to the lower value of rangeland, while the relationship between dairy cattle inventory and land values is positive. Manufacturing wage and agricultural real estate taxes are both found to have a positive and insignificant impact on livestock inventories, contrary to expectations.[50]

---

[49] This empirical analysis does not allow for an adjustment period between string and livestock inventory. It is therefore too soon to observe the response of livestock inventory to regulatory stringency.

[50] The positive sign on agricultural property taxes may indicate that the agricultural sector has shifted production from crops to ILO production in order to intensify their use of land.

Table 5.2: AU1997 OLS Results

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: LOG(AU1997)				
INTERCEPT	2.971908	-	1.188013	0.2424
STRING	0.084439	0.919233	3.110547	0.0036
LOG(TOTPOP)	0.759300	0.7593	5.277860	0.0000
CP	-0.934615	-2.86913	-1.879179	0.0681
LANDVALUE	-0.000774	-0.80602	-6.375177	0.0000
MFGWAGE	0.084408	1.15493	0.952515	0.3470
PROPTAX	0.163653	0.136687	1.382108	0.1752

$R^2 = 0.737$

Source: Author's calculations

5.1.2 Reduced Form Results

Reduced form estimates of the stringency and livestock inventory equations are presented in Tables 5.3 and 5.4. Both first stage regressions fit well, the R^2 for the regulatory stringency and livestock inventory equations are 0.513 and 0.751 respectively and each specification is statistically significant at least at 1%. As presented in Tables 5.3 and 5.4, the instrumental variables for each endogenous variable are jointly significant in their respective reduced form equations at least at 1%.

5.1.2.1 Regulatory Stringency

Bound, et al. (1995) outline finite-sample bias in instrumental variable estimations when the relationship between instruments and endogenous explanatory variables is weak. Stronger correlation between the instruments and the endogenous explanatory

variable leads to smaller bias of TSLS relative to OLS. The F statistic for the joint significance of the instruments in the first stage endogenous explanatory variable estimation provides an indication of the strength of the correlation. As shown in Table 5.3 below, the instrumental variables for STRING, including PERCENTRURAL, PERCENTRURAL*DENSITY, ENVFACTORS, NATAMENITY, DEMOCRAT, AND PCI*four*, are jointly statistically significant at least at 1%. The F statistic for the joint significance of the instruments for STRING is 3.6597 and the inverse of the F statistic is 0.2732, indicating that the finite-sample bias of STRING in the TSLS estimation of LOG(AU199) is relatively small compared to the bias due to OLS, although it may be quantitatively important.

PERCENTRURAL and PCI*four* are positive and statistically significant at least at 5%. ENVFACTORS is positive but looses statistical significance. As in the OLS analysis of the structural equation for stringency, PERCENTRURAL*DENSITY and DEMOCRAT have negative signs, contrary to expectations. Both variables are statistically insignificant at least at the 10% level. In the reduced form estimation, NATAMENITY has a negative sign and its statistical significance has dropped significantly. NATAMENITY may be correlated with LANDVALUE and LOG(TOTPOP) in the reduced form equation, causing the change in sign and the drop in the statistical significance of the NATAMENITY variable.

Table 5.3: STRING Reduced Form Results

	Coefficient	t-Statistic	p-value
Dependent: STRING			
INTERCEPT	-3.953248	-0.181029	0.8575
PERCENTRURAL	0.128782	2.052222	0.0484
PERCENTRURAL*DENSITY	-0.001304	-1.172121	0.2498
ENVFACTORS	0.463459	0.696380	0.4912
NATAMENITY	-0.415893	-0.255475	0.8000
DEMOCRAT	-0.263624	-1.581605	0.1236
PCI*four*	0.375642	2.597691	0.0141
LOG(TOTPOP)	1.990353	2.479307	0.0186
CP	0.920196	0.203311	0.8402
LANDVALUE	1.29E-05	0.011877	0.9906
MFGWAGE	-1.053580	-2.833315	0.0079
PROPTAX	-0.224511	-0.276518	0.7839
IV joint significance	$p = 0.007$	$F = 3.6597$	
Equation significance	$p = 0.007$		
$R^2 = 0.513$	$\overline{R}^2 = 0.346$		

Source: Author's calculations

The instrumental variables for livestock inventory have some interesting impacts on regulatory stringency in the reduced form equations. LOG(TOTPOP) is expected to have a positive impact on livestock inventory, and a corresponding positive impact on stringency. The reduced form results support this expectation. The opposite is true for CP and LANDVALUE, for which the reduced form parameter estimates are insignificant. These two variables should have a negative impact on livestock inventory and a corresponding negative impact on regulatory stringency. MFGWAGE and PROPTAX

are expected to have a negative impact on livestock inventory and as a consequence, a negative impact on stringency. MFGWAGE is negative and highly significant in the reduced form estimation of stringency, consistent with expectations. Similarly, the relationship between PROPTAX and stringency is negative, although statistically insignificant.

5.1.2.2 Intensive Livestock Inventory

Table 5.4 presents the reduced form results for the intensive livestock inventory equation. The instrumental variables for livestock inventory, including LOG(TOTPOP), CP, LANDVALUE, MFGWAGE, and PROPTAX, are jointly significant at least at 0.01%. The F statistic for joint significance of the instruments is 13.5735, providing an inverse of 0.0737, indicating that the finite-sample bias of TSLS compared to OLS is small and unlikely quantitatively important.

LOG(TOTPOP) and LANDVALUE remain highly statistically significant in the reduced form estimation, both maintaining the correct sign as in the structural estimation. CP and MFGWAGE have negative, although statistically insignificant, impacts on livestock inventory. The negative sign on MFGWAGE in the reduced form estimation conforms with *a priori* expectations. The change in sign from that obtained in the structural estimation indicates that MFGWAGE is correlated with the instrumental variables for stringency. As in the structural estimation, PROPTAX has a positive and insignificant impact on inventory.

Table 5.4: AU1997 Reduced Form

	Coefficient	t-Statistic	p-value
Dependent: LOG(AU1997)			
INTERCEPT	-0.669532	-0.128874	0.8983
PERCENTRURAL	0.019324	1.256602	0.2180
PERCENTRURAL*DENSITY	4.10E-05	0.220750	0.8267
ENVFACTORS	-0.137334	-0.885080	0.3827
NATAMENITY	-0.314882	-1.140483	0.2625
DEMOCRAT	-0.045452	-1.645589	0.1096
PCI*four*	0.029466	0.688184	0.4963
LOG(TOTPOP)	1.231879	5.013902	0.0000
CP	-0.442236	-0.540495	0.5926
LANDVALUE	-0.000485	-1.937280	0.0616
MFGWAGE	-0.030855	-0.289986	0.7737
PROPTAX	0.067028	0.312711	0.7565
IV joint significance	*p < 0.0001*	*F = 13.5735*	
Equation significance	*p < 0.0001*		
$R^2 = 0.751$	$\overline{R}^2 = 0.665$		

Source: Author's calculations

As expected, ENVFACTORS and NATAMENITY have a negative relationship with livestock inventory. The parameter estimate for DEMOCRAT is negative and weakly significant, indicating that intensive livestock inventory is negatively related to Democratic support. PERCENTRURAL and PERCENTRURAL*DENSITY are both positive and insignificant. Changes in livestock inventory due to changes in the percent of the population that is rural are unambiguously positive. The direct effect of a change

in PERCENTRURAL is positive, and the indirect effect of the interaction between PERCENTRURAL and DENSITY is positive.

