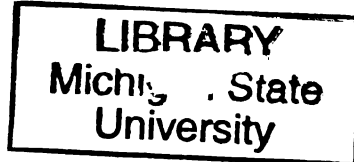


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ESSAYS IN THE POLITICAL ECONOMY OF EMINENT DOMAIN
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Dziwornu Kwami Adanu

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**ESSAYS IN THE POLITICAL ECONOMY OF EMINENT DOMAIN AND
EFFICIENT WATER RESOURCE MANAGEMENT**

By

Dziwornu Kwami Adanu

A DISSERTATION

Submitted to the
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Agricultural Economics

2009

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ABSTRACT

ESSAYS IN THE POLITICAL ECONOMY OF EMINENT DOMAIN AND EFFICIENT WATER RESOURCE MANAGEMENT

By

Dziwornu Kwami Adanu

The use of eminent domain power for economic development is an important part of public policy in the U.S. Eminent domain is however a complicated policy with divergent impacts on different segments of society. Two unresolved issues arising from the use of eminent domain include first, how the perceived benefits and costs of eminent domain affect people's positions on the reform of eminent domain law. This is addressed in the first essay of this dissertation by setting up and estimating a voting model that explains voters' decision on the reform of eminent domain and regulatory compensation laws in the U.S. The second research issue involves the choice of owner compensation levels that minimize the problem of holdouts and close the gap between the theoretically proven effectiveness of eminent domain in resolving holdouts, and observation of protracted eminent domain negotiations in practice. This is addressed in the second essay using a two-period sequential game between property owners and local governments. Finally, the third essay looks at the implications of functional form choices for cost function estimations in the U.S water industry.

The first essay investigates voter responses to referenda in the 2006 midterm elections on restricted use of eminent domain power, and regulatory takings compensation. Results indicate that voters responded to these referenda on eminent domain quite differently depending on whether the referenda included a requirement of

compensation for regulatory takings. A plurality of voters favored reforming eminent domain law to limit its use for economic development purposes. Compensation for regulatory takings was viewed less favorably. Combining these two issues on one ballot therefore increases the proportion of voters rejecting the ballot on restricted use of eminent domain. Further, county level socio-economic variables capturing the perceived benefits and costs of eminent domain power were important for referendum outcomes. Next, theoretical research findings by Miceli and Segerson (2007) indicate that the threat of eminent domain resolves owner holdout problems in property takings. Law and economics literature on eminent domain takings however abound of eminent domain cases that end up in the courts because of disagreements between owners and governments over compensation levels. The second essay reconciles the disparity between theoretical predictions and actual observations about the effectiveness of eminent domain in addressing owner holdouts. Using a two period sequential game framework it is shown that the threat of eminent domain guarantees resolution of the holdout problem only when owners have complete and perfect information about the bargaining problem. These informational assumptions are later relaxed to model more practical eminent domain bargaining problems. Finally, the third essay estimates total variable cost functions for potable water facilities in the U.S. Cost functions are parameterized using the Hyperbolically Adjusted Cobb-Douglas (HACD) and the translog functional forms. The results show wide disparity in some of the estimated efficiency parameters although the measure of fit is close for the two functional forms. The results show the importance of using more than one functional form in cost function estimations to allow for comparison and assessment of reliability of estimates.

To My Family
For Your Encouragement and Support

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ESSAY 1

Voter Decisions on Eminent Domain and Regulatory Takings Referenda

1.1 Introduction

Eminent domain refers to the power of government to take private property for public use without the owner's consent. Public use refers to purposes such as the provision of public services like highways, public utilities, community centers, schools, and other facilities that can be made available for use of the entire community (Merrill 1986). Court decisions have however gradually broadened the definition of public use (Michigan, 1981, U.S. Supreme Court, 1954, U.S. Supreme Court, 2005). By 1981, the Michigan Supreme Court decided in favor of broadening public use to include takings where public authorities condemn the properties of private owners and transferred ownership to other private owners for purposes of economic development (Michigan Supreme Court, 1981). Though the Michigan court later reversed itself on such indirect public uses, other state courts made similar decisions to broaden the concept of public use in their respective jurisdictions (Sandefur 2006, Berliner 2003). Such decisions in the Connecticut courts culminated in the U.S. Supreme Court's June 23, 2005 decision in the *Kelo v. New London* case (U.S. Supreme Court, 2005). In *Kelo*, the U.S. Supreme Court endorsed the constitutionality of a broad concept of public use, ruling that, under the U.S. Constitution, governments are permitted to use eminent domain to take property and transfer its use to other private parties as long as there is a public benefit, such as economic development (U.S. Supreme Court, 2005).

The *Kelo* case arose from the condemnation of 115 lots of private and commercial properties by the City of New London in the Fort Trumbull neighborhood

area of New London. The owners of 15 of the 115 lots marked to be taken refused to sell their properties citing violation of the fifth and fourteenth amendments of the U.S constitution that govern the taking of private property for public use. In particular, the plaintiffs in the case argued that taking private properties and transferring same to a private developer to build new structures to increase the tax base of the city and generate employment does not meet the “public use” requirement for the exercise of eminent domain power. Led by the lead plaintiff in the case, Sussette *Kelo*, owners of the 15 lots under contest argued and lost the case in the New London Superior Court, and the Supreme Court of Connecticut before taking the case to the U.S Supreme court.

Closely related to eminent domain is regulatory taking. Regulatory taking refers to the use of government police powers to limit land development by private owners without depriving them of ownership rights over the property (Flick et. al. 1995). For instance to preserve open space or protect ecologically sensitive zones governments may limit the percentage of a landowner’s property that can be developed. Although eminent domain and regulatory taking are related in the sense that both institutional mechanisms are used to provide public services they represent two different policy tools. Eminent domain taking involves forceful transfer of property rights and requires payment of compensation while property owners facing regulatory action retain ownership rights over their properties and are entitled to no compensation (Flick et. al. 1995, Goldstein and Watson 1997). Efforts to make compensation for regulatory takings a legal requirement began in 1995 when the 104th U.S. Congress passed a property rights bill calling for compensation to property owners whenever federal agency regulatory actions decrease property values by more than 20%. The bill however

failed to pass the Senate (Goldstein and Watson 1997). This led to efforts at the state level in November, 2006 to pass legislations that would require compensation for regulatory takings.

Following the *Kelo* ruling several states passed referenda to ban the use of eminent domain for economic development purposes or restrict the circumstances under which such takings should be carried out (Orthner 2007, Sandefur 2006, Berliner 2003). At the end of November 2006 the ten states included in this study (Arizona, Florida, Georgia, Michigan, Oregon, South Carolina, Louisiana, New Hampshire, Idaho and California) had presented special ballots on reforming eminent domain and regulatory taking compensation laws to registered voters with all of them except Idaho and California disapproving of unfettered use of eminent domain to take over private property (see Table 1.1). In general, two main classes of ballot measure types are identifiable from this data: eminent domain only ballots, and eminent domain and regulatory taking compensation ballots. States with eminent domain only ballots generally call for a ban or restricted use of eminent domain power for economic development purposes while eminent domain and regulatory taking compensation ballots combine restricted use of eminent domain power with compensation for regulatory takings. The differences in type of ballot proposals also imply that data on eminent domain and regulatory taking compensation election results cannot be pooled across states for comprehensive empirical studies without appropriate adjustments to account for differences in the type of proposition voters responded to in each state.

This paper analyzes the political response to the *Kelo* case by examining the factors influencing the decisions of voters to support or reject initiatives on these

measures in Ten U.S. States. The paper focuses on the effect of ballot structure on vote outcomes involving restricted use of eminent domain and regulatory taking compensation. Voter preference over these two issues is explained using a rational voter model (Deacon and Shapiro 1975, Downs 1957, Hess and Orphanides 1995). The rational voter model explains how voter decisions at the polls depended on the perceived net benefits expected from the vote choices. A cross-sectional limited dependent variable model is estimated using a logistic regression functional form to explain the vote outcomes.

The results indicate that the average voter supports imposing restrictions on use of eminent domain power but opposes requiring compensation for regulatory takings. Combining these two issues on one ballot increases the proportion of voters rejecting the ballot relative to presenting a ballot on restricted use of eminent domain only. On average, voters in economically weak counties are less supportive of restricted use of eminent domain power and regulatory taking compensation. In particular, counties with low income and/or high unemployment rates are less supportive of restricting the use of eminent domain power and requiring regulatory taking compensation. Homeownership rate fails to significantly explain the vote outcomes. This implies that renters reject unrestricted use of eminent domain just as strongly as homeowners do. Finally, education and income have a negative effect on increased property rights protection and regulatory compensation. This finding indicates that when confronted with a choice between more secure property rights and a healthier environment both educated and high income voters lean towards protecting the environment.

The remainder of the paper is ordered as follows. The next section presents and discusses the conceptual framework and research hypotheses of the paper. This is followed by the economic model section which discusses the supporting theoretical and econometric models of the paper. Discussion of the research data, results, and conclusions then follow in that order.

1.2 Conceptual Framework and Research Hypotheses

Voting on referenda and ballot propositions can be considered as voter preference revelation over the issues being voted upon. The analysis of vote outcomes on eminent domain and regulatory taking compensation in this study is therefore treated as one of revealing the demand for these two institutional mechanisms. This section of the paper begins by outlining the conceptual framework of private demand for these two institutions. The conceptual framework explains the relationship between the expected benefits and costs from voting (voter utility) and the ultimate voter decision made at the polls. The conceptual framework is followed by the statement and description of the research hypotheses to be tested.

Conceptual Framework

The rational voters model suggests that voters' decisions on public good provision can be treated as a derived demand of how much public good voters want to consume at the optimum [Downs (1957), Deacon and Shapiro (1975), Matsusaka (1993)]. This implies that voters make voting decisions on the provision of public goods to maximize utility derived from the consumption of private and public goods subject to an income constraint. This conceptual framework describes the preferences and

perceptions of benefits (direct benefits and ideological satisfaction), costs, and the income constraint of voters facing propositions on eminent domain and regulatory takings. The level of these benefits, costs, and constraints are then related to the model variables to explain the motivation for including these variables in the model. The underlying point of this analysis therefore is that the observable variables in the model (ballot measure type, homeownership, income, education, unemployment, and population density) affect the perceived benefits, costs, and income constraint of voters. These variables can thus be used to develop testable hypotheses to explain the observed vote outcomes.

The ideological positions of people on *Kelo* (property takings for development) can be described as a continuum of views ranging from outright rejection to wholesale acceptance of government intervention in property markets to take properties for economic development purposes. For instance, the November 2005 survey results by the Saint Index polling organization [reproduced in Somin (2007)] indicate that the position of respondents on *Kelo* range from “agreement” to “strong disagreement”. This background to ideological positions implies that there are voters on either side of the property takings issue. For simplicity, the analysis here is restricted to two categories of voters, voters supporting or opposing restricted use of eminent domain and regulatory takings compensation. The proportional distribution of voters holding these two views in a voting population would therefore be important in determining the likelihood of passing propositions on these issues.

In addition to ideological satisfaction voters can expect direct benefits from their vote choices (Sandefur 2006, Lazzarotti 1999). The direct benefits expected from voting

on restricted use of eminent domain power and regulatory taking compensation ballots include the value at risk (e.g. home values) that voters seek to protect (Sandefur 2006, Riddiough 1997) public goods (e.g. roads, and community centers) provided from takings (Lazzarotti 1999, Munch 1976), direct transfers (e.g. regulatory taking compensation) to landowners as a result of government regulatory action (Miceli and Segerson 1994), and nonmarket values (e.g. open space) provided by regulatory actions (Bengston et al 2004).

On the other hand, there are costs attributable to vote decisions on these issues. Such costs often take the form of higher tax obligations that can be expected to emanate from some of these decisions (Deacon and Shapiro, 1975). For instance, in order to pay the increased compensation for eminent domain and regulatory takings when the average voter supports a ballot on unrestricted use of eminent domain, and a requirement for regulatory taking compensation, voters may have to pay increased taxes to raise the necessary revenue to provide compensation. The increase in tax obligation reduces the disposable income of voters and changes the income constraint of their utility maximization problem.

Explanatory variables included in the study control for differences in the ballot measure types presented to voters and the probable incentives and disincentives associated with vote decisions at the polls. For instance, the ballot type variable is binary and is defined to equal 0 if the ballot question in a given state calls for restricted use of eminent domain only and 1 if a requirement for regulatory taking compensation is added to restricted use of eminent domain. This variable measures the effect of the ballot question structure on voter choices and allows the model to capture the extent to

which the nature of the ballot question affects the chances of passing eminent domain measures.

The next explanatory variable considered in the model is homeownership rate. Homeowners can be expected to be more concerned about use of eminent domain power and property regulatory actions than voters living in rented properties. This is because homeowners have more value at risk than renters. The implication here is that counties with high homeownership rates may be more supportive of the ballot measure since their net benefits from voting yes to restricted use of eminent domain and regulatory compensation exceed that for renters. Here, the difference in the expected response of the two subgroups (homeowners and renters) of voters is influenced substantially by the asymmetric expected effect of the ballot measure on these groups.

There are however equally relevant reasons to expect the average homeowner to vote no as well. For instance, given that a common rationale for property takings for economic development is to combat blight (Sandefur, 2006) the property price increases that may be expected to come with neighborhood improvements associated with the use of eminent domain to clean blight provides good reason for a class of property owners to vote no to restricting use of eminent domain. The resultant effect of homeownership rate may therefore be ambiguous.

The positive relationship between environmental quality and income has been reported in several studies on vote behavior and environmental and resource conservation [Deacon and Shapiro (1975), and Kotchen and Powers (2006), Khan and Matsusaka (1997), Popp (2001)]. This implies that high income voters may vote in support of regulatory compensation because of their relatively higher demand for

environmental quality and open space in urban and congested areas. If this finding holds true in this study as well then it can be expected that high income voters would reject regulatory taking compensation to promote the use of regulatory takings.

Past studies on factors affecting attitude towards the environment and natural resource use consistently show that the level of education of voters positively affects voters' attitudes towards resource management [see, Deacon and Shapiro (1975), Khan and Matsusaka (1997), Khan (2002), and Fischel (1979)]. This is because knowledge about the value of environmental quality and open space, how these can be improved, and exposure to research findings on the impact of environmental quality and open space on property values and human health are important determinants of voters' position on the environment. Education is therefore one factor that can affect the ideological position and the subsequent choices of voters on natural resource-related ballot measures. These findings can be extended to eminent domain and regulatory compensation issues since eminent domain takings involve land resource use decisions while government regulatory actions on land use often have implications for environmental and ecological resource management.

Counties with high unemployment rates can be expected to be supportive of eminent domain since use of eminent domain power for economic development purposes can be valuable for economically depressed areas that are looking forward to economic expansion and job creation [Clarke and Kornberg (1994), Bowler and Donovan (1994), and Sandefur (2006)]. On the other hand, given that regulatory taking does not involve any subsequent use of the property to provide jobs or any collective good, unemployment rate may not have a significant effect on how voters react to

regulatory compensation ballots. This implies that high unemployment rate can be expected to increase the proportion of no votes cast on restricted use of eminent domain and regulatory taking compensation.

Population density is another variable that can be linked to the potential direct benefits of eminent domain and regulatory takings. Limited land availability and high land prices in high population density areas often imply that some public services may only be provided by taking some existing properties and converting them to alternative uses. For instance, single family homes at good locations may be taken and converted to multi-story apartment complexes to serve more people and increase property tax revenues. Lanza (2006) found that population density does not explain eminent domain takings. However, Lanza's study and this paper examine eminent domain from different perspectives (actual eminent domain takings in Lanza (2006) as opposed to preference for restricted use of eminent domain in this study). Further, the ballot question here does not cover only eminent domain but regulatory takings as well; thus it is useful to still consider the role of population density in explaining voter decisions here.

The next section presents and discusses the hypotheses to be tested. Because each of these explanatory variables may affect the perceived benefits and costs of voters in several complicated ways, building testable hypotheses based on these variables requires explaining why some effects may be more influential than others. Ultimately the data must be relied upon to verify these hypotheses and reveal the net effect of each of these variables on vote choices.

Research Hypotheses

The hypotheses are founded on discussions in the conceptual framework and results from the rational voter model. As previously discussed, support for eminent domain and regulatory taking ballot measures varies across space, economic, and demographic characteristics of voters. Statewide voting initiatives provide an avenue to study how these characteristics affect support for resource-use ballot measures at the state and sub- state levels. The research hypotheses follow.

Hypothesis 1: Support for the ballot measure declines as the ballot measure extends from restricted use of eminent domain to restricted use of eminent domain and regulatory taking compensation

Summary results on eminent domain and regulatory taking ballots in the 2006 midterm election (see Table 1.1) suggest that voter support may be declining as the ballot measure extends from restricted use of eminent domain to restricted use of eminent domain and regulatory takings compensation. This is likely the case because voters supporting restricted use of eminent domain power reject regulatory takings compensation since regulatory takings do not really result in the loss of property rights over the property in question.

Of course if this relationship turns out to be positive instead, then the assertion that adding a requirement for regulatory takings compensation makes it less likely for a restricted use of eminent domain ballot to pass is untrue. This result would be suggestive of two things: that voters supporting restricted use of eminent domain power also tend to support compensation for regulatory takings, and voters who are not

supportive of restricted use of eminent domain power tend to support compensation for regulatory takings strongly enough to vote yes instead of no given that their decision on these two issues conflict.

