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Multilevel Governmental Efforts for Energy Efficiency: Policy Adoption, Implemenation, and Evaluation under the American Recovery and Reinvestment Act (ARRA)

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MULTILEVEL GOVERNMENTAL EFFORTS FOR ENERGY EFFICIENCY: POLICY ADOPTION, IMPLEMENATION, AND EVALUATION UNDER THE AMERICAN RECOVERY AND REINVESTMENT ACT (ARRA)

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ABSTRACT

This dissertation consists of three essays studying the impact of the American Recovery and Reinvestment Act in the energy policy field. The purpose of this research was to evaluate the effectiveness of ARRA funds, spent as temporary funding, on the change of energy efficiency policies, jobs, and technologies.

The first essay examined variation in local level energy-efficiency grants and corresponding initiatives from American Reinvestment and Recovery Act (ARRA) in the United States. The analysis was based upon a hurdle model of counts of energy-efficiency grants received by 348 local governments that received these grants from 2009 to 2013, as well as 348 matched local governments that did not receive such funds. City-level characteristics including amount of federal financial support, per capita income, signaling of preferences for sustainability policies, manufacturing and political influences were shown to be empirically important determinants of variation in local energy-efficiency initiatives. The evidence suggested that all else held equal, the $21.8 billion in ARRA funds expended with the intent of promoting the diffusion of local energy-efficiency programs and policies successfully led to this end.

The second essay examined the impact of the ARRA funds allocated through an intergovernmental grant provision under the Office of Energy Efficiency and Renewable Energy (EERE) of the Department of Energy. The purpose of the second essay was to evaluate the effectiveness of the large-scale federal ARRA grant provision implemented under the EERE on job creation related to energy efficiency and renewable energy at the sub-national level. In doing so, it focuses on whether federal ARRA investments, designed to spur the U.S. economy through establishing an innovative energy technologies in intergovernmental grant programs for state and local government, effectively achieved their stated objectives of increasing job. Using the first difference regression model with instrumental variables, the second essay examined the effects of federal ARRA expenditures on job creation in the energy efficiency and renewable energy sectors from 2005 to 2015. The evidence suggests that all else held equal, the ARRA funds, implemented through the intergovernmental grant programs, successfully led to job creation in the energy efficiency and renewable energy sectors . The evidence suggested that ARRA funds led to a productive cumulative return on job creation in energy efficiency and renewable energy sectors during the period of ARRA.

The third essay analyzed whether federal ARRA investments, designed to spur new energy technologies in grant programs for state and local government, effectively achieved their stated objectives. The analysis was based upon a first difference regression model with instrumental variables. This essay examined the effects of federal ARRA expenditures on innovation activities in energy technologies from 2005 to 2015. The evidence suggests that all else held equal, the ARRA funds, implemented under the decentralized networks, successfully stimulated innovative activities in energy

technologies. Results also showed that ARRA funds led to productive cumulative return on innovation activities toward alternative energy technologies and energy conservation technologies during the ARRA period.

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CHAPTER I

INTRODUCTION

On February 17, 2009 President Barack Obama signed the American Recovery and Reinvestment Act (ARRA) into law. The ARRA was a single-shot game allocated in short period of time and as a one-time grant program to support national economic recovery during the Great Recession. It included explicit goals for stimulating the economy through new job and technology development in health care, sustainable energy production and transmission, and improvements to federal and local facilities and infrastructure. The purpose of ARRA was to:

> "(A) Preserve and create jobs and promote economic recovery
>
> (B) Assist those most impacted by the recession
>
> (C) Provide investments needed to increase economic efficiency by spurring technological advances in science and health
>
> (D) Invest in transportation, environmental protection, and other infrastructure that will provide long-term economic benefits

(E) Stabilize state and local government budgets, in order to minimize and avoid reductions in essential services and counterproductive state and local tax increases"[1]

The ARRA relied heavily on instruments of networked governance system. Under the ARRA implementation, federal managers were dependent upon local networks to achieve national policy outcomes. Federal officials were also consigned to work within a networked governance system through existing networks of state, local, nonprofit, and business actors in order to accomplish program goals and provide needed services. The ARRA mandated unprecedented transparency for designated expenditures by state and local governments, nonprofit organizations, and private contractors, to spend stimulus funds as quickly as possible. Energy policy under the ARRA funds had also tended to focus on the local ground-level aspects of service delivery. Each state government decided how to allocate its share of the funding to local governments as well as non-governmental entities. State and local governments had fragmented and independent authority to craft their actions to match each of their unique circumstances. Overall, the subsidies from ARRA funds did not change hierarchically-oriented federal, state and local relationships, but, they did have the networked governance system for stimulating collaboration between state and local government as well as federal and local governments.

The ARRA had been emphasized in implementation shifted from 'government' to 'networked governance' in achieving public goals (Conlan et al., 207). In the public

[1] Public Law 111-5, it was goals cited as the American Recovery and Reinvestment Act of 2009.

administration studies, networked governance is a concept that tries generally to capture the blurring of boundaries between the public and private sectors, and the rise of multi-sector networks and partnerships in implementing public sector policies and programs (Frederickson, 1997; Peters & Pierre, 1998; Stoker, 1998). Related to the notion of networked governance are the market-oriented challenges to the traditional bureaucratic model of public administration embodied in the New Public Management (NPM) (Morgan, 2010). This concept emphasizes values such as flexibility and competition (Kaboolian, 1998). Blair (2000) suggests that decreased federal involvement and support forces states and local in the United Sates to be more creative and innovative in devising, organizing, financing, and implementing these types of activities. In the literature on networked governance, scholars have long recognized many issues of the actual effects of networked governance within the process of engaging various public and private agencies in the implementation of government programs. For example, Robert Agranoff and Michael McGuire (2003) have investigated the role of networks in local public and nonprofit service delivery arrangement. They provided valuable lessons about the effectiveness of networks which launched a more sophisticated discussion of the roles that various actors, including public managers, play in local, community-based initiative. McGuire (2000) also offered limited evidence that the presence of innovative governance system might induce higher levels of collaboration in cities. Posner (2013) mentioned that these approaches pose uniquely difficult challenges for both accountability and performance in federal programs.

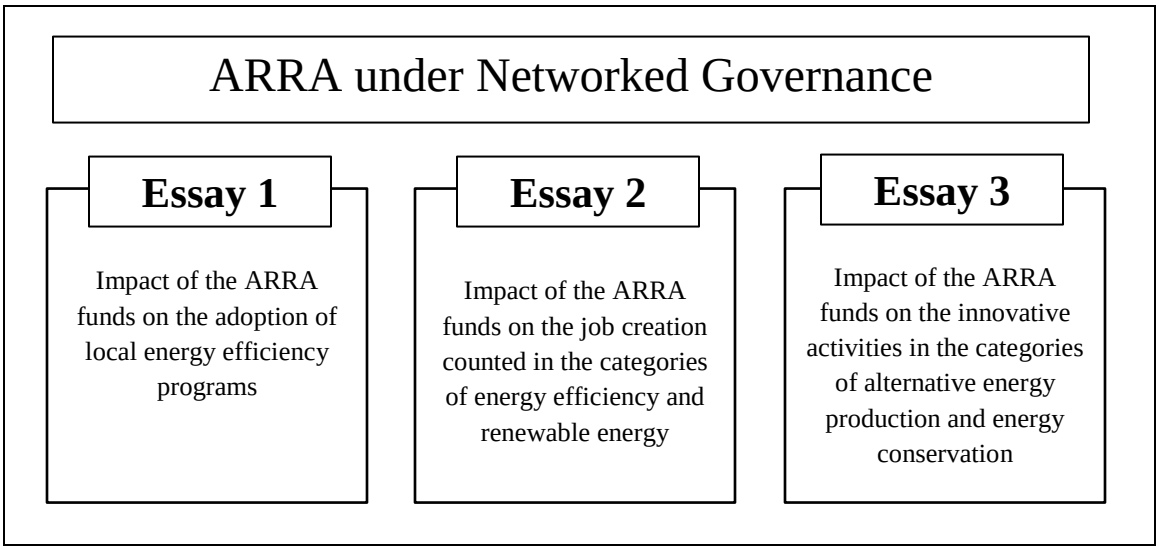
Consequently, the ARRA provided an ideal testing ground for exploring the federal role in diffuse policy implementation networks (Conlan et al., 2017). However, no

published research has yet examined empirically the effectiveness of the networked governance system in the implementation of the American Recovery Reinvestment Act. Furthermore, the policy literature lacks compelling evidence of the effectiveness of the networked governance tools that were used at the energy policy under the ARRA. Accordingly, this dissertation has tended to focus on the effectiveness of energy policies implemented under the networked governance system in a three-essay format. Specifically, each essay of this dissertation focused on the energy efficiency grants were used as a tool of networked governance within the context of mutual relationships among federal, state, and local governments.

This three-essay dissertation seeks to contribute empirical insights in terms of a set of broader conceptual frameworks that are inherently related but remain disconnected in the scholarly literature, and concurrently advance policy knowledge about the effects of American Recovery Reinvestment Act within the energy sector. Specifically, this dissertation was grounded in the networked governance framework as a commonalities between three essays into the context of evaluating ARRA expenditure for energy. It was intended to serve as a step toward evaluating how well the governments was achieving its statutory mission and goals, what have we learned about the Recovery Act, and what the discrepancy was between public perceptions of governmental performance and realities on the ground. All three essays contain empirical analyses focused on the local and state ground-level evaluative aspects of whether ARRA funds effectively achieved their stated objectives. The research approach of each essay was tailored to its guiding research question and the inherent limitations of the available secondary data. Particular attention

is given to the selection and application of each empirical model in an effort to maximize the statistical and external validity of the combined analysis.

Figure 1. Conceptual Framework



The first essay examined the impact of the ARRA energy funding on local government energy-efficiency programs and policies. The following specific questions were considered. Under what general circumstances, if any, were more energy-efficiency grants received and initiatives taken at the local government level? What factors explain variation in ARRA stimulated energy efficiency activity at the local governmental level?

The system for making and obtaining local energy efficiency grants from ARRA funds did not change the usual, top-down, hierarchically-oriented federal-state-local relationships. They have a somewhat unique structure in that local government were required to take self-initiative to compete within the federal funding process. This essay primarily focused on the effects of the ARRA funds supported through the six programs used a competitive process for making their awards: (1) Energy-efficiency and

Conservation Block Grants; (2) State Energy Program; (3) Weatherization Assistance Program; (4) Energy Efficient Appliance Rebated Program; (5) Energy Assurance and Planning Program; (6) Energy-efficiency and Renewable Energy Program.

To determine whether, on the margin, ARRA energy funding affected the numbers of local government energy efficiency grants received, and programs and policies adopted, the empirical model was tested based first upon propensity score matching to identify a set of cities as similar as possible to those that received the funds, except that they did not receive any such funds. Then a hurdle model was used to predict the number of ARRA energy efficiency grants, using controls for the similar cities. The analysis was based upon a hurdle model of counts of energy efficiency grants received by 348 local governments that received these grants from 2009 to 2013, as well as 348 otherwise similar local governments that did not receive such funds.

This essay showed that the $21.8 billion in ARRA funds expended with the state intent of improving energy efficiency did indeed stimulate the sought for energy efficiency initiatives, and adoption of local energy efficiency programs and policies. Model results reveal that the competitive process for acquiring ARRA grants at the local level seems to have been an effective mechanism for the diffusion of more energy efficiency programs and policies, at least in the short term. Model results demonstrated that city level characteristics including the land size, per capita income, signaling of preferences for sustainability policies, manufacturing and political influences were empirically important determinants of variation in local energy efficiency initiatives. The empirical results indicates, however, that although one-shot federal spending may not be optimal for achieving longer term improvements, the short term expenditures led to

effective performance in terms of promoting the diffusion of energy efficiency policies, at least in the short term and at the local level.

Job creation was the primary goal of the Obama administration's American Recovery and Reinvestment Act (ARRA). The second essay focused on how the ARRA funds had performed in creating jobs in the energy efficiency and renewable energy sector. This essay evaluated the effectiveness of ARRA funds with an empirical assessment of the relationship between the total amounts allocated through intergovernmental grant provision under the Office of Energy Efficiency and Renewable Energy (EERE) of Department of Energy (DOE) and the number of jobs counted in energy efficiency and renewable energy sectors. The primary research question of this essay was as follows: what factors influence the success of the implementation of federal ARRA-related energy policies at the state government level? This essay framed a conceptual definition of successful implementation by assessing whether the desired results were met. This essay focused on whether this implementation under the Recovery Act achieved job creation in the energy efficiency and renewable energy sectors. The jobs in the energy efficiency and renewable energy sector, were estimated both in terms of (1) energy efficiency, and (2) energy renewable sources sub-categorized in the category of "Green Goods and Services (GGS)" defined by the U.S. Bureau of Labor Statistics (BLS).

The second essay tested whether the ARRA expenditure, as a one-time event, led to a spike in job creation in the energy sector or whether it has long-term impacts on job creation. This research used panel data of 49 states in the U.S. over the period of 2005-2015. For instance, this study also included lagged variables for the ARRA expenditure

allocated in selected energy programs in order to capture any lagged effects of the ARRA funds in the previous year. To control for remaining omitted variable bias, this research used instrumental variables for the ARRA expenditure on selected grant programs. Thus, the second essay used two-stage models: this research conducted the first difference analysis with instrumental variables approach to consider the assumption for the endogeneity of the ARRA funds. This analysis was approached in first-difference two-stage least squares (FD2SLS) estimation to control the assumption that lagged ARRA variables may be correlated with the error term.

The second essay confirmed that cumulated ARRA expenditure made in intergovernmental grant programs through the EERE led to higher levels of job creation in energy efficiency, and renewable energy sectors. These positive impact of the temporary ARRA funding may be impacted by the intergovernmental grant process. The intergovernmental grants funded by the ARRA were designed to distribute funds to state or local governments so that they could quickly spend on projects that would create jobs and foster growth in their communities (Terman & Feiock, 2012). The second essay's empirical results showed that government funds implemented under these intergovernmental grants process had positive impacts in short term to stimulate employment in energy efficiency, and renewable energy sectors.