5.1.3 TSLS Results

The structural equations were tested for the presence of endogeneity between regulatory stringency and livestock inventory. Hausman tests (presented in Table 5.5 below) as shown in Greene (2000) indicated that intensive livestock inventory is exogenous in regulatory stringency and regulatory stringency is exogenous in intensive livestock inventory. Also, the residual correlation between the two structural equations was calculated at –0.2988. This indicates that the residuals explaining regulatory stringency and livestock inventory are negatively related. The negative relationship conforms with the expectation that increased regulatory stringency will decrease livestock inventory, but runs counter to the expectation that increased livestock inventory will necessitate an increase in regulatory stringency. The negative relationship between the residuals may indicate that this specification is missing an explanatory variable for the impact of the increased costs due to regulatory stringency on livestock inventory. For example, the level of enforcement of ILO environmental regulations may have a negative impact on intensive livestock inventories. In this case, exclusion of the enforcement effort variable may partially explain the negative relationship between the residuals.

Table 5.5: Two-stage Least Squares Results

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: STRING				
INTERCEPT	-12.83992	-	-1.077245	0.2885
LOG(AU1997)	1.214429	0.111555	2.349113	0.0244
PERCENTRURAL	0.119680	0.353371	3.029112	0.0045
PERCENTRURAL*DENSITY	-0.001490	-0.210714	-1.720225	0.0940
ENVFACTORS	1.276577	0.503702	2.456372	0.0190
NATAMENITY	1.191891	0.408492	1.520027	0.1372
DEMOCRAT	-0.222456	-0.961205	-1.809676	0.0787
PCIfour	0.406687	0.641851	2.942933	0.0057

Hausman test:

$LOG(\hat{AU}1997)$ *p = 0.7841*

Overidentifying restrictions:

$\chi^2_{(4)} = 5.305$ *(0.5 > p > 0.25)*

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: LOG(AU1997)				
INTERCEPT	1.295577	-	0.421317	0.6760
STRING	0.138323	1.50583	2.369854	0.0231
LOG(TOTPOP)	0.708778	0.708778	4.999270	0.0000
CP	-0.724301	-2.22349	-1.458685	0.1531
LANDVALUE	-0.000706	-0.735208	-4.413930	0.0001
MFGWAGE	0.165079	2.25873	1.303131	0.2006
PROPTAX	0.200095	0.167125	1.019448	0.3146

Hausman test:

$S\hat{TRING}$ *p = 0.2628*

Overidentifying restrictions:

$\chi^2_{(5)} = 4.482$ *(0.5 > p > 0.25)*

Source: Author's calculations

As proposed by Hausman (1983), Greene (2000) outlines a procedure for testing the overidentifying restrictions based on the Lagrange multiplier principle. Tests for overidentifying restrictions look for "evidence that there are exogenous variables in the model that have been inappropriately omitted from the equation being examined" (Greene, 2000, p. 700). In other words, if the overidentifying restrictions are rejected this implies that one of the exogenous variables included in the system but presently not included in the equation being examined, should in fact be included in the equation under examination. The Lagrange Multiplier (LM) test is performed as follows. The residuals from the TSLS analysis of a single equation are regressed on all the predetermined variables in the system. The R^2 from this regression multiplied by the sample size is tested as a Chi-square, with degrees of freedom equal to the number of overidentifying restrictions (Kennedy, 2003). The LM test did not reject the overidentifying restrictions, supporting the validity of the instrumental variables in both specifications. Results from the TSLS estimations are presented in Table 5.5.[51]

Accounting for the endogeneity of intensive livestock inventory in the stringency equation reduces the coefficient on LOG(AU1997) from 1.317 to 1.214, representing an 8 % decrease. Comparisons of elasticity calculations indicate that the regulatory response to inventory decreases slightly, from 0.121 to 0.112 when the specification accounts for endogeneity. Comparison of the elasticity estimates for livestock inventory indicate that the inventory response to regulatory stringency increases from 0.919 to 1.506, representing a 64% increase. Past estimates of the elasticity of livestock inventories with respect to stringency have ranged between –0.4 in the Roe, et al. (2002)

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[51] The Chi-square statistic for the LM test of the overidentifying restrictions are presented in Table 5.5. The p-values for each of the Chi-square statistics are also presented.

study to 1.45 in the Park, et al. (2002) study. The similarity between the Park, et al. elasticity estimates and those in this study is likely due to a couple factors. First, both studies analyze the intensive livestock sector, including beef, dairy, hogs, and poultry. The Roe, et al. study focuses solely on the hog sector, finding a negative relationship between hog inventory and regulatory stringency. Second, the method used to construct the regulatory stringency variable in this study is similar to the method used in the Park, et al. study.

The coefficients on PERCENTRURAL and PERCENTRURAL*DENSITY are roughly equivalent in the OLS and TSLS estimations, although the statistical significance of both variables improve in the TSLS estimation. The ENVFACTORS coefficient increases slightly from 1.265 to 1.277 when the TSLS model is estimated. The coefficient on NATAMENITY decreases by approximately 4.5% in the TSLS estimation, accompanied by a decrease in the statistical significance of the estimates. Elasticity estimates for ENVFACTORS and NATAMENITY follow the same patterns as the coefficient estimates. The elasticity on DEMOCRAT increases in the TSLS estimation as do coefficient estimates and statistical significance. The TSLS estimation reduces the significance of the PCI*four* coefficient, the elasticity estimates, and the statistical significance.

The impact of LOG(TOTPOP) on livestock inventory decreases in the TSLS estimation.[52] The coefficient on CP decreases and becomes less statistically significant. The corn price elasticity of livestock inventory declines by over 22% when TSLS is estimated. The TSLS results for LANDVALUE are roughly equivalent to the OLS

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[52] The inclusion of LOG(TOTPOP) as an instrument for LOG(AU1997) is questionable. Nonetheless, LOG(TOTPOP) does a good job of explaining LOG(AU1997) and the over-identifying restrictions are not rejected.

results. The coefficient and elasticity estimates for MFGWAGE and PROPTAX both increase but remain statistically insignificant.

The TSLS results reveal that the potential endogeneity between intensive livestock inventory and regulatory stringency has little impact on the determination of regulatory stringency, whereas endogeneity has a relatively large impact on the determination of intensive livestock inventory. The Hausman test fails to reject exogeneity of intensive livestock inventory in the regulatory stringency equation. This, coupled with small differences between the OLS and TSLS results, indicates that livestock inventory is a predetermined variable when regulatory stringency is formed. When the potential endogeneity of stringency was accounted for, the impact of regulatory stringency on intensive livestock inventory increased. Livestock production responds positively to increased regulatory stringency, and when accounting for the impact of livestock inventory on regulatory stringency, the magnitude of the response increases. As mentioned above, the positive relationship between regulatory stringency and intensive livestock inventory is unexpected, although not inconsistent with findings in previous studies.