Hypothesis 2: Support for the ballot measure is increasing in homeownership rate

As previously discussed, property owners concerned about price declines that may be associated with uncertainties introduced by property takings and the small chance that their properties might be expropriated may be reluctant to support increased property takings. This can be expected to result in a positive relationship between homeownership rate and yes votes at the polls. On the other hand, if indeed eminent domain takings for economic development purposes affect low-valued properties disproportionately as a measure to deal with blight (Somin 2007, Sandefur 2006) then property price increases that are expected to come with neighborhood improvements provide good reason for a class of property owners to vote against restricted use of eminent domain power. The observed sign on the coefficient for this variable would therefore depend on the net effect of these two main influences. The resultant effect of homeownership rate may therefore be ambiguous. Assuming that the incentive to property owners to protect their property investments overrides any positive external price effects obtainable from cleaning up blighted properties implies that homeownership rate can be expected to have a positive net impact on the proportion of yes votes.

Hypothesis 3: Support for the ballot measure is decreasing in level of knowledge/education

Previous studies have consistently observed a strong correlation between educational attainment and support for environment and resource management measures [Press (2003), Salka (2001), Deacon and Shapiro (1975), and Kotchen and Powers (2006), and Palfrey and Poole (1987)]. Education is therefore one factor that can affect the ideological position and the subsequent decision of voters on natural resource regulation and use. Looking at how these initiatives are written out on voting ballots, it is clear that a fair level of education is necessary to understand the ballot initiatives and be an informed voter. It can therefore be expected that the higher the proportion of voters in a county with at least high school diploma the higher would be the proportion of voters rejecting the ballot. Similarly, the higher the proportion of voters in a county with at least a bachelor degree the higher would be the proportion of voters rejecting the ballot.

If the results unexpectedly show that more educated voters are more inclined to vote yes for more restricted use of eminent domain power and regulatory takings compensation then that reveals an interesting and debatable result. It implies that more educated voters tend to choose more secure property rights over possible environmental quality gains from the use of eminent domain power and regulatory takings. Writing on the social and ideological bases of support for environmental legislation Calvert (1979) observed that “relatively high levels of support were found among college-educated, white-collar professionals”. Thus what a counter finding under this hypothesis would be indicative of is the relative importance of secure property rights and environmental

quality to educated voters. In particular, it would indicate that when confronted with a choice between more secure property rights and a healthier environment educated voters would lean towards securing property rights.

Hypothesis 4: Support for the ballot measure is decreasing in income

Given that the dependent variable in the model is made up of two main forms of takings (regulatory takings and eminent domain), the decision of voters at the polls can be expected to be motivated by two main factors: level of support for use of regulatory action to preserve green space and protect ecologically sensitive zones, and level of support for use of eminent domain for economic development and alternative public uses. Several research findings on the environment have shown environmental and resource conservation to be a normal good. The functional form of the relationship may be specified in several ways. However, the most commonly studied form of this income-environment relationship is that of the Environmental Kuznets Curve which expresses an inverted-U relationship between income and environmental attributes. [Dasgupta (2002), Grossman (1993), Harbaugh (2002), Kahn and Matsusaka (1997)]. If high income is associated with support for the environment then higher income counties can be expected to vote 'no' to requiring compensation for regulatory takings since this limits the use of regulatory action. When it comes to use of eminent domain power, the requirement to pay compensation for expropriated properties in itself draws local government authorities to low-valued properties to reduce the outlay involved in paying compensation. There is therefore good reason to expect support for a ballot measure imposing additional restrictions on eminent domain takings to be declining in income.

In other words, higher income counties are again more likely to vote ‘no’ to limiting the use of eminent domain power.

A counter finding of a positive relationship between income and yes votes would not only invalidate the Kuznets curve relationship which suggests that high income earners appreciate environmental resources better but also indicate that eminent domain taking is really not a problem that is specific to low-valued property owners only. A counter finding here would not be surprising given that the Kuznet relation is still not a well established relationship. Several authors have found evidence to suggest that this inverted U-shape relationship is highly unstable and fails to show up in several studies that investigated this relationship. See Hettige *et al.* (1992), List and Gallet (1999), Harbaugh, Levinson, and Wilson (2002), and Millimet, List, and Stengos (2003).

Hypothesis 5: Support for the ballot measure is decreasing in population density

Higher population density settlements generally have higher demand for urban services like open and green spaces, housing, shopping centers, and car parking spaces. Limited land availability and high land prices in high population density areas often imply that some of these services can only be provided by taking some existing properties and converting them to alternative uses. More densely populated counties are thus expected to show more support for policy initiatives like eminent domain that promises the provision of these much needed services. This effect is often reflected in a strong positive relationship between urban communities and approval for resource-use initiatives [Meddler and Mushkatel (1969)]. Lanza (2006) related population density and eminent domain takings along the same line by noting that “to the extent eminent

domain helps solve the holdout problem, the incidence of taking should depend on population density. As an area becomes more densely settled and ownership patterns more fractured, bargaining is likely to grow more complex. If takings reduce transaction costs, they ought to vary positively with population density". On the other hand, voters in high population density areas may react differently when it comes to requiring compensation for regulatory takings. Since properties in urban areas tend to be much more expensive than comparable properties in rural or low population density areas, voters in high population density counties may be more inclined towards voting yes to require compensation for regulatory takings. In summary, voters in counties with high population density are likely to vote no on eminent domain but vote yes on regulatory takings compensation. This implies that the impact of population density on the dependent variable (logodds of yes votes) should depend on the ballot measure type variable. This is captured by interacting ballot type and population density variables.

If population density turns out to vary positively with yes votes then this may be evidence that voters place more weight on regulatory takings compensation than on restricted use of eminent domain. If the reverse result is observed, then that may suggest that voters place more weight on eminent domain than regulatory actions.

Hypothesis 6: Support for the ballot measure is decreasing in the level of unemployment rate

Eminent domain would likely be a valuable tool for more economically depressed areas that are looking forward to economic expansion and job creation than otherwise. Some previous studies on the effect of economic conditions on vote

outcomes indicate that voter dissatisfaction with bad economic conditions tend to erode support for ballot proposals because of low support for government [Clarke and Kornberg (1994), Bowler and Donovan (1994)]. Since a common measure of economic strength is the level of unemployment, it is expected that voters in high unemployment regions would show more support for eminent domain than those in high growth areas. Given that regulatory taking does not involve any subsequent use of the property to provide jobs unemployment is not expected to have any significant effect on how voters react to regulatory taking ballots.

If high unemployment rate induces yes votes instead of the expected no votes, then the model may very well be picking up the possibility that voters are simply voting their values of ensuring that appropriate compensation is paid to property owners for all regulatory actions by government. An interaction term of unemployment and ballot measure type should pick this effect up in the model.

Hypothesis 7: Support for the ballot measure is decreasing in voter turnout

Previous empirical studies indicate that low voter turnout correlates strongly with approval of initiatives in referenda [Knox, Landry, and Payne (1984), Hadwiger (1992), Stone (1965)]. As turnout rises the proportion of favorable votes decline. One explanation offered for this result is that qualified voters who oppose ballot propositions tend to express their protest by boycotting elections (Stone 1965). Hadwiger on the other hand noted that this could be because of voting mistakes by voters that do not realize that a 'no' vote in a referendum is a vote for reform and may be mistakenly

voting no to show support for the status quo. As noted by Hadwiger, this is a result that still requires further research to explain the rationale for the finding.

1.3 Economic Model

This section of the paper outlines the econometric model used to obtain the estimated model parameters. The econometric model specification is prefaced by a brief description of the voting behavior model upon which the econometric model is founded. This voting behavior model is based largely on the individual voter preference maximization model developed by Deacon and Shapiro (1975) to describe how self-interest maximization may be integrated into voter decision-making to explain vote outcomes.

The model begins by assuming a differentiable average voter utility function for county i as,

$$U^i = U^i(x^i, q_k, h^i) \quad (1)$$

where x is a vector of private goods, q a vector of collective goods, and h represents demographic and socio-economic variables (homeownership rate, education, and population density) that characterize the voter. The set of policy alternatives available to the voter at the polls is represented by k where $k = [0,1]$ Here, $k = 0$ represents a no vote and $k = 1$ represents a yes vote. The collective goods available to the voter therefore depend on the choice made at the polls. Equation (1) thus indicates that a voter's utility is not only affected by the vector of private goods x and collective goods q consumed but also by the listed set of demographic and socio-economic variables y of the voter.

The tax liability faced by voters on the other hand is the expected tax funds needed to compensate private property owners for takings and to invest in new public infrastructure. After accounting for taxes, S_k^i the disposable income of the consumer is expended on a vector of private goods x^i yielding the budget constraint,

$$p_k x^i = I_k^i - S_k^i \quad (2)$$

where p_k is a vector of private good prices and I_k^i represents money income. Given that the budget constraint is satisfied, the indirect utility function for this problem is written as,

$$\max_{x^i} U^i(x^i, q_k, h^i) = V^i(q_k, p_k, I_k^i - S_k^i, h^i) \quad (3)$$

Equation (3) gives the maximum utility obtainable by the voter for any given policy choice made at the polls.

Thus the indirect utility outcomes under a yes (1)/no (0) voting alternative are,

$$V^i(q_0, p_0, I_0^i - S_0^i, h^i) = V_0^i \text{ for no votes} \quad (4)$$

$$V^i(q_1, p_1, I_1^i - S_1^i, h^i) = V_1^i \text{ for yes votes} \quad (5)$$

Given that voters cast ballots to maximize their self-interest, the average voter compares

(4) and (5) and votes yes if $V_1^i > V_0^i$, 'no' if $V_0^i > V_1^i$ and abstain if $V_1^i = V_0^i$.

Thus an average voter in county i votes yes if the indirect utility under this outcome is perceptively greater than that of the alternative option. To simplify the arguments of the model further, let z represent variables related to collective goods (q), private good

prices (p), and disposable income ($I - S$). Then the vote decision result described in equations (4) and (5) can be re-written in terms of differences in potential utility as,

$$V_1^i - V_0^i = \Delta V^i(z^i, h^i) \quad (6)$$

The new decision rule thus becomes vote yes if $\Delta V^i > 0$, no if $\Delta V^i < 0$, and abstain if $\Delta V^i = 0$. Thus far, both the functional form of the indirect utility and its arguments vary across counties. However, a more realistic way to control for differences in preferences across counties is to let such variations be explained by the arguments of the utility function only. The difference in indirect utility function is therefore re-written as,

$$\Delta V^i(z^i, h^i) = \Delta V(z^i, h^i) \quad (7)$$

It is assumed that ΔV is a random variable with a known distribution. Letting $\bar{z}$ and $\bar{h}$ denote the mean of the vector of variables in z and h respectively, the mean and variance of ΔV may be represented by $\mu(\bar{z}, \bar{h})$ and σ^2 respectively. Given a general distribution of ΔV for county i as, $g(\Delta V | \bar{z}, \bar{h})$, the proportion of yes votes (Y) in a county can be written as,

$$P(Y | \bar{z}, \bar{h}) = \int_{-\infty}^s g(\Delta V | \bar{z}, \bar{h}) d(\Delta V) = \Lambda(\beta_0 + \beta_z z + \beta_h h) \quad (8)$$

where S refers to all real numbers, and Λ the distribution imposed on the variables in the model. The probability of voting no on an initiative is thus, $1 - P(Y | \bar{z}, \bar{h})$. To restrict

the estimated proportion of yes votes to values that fall strictly between zero and one, $0 < \Lambda(s) < 1$ the logistic function is used to describe the distribution of the vote data.

The observed vote data (proportion of yes votes per county, F) to be modeled represents an estimate of a true (population) vote outcome, $\pi = \Lambda(\beta_0 + \beta_z z + \beta_h h)$. The model to be estimated can therefore be specified as,

$$F = \Lambda(\beta_0 + \beta_z z + \beta_h h) + \varepsilon = \pi + \varepsilon \quad (9)$$

where $F = \frac{\text{Number of Yes votes}}{\text{number of valid votes}}$, Λ is the logistic function, while z and h

represent vectors of independent variables that explain the vote outcomes. Equation (9) is however clearly nonlinear in parameters and requires nonlinear least squares estimation to obtain the estimated parameters. The model can however be linearized by taking the inverse of the logistic function to obtain,

$$\Lambda^{-1}(F) = \beta_0 + \beta_z z + \beta_h h + u. \quad (10)$$

This transformation allows for the application of linear regression since equation (10) is now linear in the parameters. Thus given that F follows the logistic

distribution,
$$F = \frac{\exp(\beta_0 + \beta_z z + \beta_h h)}{1 + \exp(\beta_0 + \beta_z z + \beta_h h)}.$$

Expressing the dependent variable in logodds form makes the right hand side of the model linear in parameters and amenable to modeling by least squares estimation:

$$\ln\left(\frac{F}{1-F}\right) = \beta_0 + \beta_z z + \beta_h h + u \quad (11)$$

where $\left(\frac{F}{1-F}\right)$ represents the odds of voting yes. The dependent variable in equation (11) is therefore the logodds of voting yes in the polls.

Imposing a logistic distribution implies the error term in equation (11) has zero mean and variance given as,

$$\text{var}(u) = \frac{1}{n\hat{\Lambda}(F)(1-\hat{\Lambda}(F))}$$

Obviously, this estimated variance depends on the observed proportions indicating that the model is Heteroskedastic and requires the application of Weighted Least Squares (WLS) estimation approach. The weight (w) applied is proportional to the inverse of the estimated variance [thus each observation is weighted by $[n\hat{\Lambda}(F)(1-\hat{\Lambda}(F))]^{1/2}$]. Since the weights are functions of unknown parameters the estimation requires a two-step procedure that uses simple least squares in the first stage to estimate the weights that are applied to the WLS regression at the second stage. The application of WLS to this model yields what is called the Minimum Chi-Square Estimator (MCSE) of β (see Greene 2003, Grizzle et al. 1969).

The variables in the model follow from the results in equation (6). Homeownership rate, education, and population density represent demographic and socio-economic variables (h) that measure variations in background and preference patterns. These variables capture the change in perceived benefits from a given vote choice across counties that is attributable to background characteristics of voters. Unemployment rate captures the potential impact property taking is expected to have on job creation and economic expansion across counties. The income variable corresponds

to the initial level of income at the time the votes were taken. The level of collective goods (q) can be particularly difficult to measure empirically. Here, state dummy variables are used to capture this effect. Following Deacon and Shapiro 2005, private good price levels p are assumed to be uniform across counties and subsumed in the constant term of the model.

Summary results on eminent domain and regulatory taking ballots in the 2006 midterm election (see Table 1.1) suggest that voter support may be declining as the ballot measure extends from restricted use of eminent domain to restricted use of eminent domain and requirements for regulatory takings compensation. This is likely the case because voters supporting restricted use of eminent domain power reject regulatory takings compensation since regulatory takings do not really result in physical loss of properties. Besides, unlike eminent domain, determining the compensable value for properties under regulatory takings can be difficult and imprecise. Paying more taxes to make compensation for such regulatory actions possible may therefore be unacceptable to some voters. The structure of the ballot question presented to voters can therefore be the difference between passing and not passing eminent domain ballots.

Since the sample data being analyzed here may be classified by the *ballottype* variable, two main options exist for estimating this cross-sectional regression model. First, two separate regression models may be estimated per ballot measure type if the model parameters are statistically different in the two models. The models for subsamples one (covering eminent domain and regulatory takings compensation), and two (covering eminent domain only) can be specified respectively as,

$$\ln\left(\frac{F_1}{1-F_1}\right) = \alpha_1 + \phi_1 \text{home}_1 + \eta_1 \text{highschool}_1 + \kappa_1 \text{bachelor}_1 + \rho_1 \text{income}_1 + \omega_1 \text{unemp}_1 + \psi_1 \text{density}_1 + \nu_1 \text{turnout}_1 + u_1 \quad (12)$$

and

$$\ln\left(\frac{F_2}{1-F_2}\right) = \alpha_2 + \phi_2 \text{home}_2 + \eta_2 \text{highschool}_2 + \kappa_2 \text{bachelor}_2 + \rho_2 \text{income}_2 + \omega_2 \text{unemp}_2 + \psi_2 \text{density}_2 + \nu_2 \text{turnout}_2 + u_2 \quad (13)$$

where F represents the proportion of yes votes for county i , $Home$ represents homeownership rate which refers to the percentage of occupied housing units that is owner-occupied. $Highschool$ is percentage of population 25 and above that has at least high school certificate, and $bachelor$ is percentage of population 25 and above with at least a bachelor degree. $Income$ refers to median income, $unemp$ to county unemployment rate in 2006, while $density$ is population density.

Alternatively, a pooled regression model that combines data across the two ballot measures may be estimated. Because the higher sample size in the pooled regression model enables more precise estimation of the model parameters, pooling the data is certainly the better option if the model parameters are stable across the two ballot types. The econometric model for the cross-sectional pooled regression is specified as,

$$\ln\left(\frac{F}{1-F}\right) = \alpha + \beta \text{ballottype} + \phi \text{home} + \eta \text{highschool} + \kappa \text{bachelor} + \rho \text{income} + \omega \text{unemp} + \psi \text{density} + \nu \text{turnout} + u \quad (14)$$

The ballot measure type variable is a binary variable that equals 1 for state ballot measures covering eminent domain and regulatory takings, and 0 for ballot measures

that cover eminent domain only. The choice between estimating separate regression models for each data subsample as in equations (12) and (13), and estimating a pooled regression model (equation 14) is made based on a test of parameter stability across the two data subsamples using the Chow test (Chow 1960). In particular, the Chow test is used to test the null hypothesis that parameter estimates in the regression model are equal across the two data groups. The null hypothesis for the Chow test can therefore be stated as,

$$\alpha_1 = \alpha_2, \phi_1 = \phi_2, \eta_1 = \eta_2, \kappa_1 = \kappa_2, \rho_1 = \rho_2, \omega_1 = \omega_2, \psi_1 = \psi_2, \text{ and } \nu_1 = \nu_2$$

A rejection of this null hypothesis indicates that the estimated parameters vary significantly across the two data groups. This calls for either estimating two separate models for the two data subsamples or accounting for variation of the estimated parameters across the two data groups using interaction terms if a pooled data is used.