The third essay examined the determinants of the innovative activities included in the categories of alternative energy production and energy conservation. This essay was focused on whether federal ARRA investments, designed to spur new technologies designed to improve alternative energy and energy conservation effectively achieved their stated objectives. The major purpose of this essay was to evaluate the effectiveness

of the ARRA funds, spent in grants at the state and local governments through Department of Energy, on innovative activities in energy technologies. Counts of patent application were used as proxies for innovative activities instead of patent publication measured as innovation output. Although patent applications may not translate into practice, their counts have the potential for most accurately representing the outcomes for technological innovative activities (Johnstone et al., 2009). Relevant patent applications were measured at the individual patent level, with using codes issued by the USPTO's Green Technology Pilot Program.

In this vein of inquiry, I conducted the first differenced analysis with instrumental variables approach so as to appropriately consider the endogeneity of the ARRA funds. The research included years both before and after ARRA from 2005 to 2015 to observe the impact of ARRA funds. This research evaluated the effectiveness of ARRA expenditures as measured by total amount spent in seven grant programs aimed to promote upgraded energy efficiency technologies under the DOE's Office of Energy Efficiency and Renewable Energy (EERE). These seven grant programs account for the vast majority if not all of the ARRA expenditures made for improving energy efficiency and greenness. Also, this research included two instrumental variables that did not enable energy technologies' innovation or promotion, but that may correlated with the level of the allocated ARRA-Energy funds. As instrumental variables, I used the unemployment rates and the total amount of ARRA funds spent under block grants based upon the results of the validity of instrumental variables.

The results of this analysis demonstrate that ARRA expenditures spent in the seven grant programs through the Office of Energy Efficiency and Renewable Energy

(EERE) led to significantly higher levels of innovation activities in energy technologies in states in individual years. After one year of ARRA expenses, the ARRA funds under the EERE led to significant and positive impacts on innovative activities in the technologies of the alternative energy and the energy conservation, as well as combined categories. However, after two years of ARRA expenses, the dollar amount of ARRA funds under the EERE led to significantly negative impacts on innovation activities only for the conservation energy technologies. Again, in three years after, the ARRA funds under the EERE led to significant and positive impacts on the innovative activities in the technologies of alternative energy and energy conservation as well as both categories.

The third essay concluded that innovation activities were strongly associated with lagged long-run (delayed) effects of the government investments. It is very noteworthy that temporary government funding evidently played a determinative role in directly stimulating more energy technology-related innovative activities, in cumulated returns, at the state level. In this perspective, innovative activities may be required extended timeframes for their achievement. Empirical evidence indicated that delayed impact in government spending should be considered to see more productive return on their investment. Model results in the third essay also reveal that ARRA funds implemented under the decentralized networks had an important impact on innovation activities related to energy technologies during the period of the ARRA. It means that state governments established their achievement in the program, designed with their authority to meet production targets, under the ARRA. These accomplishments have the implication that it is important to inject decentralized delivery systems in aspect of how should be able to

design the federal expenditure more efficiently for promoting of innovation activities toward energy technologies in the future.

CHAPTER II

DETERMINANTS AND EVALUATION OF LOCAL ENERGY EFFICIENCY INITIATIVES FROM THE AMERICAN RECOVERY AND REINVESTMENT ACT (ESSAY 1)

Introduction

The American Recovery and Reinvestment Act (ARRA) was a large-scale short-term federal initiative passed in 2009 as a Keynesian macroeconomic measure to support national economic recovery during the Great Recession. It included explicit goals for stimulating the economy through investment in sustainable energy (Recovery Accountability and Transparency Board, 2015). Unprecedented levels of federal expenditures were made to promote advanced, efficient, and clean energy. The intent of the Act included economic stabilization, job creation, job retention and regional wealth creation. The expenditures played a key role in U.S. energy policy, primarily by supporting state and local initiatives to adopt programs, policies and practices for purposes of sustainable energy (Carley et al., 2014).

The high stakes and speed needed to implement the ARRA and ward off massive recession placed a premium on decentralized and often informal collaborative networks of people and groups in federal, state and local governments, as well as nonprofit and business organizations. The widespread use of various indirect tools of governance in the Act's implementation, including grants, has raised "several theoretical puzzles" as well as a "uniquely informative" opportunity to examine the theory of "how large scale federal programs can be effectively implemented and held accountable in an era of indirect and networked governance, about how political and governmental institutions respond to large doses of fiscal shock therapy, and about the wide discrepancy between public perceptions of governmental performance and realities on the ground" (Conlan et al., 2017, p. 6).

In accordance with practices of fiscal federalism, the federal government relied in large measure on state and local actors to implement the federal policy goals in the ARRA. One way this was done was through enactment of a process in which local actors had a role in applying for and receiving new federal grants. One of the purposes of this essay is to help gain a better theoretical understanding of how a set of local factors affected this implementation process. An open question in the literature is about the reasons why some local actors apply for grants under such new programs while others do not. While the answer to this question remains largely out of reach, it has consequences for both the theory and practice of fiscal federalism and for "the achievement of federal goals when the federal government has no direct path to implementers and their implementation efforts" (Terman & Feiock, 2014, p. 322). The better understanding I seek is important for purposes of helping to identify which public finance functions are best centralized and which are best located in more decentralized governmental and other agencies, among other things.

Although the factors that determine local participation in the implementation of federal policy goals have been examined elsewhere in the literature, they have not been considered explicitly in regards to whether they influence local actors in terms of their decisions to apply for and receive newly established federal grants. The energy efficiency grants furnished by the federal government under the ARRA are a case in point. The question is: what if any identifiable conditions evoked local participation in achieving federal policy goals through these newly established federal grant programs, and what if any incentives encouraged local actors to choose to pursue them? Also, in what extent, if any, were these conditions driven by political influences such as party affiliation and representation (Inman 1988, Oates 1999, Porto & Sanguinetti 2001)? In helping to answer these questions I also extend the research conversation found in Carley's (2016) special issue of this journal by providing practical insight into some of the details of the successes of a range of ARRA expenditures vis-à-vis the experiences of localities in the energy-efficiency field. I follow those papers in considering the context of the conditions faced by local grant recipients and providing another step toward evaluating "what have we learned *about* the Recovery Act, and what have we learned *from* the Recovery Act" (Carley, 2016a, p.119).

Recent research has started to examine the actual effects of energy-related ARRA expenditures. Some has looked at how state capacity affected funding of energy programs (Carley et al., 2014; Terman & Feiock, 2014a; Terman, 2015; Terman et al., 2016). Other focused on assessment of the experiences of a range of national actors during the ARRA period (Tonn et al., 2016; Carley, 2016). Still other examined the effectiveness of related intergovernmental grant management or collaborative contract management (Terman &

Feiock, 2016; Lachezar, 2016). However, although the literature provides good reason to expect that the ARRA energy-efficiency expenditures substantially influenced levels of local government energy activities, no published research has yet examined the determinants of local-level success in the process of competing for ARRA energy-efficiency grants. Neither has any study provided an overview in terms of the implications of the ARRA expenditures for the future of federally funded sustainable energy-efficiency programs and policies. Accordingly, this research examined the impact of ARRA energy funding on local government energy-efficiency programs and policies. The following specific questions were considered. Under what general circumstances, if any, were more energy-efficiency grants received and initiatives taken at the local government level? What factors explain variation in ARRA stimulated energy-efficiency activity at the local governmental level? These are answered first through a review of the relevant literature and then through a quasi-experiment and a hurdle model designed to be as parsimonious, plausible, and informative as possible.

Theoretical Framework: Fiscal Federalism and Local Energy Policy Adoption

The fiscal federalism literature focuses, among other things, upon the relationship between federal and subnational governments. A main assumption is that the federal government plays the role of establishing a comprehensive framework and local governments then implement their own programs for meeting the performance targets written into federal goal statements (Rabe, 2011). The preferences held by federal and local governments are assumed to be aligned (Nicholson-Crotty, 2008) and federal policies are assumed to be designed to integrate all levels of government, including state and local

(Handley, 2008). Furthermore, it is assumed that this alignment and integration may be accomplished through intergovernmental grants to state and local governments and other activities in a manner that conforms to federal policy goals (Mueller, 2003). Local government is thus viewed as a subnational extension of the national government, with key roles in the production, provision and delivery of public services (Cho, 2005).

The grants and initiatives investigated in this research were funded by the ARRA through the US Department of Energy from 2009 – 2013. They went directly to local agencies so that they could quickly be spent on programs, projects and policies that would foster growth in their communities (Terman & Feiock, 2014a).[2] Table 1 shows the six categories of ARRA funded grant programs included in this research.

Table 1. Categories of Energy-efficiency Projects funded under the Department of Energy's ARRA

Office of Energy-Efficiency and Renewable Energy	Categories of Energy-efficiency Projects	• Energy-efficiency and Conservation Block Grants • State Energy Program • Weatherization Assistance Program • Energy Efficient Appliance Rebated Program • Energy Assurance and Planning program • Energy-efficiency and Renewable Energy Program

Source: Recovery Accountability and Transparency Board. 2015

For the most part, the system for making and obtaining the new local energy-efficiency grants from ARRA funds did not change the usual, top-down, hierarchically-

[2] Some funds were awarded directly to local government by the federal government on a competitive basis. Others passed through state government to local government in accordance with the guidelines of the federal governments, still on a competitive basis.

oriented federal-state-local relationships. But they did have a somewhat unique structure in that local governments were required to take self-initiative to compete within the federal funding process (Conlan et al., 2017, p.75). Specifically, the grant programs with this structure included the Energy-efficiency and Conservation Block Grant (EECBG) funds, for which the expressly stated intent was to make federal funds available locally for purposes of supporting sustainable energy initiatives. The EECBG program directly funded 59% of the total ARRA energy-related funding allocated by the federal government at the city level (DOE, 2011). The other major set of such expenditures were those made under the Weatherization Assistance Program (WAP). Expenditures for the WAP accounted for 30% of the total amount of ARRA energy related funding allocated by the federal government at the local level (Sissine, 2012). Terman and Feiock (2012) remarked that such direct local expenditures were the most straightforward possible mechanism to accomplish both federal and local energy sustainability goals while bringing better adoptability and responsibility as well as a reduction in bureaucratic redundancy and cost (Terman & Feiock, 2014a).

ARRA directed EECBG and WAP grants to local governments based upon the Energy Independence and Security Act of 2007. The EECBG program specifically provided "non-entitlement cities" with the opportunity to compete for funds for energy-efficiency improvements. These were cities not officially designated by the federal government as being among the largest in each state. Although most federal funds under the WAP were awarded in the form of formula grants, some were provided to non-entitlement cities in the form of competitive funding through categorical formula grants. These competitive grants were designated for programs that disbursed and managed

activities for upgrading heating and air conditioning equipment, and implemented other energy conservation measures (Conlan et al., 2017, p109). Special targets for WAP assistance included energy-efficiency initiatives for the low-income elderly, disabled, and families with children, all of which were handled by the US Department of Energy (DOE). The DOE made grants to state governments, which then passed the funding through to competitively successful local governments, nonprofits, as well as public community agencies that oversaw the weatherization work. State governments relied on existing local agencies to implement WAP under the ARRA; local agencies were hired through a competitive bidding process (Conlan et al., 2017, p.122). Similarly, funds allocated through the Energy-efficiency and Renewable Energy Program (EERE) also used a partially competitive process through categorical grants for making awards. The application processes were available for local governments, as well as private entities and nonprofit organizations. The Energy Efficient Appliance Rebated Program (EEARP), the Energy Assurance and Planning Program (EAPP), and the State Energy Program (SEP) also dedicated a portion of their funding temporary to provide competitively awarded financial assistance over the ARRA period (Goldman, 2011).

Expenditures under all of these programs were uniform in the sense that when allocating funds, federal policy makers used standard criteria and language that were consistently applied across places without any sort of explicit, place-specific criteria written into them. For instance, they required, without respect to any considerations of the circumstances of any particular locale, demonstration that, in general, only those locales with capacity to expend funds effectively could receive them. But they did not provide a list or otherwise enumerate any sort of determination as to whether or not any particular

locale had such capacity. Rather, it was up to the particular locale to make its own case for its own capacity. Thus, the statements of uniform federal policy goals were blind to the particular circumstances of local governments, even though some of these local circumstances played a crucial role in determining levels of policy adoption (Handley, 2008; Wheeler, 2008).

Local governments have a wide range of different characteristics, capacities and preferences, and they face a range of regional economic, social and historically contingent circumstances which differentially affected the likelihood that they might adopt and implement federally funded energy-efficiency programs. Moreover, as is recognized by a growing body of literature, all of these ideographic factors must be identified and systematically considered if one is to convincingly establish the impact of federal expenditures at the local level (Lyon & Yin, 2010; Sapat, 2004; Sharp et al., 2010; Portney, 2003; Feiock et al., 2010). Accordingly, a number of such factors have been identified, as described in the following subsections.

Federal Financial Support

Evidence indicates that the levels of available fiscal resources affect magnitudes of state and local energy initiatives. Clark and Whitford (2011) investigated the effects of grants provided by the U.S. Environmental Protection Agency (EPA) at the state level, finding evidence for a "flypaper effect" in which the more money a state received from the federal government, the more opportunity it had to apply those funds to more programs. States with greater fiscal resources thus had more environmental policies. Similarly Krause (2011), while investigating the factors that explain variation in policy adoption at the local level, found that higher levels of per capita general revenue in a given city tended to

motivate more climate-related initiatives and policies. Wang (2009) showed that California cities' climate actions were influenced by fiscal capacity. Hawkins et al. (2017) tested the hypothesis that cities with higher levels of own source revenue are more likely to invest in financial capacities that are intended to support sustainability, finding evidence that the relationship between local fiscal capacity and commitment for sustainability priorities is nonlinear. Accordingly, I hypothesized that cities that received more energy-related ARRA funds would undertake more energy-efficiency initiative and adopted more related policies and programs.

Economic and Demographic Characteristics

All ARRA funds were delivered to cities of more than 50,000 population and their adjacent urbanized clusters of at least 2,500 and less than 50,000 people. Previous research has shown that a number of city-specific characteristics are relevant at this level in determining more local energy initiatives.

The first such characteristic is city size. Lubell et al. (2009) found that increased city size, measured in terms of land area, tended to increase the level of activity for sustainable use of energy. In particular, cities with larger land size tended to adopt more energy-efficiency programs and policies.