5.1.3.1 PCIthree and PCItwo

The choice of the time span over which the change in per capita income is calculated is ad hoc. As explained earlier, a four-year time span is chosen in order to reflect the impacts of the political cycle. As a test of the validity the PCI*four* variable, PCI*three* and PCI*two* are used in place of PCI*four*. If the results in these two alternative

specifications closely resemble those in the base model, one can conclude that the choice of time span is not driving the results.

The results of the two alternative specifications are presented in Tables C.1 and C.2 in Appendix C. LM tests reveal that the overidentifying restrictions are valid for both specifications. The signs on the coefficients of all variables are consistent among the three specifications. The elasticity of both LOG(AU1997) and PERCENTRURAL do not vary significantly across the three specifications. PERCENTRURAL*DENSITY becomes more inelastic as the time span decreases from 4 to 2 years. ENVFACTORS has a relatively constant elasticity across the different time spans considered. The elasticity on NATAMENITY is lower in the model with PCI*three*, where NATAMENITY is highly insignificant, having a p-value above 0.4. The elasticity and statistical significance of DEMOCRAT both decrease when PCI*three* and PCI*two* replace PCI*four*.

The elasticity estimates for the change in per capita income variables range between 0.488 and 0.95. Formulating theories regarding the relationship between the time span of changes in per capita income and the magnitude of the elasticity estimates is difficult. One might speculate that the elasticity estimates would be greatest for the two-year time span because the shorter time span is a better reflection of the current pressure for rural development. Alternatively, the four-year time span may have a stronger impact on the pressure for rural development. The four-year time span allows for the business cycle to smooth out, and corresponds with the political cycle. Voters may see an economy's four-year record as a better indication of the pressure for rural economic development. The use of PCI*three* and PCI*two* do not significantly alter the results, and the statistical significance on both of these alternative proxies is similar to that obtained using PCI*four*.

5.1.4 TSTOBIT Results

The regulatory stringency measure is a summation of affirmative answers to a set of yes/no questions regarding the regulations imposed in a state. This variable is therefore restricted to non-negative values. A dependent variable is censored when values in a certain range are transformed to a single value. In this case, all potentially negative values have been transformed to zero. Since the dependent variable has been censored, this model is run using TOBIT. Of the 44 observations of regulatory stringency, three are zero and the remainder are less than or equal to eighteen. TOBIT analysis is typically performed in cases where zero values make up a significant fraction of total observations (Greene, 2000). In this analysis, 6.8% of the observations are zero values. While 6.8% is not a significant fraction, the stringency equation is run as a TOBIT in order to determine the impact of the zero values on the results.

Table 5.6 presents the second stage results of the TOBIT model (hereafter referred to as TSTOBIT), obtaining fitted values for LOG(AU1997) from the first stage regression of LOG(AU1997) on all exogenous variables in the system. All signs in the TSTOBIT model are consistent with the signs in the TSLS model. With the exception of the DEMOCRAT variable, elasticity and marginal effect estimates increase when the TSTOBIT model is used. Most significantly, the elasticity of NATAMENITY increases by over 18% to 0.485. Overall, there is little difference between the TSTOBIT and the TSLS regulatory stringency estimation results, indicating that the censored nature of the dependent variable is not a significant concern.

Table 5.6: TSLS TOBIT

	Coefficient	z-Statistic	p-value	Marginal Effects	Elasticity
Dependent: STRING					
INTERCEPT	-17.58633	-1.420823	0.1554	-17.53233	-
FITTED[LOG(AU1997)]	1.432957	2.580130	0.0099	1.428558	0.131225
PERCENTRURAL	0.131156	2.977402	0.0029	0.130753	0.386065
PERCENTRURAL*DENSITY	-0.001622	-1.562865	0.1181	-0.00162	-0.2291
ENVFACTORS	1.334896	2.273129	0.0230	1.330797	0.525095
NATAMENITY	1.419642	1.862657	0.0625	1.415283	0.485054
DEMOCRAT	-0.219558	-1.729620	0.0837	-0.218884	-0.945771
PCIfour	0.428694	3.177641	0.0015	0.427378	0.674506

$R^2 = 0.448$

Source: Author's calculations

5.1.5 RESNCHANGE Results

The following section provides an alternative proxy for the marginal damages of intensive livestock production. The validity of the ENVFACTORS variable is questionable as its accuracy relies on the map reading abilities of the researcher. As an alternative, the percentage change in residual manure nitrogen between 1992 and 1997, designated RESNCHANGE, is substituted for ENVFACTORS. RESNCHANGE provides a measure of the amount of manure nitrogen produced in the state, adjusted by the ability of the cropland and pastureland within that state to assimilate the manure nitrogen. Holding all else constant, if this ratio increases over time, then regulatory stringency would be expected to increase. Table 5.7 presents the TSLS results where RESNCHANGE is substituted for ENVFACTORS. The significance of the

NATAMENITY variable drops below the 30% level and as a result is dropped from the final estimation.

The results in Table 5.7 are consistent with the estimation using ENVFACTORS. The response of regulatory stringency to RESNCHANGE is inelastic, estimated at 0.019. This may be the result of the potential feedback between the two variables. Increased RESNCHANGE may increase stringency, but increases in expected stringency may decrease RESNCHANGE. If the relationship is in fact simultaneous, and since the potential endogeneity has not been accounted for, then this elasticity estimate is biased. In addition to low elasticity estimates, the significance of the RESNCHANGE coefficient is low when compared to ENVFACTORS and NATAMENITY. The elasticity on PERCENTRURAL decreases in this specification and the elasticity estimates of all other variables are roughly equivalent between the two specifications. The LM test rejects the overidentifying restrictions at least at the ten percent level, indicating that the stringency equation is misspecified when RESNCHANGE is used.

Table 5.7: TSLS Results (RESNCHANGE)

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: STRING				
INTERCEPT	-2.300705	-	-0.203117	0.8402
LOG(AU1997)	1.148626	0.105511	1.977631	0.0555
PERCENTRURAL	0.060677	0.179157	1.904748	0.0646
PERCENTRURAL*DENSITY	-0.000718	-0.101539	-1.092032	0.2819
RESNCHANGE	0.017370	0.018804	1.198398	0.2384
DEMOCRAT	-0.210867	-0.911131	-1.647069	0.1080
PCIfour	0.418355	0.660266	2.904970	0.0062

Overidentifying restrictions:

$\chi^2_{(4)} = 9.2478$ *(0.1 > p > 0.05)*

Dependent: LOG(AU1997)				
INTERCEPT	1.008960	-	0.320266	0.7506
STRING	0.147537	1.60614	2.427458	0.0202
LOG(TOTPOP)	0.700140	0.70014	4.844919	0.0000
CP	-0.688342	-2.11311	-1.357900	0.1827
LANDVALUE	-0.000695	-0.723753	-4.252206	0.0001
MFGWAGE	0.178872	2.44746	1.373831	0.1778
PROPTAX	0.206326	0.172329	1.034190	0.3078

Overidentifying restrictions:

$\chi^2_{(5)} = 2.2368$ *(0.75 > p > 0.5)*

Source: Author's calculations

5.2 Alternative Specifications

This section presents the results using a number of alternative measurements of regulatory stringency. In addition to providing verification of the original regulatory stringency variable, these alternative specifications should provide unique insights into the relationships being examined. These alternative measurements are derived from individual questions that were part of the set of initial questions used for the regulatory stringency proxy.