The Chow test is based on the restricted and unrestricted sum of squared residuals from separate regressions on the two data sub-samples, and the pooled data respectively. The test statistic is written as,

$$F = \frac{[SSR_p - (SSR_1 + SSR_2)]}{SSR_1 + SSR_2} \cdot \frac{[n - 2(k + 1)]}{k + 1}$$

where n is the total number of observations in the pooled regression model, SSR_p is the sum of squared residual from regression on the pooled data, while SSR_1 and SSR_2 refer to the sum of squared residuals from regressions on the two separate sub-samples. The number of parameters (excluding the constant term) estimated in each regression is

represented by k . Table 1.2 below shows the estimated parameters for the three (two separate sub samples and the pooled data sample) data samples.

Comparing the estimated parameters in Table 1.2 across the data samples by inspection to determine if they are close enough to warrant the use a pooled data sample for the analysis (without adjusting for differences across ballot measure type) would yield unreliable results. Using the Chow test approach, the F-statistic for the test is given as,

$$F = \frac{[84.467 - (14.238 + 26.553)]}{14.238 + 26.553} \bullet \frac{[173]}{8} = 23.157$$

The returned F-statistic value of 23.157 can now be compared with a critical value from the F-distribution table to make a decision on the hypotheses being tested. Given the critical value at the 5% level of significance as 1.94, the null hypotheses that the estimated parameters are equal across the two data sub-samples can be rejected. This finding suggests that the modeling approach must account for this difference in the two samples when the data is pooled for analysis. This is done by introducing ballot measure type interaction terms that account for shifts in the impact of the explanatory variables across the two sub-samples.

Next, extending the findings in this study to the U.S. population in general requires verifying that the sample data being used is random. The statistical theory of estimation and hypothesis testing indicates that random sampling is fundamental to obtaining accurate estimates of population parameters (Wooldridge 2006). Violation of the random sampling condition produces biased and inconsistent estimates that render

inferences drawn from this sample data valueless for purposes of explaining voter decision choices outside the data sample.

States that have considered eminent domain and regulatory taking propositions in the 2006 midterm elections may not represent a random sample of U.S. states. The decision to reform eminent domain and regulatory takings law in a given state may be influenced by several factors. For instance, the influence of special interest groups in a given state's legislative decisions may be important in explaining the decision to reform eminent domain law. Also, whether a state already had some form of restriction on use of eminent domain power prior to the 2006 elections may have affected the decision to reexamine the law. It is therefore useful to verify if any set of variables systematically affect the decision to reform eminent domain in a given state and county.

The typical approach to addressing this selection bias problem is to employ the Heckman (1976) two-step procedure that involves estimation of a first stage equation (selection equation) that explains the decision to hold a referendum. Results from the first stage estimation are then incorporated into a second stage equation (outcome equation) that explains the decision of the average voter to vote yes/no on the ballot proposition at the polls.

The selection equation here is specified as,

$$W = \delta_0 + \delta_1 \text{home} + \delta_2 \text{highschool} + \delta_3 \text{bachelor} + \delta_4 \text{income} + \delta_5 \text{unemp} + \delta_6 \text{density} + \delta_7 \text{ingroup} + \delta_8 \text{takelaw} + \delta_9 \text{incidence} + \tau \quad (15)$$

where $W = 1$ for states that placed eminent domain on the 2006 election ballots and 0 otherwise. For the Heckman procedure to be effective in addressing any non-randomness in the sample data, the main variables in the outcome equation must also

appear in the selection equation. Here, the regulation type and voter turnout variables are dropped from the selection equation because they are meaningless and counter-intuitive as far as variables affecting the decision to reform eminent domain law are concerned.

In addition to the main variables used in the outcome regression in equation (16) two other variables are included in the selection equation to control for the effect of special interest groups (*ingroup*) and existing restrictions on state eminent domain law (*takelaw*). Both are dummy variables. Finally the *incidence* variable refers to per capita property takings in a given state. Thus this value is the same for all counties within a given state. It is expected that states with higher per capita takings would be more likely to present voters with a proposition to restrict the use of eminent domain power and require compensation for regulatory takings.

The Heckman procedure computes the so-called inverse Mills ratio ($\hat{\lambda}$) which is the ratio of the standard normal probability density function (pdf) to the standard normal cumulative density function (cdf) evaluated at the estimated model parameters and mean values of the explanatory variables. This new artificial variable ($\hat{\lambda}$) is incorporated into the output equation as shown in equation (16) below,

$$\ln\left(\frac{F}{1-F}\right) = \beta_0 + \beta_1 \text{ballottype} + \beta_2 \text{home} + \beta_3 \text{home} * \text{ballottype} + \beta_4 \text{highschool} + \beta_5 \text{highschool} * \text{ballottype} + \beta_6 \text{bachelor} + \beta_7 \text{bachelor} * \text{ballottype} + \beta_8 \text{income} + \beta_9 \text{income} * \text{ballottype} + \beta_{10} \text{unemp} + \beta_{11} \text{unemp} * \text{ballottype} + \beta_{12} \text{density} + \beta_{13} \text{density} * \text{ballottype} + \beta_{14} \text{turnout} + \varpi \hat{\lambda} + \beta_{15} \text{Ariz} + \beta_{16} \text{Calif} + \dots \beta_{22} \text{Ore} + \xi \quad (16)$$

The coefficient of the inverse Mills ratio can be tested using the regular t-ratio test. If $\varpi = 0$, then τ and ξ are uncorrelated and the new variable $\hat{\lambda}$ should not appear in the voter decision regression model. This means there is no evidence of selection bias in estimation of the outcome equation. Results for the Heckman procedure are shown in Table 1.3 below.

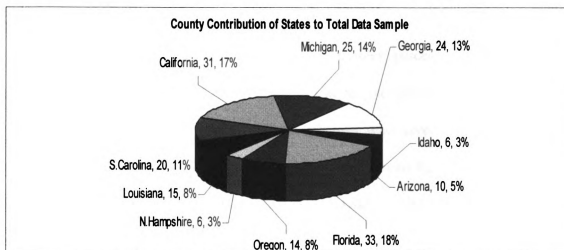
The standard error of 0.072 for the inverse Mills ratio parameter ϖ here indicates that the Mills ratio variable is not statistically significant at the 10 percent level. This implies that there is no need to control for sample selection bias in the model. The model is thus estimated without the Mills ratio parameter.

1.4 Data

The paper uses cross-sectional county level data covering yes/no vote outcomes on eminent domain and regulatory taking propositions in the 2006 mid-term elections. The dependent variable in the model is the logodds of yes votes as defined in equation (11) and the source of the vote data is the University of Michigan library government documents centre (University of Michigan, 2006). The sample size of the data is 189. Figure 1 below shows the contribution of the various states to the total sample size. Florida has the highest county contribution of 18 percent followed by California with 17 percent. On the lower end New Hampshire and Idaho contribute 3 percent each to the total sample size.

Figure 1

Composition of the data by contributing states



The variation in state contribution to total sample size is influenced by several factors including the number of reporting counties in a state, and availability of data for other variables in the model for the county concerned. Summary statistics for all variables used in the model are shown in Table 1.4 below. The table provides information on the sample size, unit of measure, mean, standard deviation, minimum, and maximum values for each variable. Data summary statistic tables are useful in identifying unusual observations and providing a quick impression about the distribution of variables in the model.

The ballot measure type variable is a binary variable that equals 1 for state ballot measures covering eminent domain and regulatory takings, and 0 for ballot measures that cover eminent domain only.

The remaining independent variables included in the model are homeownership rate, education, income, population density, unemployment rate, and turnout. Homeownership rate is represented by the percent of occupied housing units that were owner-occupied in 2006. This data is obtained from the 2006 U.S Census Bureau's

American Community Survey. The data is limited to household population and excludes population living in institutions, college dormitories, and other group quarters.

Level of education is represented by two variables: percent of people 25 years and over who have completed high school education (includes equivalency) in 2006 (*highschool*), and percent of people 25 years and over who have completed bachelors degree in 2006 (*bachelors*). The income variable is measured by the level of Median Household Income (in 2006 Inflation-Adjusted Dollars). The source for both the education and income variables is the 2006 American Community Survey data tables (American Community Survey, 2006). Population density is measured by the number of people living per square mile in each county and is computed using July 1 2006 population estimates and county area (land area in square miles) data. The source of this data is the population division of U.S. Census Bureau (U.S. Census Bureau, 2006).

County level unemployment rate data is taken from the Bureau of Labor Statistics' local area unemployment statistics. The title of this data at source is "labor force data by county, 2006 annual average (US department of labor, 2006)". Election turnout is computed as the ratio of votes cast to number of registered voters in a county.

To estimate the Heckman sample selection regression, the data sample size is increased to 661 by including counties that did not consider eminent domain and regulatory taking ballots. Additional explanatory variables included in the dataset to allow for the implementation of Heckman sample selection regression are special interest groups (*ingroup*), existing restrictions on state eminent domain law (*takelaw*), and an *incidence* of takings variable that refers to per capita property takings in a given state. Thus this value is the same for all counties within a given state. The interest group

variable is taken from Thomas and Hrebenar (2004). This variable is defined to equal 2 when the impact of interest groups in formulating laws is dominant, 1 when such groups play just a complementary role in regulation formulation, and 0 when interest groups are subordinate to other interests that influence law making in a given state. *Takelaw* is a dummy variable that equals 1 when counties in a given state had some state restrictions on the use of eminent domain power before the 2006 elections and equals 0 otherwise. The *incidence* of taking variable on the other hand is measured by per capita property taking in a state. The source of the *Takelaw* and *incidence* data is the Castle Coalition (2007).

1.5 Results

Results of the regression analyses are presented in Table 1.5 below. Three sets of results are presented, the logit estimates, odds coefficient estimates, and the odds elasticity values. The logit coefficients measure the change in logit or logodds of voting yes for a one unit increment in the explanatory variables. The odds ratio estimates indicate the value by which the odds of voting yes is multiplied for a unit increase in a given independent variable. An odds ratio of 1.0 therefore corresponds to a zero marginal effect of the logit coefficient suggesting that the independent variable concerned has no effect on the logodds of voting yes. An odds ratio of 1.5 thus implies the odds of voting yes is multiplied by 1.5 for a unit increase in the independent variable concerned.

In general, odds ratios above 1.0 indicate an increase in the odds of voting yes as the explanatory variable increases while odds ratios below 1.0 indicate that the odds of

voting yes decrease with an increase in the explanatory variable concerned. Finally, the odds elasticity estimates offer a more direct interpretation of the estimation results. The computed odds elasticity¹ values give the percentage change in the odds of a yes vote for a one percent change in an explanatory variable. A detailed explanation of the effect of right side variables on the dependent variable now follows.

The ballot measure type variable is statistically significant at the 5 percent level in explaining the vote outcomes. The result from Table 1.5 indicates that if the impact of ballot measure type on vote outcomes has nothing to do with the other independent variables in the model (all interaction terms set to zero) then moving from a measure that covers eminent domain only to one that covers eminent domain and regulatory compensation decreases the logodds of voting yes by -2.888, and gives an odds ratio of voting yes of 0.056. This implies that the odds of voting yes are multiplied by 0.056 as a result of this change in ballot measure type. This finding is consistent with the hypothesized relationship which suggests that voters appear to support imposing restrictions on use of eminent domain power but oppose requiring compensation for regulatory takings. Combining these two issues on one ballot increases the proportion of voters rejecting the ballot relative to presenting a ballot on restricted use of eminent domain only. This suggests that the strength of voter opposition to regulatory taking compensation exceeds support for restricted use of eminent domain.

¹ The (direct) *odds elasticity* with respect to a given attribute X_i (where $[z^i, h^i] \in X_i$) is given by,

$$\frac{\partial(F_i)/\partial(1-F_i)}{\partial X_i} \bigg/ \frac{(F_i)/(1-F_i)}{X_i} = \beta_i X_i \quad . \text{ See Fridstrom and Elvik (1997)}$$

When interaction of ballot measure type and other independent variables are accounted for, the unique effect of ballot measure type on vote outcome now becomes,

$$-2.888 + 0.021 * \overline{highschool} - 0.022 * \overline{income} + 0.107 * \overline{unemp} + 0.041 * \overline{popdensty}$$

Substituting the mean values of the interaction terms for *highschool*, *income*, *unemp*, and *popdensity* gives the overall logit coefficient of ballot measure type as -2.548. The corresponding odds value is 0.08. Overall, the impact of ballot measure type on the vote outcome is negative as hypothesized. In summary the finding here indicates that combining questions on restricted use of eminent domain power and regulatory compensation on the same ballot reduces the odds of passing the ballot on eminent domain.

Since the two ballot issues being analyzed here (eminent domain and regulatory takings) affect property owners directly, homeownership can be expected to be important in explaining the vote outcomes on these issues. Homeownership rate, which refers to the percent of occupied housing units that was owner-occupied in 2006, is however found to be statistically insignificant at the 5 percent level in explaining the vote results. Variations in homeownership rate do not affect the chances that a voter would vote yes at the polls. The non-significance of homeownership rate in explaining the vote outcomes is inconsistent with the hypothesized positive impact. This finding is however consistent with the November 2005 survey results by the Saint Index organization (see Somin 2007) on the *Kelo* ruling which indicates that renters reject the *Kelo* ruling almost as strongly as homeowners. In particular, 70 percent of renters opposed the ruling while 83 percent of homeowners also opposed the ruling. This implies that homeownership is simply not an important explanatory factor of voters'

position on eminent domain reforms. The results from this regression analysis show that this is true for regulatory taking reforms as well.

The capability of voters in understanding the costs and benefits associated with eminent domain and regulatory takings may also be important in explaining the vote choices. Two measures of education are included in the model (*highschool* and *bachelor*) to control for knowledge of voters. The impact of *highschool* on the vote outcome was found to be dependent on ballot measure type: *highschool* is statistically significant at the 5 percent level in explaining vote outcomes on eminent domain and regulatory takings initiatives but insignificant when the ballot measure involves eminent domain only. In other words, when ballot measure type is set to 1, the odds elasticity values indicate that the effect of a one percentage point increase in the percentage of people 25 and over that hold at least a *highschool* certificate increases the odds of voting yes by 1.8 percent. When ballot measure type is set to 0 *highschool* has zero effect on vote outcomes. On the other hand, the impact of the higher measure of education (*bachelor*) is independent of ballot measure type. A one percentage point increase in the percentage of people 25 and over that hold at least a bachelor's degree decreases the odds of voting yes by 0.35 percent.

This finding is interesting: a more broad measure of high education (*highschool*) correlates positively with yes votes while the finer and more rigorous measure (*bachelor*) results in a decline in yes votes. This points to some threshold in the effect of education on restricted use of eminent domain and regulatory compensation, and possibly on the environment in general. It takes a level of education above *highschool*

for education to have a positive impact on environmental and resource conservation measures.

In general, as the level of education of voters increases support for the ballot measure declines. Thus counties with more highly educated voters appear to be less supportive of more stringent property rights protection, and regulatory takings compensation. High education affects actual takings as well. Lanza (2006) for instance found that high education (per capita number of legal workers) positively affects the number of takings at the state level in the U.S.

Strength of the economy is another category of variables that can be expected to influence voter support for ballot propositions. Voter dissatisfaction with bad economic conditions generally erodes support for ballot proposals because of low support for government (Clarke and Kornberg 1994, Bowler and Donovan 1994). The regression analysis here controls for two measures of economic strength, household income and unemployment rate. Income is statistically significant at the 5 percent level in explaining the vote outcomes irrespective of the ballot measure type under consideration. Lower median household income counties are more likely to vote yes. Since income is measured in thousands of dollars, a \$ 1000 increase in median household income increases the logit of voting yes by $0.016 - 0.022 * \overline{ballottype}$. Setting ballot measure type to 1 gives a logit estimate of -0.006, and results in multiplication of the odds of voting yes by 0.994. On the other hand, setting ballot measure type to 0 gives a logit estimate of 0.016, and results in multiplication of the odds of voting yes by 1.016. Using the computed odds elasticity values, a one percentage point increase in income reduces the odds of voting yes by 0.28 percent

when ballot measure type is set to 1. On the other hand, when the impact of income is independent of ballot measure type, a one percentage point increase in income increases the odds of voting yes by 0.75 percent. This finding of negative relationship between income and yes votes for restricted use of eminent domain and regulatory compensation is consistent with the hypothesized relationship that benefits expected from property takings are normal goods.

In summary, the results indicate that education and income have similar effects on the dependent variable. Both have a negative effect on increased property rights protection and regulatory compensation. This finding is consistent with the hypothesized relationship which posits that both education and income would correlate negatively with yes votes. It also indicates that when confronted with a choice between more secure property rights and a healthier environment both educated and high income voters lean towards protecting the environment. This implies that this class of voters worry less about losing their property to government takings and probably confirms previously discussed reports that property takings tend to affect poorer communities disproportionately.