Secondly, as a rule, the invention, commercialization, and adoption of energy-efficiency practices and energy saving technology requires a significant investment (Koski & Lee, 2014; Sharp, Daley, & Lynch, 2010; Lyon & Yin, 2010). Previous studies have thus examined whether per capita income is associated with variation in levels of energy efficiency initiative. The prevailing theory has been that people with lower-incomes are less likely to be able to afford programs and policies oriented around energy-efficiency

technologies, so innovative energy technologies are more likely to emerge and diffuse from within cities with higher income levels. In this case, however, given that WAP grants in particular were intended to subsidize weatherization of the homes of primarily low-to-moderate-income households, I expected that cities with higher per capita income would adopt fewer energy-efficiency policy programs.

Thirdly, previously published research suggests that the size of the population influences energy efficiency initiatives, programs and policies. Less populated, sprawled cities tend to be less energy-efficient (Balbo, 1993). On the other hand, higher urban populations tend to present more opportunities for increases in energy-efficiency attributable to their greater dependency on commercial products and services relative to rural populations (Clancy, Maduka, & Lumampoa, 2008). More highly populated cities with greater concentrations of human resources and economic activities also tend to have correspondingly greater energy demand, largely attributable to the corresponding demand for urban infrastructure and greater energy consumption (Madlener & Sunak, 2011). Evidence furthermore suggests that urbanization leads to economies of scale which provide opportunities for increases in energy-efficiency (Sadorsky, 2013). Population-related patterns such as these seem likely to place policy makers in more highly populated urban communities in circumstances in which they must concentrate more on both energy-efficiency and related pollutant emissions. Therefore I expected that cities with a greater population would take more energy-efficiency initiatives and receive correspondingly more grants.

Preference for Energy-efficiency Policies

Several studies have examined the relationship between policy preferences and policy choice. Some city governments prefer relatively more stringent policies and standards for achieving reductions in GHG emissions and enhancing sustainability. One indicator of this is membership in the International Council for Local Environmental Initiatives (ICLEI) (Krause, 2010; Yi & Krause, 2017). ICLEI membership obliges cities to participate in programs for sustainability, achievement toward innovative environmental governance, and clean energy-efficiency (Yi & Krause, 2017). Such preference has been shown to correlate with the institutionalization of sustainability programs in specialized units within local governments (Kwon, Jang, & Feiock 2014, Sharp et al., 2010). Thus I anticipated that, all else equal, ICLEI member cities would have taken more initiative and established more energy-efficiency programs and policies relative to non-ICLEI cities.

Local government participation in climate protection initiatives is likely to signal an interest in energy-efficiency, and therefore to predict the decision to compete for ARRA energy-efficiency grants. Climate Protection Agreements are developed as part of longer-term plans to achieve Green House Gas emission reduction and improvements in environmental conditions. The presence of these agreements can signal a preference for efforts toward sustainable and efficient energy policies. Thus, I expected that cities which had signed climate protection agreements would have taken the initiative to obtain more ARRA energy-efficiency grants than cities that had not signed them.

Variation in levels of education between cities has been shown to influence levels of environmental preservation and willingness to embrace and actively support sustainable use of energy (Inglehart & Abramson, 1994; O'Connell, 2008; Portney, 2008).

Accordingly, I expected cities that have a higher level of education would take more initiative and receive more ARRA energy-efficiency grants.

Manufacturing Influence

Following other local environmental policy research (Krause, 2011; Sharp et al, 2010; Lyon & Yin, 2010, Koski & Lee, 2014), a greater presence of manufacturing firms is likely to have the effect of depressing environmental policy actions as a result of their tendency to avoid extra costs for energy-efficiency or energy saving. For example, low-carbon technologies or advanced technologies for clean energy or energy-efficiency, which tend to be more expensive than standard technologies, may not be popular, especially for older, established manufacturing groups, even though these technologies may contribute to a reduction of CO_2 emissions. Therefore, I expected that all else held equal, cities with a greater presence of manufacturing firms would take fewer energy-efficiency initiatives and adopt fewer related programs and policies.

Political Influence

Local governments' political orientation has been recognized as a factor that affects policy adoption. Previous research indicates that cities with an ideology aligned with the Democratic Party may be more likely to prefer governmental intervention in environmental and sustainable use of energy policy (Lubell et al., 2009). The political circumstance of a local government evidently not only affects policy choice, but also policy implementation (Peters, 2002).

The state's political orientation is reflected in the preferences of state legislators and the nature of the constraints in the policy adoption process (Clark & Whitford, 2011; Bressers & O'Toole, 1998). Accordingly, recent studies assessing the effectiveness of

energy policies have incorporated variables that represent states' political circumstances. Using the environmental scorecard of the League of Conservation Voters (LCV), Delmas et al. (2011) for instance found that the presence of a Democratically-controlled state government and a majority of Democratic representatives was positively associated with the adoption of renewable energy policies and investment in energy infrastructure. Also using the LCV, Shrimali et al. (2015) found that states with more Democratic control tended to have a greater collective preference for environmental protection and to have a positive and significant correlation with the deployment of wind energy. Other empirical studies have also found that states with a higher LCV rating were positively linked to the adoption of environmental policies, including energy policies (Clark & Whitford, 2011; Carley, 2009; Delmas & Mones-Sancho, 2011; Shrimali & Kneifel, 2011). Therefore, I expected to find that cities with high percentage of total votes that supported the Democratic candidate are more likely to adopt more energy-efficiency policy programs.

Government Type

In recent research, the direct influence of government structures has started to appear to be a significant determinant of local energy-efficiency policies. Typically, the form of government consists of either an elected mayor-council structure, with an elected mayor as a chief executive, or a council-manager structure, with a professional manager hired by the elected council (Svara & Nelson, 2008; Nelson & Svara, 2015). Accordingly, Bae and Feiock (2013) found that various forms of government differentially provide greater opportunities for cities to engage in joint problem solving and to learn new policy approaches to address sustainability actions. Kwon, Jang, and Feiock (2014) recently assessed how government structure affects the adoption of energy policies. Specifically,

they examined 172 California cities to determine the factors that influence the level of climate protection and energy sustainability policy action. They hypothesized that cities with more political obstacles tended to undertake fewer climate protection and energy sustainability policy actions. Specifically, their research suggested that professional city managers who, compared to political officials, tend to care more about administrative efficiency and productive performance for purposes of raising their personal career reputations, may be less motivated to initiate and support environmental protection policies directed to the community rather than governmental operations. On the other hand elected mayors, who tend to be more concerned about issues of political responsiveness and representation, were evidently more interested in taking climate protection and energy sustainability policy actions in order to attract electoral support from environmental interest groups in their community.

Kwon, Jang, and Feiock (2014) also analyzed survey data obtained from 8,569 local governments in the United States in 2010, and concluded that a mayor-council form of government takes 1.32 times more environmental conservation actions than cities without this form. Similarly, Nelson and Svara (2015) found support for their conjecture that local administrators tend to concentrate on their expertise rather than seeking diverse opportunities in the adoption of public policy, and that they prefer to maintain a neutral stand on controversial issues. If an issue causes a dichotomy of opinion between politicians and administrators, such as energy-efficiency policies are likely to do, administrators are less likely to adopt the policy, even though they are active in policy formulation. Deslatte et al. (2017) found strong support for the influence of council-manager government on sustainable policy innovation. Therefore, I expected to find that cities with a mayor-council

form of government would take more energy-efficiency initiatives, receive more ARRA grants, and start more related programs and policies.

Research Methods

A major purpose of this research was to examine the determinants of ARRA funds in the competitive selection processes for energy-efficiency grants, along with their associated activities, programs and policies. I tested hypotheses about the previously mentioned variables using a quasi-experimental design based first upon propensity score matching to identify a set of cities similar to those that received the funds, except that they did not receive any such funds (Rosenbaum & Rubin 1983; Dehejia & Wabha 2002). Then I calibrated a hurdle model that predicted the number of ARRA energy-efficiency grants on the basis of the previously considered variables, using controls for the similar cities.

To identify a set of cities similar to the 348 cities that received energy-efficiency related ARRA funds, except that they did not receive such funds, I retrieved all of the 10,849 cities with a FIPS code assigned by the U.S. Census Bureau from American Fact Finder. Prior to matching the observations were stratified by the four census regions: Northeast, Midwest, South and West. Cities were matched with others in the same census region on the basis of population density, since this was significantly correlated with the outcome variable but not with the set of independent variables in the model (Sadorsky, 2013; Balbo, 1993). The matching process used 1:1 nearest neighbor matching with replacement, matching cities by the nearest available propensity score (Dehejia & Wahba, 2002).[3] A summary description of the resulting balance of the cities is provided in Table

[3] Specifically, at each stage (a) one of the cities that had received ARRA funds was selected from a randomly ordered list of cities in both categories, (b) a city with the closest propensity score was identified and a match made, (c) the matched pair was removed from the pool, (d) the city that did not receive ARRA

2. Hotelling's T test results indicated no significant differences in the covariates between the two groups of cities.

Table 2. Summary of Balancing Test

Census Region	Matching Variables	Treatment	Comparison	F-value	P-value
Northeast	Population Density 2009	6620.356	6229.101	0.175	0.676
	Population Density 2010	6696.430	9285.100	0.182	0.671
	Population Density 2011	6632.067	6238.099	0.176	0.676
	Population Density 2012	6636.477	6336.477	0.170	0.681
	Population Density 2013	6791.341	6378.457	0.161	0.689
Midwest	Population Density 2009	3432.400	3430.351	0.000	0.998
	Population Density 2010	3441.794	3433.272	0.000	0.992
	Population Density 2011	3484.592	3436.644	0.003	0.955
	Population Density 2012	3495.893	3456.293	0.001	0.972
	Population Density 2013	3505.044	3474.742	0.000	0.990
South	Population Density 2009	2912.390	2917.936	0.000	0.995
	Population Density 2010	2925.729	2926.130	0.000	0.999
	Population Density 2011	2965.861	2959.9369	0.000	0.997
	Population Density 2012	6052.481	3028.225	0.000	0.983
	Population Density 2013	3052.481	3028.225	0.000	0.983
West	Population Density 2009	3121.486	3123.465	0.000	0.993
	Population Density 2010	3127.324	3128.982	0.000	0.994
	Population Density 2011	3158.631	3155.977	0.000	0.985
	Population Density 2012	3189.853	3182.304	0.002	0.968
	Population Density 2013	3223.113	3208.089	0.001	0.970

Note: the p-value of the test indicated that the matched the pairs are balanced at 5% level.

Conceptual Model

To determine whether, on the margin, ARRA energy funding affected the numbers of local government energy-efficiency grants received, and programs and policies adopted, all of the previously mentioned factors had to be statistically considered. This was done using a hurdle model, first with a conditional logistic model to control for any differences

funds was put back in to the pool, and (e) the process was repeated with the next city until all 348 cities had a pair.

between cities that applied and received ARRA energy-efficiency grants and those that could not or did not do so. Second, it used a Poisson count model truncated at zero to estimate the effect of the covariates on the number of grants received by the recipient cities. The analysis thus assumed an underlying process with two stages. The first stage generated whether or not a city applied for and received and energy-efficiency grant and the second generated the number of such grants received by the recipient cities;

$$\text{Prob}\ (Y_i = 0) = f_i\ (0)$$

$$\text{Prob}\ (Y_i = j) = \frac{1-f_i(0)}{1-p_i(0)}\ P_i\ (j),\ j=1,\ 2,\ldots 60$$

where fi(0) is the probability of the zero outcome, $P_i(j)$ is the probability of the non-zero outcomes conditioned on the outcome being greater than zero. Here, *i* represent the cities, and *j* represent the number of ARRA energy-efficiency awards.

Data

Dependent variable

The dependent variable reflected the number of energy-efficiency grants received at the local level from the six aforementioned ARRA funded programs (see Table 1). This research assumed that *ceteris paribus*, cities that received more grants undertook more activities and made more federally-funded progress in terms of greater energy-efficiency relative to those that received fewer grants. This research included all 348 local governments in the 50 states that received federal money for one or more ARRA funded projects for each year during the period from 2009 to 2013, as well as 348 additional cities

selected through the matching process, as described above, for a total of 3,480 city/year/grant observations.[4]

Independent variables

The empirical model represented the factors that, on the basis of previous research, might have influenced federal government ARRA expenditures. See Table 3 for a description and the source of each independent variable in the empirical model. The categories of these variables coincided with those considered above, including (1) federal financial support, (2) economic and demographical characteristics, (3) preference for energy-efficiency policy, (4) manufacturing influence, (5) political influence, (6) government's types, and (7) education attainment.[5]

Financial support by the federal government was measured by total amount of federal grants awarded for the six programs under the categories of energy-efficiency project between 2009 and 2013. The economic and demographic characteristic variables included (a) land size, (b) per capita personal income, and (c) population. Land size reflected land area in square miles in the city proper, and population reflected the entire corresponding population. Per capita personal income was in 2013 inflation-adjusted dollars. Preferences for energy-efficiency policies reflected whether or not a city was a member in good standing of ICLEI-USA in the respective year. Member cities were coded '1', nonmembers '0'. It also reflected whether or not the city's mayor had singed the

[4] The data are available at (http://www.recovery.gov/arra/FAQ/Pages/DownloadCenter.aspx). They are based on recipient reports made available by the Department of Energy.

[5] Two of these variables, population and land size, are time constant in that within any given city they change either very slightly, or not at all over the study period. Tests for pathologies in the error terms of the hurdle model, however, indicated that these variables did not produce significant serial autocorrelation in the estimates.

Climate Protection Agreement by 2009. Signed cities were coded '1', nonmembers '0'. Next, in regards to the effect of the presence of manufacturing, previous research has suggested that states in which manufacturing accounts for a major part of all industrial employment and output are less inclined to adopt policies related to clean energy or energy-efficiency, probably because of an aversion to incurring extra costs (Krause, 2011; Sharp et al, 2010; Lyon & Yin, 2010, Koski & Lee, 2014). Thus, the model included the number of establishments within the manufacturing sector in each city. Previous research has also shown that the presence of a Democratic governor and a majority Democratic representatives are likely to be positively related to the adoption of energy-efficiency programs and investment in energy-efficiency infrastructure (Park, 2015; Clark & Whitfor, 2011). Thus, the model included the percentage of each city's total votes that supported the Democratic candidate in the 2012 presidential election. The city government type was a dummy variable coded '1' for a council-manager structure and '0' for others. Finally, I operationalized educational attainment in terms of the percentage of the population over the age of 25 with a BA degree. The analyses also included dummy variables representing years, to account for year-specific factors potentially affecting the number of energy efficiency initiatives not otherwise captured by the other independent variables.