The first question deals with the legislation of setback distances. States that impose setback requirements are assumed to be more stringently regulating the ILO industry. SETBACK is a binary variable requiring the use of a logit model. The second question deals with the presence of legislation that requires nutrient management plans. This question provides an indication of the pressure on the industry to adhere to sound agronomic manure application procedures. Once again, a logit model is used for this specification. The third question also deals with nutrient standards. In this case, however, states are ranked according to the following three criteria: no nutrient management plan (NMP), a nitrogen based NMP, and a combined phosphorus and nitrogen NMP. A state with a NMP based on both nitrogen and phosphorus is assumed to have more stringent regulations. Since this variable is both discrete and ordered, an ordered logit model is used.

5.2.1 SETBACK Results

The results for the SETBACK model are presented in Table 5.8. The marginal

effects and their associated statistics are reported in the last three columns of Table 5.8.[53]

All signs follow those in the OLS analysis. The statistical significance of

LOG(AU1997), ENVFACTORS, and PCI*four* is maintained in this specification while

DEMOCRAT looses significance.

Table 5.8: SETBACK Logit Results

	Coefficient	z-Statistic	Marginal Effects	z-Statistic	p-value
Dependent: SETBACK					
INTERCEPT	-39.08931	-2.062643	-6.662556	-2.204	0.0275
LOG(AU1997)	0.905582	1.755681	0.154351	1.729	0.0837
PERCENTRURAL	0.100994	2.182216	0.172	2.2	0.0278
PERCENTRURAL*DENSITY	-0.000233	-0.469364	-0.398	-0.427	0.6697
ENVFACTORS	2.558268	1.942374	0.436043	3.19	0.0014
NATAMENITY	3.010179	2.001080	0.513068	2.54	0.0111
DEMOCRAT	-0.146467	-1.272422	-0.25	-1.399	0.1618
PCIfour	0.606887	2.215315	0.10344	2.234	0.0255

Source: Author's calculations

Setback regulations would be expected to prevail in states where the air quality of

rural residents is a high priority. The importance of air quality would likely be captured

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[53] The logit estimation is a non-linear functional form. This implies that the coefficient estimates derived from logit estimations do not represent the marginal effects as they do in OLS. The marginal effects of an explanatory variable on the dependent variable are a function of the coefficient estimates from a logit regression. The logit marginal effects expression for the partial derivative of the probability of $y = 1$ with respect to x_i is: $\beta_i e^{X\beta}\left(1 + e^{X\beta}\right)^{-2}$ (Kennedy, 2003). The marginal effects are calculated at the means of the explanatory variables.

primarily by the PERCENTRURAL, PERCENTRURAL*DENSITY and the

NATAMENITY variables. The first two variables represent the potential for spatial

competition between rural residents and ILO production. PERCENTRURAL is

statistically significant in this estimation, while the significance of the interaction term

falls well below the 50% level. The insignificant and incorrect sign on the interaction

term indicates that rural population density has a statistically insignificant negative

impact on the imposition of setback legislation. The NATAMENITY variable captures

the opportunity cost associated with reduced air quality. A region that is well endowed

with natural amenities has an incentive to ensure that ILO operations do not damage the

air quality associated with their natural amenities. NATAMENITY is statistically

significant at least at 2%, an improvement over the OLS results where NATAMENITY

was insignificant at least at 10%.

5.2.2 NUTSTDS Results

The presence of setback regulations was used as a proxy for the effort to maintain

the air quality of rural citizens. The effort to maintain water quality is measured by the

presence of nutrient standard regulations. Table 5.9 presents the logit results for the

NUTSTDS specification. As in the SETBACK model, the signs in the NUTSTDS model

are consistent with the OLS analysis using STRING as the dependent variable.

Since the effort to regulate nutrient standards are interpreted as the effort to

protect water quality, ENVFACTORS and LOG(AU1997) should be two of the primary

determinants of NUTSTDS. Among the independent variables, only LOG(AU1997),

ENVFACTORS, and PCI*four* are significant at the ten percent level. The marginal effect

of ENVFACTORS is insignificant at least at the 10% level. After controlling for

livestock inventory and the aggregate production of manure with LOG(AU1997), regions

that are most vulnerable to manure nutrients would be expected to be more likely to

impose nutrient standards. The sign on the ENVFACTORS coefficient is positive, and

statistically different from zero, while the marginal effects are positive and insignificant.

This inconsistency detracts from interpretations of the results, however the

ENVFACTORS variable is marginally significant and has the expected positive impact

on the imposition of nutrient standards.

Table 5.9: NUTSTDS Logit Results

	Coefficient	z-Statistic	Marginal Effects	z-Statistic	p-value
Dependent: NUTSTDS					
INTERCEPT	-23.08842	-2.133965	-2.43466	-1.95	0.0512
LOG(AU1997)	0.997344	2.327185	0.105169	2.297	0.0216
PERCENTRURAL	0.064490	1.526369	0.0068	1.57	0.1165
PERCENTRURAL*DENSITY	-0.000517	-1.109470	-0.000055	-0.98	0.3268
ENVFACTORS	0.617974	2.040987	0.0652	1.424	0.1545
NATAMENITY	0.876020	1.511932	0.0924	1.245	0.2132
DEMOCRAT	-0.046731	-0.614758	-0.00493	-0.552	0.5811
PCIfour	0.417396	1.968328	0.044	2.255	0.0241

Source: Author's calculations

The coefficient on LOG(AU1997) reveals that livestock inventory has a greater

influence on the likelihood of imposing nutrient standard legislation than it has on

setback legislation. However, evaluation of the marginal effects indicates that changes in

livestock inventory have a greater impact on the probability of imposing setback

legislation than on the probability of imposing nutrient standard legislation. This result

indicates that regions are overall more responsive to the concerns addressed by setback

legislation than they are to the concerns addresses by nutrient management legislation. In

regions where nutrient management is a primary concern, the marginal effect of changes

in livestock inventory should have a greater impact on the probability of imposing

nutrient management legislation. On the other hand, in regions where the air quality of

rural citizens is of primary concern, the marginal effect of livestock inventory on setback

legislation would be expected to be higher than the marginal effect of inventory on

nutrient management legislation. The marginal effect of PCI*four* is relatively greater for

the imposition of setback legislation compared to nutrient standard legislation. As in the

case of livestock inventory, this result may be driven by the reality that more states have

implemented setback legislation than have implemented nutrient standards.

5.2.3 RANKSTDS Results

The previous specification did not differentiate between the imposition of

nitrogen standards and the imposition of combined nitrogen and phosphorus standards.

Combined phosphorus and nitrogen standards are assumed to be more stringent than

nitrogen standards alone because the addition of the phosphorus standard increases the

requirements the ILO producer must satisfy.[54] In addition to ranking the stringency of

nutrient standard legislation from 0 through 2, the ordered logit analysis breaks

environmental factors into two categories. First, the percolation and runoff factors are

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[54] This assumption does not hold if one of the standards is irrelevant. Despite this significant shortcoming, the results of the RANKSTDS model are presented in order to assess the impact of different environmental factors on the implementation of phosphorus and nitrogen standards.

grouped and referred to as NFACTOR. Second, the soil erosion factor is referred to as

PFACTOR. This allows for an analysis of the stringency of nutrient standard legislation

in terms of the responsiveness to nitrogen and phosphorus vulnerability separately. Table

5.10 presents the results of the ordered logit model.