Unemployment rate, the second measure of economic strength is statistically significant at the 5 percent level in explaining vote outcomes irrespective of ballot measure type. Higher unemployment rates have a negative effect on the logodds of voting yes at the polls. A one percent increase in unemployment rate decreases the logit of yes votes by $-0.119 + 0.107 * \overline{ballottype}$. Setting ballot measure type to 1 gives a logit estimate of -0.01, and results in multiplication of the odds of voting yes by 0.990. Setting ballot measure type to 0 gives a logit estimate of -0.106, and results in

multiplication of the odds of voting yes by 0.888. The results therefore indicate that unemployment has greater effect on eminent domain only ballots than it has on eminent domain and regulatory takings combined.

Using the computed odds elasticity values, a one percent increase in unemployment rate reduces the odds of voting yes by 0.06 percent when ballot measure type is set to 1, and by 0.60 percent when ballot measure type is set to 0. This implies that voters in counties that are relatively weak economically tend to support relaxation of restrictions on use of eminent domain power but are less supportive of regulatory taking compensation. The effect of unemployment therefore re-enforces the finding for income: High income and low unemployment rate both result in an increase in the odds of voting yes for restricted use of eminent domain power and regulatory takings compensation.

Population density is included in the model to capture rural-urban differentials in the perceived benefits and costs of eminent domain power and regulatory takings. Population density is statistically significant at the 5 percent level in explaining changes in the vote outcome only when it is interacted with ballot measure type. When ballot measure type is 0, population density has zero effect on the vote outcomes. This is consistent with Lanza's finding of no relationship between population density and actual property takings (eminent domain takings).

When ballot measure type is set to 1, a 100 unit increase in population density is associated with a 0.041 increase in yes votes and a multiplication of the odds ratio by 1.042. Using the elasticity estimates, a one percent increase in population density increases the odds of voting yes by 0.1 percent when ballot measure type is set to 1.

This means population density does not affect voters' position on eminent domain as it does on regulatory takings compensation.

Turnout in this model has the expected negative and statistically significant (at 5 percent level) effect on the vote outcome. Higher turnout at the polls is associated with rejection of the ballot measure as hypothesized. In particular, a one percent increase in turnout reduces the logits of yes votes by 0.01 and results in a multiplication of the odds of a yes vote by 0.99. The computed elasticity value indicates that a one percent increase in turnout results in 0.50 percent decline in yes votes. As noted by Hadwiger this finding raises a question for future research.

Mean Response

Evaluating the independent variables in the model at their mean values, the model predicts that the logodds of voting yes for the average voter is 0.940. This value is associated with an odds value of 2.56 and a probability² of voting yes of 0.719. Thus the model predicts that the average voter in this dataset is more likely to vote yes to call for additional restrictions on use of eminent domain and regulatory takings than not.

Application of Results

The results from this research are insightful and useful in revealing how vote outcomes at the county and state levels could change for a given change in each of the statistically significant explanatory variables. First, it is evident from the results that if

² Probabilities can be obtained from the computed odds using the formula, $\hat{p} = \frac{odds}{1 + odds}$

the policy objective is to get voters to vote no to imposing additional restrictions on eminent domain power, then adding a requirement for regulatory taking compensation increases the chances of doing so. Taking the results for Florida as an example, 69 percent of voters voted yes to pass the measure that calls for restricted use of eminent domain power. This gives the odds of a yes vote of 2.226 as shown in Table 1.6 below. The results from this analysis indicate that adding regulatory takings to eminent domain on this ballot could have resulted in multiplication of this odds by 0.08 giving the new odds value of 0.18. Note that this reverses the observed result from a “pass” to “fail”. Similar analyses can be performed for the remaining explanatory variables at both the state and county levels. Table 1.6 below presents new odds value for yes votes for the states included in the data for this study when ballot measure type is set to 1. The dramatic impact of combining these ballots is clear from the results in this table. The percentage decline in the odds of passing the ballot is approximately 92 percent across states.

The impact of ballot measure type on the odds of yes votes is however significantly reduced when combined with the impact of other variables in the model. Table 1.7 below gives predicted odds values from the estimated model for all 51 U.S. states. Taking the Florida vote results as example again, the predicted odds of yes votes when ballot measure type =1 is 0.499 suggesting that the ballot fails when restricted use of eminent domain is combined with regulatory taking compensation. Consistent with the actual vote results, the model predicts that the ballot in Florida passes when ballot measure type = 0.

Results from Table 1.7 basically indicate that the ballot measure passes in all states when presented as an eminent domain taking only ballot. Once restricted use of eminent domain is combined with regulatory taking compensation the ballot fails in all states except in DC. The computed predicted odds for DC are particularly high because of the very high population density value for this state. The results in Table 1.7 still do not tell the whole story about what affects the passage of restricted use of eminent domain and regulatory compensation ballots since the ballot passed in Arizona (see Table 1.1) even though these two issues were combined. The Arizona ballot result shows that the negative impact of requiring regulatory taking compensation (although generally high) may not be high enough to reverse the passage of restricted use of eminent domain power measures in all cases.

1.6 Conclusions

The empirical analysis from this study has produced very interesting and insightful results about voter decision-making on property takings in the U.S. It is clear that voters do not look at eminent domain and regulatory taking compensation in the same light. While the average voter leans more towards strengthening property rights protection (restricting use of eminent domain) and providing at least market value compensation for eminent domain takings, adding compensation for property use regulations reduces this support significantly. This implies that to obtain an accurate estimate of demand for each of these two institutional measures it is important to present them to voters in separate ballot questions.

Restoring landowners to their status quo welfare position however requires full compensation for all takings (both eminent domain and regulatory takings). The results here suggest that the average voter may be looking at taking compensation in a more practical and cost effective way. For instance, while it is relatively easy to determine compensation values for eminent domain takings, determining such value for regulatory takings is a much more complicated and expensive task. Studies may have to be initiated to determine property value losses imputable to the regulatory taking action. Given that the cost of financing such studies may be substantial relative to the compensable values, it makes sense that the average voter is side-stepping this requirement.

Homeownership rate does not appear to significantly explain the vote outcomes at all. This is an interesting finding since property right is central to the entire argument on eminent domain and regulatory taking reforms. However, the November 2005 survey results by the Saint Index polling organization (Somin 2007) on the *Kelo* ruling throws more light on the non-significance of homeownership rate in explaining the vote outcomes. This survey result indicates that renters reject the *Kelo* ruling almost as strongly as homeowners. This clearly weakens any distinguishing impact of homeownership rate on vote choices.

Strength of the economy also matters in voter decision making on eminent domain takings. Counties with higher average unemployment rates are more supportive of relaxing requirements for eminent domain takings and regulatory compensation. This is in line with the hypothesis that voters in weaker economies would tend to support relaxation of the requirements for takings to promote economic activity and job

creation. The effect of unemployment also re-enforces the finding for income: high income and low unemployment rate both result in an increase in the odds of voting yes for restricted use of eminent domain power and regulatory takings compensation. This finding is consistent with those from several other studies that indicate that voter dissatisfaction with bad economic conditions erodes support for ballot proposals because of low support for government (Clarke and Kornberg 1994, Bowler and Donovan 1994).

The results indicate that education and income have a negative effect on increased property rights protection and regulatory compensation. It indicates that when confronted with a choice between more secure property rights and a healthier environment both educated and high income voters lean towards protecting the environment. This implies that this class of voters worry less about losing their property to government takings and probably confirms previously discussed reports that property takings tend to affect poorer communities disproportionately.

The results from this study as well as those from Lanza (2006) indicate that population density is not an important variable in explaining both actual eminent domain takings and voter decisions on eminent domain takings. The new finding here is that population density does explain vote outcomes on regulatory takings compensation. This is probably due to the relatively higher value of open space in highly populated urban areas as compared to rural areas. Finally, consistent with the hypothesized relationship in this study as well as previous findings on protest votes, election turnout was found to negatively affect passage of restricted use of eminent domain and regulatory takings compensation ballots.

TABLES

Table 1.1
Summary of Results for all Eminent Domain Ballots in 2006

State	Measure #	Topic Area	Pass/Fail
Arizona	<u>Prop. 207</u>	Eminent domain & regulatory takings	Pass (64.8%)
California	<u>Prop. 90</u>	Eminent domain & regulatory takings	Fail (47.6%)
Florida	<u>Amendment 8</u>	Eminent domain	Pass (69%)
Georgia	<u>Amendment 1</u>	Eminent domain	Pass (82.7%)
Idaho	<u>Prop. 2</u>	Eminent domain & regulatory takings	Fail (23.9%)
Louisiana	<u>Amendment 5</u>	Eminent domain	Pass (55%)
Michigan	<u>Proposal 06-4</u>	Eminent domain	Pass (80.1%)
Nevada	<u>Question 2</u>	Eminent domain	Pass (63.1%)
New Hampshire	<u>Question 1</u>	Eminent domain	Pass (85.7%)
North Dakota	<u>Measure 2</u>	Eminent domain	Pass (67.5%)
Oregon	<u>Measure 39</u>	Eminent domain	Pass (67.1%)
South Carolina	<u>Amendment 5</u>	Eminent domain	Pass (86%)
Washington	<u>Initiative 933</u>	Regulatory takings	Fail (41.2%)

Source: National Conference of State Legislatures: Property Rights Issues on the 2006 Ballot.

Washington State is not included in the data set considered for this study because the vote initiative involves only regulatory taking. Nevada and North Carolina are dropped from the study due to missing data problems for other variables in the model

Table 1.2

Estimated Logit Coefficients by Ballot Measure Type and Pooled Data Sample
 (Dependent variable: logodds of yes votes)

Variable	Estimated results when ballot type=1	Estimated results when ballot type=0	Estimated results when data is pooled
Homeownership	-0.005 (0.015)	0.010 (0.007)	0.038* (0.008)
High school	0.019 (0.018)	0.018 (0.011)	0.031* (0.013)
Bachelors	0.017 (0.019)	0.017 (0.010)	0.017 (0.012)
Income	0.017 (0.013)	0.027* (0.006)	-0.008 (0.007)
Unemployment rate	0.065 (0.051)	0.212* (0.021)	0.138* (0.034)
Population density	-0.052 (0.062)	0.006 (0.023)	0.045 (0.027)
Turnout	-0.008 (0.017)	-0.001 (0.004)	-0.019* (0.027)
Constant	-1.335 (1.250)	-0.542 (0.717)	-4.175* (0.724)
R-square	0.162	0.432	0.308

Note: Values in parentheses are standard errors and * implies the estimate is statistically significant at 5% level

Table 1.3**Heckman Sample Selection Regression Results**

(Dependent variable: Selection Equation-Decision to hold referendum (W))

: Outcome Equation-logodds of yes votes

Variable	Selection Equation	Outcome Equation
Ballot type	-	1.189 (1.549)
Homeownership	-0.021 (0.009)	0.020* (0.007)
Homeownership*ballot type	-	-0.028 (0.019)
High school	-0.014 (0.009)	-0.021 (0.013)
High school*ballot type	-	0.024 (0.010)
Bachelors	0.001 (0.008)	0.022* (0.010)
Bachelors*ballot type	-	-0.042 (0.023)
Income	0.008 (0.006)	-0.020* (0.006)
Income*Ballot type	-	-0.015 (0.016)
Unemployment rate	0.116 (0.004)	0.194* (0.029)
Unemployment rate*ballot type	-	-0.018 (0.040)
Population density	-0.029 (0.024)	0.011 (0.024)
Population density*ballot type	-	-0.044 (0.040)
Turnout	-	-0.012* (0.004)
Taking Law	-0.708 (0.224)	
Interest group	0.087 (0.094)	
Taking Incidence	0.046 (0.011)	
Mills ratio		0.543 (0.398)
Constant	1.119 (0.978)	-0.566 (0.875)

Note: Values in parentheses are standard errors and * implies statistically significant at 5% level

Table 1.4
Summary Statistic of Variables

Variable	Unit	Mean	Standard Deviation	Min	Max
Yes Votes (logodds)		0.931	0.806	-1.537	2.223
Yes votes	Percent	69.600	16.300	17.700	90.200
Ballot type		0.249	0.433	0	1
Homeownership rate	percent	69.740	8.247	45.200	87.800
High school	percent	83.971	6.396	62.300	96.000
Bachelors	percent	23.412	8.166	10.000	52.600
Income	'000\$	46.576	9.551	23.119	81.761
Unemployment rate	percent	5.048	2.014	2.400	15.300
Population density	Pop/miles ² ('00)	2.523	1.988	0.063	9.462
Turnout	percent	50.008	12.712	2.032	75.700

Table 1.5³

Estimated Logit, Odds, and Odds Elasticity Results
 (Dependent variable: logodds of yes votes)

Variable	Logits	Odds	Odds elasticity
Ballot type	-2.888* (0.976)	0.056	-
Homeownership	0.002 (0.004)	1.002	0.139
High school	-0.006 (0.009)	0.994	-0.504
High school*ballot type	0.021* (0.015)	1.021	1.763
Bachelors	-0.015* (0.006)	0.985	-0.351
Income	0.016* (0.004)	1.016	0.745
Income*Ballot type	-0.022* (0.010)	0.978	-1.025
Unemployment rate	-0.119* (0.035)	0.888	-0.601
Unemployment rate*ballot type	0.107* (0.040)	1.113	0.540
Population density	-0.007 (0.014)	0.993	-1.766
Population density*ballot type	0.041* (0.023)	1.042	0.103
Turnout	-0.010* (0.004)	0.990	-0.500
Constant	1.514* (0.658)	4.545	-
R-square	0.930		

Note: Values in parentheses are standard errors and * implies the estimate is statistically significant at 5% level

³ Results exclude nine State-dummy variables that were included in the regression

Table 1.6

State-Level Odds of Yes Votes When Ballot Measure Type = 1

Variable	Yes Odds for Actual Vote Results	Yes Odds for Actual Votes (When Ballot Type=1)
Florida	2.23	0.18
Georgia	4.78	0.38
Louisiana	1.22	0.10
Michigan	4.03	0.32
New Hampshire	5.99	0.48
Oregon	2.04	0.16
S. Carolina	6.14	0.49

Table 1.7
State Predicted Odds of Passing Eminent Domain Ballots by Ballot Measure Type

No.	States	Predicted Odds when ballot measure type=0	Predicted Odds when ballot measure type=1
1	Alabama	2.541	0.471
2	Alaska	2.177	0.433
3	Arizona	2.793	0.495
4	Arkansas	2.321	0.552
5	California	2.966	0.431
6	Colorado	2.360	0.421
7	Connecticut	3.774	0.529
8	Delaware	3.596	0.549
9	DC	94.550	18.580
10	Florida	2.871	0.499
11	Georgia	2.635	0.481
12	Hawaii	4.257	0.523
13	Idaho	2.756	0.526
14	Illinois	2.834	0.490
15	Indiana	2.804	0.581
16	Iowa	2.554	0.519
17	Kansas	2.391	0.498
18	Kentucky	2.122	0.492
19	Louisiana	2.874	0.542
20	Maine	2.164	0.488
21	Maryland	3.820	0.475
22	Massachusetts	3.277	0.516
23	Michigan	1.736	0.447
24	Minnesota	2.363	0.413
25	Mississippi	2.750	0.754
26	Missouri	2.541	0.471
27	Montana	2.191	0.472
28	Nebraska	2.203	0.474
29	Nevada	2.725	0.504
30	New Hampshire	3.322	0.526
31	New Jersey	3.158	0.454
32	New Mexico	4.733	0.643
33	New York	2.352	0.470
34	North Carolina	3.088	0.531
35	North Dakota	2.744	0.553
36	Ohio	2.616	0.519
37	Oklahoma	2.363	0.538
38	Oregon	3.805	0.822
39	Pennsylvania	1.985	0.448
40	Rhode Island	4.219	0.849

Table 1.7
State Predicted Odds of Passing Eminent Domain Ballots by Ballot Measure Type
Continued

41	South Carolina	3.251	0.564
42	South Dakota	2.033	0.501
43	Tennessee	2.387	0.461
44	Texas	2.365	0.512
45	Utah	2.663	0.486
46	Vermont	3.352	0.553
47	Virginia	2.291	0.438
48	Washington	3.314	0.443
49	West Virginia	2.431	0.466
50	Wisconsin	2.622	0.612
51	Wyoming	2.367	0.477

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Essay 2

Information and Bargaining Breakdowns in Eminent Domain Takings

2.1 Introduction

The fifth amendment of the U.S. constitution is non-specific on the requirement for just compensation in eminent domain takings (United States 1791). This non-specificity about the definition of just compensation makes bargaining between owners and local governments an integral part of eminent domain takings.

Eminent domain bargaining is however often plagued with owner holdouts. Holdouts generally refer to the rejection of government compensation offers by private owners in an attempt to extract higher compensation for loss of their properties (Fennel 2005, Parchomovsky and Siegelman 2004). Fennel (2005) and Parchomovsky and Siegelman (2004) distinguish between two non-selling owners. They describe holdouts as owners who refuse to sell in an attempt to extract a substantial share of government surplus from property rights transfer. Holdins on the other hand refer to owners who refuse to sell because they truly value their properties above the government compensation offer. Holdouts as used in this paper cover both categories of non-selling owners and the results derived here are relevant across these two classes of owners.

Holdouts introduce inefficiency into the economic system by imposing delay costs on government and possibly preventing mutually beneficial trades from being realized (Munch 1976, Bell and Parchomovsky 2005). The threat of use of eminent domain power reduces delay costs resulting from such holdouts by reducing the

bargaining period through forceful taking over of properties involved in protracted negotiation.

The holdout problem is further deepened by owner asymmetric information problems about the true value government places on the property under threat of taking (Menezes and Pitchford 2004, Fudenberg and Tirole 1983). This information, which is private to the government, is important in determining the ceiling price offer (maximum price government is willing to pay) of government. The main premise of this paper is that extended holdouts and bargaining breakdowns result from this asymmetric information problem because owners attempt to bargain for prices that are beyond the ceiling price of government.