Table 3. Variable Measurements at the Local Level

Variables	Measurements	Data Source
Dependent variable Policies Adoption	Number of contracts, grants adopted in categories of Energy-efficiency Programs, 2009-2013	Department of energy Data Reported by the American Recovery and Reinvestment Act(www.recovery.gov)
Independent variable Federal Financial Support	The amount of cities' obligated ARRA funds that were actually issued for energy-efficiency programs at the local government level, 2009-2013	Department of energy Data Reported by the American Recovery and Reinvestment Act(www.recovery.gov)
Economic and Demographic Land size Income Population	 1)Land Area in Square Miles 2)Per Capita Personal Income adjusted in 2013 dollars 3)Number of whole population	 U.S. Census Bureau
Preference for Energy-efficiency Policy	1)The Presence of ICLEI membership in a city (1= presence, 0=otherwise) 2)Dummy variable indicating whether or not each city had signed the Climate Protection Agreement (1= presence, 0=otherwise)	International Council for Local Environment Initiatives (ICLEI), U.S. Conference of Mayors, Mayors Climate Protection Center
Manufacturing Influence	Number of establishments by the manufacturing sector in each city	U.S. Census Bureau, County Business Patterns, NAICS 31-11
Political influence	The percentage of each city's total votes that supported the Democratic candidate in the 2012 presidential election	CQ Voting and elections Collection
Government Type	Cities with the presence of a council-manager form (1=presence, 0=otherwise)	Yearbooks of the International City/County Management Association
Education Attainment	Percentage of Population over the age of 25 with a BA or higher	U.S. Census Bureau

Results

Table 4 presents the relevant descriptive statistics for the 2009- 2013 period. The number of grants received by the cities ranged from 0 to 60 with a mean of 0.508 and standard deviation of 2.744. The amounts of these grants, again considering all cities, ranged from $0.00 to $1,971,000,000 with an average of $5,633,965 aggregated over the period of the study. Substantial variation existed among the cities in terms of size, demographic composition and government structure. The city with the smallest geographical footprint was 0.028 square miles and the largest was 606.422, with a mean of 27.858. Per capita personal income ranged from $12,917 to $160,956 with a mean of $49,610. As for the remaining variables, 11% of the cities had membership in the International Council for Local Environmental Initiatives (ICLEI) membership; population ranged from 120 to 3,897,940, with a mean of 80,449, and 76% of the cities had a council manager system of government.

In terms of climate protection agreement, 32% of the cities had in place as of 2009 a climate protection agreement with a U.S. Green House Gas reduction goal. The percentage of the city's population over age 25 with a BA degree or higher ranged from 2.7% to 68.6%, with a mean of about 18.95%. Manufacturing influence varied considerably, in the range of 0 to 4,956 of the number of establishments by manufacturing sector, with a mean of about 23.51. Finally, in regards to political support variables, the percentage of each city's total votes that supported by Democratic candidate ranged from 8.5% to 87.4% means of close to 50%.[6]

[6] Examination of the correlation matrix revealed that none of the covariates were highly correlated.

Table 4. Descriptive Statistics

Variable	Mean	SD	Min	Max
Energy-efficiency Grants and Initiatives	0.508	2.744	0	60
ARRA Fund ($1,000,000)	5.633	58.882	0	1971.731
Land Size (in square miles)	27.858	57.209	0.028	606.422
Per Capita Personal Income ($1,000)	49.610	19.936	12.917	160.956
Population (1,000)	80.450	241.058	0.12	3897.94
ICLEI	0.113	0.317	0	1
Climate Protection Agreement	0.321	0.467	0	1
Manufacturing Influence	23.514	195.627	0	4956
Political Influence	49.175	12.226	8.5	87.4
Government Type	0.765	0.423	0	1
Education Attainment	18.950	7.366	2.7	68.6

Note: N = 3480

Table 5 presents the results of the hurdle model, including both the conditional logistic model designed to control for which cities did and did not apply for grants and the zero-truncated Poisson count model designed to predict positive counts of grants received.[7] The goodness of fit results of the Poisson count model with all of the independent variables had a deviance of 1048.881, indicating that the model provided a reasonable description of the data with a p-value of less than 0.05. Also, the log likelihood ratio chi-square test, LR $\chi 2$ (14) = 1923.90, $p < .001$, indicated that the full model with ten predictors had a significantly better fit than the null model. I also used Ramsey's RESET test to indicate whether there were any important omitted variables. The results of Ramsey's RESET test were not indicative of any regression pathologies (Gujarti and Porter, 1999. p.215-217).

The coefficient estimates from the conditional logistic model are presented in terms of the natural logs of likelihood values. Accordingly, for each $1M increase in the amount of the grants, the probability that a local agent would apply for and receive a grant relative

[7] Tests for pathologies in the model provided no indication of problems. Variance inflation factor (VIF) values in the multicollinearity tests were all less than 2.0. Likelihood ratio tests indicated no evidence of any significant over-dispersion.

to not increased about 54 times. The probability that cities with a council-manager form of government would apply for and receive a grant was about 214 times greater relative to cities without this form. The probability was much greater that local agents would apply for and receive a grant in 2010, relative to not, and much less in 2013. Otherwise, the statistically significant evidence indicates that neither a city's per capita personal income nor the influence of manufacturing in the city was of any consequence in determining whether that city would apply for a grant. None of the other coefficients were statistically significant.

In terms of the count model, as American taxpayers might hope, all else held equal, increases in levels of ARRA expenditures significantly increased the number of energy-efficiency initiatives and corresponding programs and policies at the local level. Not surprisingly, cities with somewhat higher per capita income tended to adopt more energy-efficiency programs. Cities with more-general preferences for adopting such policies, as signaled through ICLEI membership, and cities with somewhat greater support by political influences also received more grants and adopted more programs and policies. As previously mentioned, cities with more manufacturing establishments tended to receive fewer grants and to adopt significantly fewer energy-efficiency programs and policies.[8]

[8] The coefficients on the year dummies were consistently significant, positive, and increasing over the time of the ARRA, when compared to the base year.

Table 5. Impact of Local Characteristics on Energy-Efficiency Policy Adoption by ARRA Energy-Efficiency Subsidies

Parameters of Count Model Equation Dependent variable: number of grants in each recipient city			
	Coefficients	Robust Std.	P-value
Constant	-10.111***	1.053	0.000
Financial Support (ARRA funds)	0.591***	0.051	0.000
Land Size	-0.002	0.002	0.347
Income	0.019**	0.008	0.011
Population	0.000	0.000	0.410
ICLEI	1.502***	0.299	0.000
Climate Protection Agreement	-0.101	0.325	0.755
Manufacturing Influence	-0.001**	0.000	0.016
Political Influence	0.010***	0.012	0.005
Government Type	-0.216	0.543	0.691
Education	0.000	0.018	0.999
Year_2010	0.217	0.142	0.125
Year_2011	0.522***	0.141	0.000
Year_2012	0.788***	0.177	0.000
Year_2013	0.954***	0.207	0.000
Parameters of Conditional Logistic Model Equation[9] Dependent variable: 0 = city with no grants, 1 = city with at least one grant			
	Coefficients	Robust Std.	P-value
Constant	-22.971***	3.118	0.000
Financial Support (ARRA funds)	3.995***	0.567	0.000
Land Size	0.021	0.199	0.288
Income	-0.047***	0.014	0.001
Population	-0.002	0.003	0.472
ICLEI	2.370	1.898	0.212
Climate Protection Agreement	-1.778	1.212	0.142
Manufacturing Influence	0.002***	0.000	0.000
Political Influence	-0.155	0.143	0.277
Government Type	5.368***	1.308	0.000
Education	-0.123	0.063	0.152
Year_2010	2.739**	1.272	0.031
Year_2011	0.164	1.197	0.891
Year_2012	-4.933	3.419	0.149
Year_2013	-11.233***	1.288	0.000

Notes: ** p<0.05, p<0.01***
Omitted category: Calendar year 2009

[9] The coefficients from the conditional logistic model are given in terms of logs of likelihood ratios. These mean, for example, the probability that manufacturing influence distinguished cities that received at least one grant relative to the probability that it did not is positive and significant. Positive coefficients imply that greater values of the corresponding variable tended to amplify the probability that applicants in a city would receive a grant relative to the probability that they would not. Conversely, negative coefficients imply that increased values of the variable tended to inhibit receipt of grants. The larger the absolute value of the coefficient, the greater the degree of amplification or inhibition.

Discussion

During the 2008 and 2009 recession, the Obama administration used ARRA funds for macro-economic purposes of helping to recover from the recession. A substantial amount of federal expenditure occurred directly at the local level, and this was designed to stimulate local energy-efficiency. This research has shown that the $21.8 billion in ARRA funds expended with the stated intent of improving energy-efficiency did indeed stimulate the sought-for energy-efficiency initiatives, and that it increased levels of adoption of local energy-efficiency programs and policies. It also showed that local factors tended to at least partially determine the levels of these initiatives. All else held equal, when financial support for energy-efficiency within any given city increased, so did the numbers of energy-efficiency grants and initiatives. Federal government expenditures can thus evidently play a central role in directly stimulating more energy-efficiency policies at the local level.

In regard to research question about how local factors affect the application and receipt of new federal grants, the probability that local actors will participate significantly increases when the amounts of the grants increase and when the local government has a council-manager form. Also, in contrast to previous research indicating that political influences would have discernable effects on participation, the results were inconclusive. Taken together, these results lead us to cautiously infer that the choice to participate in the ARRA energy efficiency grant programs was more the result of professional decisions to improve energy efficiency than of political ones to advance any sort of partisan or other normative agenda.

In regards to the extent of participation, which is to say the number of grants received by cities that received at least one of them, one of the specific expectations was that those cities which signaled a preference for efforts to promote sustainable energy, energy conservation, or energy saving would adopt more energy-efficiency programs and policies. Consistent with this expectation, I found that the presence of local government's voluntary networks, such as ICLEI membership had a significant positive effect on promoting more energy-efficiency initiatives. City governments have increasingly joined this network to better achieve sustainable energy, energy conservation, or energy-efficiency. Differing preferences and priorities of the citizenry of various cities are reflected in related policy decision-making processes, and those local citizenries that take sustainability issues more seriously are probably apt to apply for ICLEI membership. This research's findings suggest that local government participation in such voluntary programs as these are significant in promoting energy-efficiency initiatives.

The results also provide empirical confirmation for a number of specific hypotheses. Political ideology in city can evidently exert significant influence on local energy-efficiency initiatives, programs and policy adoption. The results indicate that cities are more likely to adopt more energy-efficiency programs and policies if they have a higher percentage of residents supporting Democratic candidates. This is consistent with previous results showing that Democratically-oriented political ideologies are associated with a higher likelihood of adopting environmental and energy policies toward sustainable energy.

As I also expected, the empirical evidence indicates that cities with a greater presence in manufacturing industries are less likely to adopt more energy-efficiency

programs. Evidently, from a manufacturing perspective, federally funded programs and policies supportive of improvements in local energy-efficiency are not always necessarily everything they are chalked up to be among the public at large. While this result may be counter-intuitive, it is nevertheless the one predicted by Jevon's Paradox. That is, Jevon's Paradox predicts that manufacturers will see increases in energy-efficiency as being a route to aggregate increases in total energy demanded and consumed, not decreases. Moreover, unless any given manufacturing firm's own decrease in cost per kWh attributable to energy-efficiency exceeds its share of the aggregate cost increase attributable to increased aggregate demand by all affected firms, the net effect of federally funded energy-efficiency programs would be to increase the firm's cost of energy. In any case, despite the fact that manufacturing firms have tremendous economic significance in some cities, in some instances to the point of being the city's economic lifeline, a higher presence of such firms in a city was, in the data, empirically associated with fewer ARRA grants and correspondingly fewer energy-efficiency initiatives, programs and policies.

The fact that per capita personal income had a positive effect on the number of grants received contradicted the expectation that, because of the prevalence of WAP grants, energy-efficiency initiatives would be less frequent in cities with higher income levels. But it is consistent with the alternative line of reasoning in which cities with higher income levels are more likely to be able to afford to undertake more innovations and therefore may have more motivation to undertake energy-efficiency initiatives relative to cities with lower income levels.

The statistically insignificant coefficients on several of the variables were unexpected on the basis of previous research, including education, population, land size,

government type, and Climate Protection Agreement. In regards to education variable, the level of education did not have any relationship at all with the numbers of grants received. In regard to population and land size variables, although the expectation was that larger populations and more land area would predict more energy-efficiency initiatives, evidently population and land variables measured at the local level do not have any relationship at all in this regard. Also, although local government scholars have investigated the impacts that forms of government have on policy choices to seek protection of the environment, and for sustainable energy, the findings indicate that a mayor-council government does not influence energy-efficiency initiatives or the adoption of related programs and policies. Indeed, although local government scholars have in the past found that a city's membership in the Climate Protection Agreement is associated with a higher likelihood of adopting environmental and energy policies, the findings indicate that the presence of a Climate Protection Agreement does not influence energy-efficiency initiative or the adoption of related programs and policies.

While the empirical model established that ARRA funding succeeded overall at stimulating local initiatives, it also has implications in terms of how to design cost-effective federal expenditure policies for energy-efficiency. With the ARRA, the federal government provided state and local governments with a specified temporary amount of funding designed to address broad purposes of energy efficiency. The ARRA thus provided a testing ground for exploring the federal role in diffuse energy-efficiency policy adoption, including competitive block grants, project-specific categorical grants, as well as formula grants. Together, they seem to have comprised an effective mechanism for the diffusion of more programs and policies, at least in the short term. Although further research might

be conducted to separate and tease out the differences between the levels of effectiveness of each of these types of grants, this research has shown that, should the need arise for further federal expenditures for energy-energy in the future, taken together they are effective. Past this point, the most efficient and effectively-targeted expenditure policies would evidently be those that direct relatively larger expenditures specifically toward physically higher income, Democratically-oriented cities with less manufacturing influence, and ones that signal their preference for environmental protection by such means as membership in the ICLEI.