The PERCENTRURAL, PERCENTRURAL*DENSITY, and NATAMENITY

variables are statistically insignificant at least at 70 percent.[55] Of primary interest in this

specification are the coefficients on the NFACTOR and PFACTOR variables.

NFACTOR is expected to have an impact on both the probability of imposing nitrogen

standards (Y=1) and the probability of imposing the combined standards (Y=2).

PFACTOR is expected to have a positive impact on the probability of imposing both

nitrogen and phosphorus standards. The NFACTOR variable is insignificant at least at

the 10% level while the PFACTOR variable is significant at the 10% level. Changes in

the NFACTOR have a negative impact on the probability of either imposing no standard

or imposing a nitrogen standard alone. The probability of imposing both nitrogen and

phosphorus standards increases as the potential for nitrogen contamination of water

increases. Phosphorus has the opposite effect on the probability of imposing the different

nutrient standards. Contrary to expectations, as the potential for water contamination by

manure phosphorus increases, the probability of imposing a phosphorus nutrient standard

decreases. These results indicate that the potential for manure nitrogen contamination of

water has the greatest impact on the probability of imposing more stringent nutrient

standards, including phosphorus standards.

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[55] Dropping these variables from the regression does not significantly alter the results so they are retained in this
specification in order to maintain consistency with the other results.

Table 5.10: RANKSTDS Ordered Logit Results

	Coefficient	z-Statistic	p-value	Marginal Effects		
Dependent: RANKSTDS				**Y = 0**	**Y = 1**	**Y = 2**
LOG(AU1997)	0.555548	2.139723	0.0324	-0.0929	-0.0028	0.0957
PERCENTRURAL	-0.002755	-0.120697	0.9039	0.0005	0	-0.0005
PERCENTRURAL*DENSITY	-6.00E-05	-0.158772	0.8738	0	0	0
NFACTOR	0.299243	1.406084	0.1597	-0.0501	-0.0015	0.0515
PFACTOR	-0.492210	-1.830350	0.0672	0.0823	0.0024	-0.0848
NATAMENITY	-0.154989	-0.351361	0.7253	0.0259	0.0008	-0.0267
DEMOCRAT	-0.067718	-1.108334	0.2677	0.0113	0.0003	-0.0117
PCIFOUR	0.163944	1.638449	0.1013	-0.0274	-0.0008	0.0282

Source: Author's calculations

While not significant at conventional levels, the PCI*four* variable is positive and significant at least at 11%. Increases in PCI*four* have a negative impact on the probability of imposing no standards and the probability of imposing nitrogen standards alone (the marginal effect on Y=1 is quite low). The effect of PCI*four* on the probability of imposing both nitrogen and phosphorus standards is positive. Consistent with *a priori* expectations, this indicates that states with higher per capita income growth over the previous four years are more likely to impose more stringent nutrient standard regulations.

5.3 Chapter Summary

The econometric results presented in this chapter have provided strong empirical support of the theoretical model of environmental policy formation in the US intensive

livestock sector. Specification of the stringency equation largely conformed to the predictions as outlined by the theoretical model. The livestock inventory equation provided results consistent with other empirical studies of the US intensive livestock sector.

The econometric model provided conflicting results regarding the pressure for rural economic development. The DEMOCRAT variable has a negative impact on the stringency of regulations, indicating that states where Democratic support is high are more likely to have less stringent regulations. This is inconsistent with the common perception that Democratic supporters are more supportive of environmental protection initiatives. A possible explanation of these unexpected results is that the variable captures the support for Democrats across the entire state, while rural Democratic support would be a better indication of the pressure for rural economic development.[56]   The pressure for rural economic development is also measured by the percent change in per capita income. PCI*four* had a positive impact on the stringency of regulations in all specifications considered. These results indicate that state governments implement more stringent ILO environmental regulations when the rural economy is relatively prosperous and implement weaker environmental regulations when the rural economy is performing relatively poorly. These results provide some evidence that the recent performance of the rural economy, as measured by changes in per capita incomes, has an impact on the stringency of environmental regulations imposed on the intensive livestock industry.

The other propositions derived from the theoretical model are generally supported by the econometric results. As the percent of the total population that is rural increases

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[56] Democratic support may be capturing the influence of urban voters who are not concerned with the stringency of intensive livestock environmental regulations. The dummy variable representing Democratic governors had the expected positive sign, but was statistically insignificant.

the stringency of ILO environmental regulations increases. The sign on the interaction term between the percent of the state population that is rural and the rural population density is contrary to expectations. If the interaction term, PERCENTRURAL*DENSITY provides a measure of the proportion of the state population that has environmental concerns, the sign is expected to be positive. The econometric results indicate that this interaction term has a negative impact on the stringency of regulations. This may indicate that the interaction term is capturing some of the influence of rural citizens that benefit from the intensive livestock sector. A higher proportion of rural citizens in states that have high rural population density may benefit from intensive livestock production. For example, if the prosperity of a certain rural economy is tied to a healthy dairy industry, then rural citizens are more likely to oppose the implementation of more stringent ILO environmental regulations. The interaction between rural population density and the proportion of the state population that is rural may be capturing the importance of the intensive livestock sector to the rural economy. The impact of the potential for pollution damages from ILO production is positive as was predicted by the theoretical model. This result indicates that environmental regulations are partly motivated by the public interest in response to the potential for environmental degradation.

Alternative specifications of the regulatory stringency variable supported the results of the base measure for regulatory stringency. These alternative specifications focused on the protection of air and water quality. The results in the setback legislation specification were consistent with the results for the base measure of regulatory stringency. All independent variables, with the exception of the interaction term and DEMOCRAT, were significant at least at 10%. Among the statistically significant

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variables, all signs conformed with *a priori* expectations. Results for the nutrient

standard legislation specification were not as strong. All signs in this specification were

consistent with those in the base specification, but the statistical significance of the

variables declined. LOG(AU1997) and PCI*four* remained strongly significant and

ENVFACTORS was marginally significant. The final specification ranked states

according to the stringency of their nutrient standard legislation. The results from this

specification deviate from the preferred specification results. The signs on

NATAMENITY and PERCENTRURAL change and the significance of all variables

except LOG(AU1997) and PCI*four* falls dramatically. This specification provides some

insight into the impact of vulnerability to nitrogen and phosphorus water contamination

on the stringency of environmental regulations. As of 1997, these results indicate that

nitrogen has a greater impact on the implementation of more stringent nutrient standard

legislation.

CHAPTER SIX:

SUMMARY AND

CONCLUSIONS

This chapter will provide a summary of the major conclusions that this research has drawn regarding the hypothesis and the objectives set out in Chapter 1. In addition to concluding remarks, this chapter will present some of the limitations of this study and discuss potential areas for further research.

6.1 Summary

This thesis addressed the tradeoff between environmental quality and rural economic development, controlling for factors such as the power of environmental groups, the potential environmental damages from ILO production, and the size of the ILO industry. A further objective of this study was to examine the potential endogeneity between regulatory stringency and intensive livestock inventory.