The economic modeling of holdouts in eminent domain takings has received little attention from economists. As noted by Miceli and Segerson (2007), although the holdout problem has been discussed widely in the economics literature, few authors have attempted to model the problem formally. Miceli and Segerson (2007) modeled the problem of eminent domain holdouts by considering a two-period bargaining problem between a developer and two owners. In this setting, they observed that holding out is one of two possible sub-game perfect Nash equilibria, the other being first-period sale of all parcels. When use of eminent domain power is introduced in period two to take parcels that the developer was not able to acquire consensually in period one and when compensation for takings is set at a property's market value, they found that the unique sub-game perfect Nash equilibrium is for all owners to sell in period one. Thus, the mere threat of eminent domain is sufficient to overcome the holdout problem.

In practice, the threat of eminent domain has not been sufficient in overcoming the holdout problem. Eminent domain bargainings often end up in the courts due to breakdowns in bargaining over acceptable compensation (Parchomovsky and Bell 2006). Clearly, the threat of use of eminent domain power appears to be less effective in practice than theoretical predictions suggest.

This paper reconciles the theoretical and observed results by explaining bargaining breakdowns. First, using a single owner and government bargaining model the conditions under which the threat of eminent domain guarantees resolution of the holdout problem are stated and explained. Next, the informational assumptions are relaxed to explain how owner information affects the chances of bargaining breakdown when the model accounts for uncertainty (incomplete information). Results indicate that the less informed owners are about the payoff of government the greater is the gap between the theoretical predictions of the effectiveness of eminent domain in resolving holdouts and actual observations of bargaining breakdowns. This gap declines as the owner's subjective probability that government accepts a counter price offer increases with improved owner information about the payoff of government.

In general, it is shown that eminent domain resolves holdouts completely when negotiating owners engage in a complete and perfect information bargaining game. Information is complete when the payoff of all parties in a bargaining game is common knowledge (Gibbons 1992). This implies that both government and owner are privy to each other's exact payoff at every stage of the game. A party in the bargaining game has perfect information when at every move of the game the history of the game up to that point is known to this player (Gibbons 1992). This indicates that there are no

simultaneous moves at any stage of the game. Thus at the time each player makes a move in the game, the player can review all previous moves in the game up to that point.

The rest of the paper is ordered as follows. The next section presents and solves a dynamic two period complete and perfect information game between an owner and a government. This is followed by the individual owner bargaining problem under incomplete information, discussion of results, and conclusions.

2.2 Bargaining Under Complete and Perfect Information

In this section of the paper, information about the payoffs of both agents in the bargaining game as well as the history of the bargaining process is assumed to be common knowledge to both agents. This information assumption guarantees early resolution of the holdout issue by eliminating uncertainty and directing the equilibrium price search rapidly towards a feasible price range.

To see this, consider a land market where a local government engages a property owner in bargaining to acquire the owner's property for a public project. Let the owner and government valuation of the property be given as v_L and v_G respectively. Also let the market value for properties identified for taking be represented by m . For simplicity, it is assumed that court decisions on owner challenges to the right of government to use eminent domain power always go in favor of government and courts always award the market value of properties as the appropriate compensation. This implies that owners can only look forward to market value compensation if they opt for

court settlement. The same is true when owners make overly high counter price offers that compel government to seek court settlement.

Two types of costs are considered in the payoff functions of government and owners. Government incurs delay costs of d by the time a court decision is made if the owner holds out, while both government and owners incur court costs of ℓ when court settlement becomes necessary.

Bargaining between the owner and government occurs in two sequential rounds. First, government offers the owner a price p_G . The owner responds by choosing an asking price p_L . If $p_G = p_L$, the owner accepts the government's offer and the game ends. If $p_L > p_G$, government enters the second round of negotiations and decides whether p_L is acceptable or not. Government accepts p_L if $p_L \leq v_G$ and proceeds to evoke the use of eminent domain power if $p_L > v_G$. The bargaining game is illustrated in the game tree in Figure 1.

The game tree in Figure 1 indicates that the bargaining game begins with the government (G) making the offer p_G to the owner (L). If the owner accepts the offer the owner gets the payoff $p_G - v_L$ and the government gets $v_G - p_G$. If the owner rejects this offer then the game enters the second period with the owner making a counter offer denoted by p_L . If the government accepts this counter offer then the owner and the government get the payoffs $p_L - v_L$ and $v_G - p_L$ respectively. On the other hand if the government rejects the counter offer the case is settled in court. The payoff to government and the owner when there is a court settlement is given by

$v_G - m - d - \ell$ and $m - v_L - \ell$ respectively. For simplicity, both government and owner are assumed to be patient about receipt of the net benefits from the property rights transfer and thus do not discount these values.

For a finite bargaining game of perfect information like the one described here a pure strategy unique Nash equilibrium outcome can be derived using the backward induction approach (Gibbons 1992, Mas-Collel A. et al 1995). Beginning in the second and final stage of the game, the government compares its payoff from rejecting the owner's counter-offer and settling the case in court to what is obtainable from accepting the counter offer. For government not to go to court, the payoffs from accepting the owner's counter offer $v_G - p_L$ must be equal or greater than that from a court settlement, $v_G - m - d - \ell$. Equating these two payoffs gives $p_L = m + d + \ell$ implying that government goes to court only if $p_L > m + d + \ell$. Here, assume that $v_G > m + d + \ell$ since government has no incentive to proceed with a taking otherwise. The result shows that the maximum compensation that government is willing to pay is equivalent to the sum of the market value of the property (m), delay costs (d), and estimated legal costs from court litigation (ℓ). An owner counter offer exceeding this value is rejected paving the way for a court settlement.

If government will pay $p_G = m + d + \ell$ in period 2 then it might as well offer this amount as compensation in period 1 to end the bargain game. This is because there is no benefit to government in allowing for protracted negotiations under this circumstance. Introducing discounting into the problem makes it more evident that it pays for government to end the bargaining early to maximize the discounted net

benefits from the project. The owner accepts this first offer in period 1 and the game ends.

Turning to the owner's moves in the game, it is obvious that the owner gets the worst payoff (less than market value compensation) by going to court. Thus in principle the owner would find an offer of $p_G = m - \ell$ in period 1 acceptable if offered since it is not worse than what is available to the owner after court settlement. However, the owner would reject this offer ($m - \ell$) and make a counter offer that is just less than or equal to $m + d + \ell$. This is because the owner is privy to the fact that any threat by government to use eminent domain power is not credible until the owner's counter offer exceeds $m + d + \ell$. Like all dynamic games, credibility of the threat to use eminent domain power is very important in arriving at the equilibrium outcome in this game. In fact backward induction outcomes by definition must be devoid of all non-credible threats.

In summary the backward induction equilibrium outcome of this bargaining problem is for government to offer the owner a compensation of $m + d + \ell$ in the first period ($p_G = m + d + \ell$). The owner accepts the offer and the game ends. The owner thus gets well in excess of market value as compensation when the theoretical information assumptions in this section are true. The finding that the owner receives more than market value in the unique Nash equilibrium is quite consistent with what may be expected in a free market exchange between government and the owner. Given that the owner in question did not put the property on the market for sale at the going market price before government expressed interest, it must be the case that the owner values this property above market price.

This result is consistent with the findings by Miceli and Segerson (2007) in their three-way bargaining problem that involves two owners and a developer. Miceli and Segerson observed that when both owners bargain in the first period the optimal compensation for each owner is given as, $m + \frac{2\tau + \delta}{3}$ where, τ and δ refer respectively to the transaction/litigation costs, and delay costs incurred by the developer. On the other hand, if only one of the two owners decides to bargain in the first period (with the other holding out) then the optimal compensation for the bargaining owner is, $m + \frac{\tau}{2}$ while the lone owner holding out receives m . Given that the payoff to each owner from bargaining in the first period exceeds that from holding out it is evident that both owners would bargain in the first period.

The threat of eminent domain therefore clearly solves the holdout problem and the optimal taking compensation exceeds market value compensation. However, it is worth noting that this result is only obtainable under assumptions of complete and perfect information where both government and owner are privy to information about the property's market value, delay costs, and legal costs. Without knowing these values the theoretical finding about the guaranteed effectiveness of eminent domain in addressing holdouts simply ceases to exist.

The game presented in Figure 1 does exhibit a last mover disadvantage. This occurs because the penultimate mover in the game is able to choose a price offer that makes the last mover indifferent between accepting the payoff from this offer and going to court. Given that the payoff from court settlement is worst for both agents in the game, being the last mover yields the lowest possible payoff to the last mover. To see

this, reconsider the compensation bargaining game described in Figure 1. However, assume the sequence of moves is now as follows: owner makes offer p_L which can be accepted or rejected by government. Government makes the counter offer p_G if p_L is found to be unacceptable. Finally, the owner chooses between the payoff from p_G , $p_G - v_L$ and opting for court settlement $m - \ell - v_L$. Figure 2 illustrates this version of the sequential bargaining game.

Since the owner can solve the government's problem just as well as government can solve its problem, the owner should offer $p_L = m - \ell$ in the first period to end the game. Thus if the sequence of the game requires the owner to move last, then the property is taken at less than market value instead of the original compensation that exceeds market value.

The nature of the eminent domain taking problem however does not lend itself very well to the latter representation of the interaction between government and the owner. Since the owner and government are not equally interested in this trade, there is no incentive for an owner to go to court if a compensation offer is unacceptable. This calls for government to always make the last move of enforcing eminent domain law by seeking a court action to take the property as shown in Figure 1.

2.3 Bargaining Under Perfect but Incomplete Information

Although the rather strong assumptions of perfect and complete information in eminent domain bargaining substantially simplify the bargaining problem, it is not hard to imagine instances where at least one of these assumptions is violated. Under this section of the analysis, the complete information assumption is relaxed to allow for

uncertainty where both the government and owner have incomplete information about the payoffs in the game.

Actual bargains between government and owners occur under significantly limited information resources compared to the informational assumptions made in the last section of this paper. First, both the government and owner are usually not privy to information about the true value of the property to each other. Further, delay and court costs are not common knowledge. These informational deficiencies affect the offers and counter offers of the bargaining game and the occurrence of bargaining breakdowns that result in court cases.

A starting point to modeling problems of this nature is finding a framework to describe the problem and estimate unknown parameters. The most difficult issue to deal with here is the ceiling price of government. The ceiling price of government is assumed to be private information for the government. The owner's reservation price on the other hand is really irrelevant to reaching bargaining equilibrium. This is mainly because of the overwhelming bargaining power of government in the bargaining game.

To analyze the eminent domain bargaining problem under uncertainty, reconsider the land market problem described in the previous section where a government wishes to acquire an owner's property for a public project. Again, assume bargaining between the government and owner occurs in two sequential rounds. First, the government offers the owner a price, p_G . The owner responds by choosing an asking price p_L . If $p_L = p_G$, the owner accepts the government's offer and the game ends. If $p_L > p_G$, the government enters the second round of negotiations and decides

if p_L is acceptable or not. The government accepts p_L if $p_L \leq p_C$, where p_C is the ceiling price of government and $p_C < v_G$. It is assumed here that p_C is private information to government. Again, let the expected legal expenses from court resolution and costs incurred by government as a result of delays in acquiring an identified property be represented by ℓ and d respectively. Further, assume the market value of properties m is common knowledge. This implies that the bounds of the equilibrium price (market price and ceiling price of government) are known to government but only the property's market price is known to the owner. The main problem that needs to be solved then is the optimal pricing rule for the owner when government's price ceiling is unknown.

Given that the price ceiling of government p_C is unknown to the owner, an owner needs to come up with an estimate of p_C prior to choosing p_L . Eckart (1985) derived a similar but more general model for a land assembly problem where a developer acquires contingent land parcels from n -owners for a development project. Here, the developer acquires the land parcels if all owners involved in the bargaining agree to sell and abandons the project otherwise. Eckart addressed the problem of owners' ignorance about the maximum price the developer can pay by assuming owners know some 'prohibitive' price that exceeds the price ceiling of the developer with certainty. This assumption works for the hypothetical case addressed in Eckart's model but may be difficult to adapt to practical problems. Strange (1995) on the other hand assumed that owners have prior beliefs about the value of the land to the developer and can update these using Bayes's rule whenever this is possible. The Strange (1995)

approach is more practical in terms of how owners' prior beliefs are updated over time but uninformative about how the prior beliefs are formed.

Here, suppose the owner has a prior belief $\mu(p_C)$ about the true value of p_C . Ideally, this is based on some educated guess of p_C from information available to the owner. For instance, this prior belief could be constructed from some estimate of the maximum compensation government is capable of paying under the complete and perfect information scenario, $m+d+\ell$. Based on the prior belief $\mu(p_C)$ about p_C the owner can obtain a probability that the counter price offer is accepted by government as $\pi_r(p_L)$. Once government reveals p_G the owner updates the prior belief $\mu(p_C|p_G)$ about the location of p_C . If the owner judges from the size of the initial government offer that the government is willing and capable of paying a high compensation then the price ceiling estimate is revised upwards accordingly. On the other hand, the price ceiling estimated is revised down if the initial government offer is low. Assume the owner can adjust the estimated price ceiling to all possible offers from government. The updated probability that government accepts p_L is now given as $\pi(p_L|p_G)$.

The probability that government accepts a counter price offer from the owner $\pi(p_L|p_G)$ is assumed to be decreasing in the counter offer price p_L . This is because the higher the value of p_L the more likely it is that the counter price offer exceeds the true price ceiling p_C .

The equilibrium of the taking game under uncertainty here emerges as follows. In the last move of the game, government chooses between accepting an owner's counter price offer p_L and opting for court settlement. Again, for government not to go to court, the payoffs from accepting the owner's counter offer $v_G - p_L$ must be equal or greater than that from a court settlement, $v_G - m - \ell - d$. Equating these two payoffs gives $p_L = m + \ell + d$ implying that government goes to court only if $p_L > m + \ell + d$.

Moving a step backwards in the game, the owner chooses a counter price offer p_L to the initial offer from government. There is however no way for an owner to know when the condition $p_L > m + \ell + d$ is satisfied for government in the last period because the owner does not know at least one component of government's payoff. In this case government's delay cost d is unknown. Otherwise, the owner will choose $p_L = m + \ell + d$ precisely.

Owners are assumed to be risk neutral and thus maximize the expected wealth value from this transaction. The objective of the owner therefore is to choose an asking price to maximize a linear combination of the owner's payoff in the two states of ownership, when owner retains property rights over the property, $[1 - \pi(p_L | p_G)](m - \ell)$ and when property right is transferred to the local government at the asking price, $\pi(p_L | p_G)p_L$.

The owner's problem is thus represented as,

$$\underset{p_L}{\text{Max}} \quad H(m, p_L) = [1 - \pi(p_L | p_G)](m - \ell) + \pi(p_L | p_G)p_L \quad (1)$$

The solution concept in use here is the perfect Bayesian equilibrium for incomplete information games (Gibbons 1992, Mas-Collel A. et al 1995). The first order condition for equation (1) is given as,

$$\frac{\partial H}{\partial p_L} = -\pi_{p_L} (m - \ell - p_L) + \pi = 0 \quad (2)$$

Rearranging and simplifying equation (2) gives,

$$p_L^* = (m - \ell) - \frac{\pi}{\pi_{p_L}} \quad (3)$$

where, $\pi_{p_L} \neq 0$. The optimal owner asking price p_L^* is given by two terms; a constant term that represents the net market price after accounting for anticipated court costs $(m - \ell)$ and a second term that depends on the owner's perceived probability of

government accepting a counter price offer $\frac{\pi}{\pi_{p_L}}$. Clearly, the higher the perceived

probability of government accepting a counter price offer π the higher is the owner's optimal counter asking price. A major driver of the owner's counter offer here is the sensitivity of the owner's subjective probability to marginal increases in the asking price π_{p_L} . The more insensitive the owner's subjective probability that government accepts a counter price offer p_L , the greater is the optimal counter price offer. For ease of interpretation, this optimal owner asking price offer is rewritten as a function of an elasticity of the owner's subjective probability of government accepting a counter offer π relative to p_L . To do this, rewrite equation (2) as,

$$\pi_{p_L} \frac{p_L}{\pi} \frac{(m - \ell)}{p_L} - \pi_{p_L} \frac{p_L}{\pi} = 1 \quad (4)$$

Letting $\varepsilon_{\pi p_L} = \frac{p_L \pi p_L}{\pi}$, equation (4) can be rewritten as,

$$p_L^* = (m - \ell) \left[\frac{\varepsilon_{\pi p_L}}{1 + \varepsilon_{\pi p_L}} \right] \quad (5)$$

where $\varepsilon_{\pi p_L}$ is the elasticity of the owners subjective probability that government accepts a bid relative to the owner's stated acceptance price p_L . The market value is reduced by litigation costs ℓ because of the owner's uncertainty about government's walk-away price. Litigation costs ℓ thus represent the cost of uncertainty. The owner needs to make provision for this litigation cost when choosing the counter asking price because the probability of overshooting the government ceiling price and litigating in court is strictly positive.

Note that the elasticity of owner's subjective probability that government accepts a counter bid $\varepsilon_{\pi p_L}$ relative to the owner's stated acceptance price p_L is negative. This implies that the more elastic the subjective probability of government acceptance of a counter price offer, π relative to the owner asking price p_L the lower is the optimal asking price. This latter result indicates that the owner's perception of government's sensitivity to marginal increases in the owner asking price p_L is an important determinant of the size of the optimal owner asking price p_L^* . Here, a relatively high elasticity of owner's subjective probability of government's acceptance of marginal increases in p_L emanates at least in part from the right that government wields to use eminent domain power. Further, the result in equation (5) is meaningless for elasticity values above negative one ($\varepsilon_{\pi p_L} > -1$). Therefore, for reasonable

interpretations of the owner pricing rule in equation (5) there is a more than proportionate government response to a marginal increase in the owner asking price.