Finally, it is worth briefly pointing out that the use of the hurdle model is not only appropriate but highly desirable in this and a range of similar contexts in which the underlying process has two stages. Public administration scholars often encounter such contexts. In this research for instance, in the first stage of the process, cities self-selected to apply for and receive ARRA energy-efficiency grants in any given year, or not. In the model, cities that received one or more grants were thus first distinguished from cities that received no grants at all. Then, in the second stage, for those cities that received at least one grant, the number of grants received was determined. The basic idea is that a Bernoulli probability governs the binary outcome of the first stage, and then, if the outcome is assigned a positive value then the "hurdle" is crossed and the conditional distribution of counts for all observations that crossed it is governed by a truncated-at-zero count data model. The structure of this model is thus suitable for a wide range of research applications in the public administration and policy fields.

Conclusion

The American Recovery and Reinvestment Act (ARRA) was the largest federal energy-efficiency investment in U.S history. The awards it provided helped local governments and agencies to make countless initiatives toward developing and adopting energy-efficiency programs and policies. At the same time, it is important to examine and evaluate the choices made and programs and policies undertaken as a result of this investment, as a means of informing energy policies in the future. Without well-designed policy evaluations, it will remain difficult, at best, to say whether policies have the effects stipulated in statements of legislative intent.

Accordingly, this analysis of the ARRA energy-efficiency expenditures made directly to local levels shows clearly that the $21.8 billion in ARRA funds expended with the stated intent of improving energy-efficiency actually led to more energy-efficiency grants, programs and policies within local communities. It also established a range of determinants of the levels of initiative taken by the various cities that received these grants.

ARRA-funded energy-efficiency grants were a one-time federal investment or single-shot stimulus in the energy policy field (Carley, 2016a). The grants were thus limited in the sense that continuous local-level improvements through similar investments in the future would require the long term stability and predictability of similar investments by the federal government (Terman et al., 2016). Although one-shot federal spending may not be optimal for achieving longer term improvements, the empirical evidence herein suggests that the short-term expenditures led to effective performance in terms of promoting the diffusion of energy-efficiency policies, at least in the short term and at the local level. From this viewpoint, future research should include empirical study of whether

short-term investment might be important for achieving longer-term energy-efficiency policy goals. Future studies are also needed using Bayesian multilevel models to determine the impact of previously enacted state policies on the adoption of related local policies, as well as other models and data to examine competing perspectives concerning the use of block grants versus other grant mechanisms to achieve national sustainable energy goals.

CHAPTER III

JOB CREATION GENERATED BY THE AMERICAN RECOVERY AND REINVESTMENT ACT: EVIDENCE FROM THE SECTORS OF THE ENERGY EFFICIENCY AND RENEWABLE ENERGY (ESSAY 2)

Introduction

The American Recovery and Reinvestment Act (ARRA) was a large-scale short-term federal initiative passed in 2009 as a Keynesian macroeconomic measure to support national economic recovery during the Great Recession. Job creation was important in the ARRA. ARRA's immediate goal was to stabilize the economy and preserve and restore jobs (Conlan et al., 2017). The goal of the ARRA funds was to invest in the foundation for a robust and sustainable 21st century economy (Charles, 2011). Over $ 90 billion of ARRA funds was invested in energy projects that improved long-run productivity through the development of sustainable energy technologies. These investments covered renewable energy generation, clean transportation, energy

efficiency, grid modernizations, advanced vehicles and fuels, carbon capture and storage, and green innovation.

The primary goals in the Department of Energy (DOE) under the ARRA included rapid job creation, job retention in energy use, and energy savings. The ARRA funds had played an important role in the rapid growth in the renewable energy and energy efficiency market. The federal government expected that roughly 5 million new jobs would be created as a result of ARRA investments (Charles, 2011).

Recently, performance assessments of the energy programs created under the ARRA have received considerable attention (Carley et al., 2014; Terman et al., 2016). Researchers have studied the ARRA implementation process (Carley et al., 2014; Terman et al., 2016), state experiences with the ARRA (Carley, 2016), and the effect of ARRA funds on specific programs such as the Weatherization Assistance Program (WAP) (Tonn et al., 2016). However, although the literature provided sound reasons to expect that the ARRA expenditures supported many jobs, no published research has yet examined empirically how the ARRA funds performed in creating jobs with regard to energy efficiency and renewable energy sector. Accordingly, this study empirically evaluated the effectiveness of the ARRA funds on job creation generated in the energy efficiency and renewable energy sector by focusing on the impact of federal energy programs spent in the Department of Energy (DOE) under the ARRA. In particular, this research focused on the impact of the ARRA funds allocated through each contract or grant provision within the DOE under the ARRA.

Grants or contract programs funded through the DOE under the ARRA had tended to focus on the state and local ground-level aspects of service delivery. Overall, the subsidies from the ARRA did not change hierarchically-oriented federal-state-local relationships. However, allocation through grants or contract provisions were dependent on state or local networks to achieve national policy outcomes. In addition, each state government decided how to allocate its share of the ARRA funds to local governments as well as non-governmental entities. Thus, this research focused specifically on the effectiveness of energy policies implemented through grant or contract provision under the ARRA funds. Nevertheless, tax incentive or tax credit programs did not rely on the DOE's approval regarding their criteria of allocation.

The ARRA of 2009, commonly called the "stimulus," was designed to spur economic growth while creating new jobs (Conlan et al., 2017). Many ARRA projects focused on immediately jumpstarting the economy. Some projects, such as those involving investments in energy technology, were expected to contribute to economic growth. Ultimately, the objective of renewable energy, or energy efficiency policies implemented under the ARRA was concentrated on energy-related jobs creation through promoting new advanced clean technologies (Carley, 2011; Mundaca & Richter, 2015). This research was intended to evaluate whether the ARRA achieved its stated objective of increasing job creation. Accordingly, this research reviewed the definition of implementation and the meaning of its related "success". Next, this research described a theoretical approach to successful implementation. Then, this study described and statistically tested the hypotheses related to the factors that influence successful job creation in the sector of efficient energy and producing energy from renewable sources in

the short-term (2009-2013 years), as well as in mid-term (2007-2013 years) and long-term (2003-2013 years) periods. In the short term approach, this research focused on assessment of the impact of ARRA funds on job growth in the energy efficiency and renewable energy sectors.

Theoretical Framework: Successful Implementation of Federal Energy Policy

Policy refers to the principles or intentions that guide specific actions, such as specific legislative acts or programs (Palumbo et al., 1984). Policy is programs that are implemented. Programs can be aimed at achieving a particular policy (Palumbo et al., 1984). Procedures in the programs are also intended to accomplish statutory goals.

In the public administration literature, scholars have pointed that policy outcomes are theoretically dependent on the implementation activities. Specific goals and well-designed interventions are essential for successful implementation (Pressman & Wildavsky, 1973). Ong (2012) also identified that successful implementation requires several factors: purposeful attention, procedures and processes to overcome internal and external barriers, explicit and quantifiable objectives to monitor progress, ongoing assessments to identify implementation problems, and a willingness to revise and refine efforts when required.

The majority of empirical research on general assumptions of the successful implementation has been focused on whether administrators strive to meet performance goals (Hood, 2006; Terman & Yang, 2013). In particular, few qualitative studies have highlighted the problems associated with policy implementation of the ARRA (Carley et al., 2014; Terman et al., 2016). They defined the concept of successful implementation

that stated goals were accomplished in the planned timeframe and without exceeding budgetary constraints. They concluded that implementation delays was one factor that hinders successful policy implementation under the ARRA. However, despite the goals under the ARRA expected to have more tangible outcomes such as creating jobs and cutting electricity bills, no empirical studies have been analyzed the effectiveness of the ARRA expenditures targeted in job creations.

Accordingly, this research framed a conceptual definition of successful implementation by assessing whether the desired results were met. This research focused on whether implementation under the Recovery Act achieved job creation. Specifically, this study was focused on the job creation counted in the energy efficiency and renewable energy sector.

ARRA Funding

Funding and investment at the intersection between economic development, energy policy and planning has been on the rise over the last decade (Carley, 2016). Most recently, ARRA provided a wide array of policy instruments to stimulate the U.S. economy and establish a robust technological infrastructure for long-term economic growth (Aldy, 2013). ARRA was designed to emphasize the connection between economic development and energy policy by specifically targeting the energy sector. Approximately $60 billion were spent on the energy sector (U.S. Government Printing Office, 2009) on renewable energy, energy efficiency, smart grids, and advanced fossil fuel energy programs among multiple others. Much of the ARRA funding was designed to support existing energy programs, but some funds were dedicated to new energy

programs focused on energy planning and economic development (Carley et al., 2011). In particular, the ARRA had overall goals: (1) create new jobs and save existing ones, (2) spur economic activity and invest in long-term growth (Hall & Jennings, 2011).

Recent research has started to examine the actual effects of energy-related ARRA expenditures. Specifically, the Council of Economic Advisers (Executive Office, 2016) estimated that ARRA clean energy-related programs supported roughly 900,000 jobs in innovative clean energy fields between 2009 and 2015. Link and Scott (2012) discussed how Small Business Research (SBIR) programs in the U.S. created and administered by such agencies as the Department of Defense, and the National Institutes of Health, NASA, and the U.S. Department of Energy can be credited with an average of about 42 new jobs per $1,000,000 of government award funding. However, most assessments on the relationship between ARRA expenditures and its actual effects have focused on the general effects inferred from all federal ARRA funds rather than expenditures specifically designed for energy.

Furthermore, still no published research has yet examined the impact of the ARRA funds implemented under the intergovernmental grant. Federal ARRA funds allocated under the EERE of DOE relied on networked governance system through existing networks of state and local. State and local governments, under the DOE, designed their programs and procedures and allocated the ARRA funds at their own discretion. The ARRA funds were passed through state governments with their direction to competitively award the funds to local governments. It was managed by state office with their own discretion, not by federal DOE governments. In other words, each state government decided how to allocate its share of the funding to local governments as well

as non-governmental entities. Under the these structure, some state spent larger amount of ARRA funds activity their programs in their own discretion with more ARRA money, other states might not or did not do so. However, most of ARRA funds studies focused on national-level impacts, neither has any study tested empirically on the association between spent ARRA expenditures and energy relevant job creation at the state level. Accordingly, this research hypothesized that state governments that spent a larger amounts of ARRA funds were more likely to create more jobs in the energy efficiency and renewable energy sector.

Subnational Government Capacity

Scholars have long recognized that the capacity of subnational governments is essential to the implementation of federal policy (Derthick, 1970; Elazar, 1984; Gamkhar & Pickerill, 2012; Hall et al., 2011; Jennings et al., 2012; Carley et al., 2015). The term of the capacity is broadly defined as the ability of organizations to carry out their missions and achieve their goals (Ingraham, Joyce, & Donahue, 2003). Capacity, defined in various ways, has been shown to correlate with implementation success for all three levels of government, federal, state and local (McDermott, 2006). State capacity is especially crucial to the efficiency with which federal dollars are spent (Carley et al., 2015). Subnational capacity includes inputs such as labor and finances (Honadle, 1981; Hall, 2008; Carley et al., 2015), and depends on the stock of institutional, organizational, and individual resources (Honadle, 1981; Bowman & Kearney, 1988). The presence of greater capacity of all types in subnational governments can lead to greater progress toward their policy goals and implementation (Hall, 2008).

A rich theoretical body of scholarship has analyzed empirically the relationship between subnational government capacity and the variation of policy outcome. Specifically, Terman and Feiock (2014) investigated the relationship between energy policy outcomes and local administrative capacity based on a principal-agent theory. Specifically, they estimated administrative capacity in terms of the number of financial management staff members in a municipal government per 1000 residents. They measured implementation timing, defined as the deviation in days of delay for each energy project implemented, and used it as a dependent variable. Their result showed that lack of staff capacity had a statistically negative effect on energy policy implementation. Although the federal government provides increased funding with various training and technical support opportunities to help implement energy efficiency and conservation projects, it is important to ensure sufficient local staff for proper policy implementation. Also, Krause et al (2014) assessed the sustainability programs in US cities based on interest group support, governmental capacity, policy characteristics, and institutional structures. The authors suggested that relationships among numerous specialized departments and agencies are important to facilitate sustainability efforts, and those institutional environments shape the motivations of local government officials. Furthermore, they linked fiscal resources to policy performance. This research argued that establishing an office focused exclusively on sustainability is likely to involve substantial start-up costs. One of their areas of interest, the support from local environmental groups, was measured based on data the Integrated City Sustainability Database (ICSD) of 2005. The results showed that local governments with greater financial resources and institutional environments with greater support from

environmental groups had a significantly positive effect on sustainability policy management in the executive branch at the city level.

In terms of the ARRA process, Carley and Hyman (2014) asserted that multiple local and state governments, much like the U.S. Department of Energy (DOE), were unprepared to implement ARRA's requirements (in terms of lacking sufficient qualified personnel, or relevant policies and procedures to handle extensive amount of ARRA funds) in the required time frames. Government data, provided by the Recovery Accountability and Transparency Board, demonstrated that there were spending delays both within and outside of government and that ARRA was significantly more difficult to implement in a timely manner than policymakers intended; some states also encountered more difficulties than others. Therefore, based on these previous findings, this research hypothesized that state governments with larger expenditures allocated by federal government are more likely to create more jobs in the energy efficiency and renewable energy sector.

Furthermore, this research considered the impact of the non-government expenditures as mechanisms consists of voluntary collaborations that are made between government agencies and non-government donors in supporting mutual initiatives. According to DOE's strategic investment in science and technology, State Energy Office (SEO) was inviting proposals funded by cooperative agreements, between government and private industry (DOE, 2014). Specifically, the projects related to the Clean Coal Power Initiative and America's Next Top energy Innovator, as well as Energy Innovation Portal are implemented through federal programs with non-governmental funding. Even though these programs operate out of the state government, their participation is never

funded by this SEO. In theoretical perspective, non-government funding's participation, provided by external entities like non-government organization, have been recognized as important strategies to expend their effectiveness into broader trends associated with the energy policy (Carley, 2011). However, the effectiveness of the decentralized fiscal funds in the implementation stages of energy policy have not been investigated empirically. Therefore, this research considered the categories of expenditure allocated by the non-government sources on activities that are specifically related to energy. This study expected that state governments with larger magnitudes of non-government expenditures are more likely to have more jobs in the energy efficiency and renewable energy sector.