A review of the political economy literature pertaining to trade and environmental policy examined the general role of special interest group lobbying in the formation of public policy. Essentially, this literature focuses on the specification of the government's objective function. According to the model developed by Grossman and Helpman (1994), incumbent governments are concerned strictly with improving their chance at

reelection. As a result, their objective function is comprised of campaign contributions from special interests and the aggregate welfare of society, both of which improve their chances at re-election. The weight an incumbent government places on aggregate social welfare determines the rate that the government is willing to trade aggregate social welfare for campaign contributions.

The G-H model has provided the foundation for recent literature dealing with the political economy of environmental policy (Fredriksson, (1997), Aidt (1998), and Schleich (1999)). This literature is based on models that specify government objectives functions in the same manner as G-H. Empirical applications of these models use measures of government corruption for the weight the government places on aggregate social welfare relative to campaign contributions (Damania, et al. (2003), Fredriksson, et al. (2003), and Fredriksson and Svensson (2003)). An early empirical application to agriculture examined the endogenous relationship between regulatory stringency and government transfers to the polluting industry (Eliste and Fredriksson, 2000).

The literature dealing with the US intensive livestock sector has focused on the relationship between intensive livestock inventory and the stringency of ILO environmental regulations. These studies examine the impact of state-level regulations on the spatial location of intensive livestock production. Among these studies, Metcalfe (2001) and Park, et al. (2002) account for the potential endogeneity between livestock inventory and regulatory stringency. Metcalfe proposes instrumental variables for regulatory stringency, but does not provide a theoretical foundation for the determination of regulatory stringency in the US intensive livestock sector.

The theoretical framework developed in this thesis was based on the model presented by Fredriksson (1997). The theoretical model solved a two-stage game

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between the ILO sector lobby and the incumbent government. The weight the government places on aggregate social welfare relative to the profitability of the ILO sector is dependent on the pressure the government is under to stimulate rural economic development. This reflects the political tradeoff between rural economic growth and environmental quality as perceived by the incumbent government.

A number of predictions emerged from the theoretical model. Of central importance to this thesis, the model predicted that the weight the government places on aggregate social welfare relative to ILO sector profitability has a positive impact on the stringency of environmental regulations. The model further predicted that the pollution damages and the marginal disutility from pollution (representing the power of environmental groups) have a positive relationship with regulatory stringency.

The empirical analysis examined the determination of US state-level intensive livestock environmental regulations as they stood in 1997. An index measuring 1997 regulatory stringency was constructed based on the ACPNTF survey; similar indices based on the ACPNTF survey have been used in a number of studies of the US intensive livestock industry (Metcalfe (2001), Park, et al. (2002), Roe, et al. (2003), and Hepath, et al. (2003),). In order to substantiate the results derived from the preferred measure of regulatory stringency, a number of alternative measures of regulatory stringency were constructed based on individual questions as selected from the ACPNTF survey. In addition to the regulatory stringency equation, the empirical analysis component of this thesis specified an equation explaining intensive livestock inventory. Aggregate intensive livestock inventory was measured based on AU equivalents as developed by the USDA (Kellogg, et al., 2000).

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The pressure for rural economic development was measured based on percent changes in rural per capita income over four years. This variable was interpreted as follows; incumbent governments in states with higher percent changes in four-year per capita incomes are under less pressure to pursue rural economic development initiatives. According to the theoretical model, this implies that governments in states with relatively high percent changes rural per capita income place a greater weight on aggregate social welfare and as a result implement more stringent intensive livestock environmental regulations.

In addition to the percent change in rural per capita income, a measure of the percent of the population that voted for the democratic presidential candidate in the 1996 election served as a measure of the political preference for rural economic development versus environmental quality. Democratic voters are generally perceived as having greater concern for protecting the environment. Therefore, a state that voted for the democratic presidential candidate was expected to have a stronger preference for maintaining environmental quality and as a result more stringent intensive livestock environmental regulations.

The null hypothesis presented in Section 1.3 states that the pressure for rural economic development has no effect on the stringency of US intensive livestock environmental regulations. Measured as the percent change in rural per capita income, the econometric results obtained in this study rejected the null hypothesis. Additionally, this measure of the pressure for rural economic development had a positive relationship with the stringency of environmental regulations. These findings are consistent with Prediction 1 of the theoretical framework, lending support to the theoretical model developed for this thesis.

The variable representing state preference for the Democrat party had the wrong sign in all specifications. These unexpected results may have resulted from aggregation over the entire state, whereas the percent of the state rural population that voted for the democratic candidate would have provided a better measure of the rural preference for environmental quality. The statistical significance of the democrat variable was generally lower than the statistical significance obtained for the four-year percent change in rural per capita incomes.

In addition to the impact of rural development pressure on regulatory stringency, the empirical component of this thesis examined the role of the size of the ILO industry, the pollution damages from intensive livestock production, and the disutility resulting from intensive livestock pollution. Endogeneity tests indicated that the relationship between intensive livestock inventory and regulatory stringency is potentially endogenous. TSLS was used in order to account for the endogenous relationship between these two variables. Instrumental variables for intensive livestock inventory included the log of total state population, state corn prices, state agricultural land values, average state manufacturing wages, and state property taxes on agricultural land.

The econometric analysis found that the size of the intensive livestock sector within a state had a positive impact on the stringency of regulations. Since aggregate livestock inventory was calculated based on AU equivalents, this variable measured the potential for manure nutrients to exceed the assimilative capacity of the environment, and therefore measured the potential for damages from intensive livestock production. The positive and statistically significant sign on the AU1997 variable indicated that the size of the ILO industry and the potential damages from ILO production both had positive impacts on regulatory stringency.

The econometric analysis controlled for the disutility from intensive livestock pollution. Three variables served as proxies for the disutility from pollution: (i) the percent of the total population that is rural, (ii) an interaction term between the aforementioned variable and the rural population density, and (iii) natural amenity endowments. According to Prediction 2 of the theoretical framework, these variables were expected to have a positive relationship with regulatory stringency. The percent of the population that is rural had the expected positive sign and was statistically significant in a number of specifications. The interaction term, however, had a negative sign in all specifications and was generally statistically significant. The natural amenity variable measured the attractiveness of each state as a retirement or vacation destination. High natural amenity scores were correlated with high opportunity costs associated with expansion of the intensive livestock sector. The natural amenity scores were therefore expected to have a positive relationship with regulatory stringency. The natural amenity index generally had the expected sign and was statistically significant in a number of specifications.

The econometric model further controlled for the impact of potential pollution damages due to intensive livestock production on regulatory stringency. Environmental factors provided a measure of state vulnerability to water contamination due to manure nutrients. This variable had the expected positive sign in all specifications and was generally statistically significant. An alternative measure of the pollution damages from ILO production was based on changes in the residual levels of manure nitrogen produced in a state between 1992 and 1997. This variable had the expected sign but was statistically insignificant.

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Alternative proxies for regulatory stringency were constructed based on individual questions from the ACPNTF survey. The three variables constructed provided measures of regulatory stringency based on setback standards and the stringency of NMPs. The results of these specifications generally confirmed the results of the preferred regulatory stringency specifications. The ordered logit analysis of nutrient standard legislation found that the potential for water contamination by manure nitrogen was the driving force behind the implementation of legislation dealing with NMP regulations.