From equation (5) it is clear that the lowest owner's optimal counter offer asking price $p_L^* = (m - \ell)$ is observed as the elasticity of owner's subjective probability of government's acceptance of marginal increases in p_L becomes highly elastic (approaches $-\infty$). On the other hand, the highest owner payoff of $p_L^* = m + \ell + d$ is observed when the condition $\varepsilon_{\pi p_L} = \frac{m + \ell + d}{-2\ell - d}$ is satisfied. This result is obtained by equating the result in equation (5) to the owner's optimal asking price under the complete and perfect information assumptions. Thus for $\ell < m$, the owner's subjective probability of acceptance is bound from above by negative one, $\varepsilon_{\pi p_L} < -1$.

Once the owner reveals p_L government decides on the optimal first period compensation offer, p_G . The objective of government is to pay the lowest possible price for the property in order to maximize government surplus from the taking. Given that government's initial price offer p_G affects the optimal counter price offer of the owner, this linkage can be exploited to achieve government's objective of maximizing surplus from the property taking. This approach is consistent with that adopted by Eckart (1985) in discussing the optimal strategy of a developer bargaining with colluding owners for the acquisition of complementary land parcels.

Here, it is assumed that government can form a rational expectation about the owner's subjective probability of government accepting a counter price offer π . This assumption suggests that government does not make systematic errors in predicting the

owner's counter price offer given government's initial offer. Any deviation from government's foresight of the owner's choice of a counter price offer is purely random with zero expected value. Although this is a rather strong assumption to make about government's knowledge of the owner's subjective probability it makes two contributions to the analysis. First, it simplifies the analysis substantially. Beyond that, it provides an opportunity to design a mechanism that enables information exchange between government and the owner. For instance, a neutral negotiator can stand between government and the owner to collect information on government price ceiling and owner's subjective probability and then follow the results derived in this paper to compute an equilibrium taking price that will be acceptable to both parties.

Given the optimal counter offer rule of the owner, the optimal strategy of government in the first period of the game involves choosing p_G to solve,

$$\underset{p_G}{\text{Min}} \quad [p_L (m , \ell , p_G) = (m - \ell) - \frac{\pi}{\pi p_L}] \quad (6)$$

Consistent with the owner's prior beliefs it is expected that the owner's counter offer asking price will be increasing in government's initial price offer, $\frac{\partial p_L}{\partial p_G} > 0$. Now,

since higher initial government price offers bring the owner closer to the government price ceiling, the rate of change in the owner's counter price with government price

offer is expected to decline with the initial government offer, $\frac{\partial^2 p_L}{\partial p_G^2} < 0$.

Differentiating equation (6) with respect to p_G gives the condition,

$$\frac{\partial p_L}{\partial p_G} = - \frac{\pi_{p_G}}{\pi_{p_L}} + \frac{\pi_{p_L p_G}}{[\pi_{p_L}]^2} > 0 \quad (7)$$

where $\pi_{p_L p_G} > 0$, $\pi_{p_G} > 0$. The assumption in equation (7) that $\pi_{p_L p_G} > 0$ implies that the rate of decline of the subjective probability of government acceptance of a counter price offer with respect to the owner asking price p_L is decreasing in the initial government offer, p_G . The two probabilities, p_G and p_L , have opposing effects on the subjective probability of government acceptance. Equation (7) indicates that the higher the initial government offer, the higher is the counter price offer from the owner.

The second order derivative of equation (6) is given as,

$$\frac{\partial^2 p_L}{\partial p_G^2} = \frac{\pi_{p_L} \pi_{p_G p_G} + \pi_{p_G} \pi_{p_L p_G}}{[\pi_{p_L}]^2} + \frac{\pi_{p_L p_G} \pi_{p_G}}{[\pi_{p_L}]^2} - \frac{2\pi_{p_L p_G} \pi_{p_L p_G}}{[\pi_{p_L}]^3} < 0 \quad (8)$$

where $\pi_{p_L} < 0$, and $\pi_{p_G p_G} < 0$. The assumption that $\pi_{p_G p_G} < 0$ indicates that the owner's subjective probability of government accepting a counter price offer is increasing in the initial government offer p_G and does so at a decreasing rate. The result in equation (8) shows that the rate of increase in the owner's counter offer may increase or decrease with p_G depending on the sign of the middle term in the equation. In either case, the reaction of government is to choose the lowest possible value of p_G in order to minimize its outlay on the property and maximize the surplus from taking. With the restriction that the government must pay at least the market value

of the property in question as compensation this result suggests that government will begin the negotiation by offering the market value as the appropriate compensation value.

Therefore in a perfect Bayesian equilibrium of this game government offers $p_G^* = m$ in the first period and the owner responds by choosing the counter offer p_L^* with a subjective probability that government accepts p_L^* of $\pi(p_L^*, p_G^*)$. This result indicates that there is no guarantee of avoiding negotiation conflict between government and owner in this case. Much depends on how close the owner's guess of government's price ceiling is to the true price ceiling. Further, the more sensitive owners are to the probability of government acceptance of owner's counter offer the lower is the optimal counter offer.

2.4 Summary and Conclusions

This paper investigates the problem of holdouts and compensation bargaining breakdowns in eminent domain takings. The paper is in two main sections. The first section demonstrates the value of information in making eminent domain power an effective tool in resolving holdout problems. The results indicate that under the assumptions of complete and perfect information the threat of eminent domain power guarantees resolution of owner holdouts and prevent bargaining breakdowns that lead to litigations. Owners also receive the maximum compensation government is willing to pay in equilibrium. This finding clarifies recent findings on the effect of the threat of eminent domain on protracted eminent domain negotiations in Miceli and Segerson (2007). In particular, the findings indicate that the threat of eminent domain is effective

in preventing delays in eminent domain takeovers only under restricted information requirements that are not explicitly specified in Miceli and Segerson (2007).

Next, relaxing the informational assumptions to allow for incomplete information in the bargaining game, an optimal owner asking price rule is derived under uncertainty. This pricing rule is shown to depend critically on the owner's subjective probability of overshooting the government price ceiling. It is evident from the analysis that the plausible and straight forward way of closing the gap between observed and theoretical effectiveness of the threat of eminent domain in resolving holdouts is to require compensation levels to at least equal the market value of properties $p_G \geq m$. Taking compensation values exceeding market value weaken owner incentive to holdout or litigate by reducing the perceived probability of government accepting a counter price offer π .

Using property market value as the lower bound of taking compensation does not only discourage excessive inefficient takings that have adverse effects on private investments in properties, but also reduces the incentive to owners to pursue legal actions to stop takings or extract higher compensation. In any case, given that private owners often do not place their properties on the market for sale before government initiates takings, it follows that owners value their properties to be at least equal to the market value. Under the assumptions made in this paper about court-imposed taking compensations, no property owner has the incentive to litigate if offered at least the market value of the property in question as compensation. This is because owner payoffs from court-imposed settlements are always worse-off than market value compensations offered at the start of the bargaining process.

Second, to reduce owner overshooting that sometimes lead to litigation it is important to require detailed financial information disclosure on the part of government, and provide essential professional help to owners to make good use of this information. Information on projected net flows of funds from proposed projects as well as a breakdown of these net flows across different subsections of the proposed project site can allow for estimation of the value of a given piece of property to the proposed project. At minimum a reasonable range over which government's price ceiling is located can be estimated from this information. Upon imposing an appropriate distribution the probability of government accepting a counter offer from the owner as well as the elasticity of this probability with respect to marginal changes in the owner asking price can be computed.

There are several powers at play here. First, apart from the power to use eminent domain power, government has substantial information power in the bargaining game since the maximum price payable to the owner is known only to government. Second, government suffers a last mover disadvantage in the bargaining game since the owner can make a counter offer choice that makes government indifferent between the payoff to government from court settlement and that from accepting the owner's counter offer. This to some extent offsets information rents from government's information advantage in the bargaining game. However, an owner can only make use of this structural advantage in the bargaining game if there is reliable information about government's delay costs. Without knowing the delay costs the owner is unable to determine government's payoff from court settlement. Although some of this information may be

gleaned by the owner from government's first offer this may be highly inadequate to exploit for decision making in many cases.

The net effect of the interaction of these relative powers of government and owner on the equilibrium taking price depends on the relative weight of each informational advantage in affecting the equilibrium terms of exchange. Overall, it is clear that the owner has very little to go on to improve the owner's payoff. The only effective action open to the owner under the circumstance is to threaten protracted bargaining and litigation to compel government to cede more of the surplus from the taking. This explains a somewhat irrational decision making observed by some authors about practical protracted bargaining problems. As noted by Ausubel et al (2002), the central issue in protracted bargaining problems is to explain the decision by bargaining agents to engage in lengthy bargains and legal battles even when it is evident that the parties could settle at the same terms without the protracted dispute. The general explanation in the economic literature for this behavior is that bargaining agents use delays as a strategic signaling response to the presence of incomplete information (Feinberg and Skrzypacz 2005, Bac 2000). The results from this study generally indicate that delays in eminent domain taking bargainings are partly signals from owners dissatisfaction with government's compensation offer, and partly due to pure mistakes made by owners in choosing counter price offers because of limited information.

Figure 1. Sequential Bargaining Under Complete and Perfect Information (When Government Moves First)

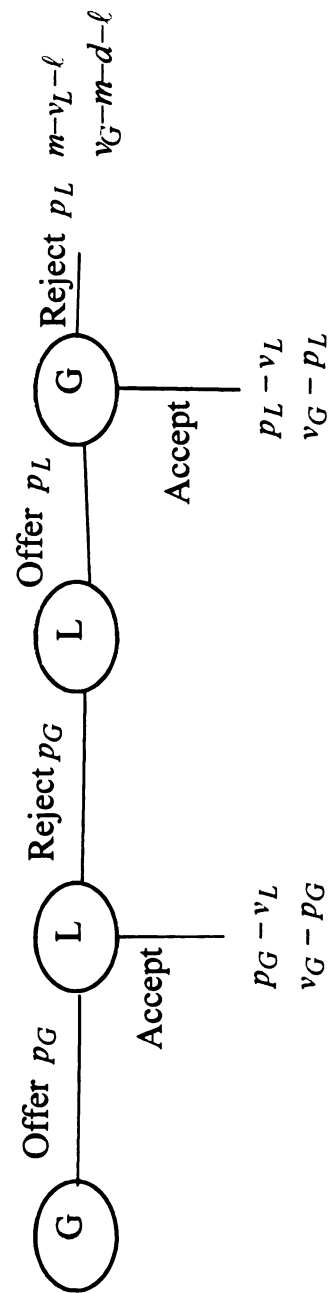
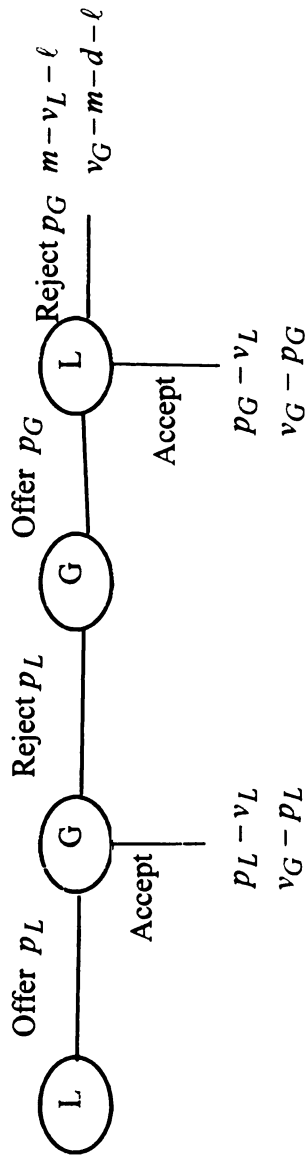


Figure 2. Sequential Bargaining Under Complete and Perfect Information (When Owner Moves First)



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Essay 3

Cost Function Estimation in the Water Industry – Functional Forms and Efficiency Measures

3.1 Introduction

Cost function estimation is an important component of efficiency analysis of firms when multiple outputs are involved (Greene 1993). Managers often have to make decisions on output expansion, input mix, and even location of plants based on the interactive effects of output and input prices. Since there are usually many efficiency-impacting factors at play in most production processes, relatively technical cost function analyses are necessary to provide reliable information upon which managerial decisions can be based. In the potable water provision industry for instance, while the per unit cost of water extraction and treatment may increase with output as exploitation moves to less accessible and lower quality water resources, the per unit cost of water production may also decline with output expansion due to scale economies. The rising cost of water extraction, treatment, and transmission may thus offset partially, completely, or even more than offset cost-savings that may be derived from scale economies. An estimated cost function for water provision therefore serves as an effect aggregating tool that helps to extract the net effect of cost-impacting factors and provides information to make decisions on output levels, efficiency-improving input substitutions, and efficient system size.

Since the true production technology is unknown in most empirical estimation problems and needs to be approximated, flexible functional forms play a valuable role

in cost function estimations (Tishler and Lpovetsky 2000, Salvanes and Tjøtta, 1998). A function is considered to be flexible when its shape is restricted only by theoretical consistency (Sauer, et al., 2006). Some frequently used flexible functional forms include the Box-Cox, Box-Tidwell, Leontief, Minflex-Laurent, and the translog forms (Shaffer, 1998). Among the class of flexible functional forms, the translog function (Christensen *et al.* 1973) has emerged as one of the most popular flexible functional forms used for efficiency analyses that involve cost function estimation (Salvanes and Tjøtta, 1998) 2001).

Recently however, Shaffer (1998) discussed a hitherto unknown weakness in the translog's ability to adequately model data that exhibit monotonically declining average cost functions. Analytical and simulation results presented by Shaffer indicate that the translog tends to produce spurious finite minimum efficient scale (MES) results even when the true MES is infinite. This implies that application of translog functional forms to data by researchers in empirical studies may be producing coefficient estimates consistent with the imposition of U-shaped average cost structure on the data when the true average cost represented by the data declines monotonically with output. The biased estimates produced by such functional form misspecifications provide misleading information upon which management decisions are based. Shaffer introduced the Hyperbolically Adjusted Cobb-Douglas (HACD) as an alternative functional form specification that is capable of differentiating between the regular U-shaped average cost function and the monotonically declining average cost functions. This suggests that the fit provided by the HACD can be expected to be at least as good as that of the translog for data exhibiting a monotonically declining average cost. On

the other hand, when the data exhibits a U-shaped average cost these two functional forms are expected to be competitive.

This paper estimates two multi-product total variable cost functions with two inputs (capital and labor) using the translog and HACD functional forms. Estimates of cost economies, input demand functions, and Allen-Uzawa partial elasticities of substitution values are also computed for potable water provision across the US.

To assess the relative fit of the two functional forms to the data Vuong (1989) and Mizon and Richard (1986) functional form tests are employed. Bontemps and Mizon (2008) distinguished between these two competing functional form tests by classifying the Vuong (1989) test as a model selection test and the Mizon and Richard (1986) as a model comparison test. The model selection test procedure selects a winning model to minimize or maximize a given criterion. This implies that the preferred or winning model does not allow for the possibility that the alternative models considered collectively contain information that could lead to the development of a better model. On the other hand, the model comparison procedure uses an encompassing principle that considers the effectiveness of each model in accounting for the explanatory power of the other competing models. The preferred model in this case therefore incorporates useful specific characteristics of the alternative models not selected.

The results generally indicate that the HACD provides a better fit to the data. Results for the HACD indicate that a one percent increase in the price of capital and labor results in 0.06 and 2.856 percent decline in the quantity of capital and labor demanded respectively. Using the translog parameters, the same increase in price results in a 0.05 and 0.09 percent decline in the quantity of capital and labor demanded

respectively. Finally, the HACD provides statistically significant cost economies estimates that represent economies of scale to water provision. In particular, a one percent increase in the quantity of water and population served increases costs by 0.48 and 0.43 percent respectively. The translog parameter estimates on the other hand point to diseconomies of scale. A one percent increase in the quantity of water and population served increases costs by 4.7 and 2.31 percent respectively.

The remainder of the paper is ordered as follows. The next section presents the theoretical framework of the paper. This is followed by discussion of the data and research hypothesis, results, and conclusions.

3.2 Theoretical Framework

A cost function represents the minimum cost of producing a given output with given input prices (Mas-Colell, Whinston, Green 1995). Estimated cost functions provide valuable information about the performance of firms. Useful performance measures often extracted from estimated cost functions include pairwise input elasticities of substitution, cost economies of scale values, and input demand functions. These performance measures are common in cost function analyses partly due to the difficulty of interpreting parameter estimates from flexible cost functions (Andrikopolos and Loizides, 1998 Bhattacharyya, et al., 1995) as marginal effects.

The Pairwise input elasticity of substitution values shed light on how efficiently the firm is using each input relative to the other. This represents a description of the relationship between the various inputs employed in the production process and indicates whether two inputs can be considered as substitutes or complements. The cost

economies values on the other hand measure the percentage change in total variable cost as a result of a one percent change in outputs while the input demand function indicates the percentage change in inputs used as result of a percentage change in the input prices (Mas-Colell, Whinston, Green 1995).