Political Influences

It is generally argued that liberal political ideology is associated with green energy policies and renewable energy programs (Yi & Feiock, 2014). The ideological propensity of the governor and the legislators not only shapes the support for green energy regulations, but also influences innovative green energy technologies' development and diffusion (Coley & David, 2012). Stable and predictable political circumstances are essential for the deployment and development of green energy. Recent research has analyzed the direct relationship between states with a democratic governor and policy implementation outcomes (Carley et al., 2015; Jennings et al., 2012; Delmas & Montes-Sancho, 2011; Lyon & Yin, 2010). These studies have stipulated that democratic governors may have tighter goal alignment with the Obama administration's stimulus program and seek to implement the programs more efficiently and effectively. According to Jennings, Jennings and Zhang (2012), ARRA was a highly politically-charged policy. Democrats strongly supported President Obama's claims that ARRA

would create jobs, while zero Republicans in the House and only three Republican senators cast votes in favor of the bill. In this context, the findings of Jennings, Hall and Zhang, Carley, Nicholson-Crotty, and Fisher (2015) confirmed a relationship between political affiliation and states' ability to spend on energy. Delmas and Montes-Sancho (2011) demonstrated how political influence can affect energy policy by showing that the percentage of House and Senate seats in the states' government occupied by Democrats is positively and significantly related to the effectiveness of RPS policies. Lyon and Yin (2010) also found that states with a strong democratic presence were more likely to adopt an RPS. Based on these findings, this research expected that states served by Democratic governors were more likely to successfully create jobs in the energy efficiency and renewable energy sectors.

Circumstances that Use Renewable Energy Sources

Following other local environmental policy research (Ong, 2012; Yi, 2014; Krause et al., 2015), a greater presence of firms that use renewable energy is likely to provide more job opportunity for green business or employment that are specifically related to renewable energy or efficient energy. If state have industry or establishment that use more renewable energy, it may be able to attract more employment opportunities in the energy efficiency and renewable energy sector. Therefore, we expected that all else held equal, states with a greater circumstances that use renewable energy resources in electric power generation are more likely to create more jobs in the energy efficiency and renewable energy sector.

Economic Characteristics

Following previous studies, state-specific economic characteristics are always relevant in the growth of clean or green energy. The first such factor is the overall level of state economic activities, as characterized by greater per capita gross domestic product (GDP). A recent study found that the higher a state's per capita GDP, the larger the market size in the state, which creates a sufficiently large market to achieve economies of scale for green energy or clean energy and for related industries to develop and grow (Yi, 2013). Bowen et al. (2013) confirmed that empirical evidence consistent with the positive impact of per capita gross state product (GSP) on increasing in green business. Porter and Stern (2001) showed a positive relationship between creation of the green jobs and per capita GSP, which was a main determinant for patterns of technological performance. Thus, this study expected that state governments with vibrant economies are more likely to have more jobs in the energy efficiency and renewable energy sector.

Secondly, in the literature on the relationship between population density and job creation. Previously published empirical research also demonstrated that greater population sizes tend to present more job opportunities to provide services of efficient energy or renewable energy. They argued that if a state has greater population, it may have a greater chance of creating new innovative technologies (Sadorsky, 2013). More highly populated states with greater concentrations of human resources also tend to have correspondingly more green jobs employed for installation and maintenance (Madlener & Sunak, 2011). Moreover, this study expected that more highly populated state with greater concentrations of human resources are more likely to have more jobs in the energy efficiency and renewable energy sector.

Research Methods

Conceptual Model

The purpose of this research was to analyze the factors that influence job creation in the sectors of efficient energy and producing energy from renewable sources. This research focused on the impact of the ARRA funds allocated through intergovernmental grant provision under the Office of Energy Efficiency and Renewable Energy (EERE) of the Department of Energy. This research tested whether the ARRA expenditure, as a one-time shot, leads to a spike in job creation in the energy sector or whether it has long-term impacts on job creation. This research used panel data of 49 states in the U.S. over the period 2005-2015. All of the previously mentioned factors had to be statistically considered.

To isolate the effects of the ARRA funds, this research first included a set of control variables to account for those confounding factors. In addition, this study also included lagged variables for the ARRA expenditure allocated in selected energy program in order to capture any lagged effects of the ARRA funds in previous year. To control for remaining omitted variable bias, this research used instrumental variables for the ARRA expenditure on selected grant programs. Thus, this research estimated two-stage models: This research conducted the first differenced analysis with instrumental variables approach to consider the assumption for the endogeneity of the ARRA funds. It was approached in first-differenced two-stage least squares (FD2SLS) estimation to control the assumption that lagged ARRA variables may be correlated with the error term. All results included robust standard errors to adjust for potential heteroscedasticity

and serial autocorrelation in the model (Wooldridge, 2003), this was done with allowing fixed effects.

The analysis assumed an underlying process with two stages. The first stage generated whether or not ARRA funds (endogenous variable) associated with instrumental variables and the second generated the model captured the two effects included the direct effect from the explanatory variables, and the proxy effect from the omitted variables:

$$ARRA\_Funds_{st} = \pi_0 + \pi_1 ARRA\_Block_{st} + \pi_2 State\_Energy\_Policy_{st} + \pi_3 X'_{st} + \alpha_s + \vartheta_{st} \quad (1)$$

In the first stage equation (1), $ARRA\_Funds_{st}$ represents the total amount of federal ARRA expenditures allocated in seven grant programs (See Table 8) under the Office of Energy Efficiency and Renewable Energy (EERE) by the Department of Energy, under the ARRA, in state s, and individual year t. This research included two instrumental variables that did not enable job creation or promote, but it may correlated with the level of the allocated ARRA funds. As instrumental variables, this research used the $ARRA\_Block_{st}$ which means the amount of ARRA funds spent under the block grant types in state s, and individual year t, $State\_Energy\_Poilcy_{st}$ which means policy duration that has been adopted Renewable Portfolio Standard (RPS) and Energy Efficiency Resources Standards (EERE). This study expected that two instrumental variables are highly correlated with the $ARRA\_Funds_{it}$ it which means total amount of ARRA expenditures allocated in seven energy grant programs under the Office of Energy Efficiency and Renewable Energy (EERE).

$$Job\ creation_{st} = \beta_0 + \beta_1 ARRA\_Funds_{st} + \beta_2 ARRA\_Funds_{s(t-1)} + \beta_3 X'_{st} + \beta_4 * T + \beta_5 * S + \vartheta_{st}$$

(2)

In the second stage equation (2), $Job\ creation_{st}$ is the total number of jobs counted in energy efficiency and energy from renewable sources in the classification identified in the Green Goods and Services (GGS) in state s and year t. In all equations, $ARRA\_Funds_{s(t-i)}$ represents the total amount of federal ARRA expenditures allocated in seven energy grant programs under the EERE, under the ARRA, in state s, and individual year t with lag length of *i*. It was meant lagged effects of total amount spent in seven energy grant programs by EERE under the ARRA. The lag length of *i* was used from one year to three years. The appropriate lag length was determined by the Akaike Information Criterion (AIC) (Popp, 2016). Where X'_{st} was a vector of independent variables including government financial capacity, political circumstance, renewable energy circumstances, and economic characteristics in state *s* and year *t* was error term into identically distributed state-effect term.

Data

Dependent variable

The dependent variable reflected the number of jobs created in the energy efficiency and renewable energy sectors. This research used the definition of category of "Green Goods and Services" (GGS) as defined by the U.S. Bureau of Labor Statistics (BLS). This study focused only for the first and second categories of energy efficiency and energy from renewable sources (See Table 6). This research did not include all 5 categories of GGS as defined by the Bureau of Labor Statistics (energy from renewable

sources; energy efficiency, pollution reduction and removal; natural resource conservation, and environmental compliance). The first and second categories, within the GGS, were counted as a proxy for jobs related to the energy efficiency and renewable energy (See Table 6).

Table 6. Classification of the Green Goods and Services (GGS)

	Classification of the Green Technology under Green Technology Piot Program
1	**Energy from Renewable Sources**
2	**Energy Efficiency**
3	Pollution Reduction and Removal, Greenhouse Gas Reduction, and Recycling and Reuse
4	Natural Resources Conservation
5	Environmental Compliance, Education and Training, and Public Awareness

Source: U.S. Bureau of Labor Statistics, Retrieved from https://www.bls.gov/ggs/

Independent variables

The empirical model represented the factors that, on the basis of previous research, might have influenced in energy-related job creations. See Table 7 for a description and the source of each independent variable in the empirical model. The categories of these variables coincided with those considered above, including (1) ARRA funds, (2) subnational government capacity, (3) political circumstances, and (4) circumstances that use renewable energy sources (5) economic characteristics.

Table 7. Variables Measurement

Variables	Measurements	Sources
Dependent Variable Job in Energy Efficiency and Renewable Energy Sector	The number of jobs counted in energy efficiency and energy from renewable sources, into the definition of category of Green Goods and Services (GGS) as defined by the Bureau of Labor Statistics	Bureau of Labor Statistics (BLS)
Independent Variable ARRA Funds	1) Total amount of federal ARRA expenditures spent in 7 grant programs under the Office of Energy Efficiency and Renewable Energy (EERE) ($10,000,000). 2) The lag length was used from one year to three year ($10,000,000).	Department of Energy Data Reported by the American Recovery and Reinvestment Act (www.recovery.gov)
Sub-National Government Capacity	1) Total amount of federal expenditures annually allocated by the U.S. Department of Energy (DOE) ($10,000,000) 2) Total amount spent under the federal DOE program through non-government funding participation ($10,000,000)	USASPENDING.GOV (www.usaspending.gov)
Political Circumstances	State with a Democratic governor (1 indicating the governor is a Democrat and 0 if not)	Multistate Associates Incorporated (MAI)
Circumstances that Use Renewable Energy Sources	Number of establishments that use renewable energy resources	U.S. Census Bureau
Economic Characteristics	1) Per capita Real GDP adjusted in 2015 2) Number of people residing per square mile of land	Census of Governments and Bureau of Economic Analysis (BEA)
Instrumental Variable ARRA Funds in Block Grant Circumstances of State Energy Policy	1) Total amount of federal ARRA expenditures spent under the CCDBG, CSBG and CDBG 2) Duration of Renewable Portfolio Standards (RPS) and Energy Efficiency Resources Standards (EERE), in years	Bureau of Labor Statistics(BLS), Database of State Incentives for Renewable & Efficiency (DSIRE)

This study used federal government ARRA expenditures awarded through intergovernmental grants under the Office of Energy Efficiency and Renewable Energy (EERE). The variable contained observations of the total amount spent in seven intergovernmental grant programs aimed to energy efficiency and renewable energy innovation under the EERE (See Table 8).

This research expected that the ARRA expenditures spent in intergovernmental grant programs, intended to support the energy efficiency and renewable energy, would be associated with the job creation in the energy efficiency and renewable energy sector. Because, the ARRA goal was intended to create new jobs, with the perspective of energy-based economic development, within strategies to produce new advanced energy technologies (Carley et al., 2014). Indeed, this research employed ARRA expenditure's lagged variables with length of three years to address the short-run and long-run effects of ARRA expenditures. It had been represented as the cumulative effects of the ARRA expenditures for the past three years. Accordingly, this research used the amount of the ARRA funds that were actually spent in the seven intergovernmental grant programs under the EERE of the DOE aimed to promote renewable energy or energy efficiency (See Table 8).

In order to conduct the analysis at the state level, this research focused on selected seven intergovernmental grant programs that were managed by State Energy Office (SEO), not by the federal DOE. According to implementation process for selected energy programs, each state decided how to award these sub-grants at their own discretion. The recipients of these grants were determined by the state governments. SEO designed and carried out their own renewable energy and energy efficiency program. They had

responsibility to coordinate the development of projects and funds allocation. Thus, this research focused on state level impact of the ARRA federal funds implemented through intergovernmental grant program. The ARRA data were collected from Department of Energy Data reported by the American Recovery and Reinvestment Act (www.recovery.gov).

Table 8. Intergovernmental Grant Funded under the DOE's ARRA

DOE Office	Grant Provision	Grant Purpose
Office of Energy Efficiency and Renewable Energy (EERE)	1) Energy Efficiency and Conservation Block Grants	Grant for supporting energy conservation in the transportation, building, and other sectors and renewable energy development
	2) Weatherization Assistance Grant Program	Grant for purchase of the energy efficient equipment for low income household
	3) State Energy Grant Program	Grant for state-led energy initiatives. It was aimed to promote the energy efficiency and energy conservation.
	4) State Energy Efficient Appliance Rebate Program	Grant for the purchase of energy-efficiency Energy Star products
	5) Advanced Battery Manufacturing Grants	Grant for developing advanced battery and battery system
	6) Transportation Electrification Grants	Grant for conducting demonstration (evaluation) on advanced electric drive vehicles technologies.
	7) Alternative-Fueled Vehicles Grants	Grant for the purchase of alternative fuel and advance technology vehicles

Source: Energy Provisions in the American Recovery and Reinvestment Act of 2009, Retrieved from http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R40412.pdf

In addition, this research expected that state governments with greater financial capacity were more likely to create jobs in the energy efficiency and renewable energy sector. It focused separately on each category of expenditure allocated by the federal government and non-government sources toward sustainable energy. Most state energy programs that supported renewable energy or efficient energy relied on existing federal government mandating spending. At the same time, government has also invited non-

federal expenditures as mechanisms consists of voluntary collaborations that are made between government agencies and non-government donors in supporting mutual initiatives. According to DOE's strategic investment, they were inviting proposals funded by cooperative agreements, between government and private industry (DOE, 2014). Even though these programs operate out of the federal government, their participation was never funded by this government. Accordingly, the magnitude of subnational government capacity were estimated using two sources, specifically, (1) total amount of federal expenditures allocated annually by the Department of Energy (DOE) , (2) total amount allocated within federal DOE programs with non-government funding participation. Relevant data were gathered from USA Spending (www.usaspending.gov).