6.2 Study Limitations

The primary limitations of this study are associated with the validity of the proxy variables used in the econometric analysis and the possible misspecification of the intensive livestock inventory equation. In terms of proxy variables, the variables used to measure regulatory stringency, pollution damages, and the pressure for rural economic development are the most questionable. Possible misspecification of the intensive livestock inventory equation is potentially troublesome regarding the use of intensive livestock inventory instrumental variables in the stringency equation.

Regarding regulatory stringency, the variable constructed for this empirical analysis treated all types of regulations as having an equal impact on the compliance costs of intensive livestock producers. As a result, two states with a different mix of regulations but an equal number of regulations will have identical scores. In reality, different types of regulations will impose different compliance costs on the producers. As constructed in this analysis, the regulatory stringency variable does not distinguish between the compliance costs associated with different types of regulations.

In addition to problems in measurement, the regulatory stringency variable simply captures the written stringency of regulations, whereas enforcement of the regulations may provide a more accurate measure of compliance costs due to environmental regulations. Nonetheless, despite the measurement error in regulatory stringency, the variable constructed for this analysis is the best of available alternatives and has been used in a number of previous published studies regarding the US intensive livestock industry (Metcalfe (2001), Roe, et al. (2002), and Park, et al. (2002)).

The environmental factors and natural amenity indices are aggregated over the entire state, therefore limiting their accuracy. The potential for pollution damages from intensive livestock production are highly site specific. Local variations in topography, soil texture, and proximity to water resources all have an impact on the potential for damage from intensive livestock production. The measures of environmental factors and natural amenity endowments used in the econometric specifications do not provide the detail required for an accurate analysis of the potential for water pollution.

The validity of the proxy for the pressure for rural economic development used in this thesis is tenuous, thereby limiting the strength of the conclusions that can be drawn from the study. In addition to the questionable validity of the percent change in four-year per capita income, the unexpected sign on the democrat variable casts doubt on the results regarding the political preferences for rural economic development.

The second limitation of this thesis deals with specification of the intensive livestock inventory equation. The specification used in this econometric analysis was based on specifications used in previous studies (Metcalfe (2001), Roe, et al. (2002), Park, et al. (2002), and Hepath, et al. (2003)). Together, the results of these studies revealed an ambiguous relationship between intensive livestock inventory and regulatory

stringency. Since this study required instrumental variables for intensive livestock inventory, the ambiguity surrounding the relationship between intensive livestock inventory and regulatory stringency detracts from the results derived in this research. Unique among previous studies, Roe, et al. (2002) found a negative relationship between county-level hog inventories and state regulatory stringency. With the exception of the regulatory stringency variable, the Roe, et al. analysis was conducted at the county level, thereby allowing for the control of agglomeration economies. The specification used in this analysis does not control for agglomeration economies and as a result potentially biases the set of instrumental variables used for intensive livestock inventory.

6.3 Future Research

The study of environmental policy in the context of regional economic development has a number of potential areas suitable for future research. Empirical studies of the G-H trade model have examined the level of trade protection across industries as provided by the US federal government. A similar study examining differential enforcement of US federal environmental policy across industries would be interesting. Perhaps an index of regulatory stringency across industries could be constructed based on the compliance costs as a percent of total value added in each industry. A previous study examined the impact of corruption and state environmental policy on FDI (Fredriksson, et al., 2003). This analysis could be modified, allowing for an examination of the impact of political pressures for economic development on the determination of environmental policy and as a consequence on state FDI.

Further research into the nature of the political tradeoff between economic development and environmental quality is a potential area for further research. This study used the percent change in per capita income over four years as the primary proxy for rural development pressure. As described in the previous section, the validity of this proxy is questionable. Further research investigating the determinants of the strength of the pressure for rural economic development would be useful.

The empirical analysis performed in this thesis did not explicitly examine the impact of lobbying efforts on the stringency of environmental regulations. Accounting for the strength of the ILO sector lobby would improve interpretation of the results. The share of livestock in total agricultural production would give an indication of the strength of the ILO sector lobby. A predetermined measure of this variable, such as the percent of agricultural receipts due to livestock production in 1980, would measure the establishment of an ILO sector lobby that is not endogenously determined with current environmental stringency. Further analysis could examine the impact of other economic interests on the stringency of intensive livestock environmental regulations.

6.4 Conclusions

The primary objective of this thesis was to examine the impact of the perceived short-run political tradeoff between environmental quality and economic development in the context of the US intensive livestock industry. The theoretical model presented in this thesis proposed that the pressure for rural economic development has a negative relationship with the stringency of environmental regulations in the intensive livestock industry. The econometric model tested this relationship based on different levels of

regulatory stringency and on changes in rural per capita incomes among states. The null hypothesis stated that pressure for rural economic development has no effect on the stringency of regulations. The econometric analysis performed in this thesis rejected the null hypothesis, finding that the percent change in rural per capita income had a statistically significant positive impact on the stringency of US intensive livestock environmental regulations. Therefore, the primary conclusion from this research is as follows: an incumbent state government that is under greater pressure to pursue rural economic development initiatives will implement less stringent environmental regulations on the intensive livestock industry. Whereas the EKC literature focuses on the long-run relationship between environmental quality and income levels, this study examined the short-run impact of political forces on the determination of environmental regulations.

Secondary conclusions from this research deal with the impacts of the size of the intensive livestock sector, the marginal disutility from pollution, and the potential pollution damages from intensive livestock production on the stringency of regulations. The econometric analysis found evidence that the relationship between intensive livestock inventory and environmental regulations is potentially endogenous. The econometric tests found that intensive livestock inventory has a positive and statistically significant impact on the stringency of regulations. The results concerning the marginal disutility from pollution were ambiguous. The percent of the population that is rural had an expected positive impact on regulatory stringency, while the interaction term between the percent of the population that is rural and the rural population density had a negative impact on the stringency of regulations. As expected, controls for the potential pollution

damages of intensive livestock production had positive impacts on the stringency of environmental regulations.

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APPENDIX A

1998 National Survey of Animal Confinement Policies: Selected Questions

7. Are minimum setback distances required by state government for site approval? Describe any required setbacks.

8. Are any physical or geological tests required? (e.g. floodplain restrictions, soil borings, compaction requirements) Describe.

9. Are public notices or hearings required by state government prior to site approval? Describe any requirements and legal priorities or limitations.

10. Does manure management, confinement facility construction, or facility operation require approval or a permit by any government entity in your state? Which level? Describe activities requiring approval by state agencies.

11. Are regulatory staff required to make site visits before state government approval is given? If "yes", please describe.

12. Must manure faculty design plans be provided and/or other criteria for manure management structures be met before state government approval is given. If "yes", please describe.

13. Is a waste management plan required by state government before approval is given? If "yes", please describe information required in the plan.

14. Does your state government assess any fees during the approval process for manure management, confined livestock facility construction, facility operation, or site location? If "yes", please describe.

15. Does your state government impose nutrient standards or other limits which restrict amounts of manure applications, timing of land application, set backs for application, irrigation, or other forms of manure disposal from confined livestock operations? If "yes", please describe.

16. Does your state government impose any bonding or financial assurance requirements to pay the costs for clean up of any spills or to pay for closure of abandoned facilities, etc.? If "yes", please describe.

17. Are odor standards, such as number of objectionable days per year, etc., imposed as a matter of state government policy or court decisions in your state? If "yes", please describe the standards.