The definition of water production outputs in cost functions can significantly affect the estimated cost economies values. Output in a network industry like water may be defined in terms of volume of water produced, number of customers served, and scope of services (Torres and Paul 2006). Thus in the water provision industry, output increases may involve increases in the volume of water due to increased demand by existing users, increase in number of water users, or increased scope of services. When production increases due to higher demand of existing customers, then utilities may be expected to enjoy some economies of scale. However this is not likely when the volume increase is associated with an increase in the number of customers. This is because the cost of extending services to additional customers may cause costs to increase more proportionately than the cost economies attributable to output expansion.

Cost function analysis is usually based on the assumption that firms choose inputs to minimize production cost. Determining whether empirical results conform to cost minimization requires testing and verifying that the regularity conditions are satisfied. These regularity conditions (Salvanes and Tjøtta, 1998) are listed as follows,

1. Non-negativity of production costs, $c(y, p) > 0$, $\forall p > 0, y > 0$. This condition simply states that no positive output can be produced without incurring some positive cost.
2. Monotonicity in prices, $c(y, p') > c(y, p)$, for $p' > p$

3. Cost is homogeneous of degree one in prices,
 $c(y, tp) > tc(y, p)$, for $t > 0$. This indicates that when all input prices change by a given proportion total cost changes by the same proportion.
4. Cost is strictly increasing (monotonic) in output,
 $c(y', p) > c(y, p)$, for $y' > y$. In other words, marginal cost cannot be negative.
5. Cost is concave, continuous and differentiable in prices (p)

From duality theory, functions satisfying 1-5 satisfy the requirements for a cost function and for each of these cost functions there exist a production technology from which this cost function can be derived (Hunt 1980).

Given that symmetry and linear homogeneity are imposed *a priori* on the cost functional forms, the conditions left to be verified are non-negativity of costs, monotonicity in input prices and output, and concavity of the cost function in input prices. Since the dependent variable is the natural log of total cost, the non-negativity condition on the cost function is automatically satisfied. Monotonicity is verified by ensuring that all estimated marginal costs and cost elasticities are strictly positive. Finally, to assess concavity of the cost function in input prices, the Hessian matrix must be negative semi-definite.

The Hessian, H , which is a matrix of second order derivatives of the estimated cost function with respect to the inputs is defined as,

$$H = \begin{pmatrix} \frac{\partial^2 c}{\partial p_K \partial p_K} & \frac{\partial^2 c}{\partial p_K \partial p_L} \\ \frac{\partial^2 c}{\partial p_L \partial p_K} & \frac{\partial^2 c}{\partial p_L \partial p_L} \end{pmatrix} \quad (1)$$

One common problem with cost function estimations in the water industry and empirical studies in general is the violation of these regularity conditions (Diewert and J., 1991, Salvanes and Tjøtta, 1998, Fabbri and Fraquelli, 2000). In a study of the Italian water industry, Fabbri and Fraquelli (2000) observed that the technology underlying the water industry is not characterized by the conditions of regularity in costs. In a commonly cited study by Salvanes and Tjøtta (1998), Salvanes and Tjøtta reexamined the U.S Bell cost function estimated in Evans and Heckman (1984) by calculating the region where the cost function meets the regularity conditions. The study concluded that the estimated function is not a valid cost function since it failed to meet the non-negative marginal cost condition in most of the test region.

Failure to satisfy the concavity condition is particularly very common in empirical cost function estimations (Christopoulos et al, 2001, Rao and Preston 1984, Conrad and Jorgenson 1977). Violation of this condition generally implies that the data being modeled does not exhibit the theoretical assumption of cost minimization. In fact, in a survey of some recently published agriculture-related papers that made use of the translog functional form Sauer et. al. (2006) found that the estimated translog functional form in all seven publications failed to fulfill at least one local regularity condition at the sample mean. Further, all the estimated functions fail to fulfill the curvature requirement of quasi-concavity.

The econometric model presented in the next section is used to estimate the two cost functions and to verify the theoretical consistency requirements described here in the theoretical framework. The methods and steps taken to verify satisfaction of these theoretical constraints are also described.

3.3 The Econometric Model

The econometric model considers water producing firms that use labor and capital inputs to transform untreated water into outputs measured by volume of water produced and number of customers served. Using the economic theory of duality between production and cost functions allows for observable input prices and outputs to be used in analyzing these production activities without knowing the underlying technology of production (Mas-Colell, Whinston, Greene 1995). As previously noted, the two functional forms used for the estimation are the Tanslog and the HACD.

Starting with the translog model, the model estimated is specified as,

$$\begin{aligned} \ln C = & \alpha + \sum_i \beta_i \ln Y_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln Y_i \ln Y_j + \sum_i \omega_i \ln P_i + \frac{1}{2} \sum_i \sum_j \omega_{ij} \ln P_i \ln P_j + \\ & \sum_j \sum_i \lambda_{ji} \ln P_j \ln Y_i + \varepsilon \end{aligned} \quad (2)$$

where C represents total variable cost of water production. The explanatory variables in the model include data on a vector of input prices (P), and a vector of output definitions (Y). The input price vector covers the costs of capital (k), and labor (l) while the vector of outputs on the other hand comprises volume of water (q) and population served (s).

To impose continuity on the estimated translog cost function the following symmetry conditions are imposed,

$$\beta_{ij} = \beta_{ji}, \omega_{ij} = \omega_{ji}, \lambda_{ij} = \lambda_{ji} \text{ for all } ij.$$

Imposition of this symmetry condition is based on Young's theorem (Jehle and Reny 2003) which indicates that these coefficients are the same (i.e. the order of the interaction terms is irrelevant). In particular, Young's theorem indicates that differentiating this cost function with respect to labor and then with respect to capital should give the same result as differentiating in the reverse order so long as both cross-partial derivatives are continuous.

To satisfy theoretical assumptions of linear homogeneity of the cost function in input prices the following additional restrictions are imposed,

$$\sum_{i=1} \omega_i = 1, \sum_{i=1} \omega_{ij} = 0 \text{ and } \sum_{i=1} \lambda_{ji} = 0$$

Using Shephard's (1970) lemma, the derived input demand functions can be obtained by differentiating equation (2) with respect to the input prices to obtain,

$$M_i = \frac{\partial \ln C}{\partial \ln P_i} = \omega_i + \sum_j \omega_{ij} \ln P_j + \sum_i \lambda_{ji} \ln Y_i \quad (3)$$

The vector of a given input used is therefore a function of the vector of other input prices and the output vectors.

Two measures of input elasticity are employed, the Allen-Uzawa partial elasticities of substitution between inputs i and j , Z_{ij} , and the regular price elasticities of input demand ξ_{ij} . The Allen-Uzawa elasticity of substitution measures the

percentage change in factor proportions due to a change in marginal rate of technical substitution (input price ratios) while the price elasticity of input demand represents elasticity of the i th input (X_{ij}) with respect to the price of the j th input P_j

$\left[\xi_{ij} = \frac{\partial \ln X_{ij}}{\partial \ln P_j} \right]$. As noted by Segerson and Ray (1989) these two elasticity measures

are not the same (except for the CES and Cobb-Douglas). The elasticities are defined as follows,

$$z_{ij} = \begin{cases} (\omega_{ii} + M_i^2 - M_i) / M_i^2, & \text{for } i = j \\ (\omega_{ij} + M_i M_j) / M_i M_j, & \text{for } i \neq j \end{cases} \quad \xi_{ij} = \begin{cases} z_{ii} M_i, & \text{for } i = j \\ z_{ij} M_j, & \text{for } i \neq j \end{cases} \quad (4)$$

where ξ_{ii} is own input price elasticity of demand while ξ_{ij} is the input cross partial elasticity. The computed elasticity of substitution values may be positive (input substitutability) or negative (input complementarity).

Finally, the estimate of economies of scale is computed as,

$$\nu_{yi} = \frac{\partial \ln C}{\partial \ln Y_i} = \beta_i + \sum_j^n \beta_{ij} \ln(Y_j) + \sum_j^n \lambda_{ij} \ln(P_j) \quad (5)^4$$

For proportional increases in volume of water produced and population served the resultant economies of scale is given by the sum of cost economies associated with each output type,

⁴ This can also be looked at in levels form as $\frac{\partial C}{\partial Y_i} = \frac{\bar{Y}_i}{C} \frac{\partial \ln C}{\partial \ln Y_i}$.

$$v_y = v_q + v_s$$

Turning to the HACD model the estimated model is specified as,

$$\begin{aligned} \ln C = & \alpha + \sum_i \theta_i \ln Y_i + \sum_i \eta_i \frac{1}{\ln Y_i} + \sum_{i \neq j} \sum_{j \neq i} \rho_{ij} \frac{1}{\ln Y_i \ln Y_j} + \sum_i v_i \ln P_i + \frac{1}{2} \sum_i \sum_j v_{ij} \ln P_i \ln P_j + \\ & \sum_j \sum_i \mu_{ji} \frac{\ln P_j}{\ln Y_i} + \varepsilon \end{aligned} \quad (6)$$

The definitions of cost, output, and input vectors are exactly the same as defined for the translog model. The symmetry conditions here are $\rho_{ij} = \rho_{ji}$, $v_{ij} = v_{ji}$, $\mu_{ij} = \mu_{ji}$ for all ij where $i \neq j$ and the linear homogeneity conditions

$$\text{are, } \sum_{i=1} v_i = 1, \sum_{i=1} v_{ij} = 0 \text{ and } \sum_{i=1} \mu_{ji} = 0.$$

Comparing equation (2) and equation (6), it is clear that the difference between the translog and HACD is in the representation of the nonlinear terms of output. While the translog uses quadratic terms to accomplish this, the HACD makes use of inverse output terms.

Using Shephard's lemma (1970), the derived input demand functions can again be obtained by differentiating (6) with respect to the input prices to obtain,

$$N_i = \frac{\partial \ln C}{\partial \ln P_i} = v_i + \sum_j v_{ij} \ln P_j + \sum_i \mu_{ji} \frac{1}{\ln Y_i} \quad (7)$$

The Allen-Uzawa partial elasticities of substitution between inputs i and j a_{ij} , and the corresponding price elasticities of input demands, ϵ_{ij} are computed as,

$$a_{ij} = \begin{cases} (\psi_i + N_i^2 - N_i)/N_i^2, & \text{for } i=j \\ (\psi_j + N_i N_j)/N_i N_j, & \text{for } i \neq j \end{cases} \quad \epsilon_{ij} = \begin{cases} z_{ij} N_i, & \text{for } i=j \\ z_{ij} N_j, & \text{for } i \neq j \end{cases} \quad (8)$$

where ϵ_{ii} is own input price elasticity while ϵ_{ij} is the cross partial input price elasticity.

Finally, the equivalent of the translog's estimate of cost economies is derived as,

$$\xi_{y_i} = \frac{\partial \ln C}{\partial \ln Y_i} = \theta_i - \sum_i \eta_i \frac{1}{(\ln Y_i)^2} - \sum_{i \neq j} \sum_{j \neq i} \rho_{ij} \frac{1}{(\ln Y_i)^2 \ln Y_j} - \sum_{j \neq i} \sum_i \mu_{ji} \frac{\ln P_j}{(\ln Y_i)^2} \quad (9)$$

The estimation is done using the Seemingly Unrelated Regression Estimation (SURE) method. This estimation approach is appropriate for analyzing a system of equations with cross-equation parameter restrictions and correlated error terms as in this paper. Although the equations here are not estimating the same dependent variable, they share some independent variables, use the same data, and may have errors that are correlated across the equations. Estimating the system of equations separately with OLS (ignoring correlation of disturbances) yields inefficient but unbiased and consistent estimates for each separate equation. SURE exploits the contemporaneous information in correlated errors to achieve greater efficiency in the estimates. The cost functions are estimated along with the capital share equation only to avoid the problem of singularity of the variance-covariance matrix.

Theoretical Consistency

The first step in evaluating the estimated model results is to verify the theoretical consistency requirements. Examining theoretical consistency of the estimated model requires checking the regularity conditions. For both the translog and HACD models, the regularity condition that costs be strictly positive is met through the choice of functional form since $\exp(\ln(C))$ is strictly positive for all feasible (Y, P) . The estimated cost functions are also homogeneous of degree one in prices since this was imposed *a priori*. The next set of conditions requires that marginal costs be nonnegative and that the estimated cost function is non-decreasing in input prices.

The final regularity condition requires that the estimated function be concave in input prices. The estimated cost function is concave in input prices if the Hessian matrix $\nabla_{pp}C$ is negative semi-definite. This condition can be assessed using the computed elasticity of substitution values. For the estimated cost function to be concave in prices, the own partial elasticity of substitution values, (z_{ii}, a_{ii}) should be negative (Andrikopolos and Loizides, 1998). Alternatively, concavity may be assessed by constructing the matrix of second order derivatives of cost with respect to input prices (Chew et al. 2005),

$$\frac{\partial^2 C}{\partial p_i \partial p_j} = \frac{\partial x_i}{\partial p_j} = \frac{\partial x_i}{\partial p_j} \frac{p_j}{x_i} \frac{p_i x_i}{C} \frac{C}{p_i p_j} = \xi_{ij} M_i \frac{C}{p_i p_j} \quad (10)$$

Since equation (10) is a symmetric matrix the matrix that needs to be evaluated for concavity can conveniently be presented in quadratic form as,

$$H_{ij} = \frac{1}{C(p)} p' \frac{\partial^2 C}{\partial p_i \partial p_j} p = \frac{1}{C(p)} p' \nabla^2 C(p) p = \xi_{ij} M_i \quad (11)$$

The matrix in equation (11) is negative semi-definite when the HACD is concave. A negative semi-definite matrix has non-positive diagonal elements and the principal minors alternate in sign.

Imposing Quasi-Concavity

As previously noted, violation of the concavity condition is common in cost function estimations. To obtain parameter estimates that are consistent with the objective of cost minimization, concavity may be imposed locally on the cost function. In this paper the results derived in Jorgenson and Fraumeni (1981) are followed. Imposing quasi-concavity here then requires replacing the elements in equation (1) by the condition,

$$v_{ij} = -(DD')_{ij} + v_i \delta_{ij} + v_i v_j$$

where $\delta_{ij} = 1$ if $i = j$ and 0 otherwise and $(DD')_{ij}$ is the ij -th element of the matrix

$$-(DD) = - \left[\begin{pmatrix} d_{kk} & 0 \\ d_{lk} & d_{ll} \end{pmatrix} * \begin{pmatrix} d_{kk} & d_{kl} \\ 0 & d_{ll} \end{pmatrix} \right] = \begin{pmatrix} -d_{kk}d_{kk} & -d_{kl}d_{kk} \\ -d_{lk}d_{kk} & -d_{lk}d_{kl} - d_{ll}d_{ll} \end{pmatrix} \quad (12)$$

Imposing this concavity locally requires choosing a point of approximation. The mean is chosen as the point of approximation in this study. Substituting the results in equation (12) into the HACD model specified in equation (6) gives the new model to be estimated as,

$$\begin{aligned}
\ln C = & \alpha + \beta_q \ln Y_q + \beta_s \ln Y_s + \frac{1}{2} \beta_{qq} \frac{1}{\ln Y_q} + \frac{1}{2} \beta_{ss} \frac{1}{\ln Y_s} + \\
& \frac{1}{2} \beta_{sq} \frac{1}{\ln Y_s \ln Y_q} + \nu_k \ln P_k + \nu_l \ln P_l + \frac{1}{2} (-d_{kk} d_{kk} + \nu_k - \nu_k \nu_k) \ln P_k^2 + \\
& \frac{1}{2} (-d_{kl} d_{kl} - d_{ll} d_{ll} + \phi_l - \phi_l \phi_l) \ln P_l^2 + \frac{1}{2} (-d_{kl} d_{kk} - \phi_k \phi_l) \ln P_k P_l + \\
& \lambda_{kq} \ln P_k \ln Y_q + \lambda_{ls} \ln P_l \ln Y_s + \varepsilon
\end{aligned} \tag{13}$$

The resultant model to be estimated (equation 13) is nonlinear in parameters. The model is therefore estimated using the nonlinear estimation method in Stata. Satisfaction of all the regularity conditions establishes a common ground for comparison of the relative performance of the two functional forms to proceed.

Test of Functional Form Fit

The Vuong (1989) model selection test is employed to compare the performance of the two functional forms. The Vuong test is a likelihood-ratio-based test that tests the null hypothesis that the two estimated models are equivalent (i.e. are equally close to the true model). The test statistic is given as,

$$\psi = \frac{\ln \left[\frac{\ell_{HACD}}{\ell_{TRAN}} \right]}{\sqrt{n} \left\langle se \left\{ \ln \left[\frac{\ell_{HACD}}{\ell_{TRAN}} \right] \right\} \right\rangle}$$

where ℓ_{HACD} represents the log-likelihood value from the HACD model, ℓ_{TRAN} , the corresponding value from the translog model, and n is the sample size. Here, a positive test statistic suggests that the HACD is closer to the true model than the translog. On the other hand, a negative test statistic indicates that the translog is closer to the true model

than the HACD. Vuong (1989) has shown this test to be asymptotically distributed as a standard normal under the null hypothesis. This implies that the null hypothesis can be tested using critical values from the standard normal distribution.

Next, the Mizon and Richard (1986) [MR] test is used to test the fit of the two functional forms. The MR test constructs a comprehensive model that contains one model as a special case and then tests the restrictions that represent additional parameters to the model being tested. For instance, testing whether the translog functional form fits the data better than the HACD would require adding variables that appear in the HACD model (but not in the translog model) to the translog model and testing for the joint significance of the additional restrictions. Finding these new variables jointly significant implies that the translog functional form is deficient in adequately modeling the data.