Next, previous research has shown that the presence of a political orientation of the Democratic are more likely to support to green economies that are associated with the effect on the quality of the environment (Clark & Whitfor, 2011; Krause et al., 2014). Therefore, this research expected state served by Democratic governors are more likely to successfully create job in the energy efficiency and renewable energy sector. The independent variable related to political circumstances were measured by dummy variable coded '1' for state with a Democratic governor and '0' for others.

Furthermore, this research has expected that the state with a great circumstances that use renewable energy resources are more likely to create job in the energy efficiency and renewable energy sector. Thus, the model included the number of establishments that use renewable energy resources in the electric power generation industries. The industries that use wind, geothermal, biomass, and solar electric power generation has defined from the Economic Census under the North American Industry Classification System

(NACIS). It has been counted at the six digit NAICS codes within six sub-categories (See Appendix C); (1) Hydroelectric power generation (NACIS 221111), (2) Solar electric power generation (NACIS 221114), (3) Wind industries (NACIS 221115), (4) Geothermal (NACIS 221116), (5) Biomass (NACIS 221117). Data was retrieved from the Census Bureau Economic.

In addition to the main variables of interest discussed earlier this research control for state economic characteristics, including population density and per capita Gross State Product (GSP). Previously published research suggests that population density influences the level of green job creation (Balbo, 1993; Yi, 2014). If state area is experiencing a less population density, energy-relevant job can hardly experience any growth. More densely populated areas are expected to lead to increased demand for energy, which magnifies the pressure for energy efficiency, resulting in government and utility investment in energy efficiency and thus creating energy-relevant jobs. Population density was measured by the number of people residing per square mile of land. Also, state's economic characteristics have been previously found to influence administrative implementation and behavior (Portney, 2003). States' wealth might impact the proportion of their funds allocated for energy programs (Carley et al., 2014). Park (2015) argued that during the Great Recession administrators were forced to slow down the increase in the green energy sector and shift expenditures to social policies and elsewhere. Thus, this research expected that that s states with vibrant economies were more likely to create jobs in the energy efficiency and renewable energy sector. The data related to the conditions of the state economies were collected from the U.S. Census and Bureau of Economic Analysis

(BEA), and U.S. Census of Government. All relevant numbers were adjusted for inflation and listed in 2015 dollars suing the GDP deflator.

Instrumental variables

The first instrumental variable was the total amount of federal ARRA funds spent in three block grant programs aimed to provide federal grants to state or local governments: (1) Child Care and Development Block Grant (CCDBG) program, (2) Community Services Block Grant (CSBG) program and (3) Community Development Block Grant (CDBG) program. . Under the ARRA, block grant programs were designed to stimulate innovation at the state and local levels (Conlan et al., 2017). The ARRA funding, through the block grant programs, increased rapidly over the time period of the ARRA (Dilger & Boyd, 2014). Specifically, state and local governments received $52.9 billion in the form of grant-in-aid funds under the ARRA (Conlan et al., 2017, p.33). This funding was intended to reform federalism relationships as well as to reduce bureaucratic redundancy and cost (Terman & Feiock, 2014). These funds were also allocated under the decentralized framework. What this research proposes is that the funding of the ARRA block grants was analogous to that of ARRA energy intergovernmental grants implemented through the EERE. Because, governments tend to pursue similar reforms (Urpelainem & Yang, 2017); when the ARRA energy funds were allocated under the decentralized framework for simulating energy innovation, they were so allocated as to mirror the funding of the block grants. Therefore, this research assumed that states with greater ARRA expenditure spent in three block grant programs might be spent more intergovernmental grant implemented under the seven programs of EERE.

The second instrumental variable was the circumstance of state energy policy. A comprehensive energy policy plan entails long-term commitments to enhance social values and goals toward sustainable energy (Baumol & Oates, 1988). States differ by existing policies and expertise accumulated through experiences in energy policy implementation toward sustainable energy. For this reason, motivation to implement energy policies tends to vary between state and municipal governments. Some states respond with minimal efforts towards sustainable energy policies, other states have implemented programs early and actively provided resources and diverse policy instruments. In this context, one might expect that that governmental agencies with more experience in state energy policy implementation have more accumulated information on how policies can be better implemented, what is feasible or preferable, when agencies should act to implement a policy, and what should be changed for better performance. In this perspective, this research assumed that states with more accumulated implementation experience related to state energy policies would have spent more energy related ARRA grants.

For the instrument to be valid, this research confirmed that the total amount of ARRA expenditures spent in the CCDBG, CSBG and CDBG, were highly correlated with the total amount of ARRA expenditures allocated through seven intergovernmental grant programs under the DOE's EERE, but not directly related to variation of job created in energy efficiency and renewable energy sector. The circumstances of state energy policy was also correlated with the total amount of ARRA expenditures spent in seven intergovernmental grant programs under the EERE (See Appendix D).

According to the results of the first stage with the instrumental variables, there was a strong positive association between the ARRA funds spent in three block grant programs and the ARRA energy funds spent in seven intergovernmental grant program under the EERE. Also, when the ARRA energy grant were spent under the EERE, there was a significant difference between states with more accumulated implementation experience related to state energy policies and those with less experience related to state energy policies. Those states with more implementation experience related to energy policies had higher rates of the ARRA funding expenditure in seven intergovernmental grant programs. Thus, this research discovered that the potential drivers behind ARRA energy investment were the amount of ARRA funds spent in the tool of block grants and the circumstances of state energy policies.

In order to suggest validity of the instrumental variables, the week identification test was used based on the F-statistic (Staiger and Stock, 1997). The results of this test showed that the instrumental variables were strong. The F-statistic for the first-stage regression analysis was consistently much larger than 10 (Table 9). A test of overidentifying restrictions was performed in order to verify the validity of instrumental variables. The null hypothesis that the instrumental variables are valid was not rejected.

Table 9. First-Stage Results with Instrumental Variables (IVs)

Model 1	Coef.	Std. Err	P-value
ARRA Funds Spent under the Block Grant Types	0.730***	0.182	0.000
Circumstance of State Energy Policy	0.212*	0.127	0.095
ARRA Funds under the EERE			
One-year lag	0.946***	0.042	0.000
Two-year lag	-0.135*	0.069	0.052
Three-year lag	-0.197***	0.056	0.001
Government Financial Capacity			
Federal DOE Expenditures	-0.000	0.002	0.923
Non-Government Expenditures	-0.022	0.023	0.345
Political Circumstance			
Democratic Governor	0.053	1.381	0.970
Renewable Energy Circumstance			
Establishment that Use RE in Electric Power	-1.80e+05	1.20e+05	0.136
Economic Characteristics			
Per Capita Real GDP	-0.000	0.000	0.388
Population Density	0.000	0.000	0.141
Under-identification Test p-value	0.000		
Weak-identification Test (F-statistic)	27.625		
Over-identification Test of instruments Test p-value	0.141		
Year FE	YES		
Observation	539		

Note: * p<0.10, ** p<0.05, p<0.01*** Dependent variable was total amount of ARRA expenditures spent in seven grant programs under the Office of Energy Efficiency and Renewable Energy.

Results

Table 10 presents the relevant descriptive statistics for the states, excluding D.C. and Hawaii from 2005 to 2015. The number of job counted in energy efficiency sector ranged from 61.74 to 19498.56 with a mean of 1983.172 and standard deviation of 2548.957. The number of job counted in renewable energy sector ranged from 10.98 to 7986.47 with a mean of 752.063 and standard deviation of 1050.341. The number of job,

counted in combined sectors in energy efficiency and renewable energy, ranged from 72.72 to 27319.77 with a mean of 2735.235 and standard deviation 3579.751.

The ARRA funds spent in the seven grant programs administered by the EERE ranged from $0 to $2,109,441,787 with an average of $1,851,895 over the period. Next the amount of federal expenditures allocated annually by the DOE ranged from $258.824 to $42,601,587,316 with an average of $805,128,732 aggregated over the period of the study. The total amount spent within state DOE programs through non-governmental funding ranged from $0 to $3,405,072,313 with an average of $70,658,346 over the period of the study.

In terms of political circumstances, 53.8% of the states had Democratic governor, the influence of industries that use renewable energy resources in electric power generation varied considerably, in the range of 0 to348, with a man of 30.15. Finally, in regards to economic characteristics, per capita GDP ranged from $31.169 to $78,835 with a mean of $49,579; population density ranged from 279.022 to22889.19 people per square mile, with a mean of 5224.836. As instrumental variables, the amount of ARRA funds spent in the CCDBG, CSBG, and CDBG ranged $0 to $674,560,200 with an average of $15,514,690 over the period. In terms of circumstances of state energy policies, the duration of the RPS and EERS ranged from 0 to 34 with a mean of 4.56 years.

Table 10. Descriptive Statistics

Variable	Mean	SD	Min	Max
The number of jobs counted in energy efficiency sectors (1,000)	1983.172	2548.957	61.74	19498.56
The number of jobs counted in renewable energy sector (1,000)	752.063	1050.341	10.98	7986.47
The number of jobs counted in energy efficiency and renewable energy sector (1,000)	2735.235	3579.751	72.72	27319.77
ARRA Funds ($10,000,000)	18.51895	36.16792	0	210.9442
Federal DOE funds ($10,000,000)	80.512	218.920	0.025	4260.159
Non-Federal Funds ($10,000,000)	7.065	26.007	0	340.5072
Democratic Governor	0.538	0.499	0	1
Establishment that Use RE in Electric Power	30.153	44.873	0	348
Per Capita Real GDP ($)	49579.61	9672.184	31,169	78835.42
Population Density	5224.836	5432.428	279.022	22889.19
ARRA Funds in Block Grants ($10,000,000)	1.551	5.298	0	67.456
Circumstance of State Energy Policy	4.560	6.419	0	34

Note: N = 539

Table 11 presented the results of the first difference model with instrumental variables allowing fixed effects. In the results of the test of endogeneity, this research presented the p value of the endogeneity test, these results indicate that the instrumental variables lead to changes in the results. Null hypothesis, that ARRA funds spent in seven intergovernmental grant programs are exogenous, were rejected at the all models, as the p-value of the endogeneity test was 0.000. This research captures that state government may be able to attract more ARRA funds if they have more experiences on energy policies, or similar policy implementation tool. These measures helped correcting for the ARRA funds' effects. This research's results have controlled all the omitted variables in each model.

Table 11 showed the results on the job creation for both individual years and the cumulative effect. ARRA funds, spent in seven intergovernmental grant, had the positive cumulative effect in job creation in energy efficiency sector (Model 1), renewable energy sector (Model 2), and combined sectors (Model 3). In addition, all models showed the importance of lagged ARRA funds' effects. After two years, the ARRA funds had a highly significant impact in job creation despite a negative impact occurred after one year of the ARRA expenses.

As previously mentioned, states with more densely populated areas tended to have more job related to energy efficiency and renewable energy. States with vibrant economies were also tended to have more jobs in the energy efficiency and renewable energy sector.

At the second column for each model includes results assuming all variables are exogenous. These results were similar to those from the main first difference models. Also, in all of the statistical models, the year dummy variables for year specific effects showed that more energy technologies were generated in 2009 and 2013 since the American Recovery and Reinvestment Act was enacted in 2009. These results give us evidence of the effectiveness of Federal stimulus package under the ARRA of 2009.[10]

[10] Autocorrelation had been checked through the Durbin-Watson statistic and did not find any problem in three different models.

Table 11. Job Creation in Energy Efficiency and Renewable Energy Sector

	Model 1: EE		Model 2: RE		Model 3: EE and RE	
	IV	exog	IV	exog	IV	exog
ARRA Funds under the EERE	28.414*** (4.630)	2.682*** (0.973)	11.190*** (1.946)	1.299*** (0.456)	39.604*** (6.481)	3.980*** (1.384)
One-year lag	-11.407*** (1.953)	-4.934*** (1.044)	-2.586*** (0.821)	-0.098 (0.489)	-13.994*** (2.734)	-5.032*** (1.485)
Two-year lag	8.489*** (2.312)	4.133*** (1.417)	3.240*** (0.972)	1.566** (0.665)	11.728*** (3.236)	5.699*** (2.016)
Three-year lag	25.406*** (2.286)	25.030*** (1.479)	12.010*** (0.961)	11.865*** (0.694)	37.415*** (3.200)	36.896*** (2.104)
Government Financial Capacity						
Federal DOE Expenditures	0.067 (0.067)	0.009 (0.042)	0.027 (0.028)	0.005 (0.020)	0.093 (0.093)	0.014 (0.061)
Non-Government Expenditures	0.095 (0.720)	-0.394 (0.463)	-0.034 (0.302)	-0.222 (0.217)	0.061 (1.008)	-0.615 (0.658)
Political Circumstance						
Democratic Governor	-55.486 (63.631)	-22.339 (41.027)	-17.448 (26.756)	-4.706 (19.244)	-72.934 (89.070)	-27.046 (58.356)
Renewable Energy Circumstance						
Establishment that Use RE	-1.51e+07 (1.08e+07)	-9.28e+06 (6.96e+e6)	-7.86e+06 (4.54e+07)	-5.64e+06* (3.26e+06)	-2.29e+07 (1.51e+07)	-1.49e+07 (9.90e+06)
Economic Characteristics						
Per Capita Real GDP	0.040* (0.022)	0.012 (0.013)	0.016* (0.009)	0.005 (0.006)	0.056* (0.030)	0.017 (0.019)
Population Density	1.598** (0.678)	1.154*** (0.436)	0.735*** (0.285)	0.565*** (0.204)	2.333*** (0.949)	1.719*** (0.620)
Cumulative Effects of ARRA	50.900*** (5.214)	26.911*** (2.099)	23.852*** (2.192)	14.631*** (0.984)	74.753*** (7.299)	41.542*** (2.986)
Endogeneity Test P-value	0.000		0.000		0.000	
Observation	490		490		490	
Country FE	Yes		Yes		Yes	

Note: * $p<0.10$, ** $p<0.05$, $p<0.01$***

Discussion

From energy security (Valentine, 2011) and mitigation of climate change (Edenhofer et al., 2011; Liang & Fiorino, 2013) to boosting economic growth (Bowen et al., 2013; Yi, 2013; Apergis & Payne, 2010) and employment (Lambert & Silva, 2012), sustainable energy has been found to positively affect multiple aspects of our lives. Federal, state, and local government has been offering numerous programs and financial provisions to support and further encourage the production of renewable energy.