18. Does your state government impose any requirements for controlling flies or other insects related to manure management or confined livestock operations? If "yes", please describe.

19. Does your state government require any ground water monitoring wells or systems? If "yes", please describe.

20. Does your state government regulate any legal surface discharges from manure management systems of confined livestock operations? If "yes", please describe.

21. Does your state government impose any penalties for illegal discharges into streams or waterways from manure management systems of confined livestock operations? If "yes", please describe.

22. Does your state government impose any limits for consumptive water use that apply to confined livestock operations? If "yes", please describe.

23. Does your state government impose any dead animal disposal requirements for confined livestock operations? If "yes", please describe.

24. Does your state government impose any animal welfare requirements on confined livestock operations? If "yes", please describe.

25. Does your state government impose any education or training requirements for manure application operators, manure handlers, or confined livestock operation managers? If "yes", please describe.

27. Does your state government prohibit corporations or other entities from owning farmland or engaging in confined livestock operations? Please explain.

28. Does your state government impose restrictions on packers owning or contracting livestock supplies? Please describe.

29. Does your state government require packers to publicly report contract prices for livestock? Please explain.

30. Does your state government prohibit or limit packers from providing price premiums or long term minimum price contracts for large suppliers of livestock? Please explain.

31. Does your state government have any laws or policies which either encourage or limit innovative business arrangements for purposes of confined livestock operations (such as marketing alliances, closed cooperatives, and network entities)? Please describe.

32. Have any statewide or local moratoria on confined livestock operations been enacted in your state? Please describe.

33. Does your state government exempt confined livestock operations and/or land applications of manure from local zoning authority? Please explain.

34. Does your state government authorize local option referendums on confinement issues and/or impose any preemptions on local authority for regulating confined livestock operations? Please explain.

35. Does your state government provide nuisance suit protection for some or all confined livestock operations under specific or general state statutes, such as "right to farm" legislation? Please describe.

APPENDIX B

Preferred specification:

$$STRING = \beta_1 + \delta_1 LOG(AU1997) + \beta_{12} PERCENTRUR\ AL$$
$$+ \beta_{13} PERCENTRUR\ AL * DENSITY + \beta_{14} ENVFACTORS$$
$$+ \beta_{15} NATAMENITY + \beta_{16} DEMOCRAT + \beta_{17} PCIfour + \varepsilon_1$$

$$LOG(AU1997) = \beta_2 + \delta_2 STRING + \beta_{22} LOG(TOTPOP) + \beta_{23} CP$$
$$+ \beta_{24} LANDVALUE + \beta_{25} MFGWAGE + \beta_{26} PROPTAX + \varepsilon_2$$

Section 5.1.1: OLS results presented.

Section 5.1.2: Reduced form estimations presented. Validity of instrumental variables tested

Section 5.1.3: TSLS estimated due to the potential endogeneity between *STRING* and $LOG(AU1997)$. Overidentifying restrictions tested.

Section 5.1.4: TSTOBIT estimated due to the potential that *STRING* is a censored variable and this has materially affected the results.

Section 5.1.5: *RESNCHANGE* is substituted in place of *ENVFACTORS* in the TSLS estimation (section 5.1.3) due to the potential that *ENVFACTORS* has been improperly constructed.

Alternative specifications:

$$SETBACK\ (orNUTSTDS) = \beta_1 + \beta_2 LOG(AU1997) + \beta_3 PERCENTRUR\ AL$$
$$+ \beta_4 PERCENTRUR\ AL * DENSITY + \beta_5 ENVFACTORS$$
$$+ \beta_6 NATAMENITY + \beta_7 DEMOCRAT + \beta_8 PCIfour + \varepsilon_1$$

$$RANKSTDS = \beta_1 + \beta_2 LOG(AU1997) + \beta_3 PERCENTRUR\ AL$$
$$+ \beta_4 PERCENTRUR\ AL * DENSITY + \beta_5 NFACTOR + \beta_6 PFACTOR$$
$$+ \beta_7 NATAMENITY + \beta_8 DEMOCRAT + \beta_9 PCIfour + \varepsilon_1$$

Section 5.2.1: *SETBACK* is used in place of *STRING*. Logit model accounts for binary dependent variable.

Section 5.2.2: *NUTSTDS* is used in place of *STRING*. Logit model accounts for binary dependent variable.

Section 5.2.3: *RANKSTDS* is used in place of *STRING*. Ordered logit model accounts for rank ordered dependent variable.

APPENDIX C

Table C.1: TSLS Results (PCI*three*)

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: STRING				
INTERCEPT	-9.461117	-	-0.707673	0.4837
LOG(AU1997)	1.244812	0.114346	2.177172	0.0361
PERCENTRURAL	0.113210	0.334267	2.750458	0.0093
PERCENTRURAL*DENSITY	-0.001319	-0.186531	-1.656751	0.1063
ENVFACTORS	1.193449	0.4709	2.376786	0.0229
NATAMENITY	0.599120	0.205334	0.827893	0.4132
DEMOCRAT	-0.213535	-0.922659	-1.652442	0.1071
PCIthree	0.423349	0.487599	2.036456	0.0491
$\chi^2_{(4)} = 6.6704$	(p ≈ 0.25)			
Dependent: LOG(AU1997)				
INTERCEPT	1.089727	-	0.348553	0.7294
STRING	0.144940	1.57787	2.416535	0.0207
LOG(TOTPOP)	0.702574	0.702574	4.890269	0.0000
CP	-0.698475	-2.14421	-1.386735	0.1738
LANDVALUE	-0.000698	-0.726877	-4.299764	0.0001
MFGWAGE	0.174985	2.39427	1.355788	0.1834
PROPTAX	0.204570	0.17086	1.030389	0.3095
$\chi^2_{(5)} = 4.1793$	(0.5 > p > 0.25)			

Source: Author's calculations

Table C.2: TSLS Results (PCI*two*)

	Coefficient	Elasticity	t-Statistic	p-value
Dependent: STRING				
INTERCEPT	-15.51301	-	-1.301098	0.2015
LOG(AU1997)	1.165881	0.107096	2.409397	0.0212
PERCENTRURAL	0.104444	0.308384	2.667742	0.0114
PERCENTRURAL*DENSITY	-0.000937	-0.132509	-1.274102	0.2108
ENVFACTORS	1.226583	0.483976	2.569280	0.0145
NATAMENITY	1.238835	0.424581	1.720983	0.0938
DEMOCRAT	-0.176163	-0.761179	-1.448406	0.1562
PCItwo	0.824684	0.949842	3.016021	0.0047
$\chi^2_{(4)} = 6.1947$	(0.5 > p > 0.25)			
Dependent: LOG(AU1997)				
INTERCEPT	0.912776	-	0.303284	0.7634
STRING	0.150628	1.63979	2.885487	0.0065
LOG(TOTPOP)	0.697241	0.697241	4.902371	0.0000
CP	-0.676275	-2.07606	-1.367842	0.1796
LANDVALUE	-0.000691	-0.719587	-4.336351	0.0001
MFGWAGE	0.183501	2.51079	1.504464	0.1410
PROPTAX	0.208417	0.174076	1.044910	0.3028
$\chi^2_{(5)} = 3.9174$	(0.5 > p > 0.25)			

Source: Author's calculations