Thus to evaluate the fit of the translog model the new model estimated is specified as,

$$\begin{aligned} \ln C = & \alpha + \sum_i \beta_i \ln Y_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln Y_i \ln Y_j + \sum_i \omega_i \ln P_i + \frac{1}{2} \sum_i \sum_j \omega_{ij} \ln P_i \ln P_j + \\ & \sum_j \sum_i \lambda_{ji} \ln P_j \ln Y_i + \sum_i \eta_i \frac{1}{\ln Y_i} + \sum_{i \neq j} \sum_j \rho_{ij} \frac{1}{\ln Y_i \ln Y_j} + \sum_j \sum_i \mu_{ji} \frac{\ln P_j}{\ln Y_i} + \varepsilon \end{aligned} \quad (14)$$

This comprehensive model is made up of the translog model and four additional terms from the HACD model. The Wald test is used to test the restriction, $\eta_i = \rho_{ij} = \mu_{ji} = 0$. This involves performing a joint test on the six additional parameters introduced from the HACD function.

A well known characteristic of these non-nested functional form tests is that rejection of one functional form does not necessarily mean the other functional form is the correct model. In fact there may or may not emerge a winning functional form out of the pair of functional forms being tested. Both functional forms may be rejected, one rejected and the other accepted, or both may be accepted (Wooldridge 2006).

The test is reversed with the HACD now being the base model augmented by additional terms from the translog. The model specification for this reversed test is given as,

$$\begin{aligned} \ln C = & \alpha + \sum_i \theta_i \ln Y_i + \sum_i \eta_i \frac{1}{\ln Y_i} + \sum_{i \neq j} \sum_{j \neq i} \rho_{ij} \frac{1}{\ln Y_i \ln Y_j} + \sum_i \nu_i \ln P_i + \frac{1}{2} \sum_i \sum_j \mu_{ij} \ln P_i \ln P_j + \\ & \sum_j \sum_i \mu_{ji} \frac{\ln P_j}{\ln Y_i} + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln Y_i \ln Y_j + \sum_j \sum_i \lambda_{ji} \ln P_j \ln Y_i + \varepsilon \end{aligned} \quad (15)$$

Here, the HACD function is the nested functional form and the Wald test is used to test the restriction, $\beta_{ij} = \lambda_{ji} = 0$. Again, finding this joint restriction statistically significant implies that the HACD functional form is deficient in adequately modeling the data.

3.4 Data

Cross-sectional data covering 73 water and waste water utilities in the U.S is employed for this analysis. The data is taken from the 2004 General Utility Information and Basic Utility Operating database of the American Water Works Association (AWWA, 2004). The survey data covers utilities that serve populations ranging from 1,200 to 9,000,000.

Stratified random sampling is employed in the survey data collection. The data sample includes states that voluntarily participated in the AWWA survey. The survey list was later supplemented by wastewater utilities from the National Pollutant Discharge Elimination System (NPDES) database. This list includes companies that provide waste treatment services and may or may not be providing potable water services. Extension of results from this study to the population of water and wastewater services in the U.S. must therefore be cautiously done since it is not clear if any factor systematically affected the decision of companies to respond to the survey.

Total variable cost is in 2002 U.S. dollars. Variables representing the input price vector are capital and labor price vectors while variables in the output vector are volume of water, service population, and a dummy variable for scope of services (whether at least one other service is provided along with potable water).

The input prices are computed in 2002 U.S. dollars. Price of labor is computed as the ratio of total personnel expenses to the number of full time workers. Price of capital on the other hand is defined as the weighted average of the cost of equity and after-tax cost of debt (Modigliani and Miller 1958, Miller and Modigliani 1963, Miles and Ezzell 1980). The weights applied are the respective ratios of equity and accumulated debt to total capital. The cost of capital is therefore computed as,

$$\text{price of capital} = \text{cost of equity} * (E / D + E) + \text{After-tax cost of debt} * (D / D + E)$$

where, E = equity of water utility (i.e. total assets less total liabilities)

D = debt of water utility (revenue bonds and financial notes)

Cost of equity refers to the opportunity cost of investment and is estimated using results from the capital asset pricing model as,

$$\text{cost of equity} = \text{risk free rate} + \text{beta}(\text{risk premium}).$$

The average monthly discount window borrowing rate for 2002 is used to represent the risk-free rate. This discount window borrowing rate is the rate at which the Federal Reserve banks lend money to depository institutions like banks and U.S. agencies of foreign banks. This data was taken from the economagic database (Economagic 2002). The estimated average value for 2002 used in this computation is 1.17.

Beta is a measure of the volatility of stocks in the water industry relative to the rest of the stock market. The average beta for the water sector (0.73) estimated by Damodaran is used (Damodaran 2007). It is estimated using the stock returns of 16 of the largest investor-owned water companies in the U.S. A risk premium of 5.5% used by Damodaran is retained. Cost of debt is computed in the data as total interest payments / total debt, and debt is defined to include both short and long-term debt (but not accounts payables). Since cost of debt expense is tax deductible, this adjustment is made in the computation using the average effective tax rate (29.78%) computed by Damodaran for the water sector.

The volume of water variable is represented by total gallons of water produced (in millions of gallons) and/or purchased from other providers while population served refers to total water consuming population served by the water company. For water companies providing both retail and wholesale water services, total population

represents the sum of the population served by retail service and population in communities purchasing bulk/wholesale water from them.

Other variables considered in the model are Water loss and Ownership. Water loss refers to the percentage of treated water that is unaccounted for in the 2002 operating period. This is the difference between what is produced and what is used by consumers. Ownership is a binary variable defined to equal 1 if the company in question is government owned and 0 otherwise.

Table 3.1 below provides additional information on the variables in the model. Summary statistics covering sample size, unit of measure, mean, standard deviation, minimum, and maximum value of each variable are shown.

3.5 Results

Results of the model estimations appear in Table 3.2 below. Two sets of results representing the translog and HACD parameter estimates are shown. The performance parameters estimated from the regression results are presented and discussed. Further, the models are evaluated for functional form fits, Heteroskedasticity, and theoretical consistency requirements for cost functions.

Omitted from the final results are three dummy variables (ownership, wastewater, and water loss). Ownership was initially included to measure the impact of private water company ownership on cost levels relative to public ownership. The variable 'wastewater' was included to measure the impact of joint service provision (water and at least one other service) on costs. Most companies providing more than one service provide water and waste treatment services. Water loss represents the

percentage of water lost in transit from the water company to the consumer. Such losses are attributable mainly to pipe bursts. All three turned out to be statistically insignificant and were dropped.

Allen-Uzawa and input demand elasticity values are computed from the estimated results shown in Table 3.2 above. These values and their associated standard errors appear in Table 3.3 below. The standard errors provide precision information about the elasticity estimates and are used to evaluate the elasticity estimates for statistical significance. These standard errors are computed following the derivations in (Toevs 1982).

The computed Allen-Uzawa partial elasticity of substitution values for the translog model indicates that a one percent increase in the price of capital results in a 0.05 percent decline in the quantity of capital demanded. For labor, a one percent increase in labor price results in a 2.099 percent decline in quantity of labor demanded. Thus although both inputs face the conventional negatively sloped input demand function, demand for labor is more elastic than that for capital. The positive estimated cross partial elasticity of substitution (0.287) indicates that the two inputs are complements. Here, a one percent increase in the price of capital results in 0.287 percent increase in quantity of labor used. This is a reasonable finding since capital cannot be expected to stand alone in water production. The estimates for own and cross input price elasticities of demand, ξ_{ii} and ξ_{ij} from the translog model confirm the earlier findings for the Allen-Uzawa elasticity of substitution values. Although these values are smaller, they also point to a negatively sloped demand for both inputs with the input demand for labor being more elastic.

Turning to results from the HACD model, it is observed that a one percent increase in the price of capital results in 0.066 percent decline in quantity of capital demanded while a one percent increase in labor cost results in 31.822 percent decline in quantity of labor demanded. Comparing these results to that of the translog, it is evident that while the elasticity of substitution estimates for capital are quite identical for the two models the corresponding estimates for labor are quite different. In particular, the elasticity of substitution estimate for labor in the HACD model is much larger than the corresponding estimate in the translog model. In summary, all the elasticity estimates from the HACD are greater than the equivalent estimates from the translog model. Given that the HACD provides a closer fit to the data than the translog the HACD estimates can be considered to be relatively more reliable.

Estimated input share values for the two models indicate that the water and waste industry may be very capital intensive. The estimated share of capital in total cost is 0.956 in the translog and 0.913 in the HACD. The corresponding values for labor are therefore 0.044 and 0.087 respectively.

Cost economies estimates computed from the estimated models are presented in Table 3.4 below. The estimated parameters give conflicting results about economies of scale to water provision. In particular, a one percent increase in the quantity of water and population served increases costs by 0.48 and 0.43 percent respectively in the HACD. These represent measures of economies of scale for increases in quantity of water and population served. Considering the cumulative change in costs for changes in both measures of outputs, a one percent simultaneous increase in quantity of water and

population served increases costs by 0.91 percent. This still constitutes cost economies for size expansion.

The translog parameter estimates on the other hand point to diseconomies of scale. A one percent increase in the quantity of water and population served increases costs by 4.7 and 2.31 percent respectively. These two sets of results exemplify how the choice of functional forms may drastically influence conclusions and policy recommendations that are obtained from empirical cost function analyses.

To evaluate the models' satisfaction of regularity conditions that are not imposed *a priori* or met through the choice of functional form the first order partial derivative of each estimated function with respect to $\ln Y_i$ and $\ln P_i$ is computed for each data point. The computed changes in cost with respect to the output measures and input prices are strictly positive, satisfying the respective regularity conditions that the estimated total variable cost function is increasing in prices and outputs. This satisfies the requirement that the marginal cost is nonnegative and that the estimated cost function is non-decreasing in input prices.

The final regularity condition requires that the estimated function be concave in input prices. Looking at the partial elasticity of substitution values for the estimated translog model below (Z_{ij}), it is clear that the concavity condition is satisfied since the principal diagonal values (as defined in equation 1) are negative. The equivalent estimates for the HACD model (a_{ii}) indicated that the model failed to satisfy the concavity requirement since the own partial elasticity value for capital turned out positive. Concavity was imposed on the HACD function following the results in

equations (12) and (13). The new set of results is shown in Table 3.2 along side the parameter estimates from the translog model.

Overall, the R^2 measures suggest that the HACD provides a better fit to the data. For functional forms with the same dependent variable, the adjusted R^2 is an appropriate basis for comparing the relative fit of non-nested functional forms (Wooldridge 2006). Here, since the number of variables in the two models are equal, the R^2 provides an adequate basis for comparison of the two functional forms. Also, the root mean square percentage error of 0.36 from the translog model as against 0.32 from the HACD shows that deviations of in-sample predictions from the HACD are smaller than those from the translog.

The Vuong (1989) test is employed to determine if the difference in fit of the two models is statistically significant. The log-likelihood values obtained from the estimated models are 116.861 and 109.75 for the HACD and translog models respectively. Given the sample size and standard error of log-likelihood differences as 73 and 1.037 respectively the computed test statistic is 0.863. The positive test statistic here indicates that the HACD marginally fits the data better. To determine if the difference between the two models is statistically significant, the computed test statistic is compared to the 5 percent critical value from the standard normal distribution of 1.96. Since the computed test statistic is less than the critical value it is concluded that the null hypothesis that the two models are equivalent cannot be rejected.

Results from the Mizon and Richard (1986) test confirm the earlier findings from comparing the R^2 from both models. The Mizon and Richard (1986) test involves using the Wald test to test the restriction, $\eta_i = \rho_{ij} = \mu_{ji} = 0$ in equation

(14) for the translog model, and $\beta_{ij} = \lambda_{ji} = 0$ in equation (15) for the HACD model.

Evaluating the fit of the translog involves performing a joint test on the six additional parameters introduced from the HACD function. The computed chi-square statistic of 14.16 was obtained with an associated p-value of 0.028 indicating that the null hypothesis that these additional restrictions jointly equal zero is rejected. This suggests that the translog specification inadequately accounts for nonlinearities in output in the cost function. The corresponding test for the HACD model gives the chi-square statistic value of 10.97 and a p-value of 0.140. Here, the additional terms from the translog model are jointly statistically insignificant. The Mizon and Richard (1986) test therefore indicates that HACD provides a better fit to the data than the translog. Overall, it can be concluded that the HACD marginally fits the data better.

The Breusch-Pagan Heteroskedasticity tests conducted on the residuals from both models indicate that the null hypothesis of Homoskedasticity cannot be rejected at the 10 percent level. The chi-square test statistic and associated p-value for the test on residuals from the translog functional form are 0.039, and 0.844 respectively. The corresponding test statistic and p-value for the HACD are 0.84 and 0.629 respectively.

3.6 Conclusions

This paper investigated the performance of two flexible functional forms (translog and HACD) in multiple output cost function estimation for water and wastewater facilities in the United States. Important performance measures like input elasticity of substitution, economies of scale, and input demand functions are also derived and compared.

Results for the HACD indicate that a one percent increase in the price of capital and labor results in 0.06 and 2.856 percent decline in the quantity of capital and labor demanded respectively. Using the translog parameters, the same increase in price results in a 0.05 and 0.09 percent decline in the quantity of capital and labor demanded respectively. Finally, the HACD provides statistically significant cost economies estimates that represent economies of scale to water provision. In particular, a one percent increase in the quantity of water and population served increases costs by 0.48 and 0.43 percent respectively. The translog parameter estimates on the other hand point to diseconomies of scale. A one percent increase in the quantity of water and population served increases costs by 4.7 and 2.31 percent respectively. Thus while the HACD estimates suggest economies of scale to increases in quantity of water and population served, the translog estimates suggest diseconomies to scale. Overall, the functional form tests and analyses suggest that the HACD provides a better fit to the data. The difference in fit of the two models is however quite small.

The contrasting result for the cost economies parameters is determined to be attributable to the difference in structure of the two models. Once the derivative of the estimated models is taken, the constant terms disappear and the computed cost economies from the HACD becomes much smaller than those from the translog because of the inverse output terms inserted to replace the quadratic terms in the translog.

In a purely economic sense, these cost economies estimates are decision-making parameters that indicate whether expansion, contraction, or retention of current output level should be pursued. Given that the choice of functional form may reverse such

decisions underlines the importance of using more than one functional form for studies of this nature to allow for comparison and assessment of reliability of the estimates.

TABLES

Table 3.1

Summary Statistic of Main Variables

Variable	Unit	Mean	Standard Deviation	Min	Max
Total cost	Million \$	38.50	54.8	2.70	327.00
Water production	Million Gal.	22140.20	30566.92	1569.50	155125.00
Service population	Thousands	385.75	522.34	29.99	2,390.00
Capital price	percent	0.04	0.01	0.02	0.060
Labor price	\$/employee	67569.46	38516.26	8087.15	176,770.90

Table 3.2

Estimated TRANSLOG and HACD Model Results
Dependent Variable: Log Total Variable Cost

Translog Models Estimated Results		HACD Estimated Results	
Parameters	Estimated coefficient	Parameters	Estimated coefficient
α (intercept)	13.220* (7.635)	α (intercept)	-186.682* (80.053)
β_q	-1.592 (2.334)	θ_q	4.589* (1.090)
β_{qq}	0.643 (0.508)	θ_s	2.605 (1.643)
β_s	1.609 (2.810)	η_q	1344.336* (349.379)
β_{ss}	0.218 (0.610)	η_s	528.033 (600.201)
β_{qs}	-0.722 (1.075)	ρ_{qs}	-8119.938* (2886.812)
ω_k	1.134* (0.119)	v_k	1.006* (0.004)
ω_{kk}	-0.007* (0.004)	v_{kk}	0.024* (0.034)
ω_l	-0.134 (0.119)	v_l	-0.007 (0.016)
ω_{ll}	0.038* (0.008)	v_{ll}	-0.169* (0.009)
ω_{lk}	-0.030* (0.007)	v_{lk}	-0.007 (0.016)
λ_{qk}	-0.012 (0.018)	μ_{qk}	-0.962 (1.696)
λ_{ql}	0.103 (0.069)	μ_{ql}	-29.006* (11.663)
λ_{sk}	0.020 (0.019)	μ_{sk}	2.027* (3.041)
λ_{sl}	-0.110 (0.070)	μ_{sl}	62.700 (20.308)
R-square	0.879		0.904

• Values in parentheses are standard errors

* Values with asterisk indicate statistical significance at 10 percent level

Table 3.3

Elasticity of Substitution and Input Elasticity Estimates

Translog		HACD	
Elasticities	Estimated Parameters	Elasticities	Estimated Parameters
z_{kk}	-0.054* (0.028)	a_{kk}	-0.066* (0.038)
z_{ll}	-2.099* (0.910)	a_{ll}	-31.822* (17.211)
z_{lk}	0.287* (0.111)	a_{lk}	0.912* (0.511)
ξ_{kk}	-0.051* (0.027)	ϵ_{kk}	-0.061* (0.035)
ξ_{ll}	-0.092* (0.040)	ϵ_{ll}	-2.856* (1.497)
ξ_{lk}	0.013* (0.005)	ϵ_{lk}	0.079* (0.044)

* Values with asterisk indicate statistical significance at 10 percent level

Table 3.4**Economies of Scale Estimates**

Translog		HACD	
Estimated parameter	Estimated value	Estimated parameter	Estimated value
ξ_q	4.700* (1.688)	ν_q	0.480* (0.264)
ξ_s	2.310* (1.046)	ν_s	0.430* (0.210)

* Values with asterisk indicate statistical significance at 10 percent level

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