The ARRA of 2009 provided a wide array of policy instruments to stimulate the US economy and establish a robust foundation for long-term economic growth. The clean energy package played an important role in the ARRA job creation activities (Aldy, 2013). This research has focused that whether federal ARRA investments implemented through intergovernmental grant programs, designed toward clean energy, lead to a spike in job creation in the energy efficiency and renewable energy sector at the state level. This research has provided a new policy insight by investigating the effectiveness of the temporary investment allocated through the ARRA, on creating jobs in energy-related area.

Specifically, this research confirmed that cumulated ARRA expenditures allocated through State Energy Office (SEO) from federal EERE led to higher level of job creation in energy efficiency and renewable energy during the ARRA period. Although the results showed that the ARRA spending had a negative impact in the short-term (one-year after), these results had been matched the previous proposition that some states encountered more difficulties to implement ARRA funds which raised several intergovernmental challenges related to communication and administration (Carley &

Hyman, 2014). Two years after, the ARRA funds led to positive impact on more job creation. This research's results support that job creation activities require some time. It was strongly associated with delayed effects of government investment.

This research's results also provide empirical confirmation that that temporary government funding evidently played a determinative role in directly stimulating more jobs in energy efficiency, renewable energy fields, despite the previous theoretical scholarship that recognized only long-term governmental funding positively affecting policy outcome. These positive impact of the temporary ARRA funding may be impacted by the intergovernmental grant process. The intergovernmental grants funded by the ARRA were designed to distribute funds to state or local governments so that they could quickly spend on projects that would create jobs and foster growth in their communities (Terman & Feiock, 2012). These empirical results showed that government funds implemented under these intergovernmental grants process had positive impacts in short term to stimulate employment in energy efficiency, and renewable energy sectors.

Also, it comes as no surprise that the number of jobs in energy efficiency (Model 1), renewable energy (Model 2), and combined sectors (Model 3) were directly related to per capita gross state product. States with higher per capita gross state product are likely to be more economically productive and prosperous, thus making job creation more likely in energy efficiency and renewable energy sectors. Indeed, as we also expected, this research's empirical results confirmed that population density are positively associated with energy efficiency and renewable energy relevant job. Empirical evidences showed that more highly populated state with greater concentrations of human

resources are more likely to have more jobs in the energy efficiency and renewable energy sector.

Conclusions

The ARRA was the largest federal investment in U.S. history to support national economic recovery during the Great Recession. It included explicate goals for stimulating the job creation through investment in new energy technologies with respect to the sustainable use of energy. This research tested whether the ARRA expenditures, that were intended to stimulate the U.S. economy through establishing an innovative energy technologies, achieve their goals. This research confirmed that cumulated ARRA expenditure made in intergovernmental grant programs through the EERE led to higher levels of job creation in energy efficiency, and renewable energy sectors.

At the same time, the ARRA funds, as one-shot grants, were intended to be simulative, quickly spending of the money was important for achieving the goals in the short term (Terman et al., 2016). Intergovernmental grant program was important tool to stimulate that the ARRA funds were spent quickly. This research provides the empirical results on the link between the ARRA funds implemented through the intergovernmental grant program and its effects. These finding has implications that it is important to inject a decentralization approach through intergovernmental grants regarding how government expenditures can more efficiently promote for job stimulating.

Although one-shot federal spending may not be optimal for achieving longer term impacts of job creation, the empirical evidence suggests that the short-term expenditures led to effective performance in terms of job creation through investment in advanced

energy technologies with respect to the sustainable use of energy, at least in the short term and at the state level. From this viewpoint, future research should include empirical study of whether government temporary investment might be important for achieving longer-term job creation. Future studies are also needed investigation on the impact of government expenditures implemented through the non-governmental contractors to achieve national sustainable energy goals.

CHAPTER IV

TECHNOLOGICAL INNOVATION ACTIVITIES GENERATED DURING THE AMERICAN RECOVERY AND REINVESTMENT ACT: EVIDENCE FROM THE ALTERNATVIE ENERGY PRODUCTION AND ENERGY CONSERVATION (ESSAY 3)

Introduction

Technological change has been heavily influenced by changes in market demand or by advances in science and technology (Nemet, 2009). Governments have employed various strategies to promote the adoption of innovative energy technologies into the technology-push (supply-side) and demand-pull (demand side). One of the most commonly applied strategies to facilitate technology development is policy-directed investment that subsidizes the cost of research and development (Siddiki et al., 2015). President Obama signed into law the American Recovery and Reinvestment Act (ARRA) of 2009. It was to support national economic recovery during the Great Recession. It included explicit goals for stimulating the economy through energy efficiency, energy savings, and energy conservation with energy technologies (Carley, 2012). During the

period of the ARRA, unprecedented investments were made to promote advanced, efficient and clean energy in ways that contribute to reginal wealth creation. According to the Act, some of the highlights of the ARRA funds, administered through the Department of Energy (DOE), included the Advanced Research Project Agency's Energy program (ARPA-E) to support innovative energy technology. ARPA-E, within the Department of Energy, supported energy technology research projects with the goal of enhancing the nations' economic and energy security.

To achieve these goals, the ARRA funds infused $275 billion in grant funds to state and local governments, and another $224 billion for purposes such as enhanced innovative technology systems (Conlan et al., 2017). Energy-related policy goals stipulated in the rationales for these ARRA expenditures, over $36 billion was intended specifically to catalyze innovation. These funds were allocated to academic institutions, companies, research foundations, and industry research collaboration through state and local government. These were focused largely on upgrading the energy technologies in the areas of energy efficiency and renewable energy projects and programs.

Recent research has started to discuss the actual effects of the ARRA expenditures. Some has looked at the impact of ARRA expenditures aimed at renewable energy (RE) technologies on the job creation and environmental dimensions using qualitative research (Toepler & Sommerfeld, 2017). Other has focused on assessment of the ARRA expenditures in terms of helping to bring new technologies related to solar, wind, geothermal, and other renewable energy sources at the national-level (Executive Office of the President., 2016). The National Academy of Sciences (NAS) also evaluated how well ARPA-E was achieving its goals and mission (National Academies of Sciences,

2017). Still other research focused on assessment of the experiences of a range of national actors during the ARRA period (Carley, 2016; Terman et al., 2016; Tonn et al., 2016; Hall & Edward, 2011a; Hall & Edward, 2011b; Jennings et al., 2012). However, although the literature provides sound reason to expect that the ARRA expenditures substantially influenced innovation and development within the advanced energy sector, no published research has yet examined empirically whether they effectively achieved their stated objectives in regards specifically to technological energy innovation. Accordingly, this research empirically evaluated the effectiveness of the ARRA funds that tended to focus on the state and local ground-level aspects of grants aimed toward technologies energy innovation. It focused specifically upon grant program designed for purposes of stimulating innovation in the areas of alternative energy production and energy conservation.

Theoretical Framework: Technological Innovation in Fiscal Decentralization

The American Recovery and Reinvestment Act (ARRA) emphasis in implementation shifted from 'government' to 'networked governance' in achieving public goals (Conlan et al., 2017). ARRA funds were spent by state and local governments. Each state government decided how to allocate its share of the funding to local governments as well as others. State and local governments had fragmented and independent authority to craft their actions to match their unique circumstances. The grants from the ARRA funds did not change hierarchically-oriented federal-state-local relationships. But they did stimulate collaboration between state and local governments as well as federal and local governments.

Specifically, the renewable energy and energy efficiency grant programs implemented under the networked governance system included the State Energy Program (SEP), Energy Efficiency and Conservation Block Grant (EECBG), Weatherization Assistance Program Grant (WAP), and State Energy Efficient Appliance Rebate Program (SEEARP). These grants were provided in Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). In terms of the implementation of SEP, EECBG, WAP, and SEEARP, all states were eligible to apply for direct formula grants and competitive grants from federal DOE. Grants were allocated to state energy offices through formula grants for projects and planning, and they were was allocated through competitive grants to local entities. Each state decided how to award these sub-grants[11]. The recipients of these grants were determined by the state governments, not the federal government. The ARRA amount received by each state was sub-granted to units of local government in the state that were not eligible for direct formula grant from federal DOE. In other words, the states designed and carried out their own renewable energy and energy efficiency programs. They were managed by state energy offices, not by the federal DOE. The federal DOE provided administrative and institutional support, such as the scope and goals of each energy program.

In particular, the application for the EECBG was strongly restricted depending on the population. Cities were eligible for EECGB grants either directly from the federal DOE or from the state in which they were located. A city with a population of at least

[11] Goldman, C. A., Stuart, E., Hoffman, I., Fuller, M. C., & Billingsley, M. A. (2011). Interactions Between Energy Efficiency Programs funded under the Recovery Act and Utility Customer-Funded Energy Efficiency Programs. Lawrence Berkely National Laboratory.

35,000 was eligible for a direct formula grant from federal DOE. A city with a population below 35,000 was eligible for a sub-grant from the state energy offices. All cities were eligible to apply for competitive grants from DOE regardless of population. The recipients of competitive grants were smaller cities, and a recipient city was determined by the state, not the federal government.

As part of the ARRA, DOE's National Energy Technology Laboratory (NETL), on behalf of the Office of Energy Efficiency and Renewable Energy, provided funding opportunities for Advanced Battery Manufacturing Grants[12]. Eligible applicants for this grants were unrestricted. Grants under this program was awarded to meritorious projects through a competitive process. Local governments, or non-government entities in each state that were interested in applying for competitive grants, were eligible to make their application. Also, Transportation Electrification Grants and Alternative-Field Vehicles Grants were administered by the State Energy Office (SEO)[13]. State or local officials made choices in how these grants programs would related to existing program. SEO had responsibility to coordinate the development of projects and funds allocation[14].

State and local governments, under the Department of Energy, designed their own competitive programs and procedures and allocated the (cash) grants at their own discretion. Some parts went directly to local agencies so that they could quickly be spent

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[12] Transportation Electrification Grant Program, National Energy Technology Laboratory, 16 Mar. 2009. Retrieved from https://www.netl.doe.gov/research/coal/carbon-storage/carbon-storage-infrastructure/arrasitechar
Retrieved from https://www.netl.doe.gov/File%20Library/Library/Environmental%20Assessments/12-20-12-Signed-Chemetall-Foote-Silver-Peak-FONSI.pdf

[13] Retrieved from https://www.arc.gov/funding/EnergyARRAGrantInformation.asp

[14] Goldman, C. A., Stuart, E., Hoffman, I., Fuller, M. C., & Billingsley, M. A. (2011). Interactions Between Energy Efficiency Programs funded under the Recovery Act and Utility Customer-Funded Energy Efficiency Programs. Lawrence Berkely National Laboratory.

on programs, projects and policies that would foster growth in their communities (Terman & Feiock, 2014). Some of them were directly awarded to non-governmental agencies.

In the perspective of how large amounts of ARRA funds were effectively implemented, or not, recent studies have mentioned that the federal government relied on existing state and local agencies to implement ARRA funds. The implementation process offered very flexible aid to stimulate innovation at the state and local levels (Conlan et al., 2017, p.5). ARRA's design reflected tools of fiscal decentralization in federal policies. The ARRA preferred a mixed program with state and local governments as well as nonprofit, or private entities for purposes such as enhanced innovative technology systems (Sissine, et al., 2009). Much of the Recovery Act's funding was primarily intended to help state and local governments finance their own policy goals.

In the related stream of public administration, previous research has also focused on decentralized networks approaches in achieving national objectives. Specifically, Robert Agranoff and Michael McGuire (2011) remarked that the key to networked government is that various actors, including public managers should have a role to play in local, community-based initiatives. Goldsmith and Kettl (2009) have explored the role of federal policymakers in effectively utilizing decentralized networks in federal policy implementation. However, no studies have empirically tested the association between financial resources allocated under the decentralized networks and innovation in energy technologies.

Moreover, as is recognized by a growing body of literature, all of these ideographic factors must be identified and systematically considered if one is to

convincingly establish that decentralized networking has a positive impact on innovation activities related to energy technologies at the state level. This study focused on the fiscal decentralization framework and state governments who had autonomy in ARRA grant allocation to serve their goals in the energy sector. A number of such factors have been identified, as described in the following subsections.

Government Financial Capacity

Governments employ various strategies to reduce barriers to technology, particularly where widespread adoption would align with broader policy goals. The U.S. government has invested heavily in policies to support the development of innovative energy technologies. A portion of this investment has been specifically targeted at improving energy efficiency and renewable energy. In the past decade, scholars have written that many technology innovation activities or strategies require large, consistent, and long-term financial investments to encourage an uptake in technologies (Kalter & Vogely, 1976). A rich theoretical body of scholarship has analyzed empirically the relationship between the pattern of financial investment by governments and the variation of energy technology innovations. Liang and Fiorino (2013) investigated the relationship between policy stability in public resource allocation and policy outcomes in renewable energy technologies from 1974 to 2009 at the national level. They found technology innovation is affected by both the magnitude of federal research and development (R&D) expenditures and the stability of government financial commitment. Margolis and Kammen (1999) concluded that inadequate energy R&D spending and low R&D intensity in the energy sector led to low levels of energy technology patenting activities. Backstrom et al. (2014) demonstrated that large amounts of public R&D financial support

had an important impact on solar photovoltaic (PV) innovations for 13 countries over the time period 1978 to 2008. Most existing empirical studies have only focused on the effects of the expenditure patterns of the federal government; they have criticized rapid changes of funding levels and instability in funding trends in regard to the development of technologies within the influence of the federal government's expenditures.

Furthermore, most programs that supported technological innovation relied on existing federal government mandating spending. At the same time, government has also invited non-federal expenditures as mechanisms consists of voluntary collaborations that are made between federal agencies and non-government donors in supporting mutual initiatives. According to DOE's strategic investment in science and technology, DOE was inviting proposals funded by cooperative agreements, between government and private industry (DOE, 2014). The projects related to the Clean Coal Power Initiative and America's Next Top Energy Innovator, as well as Energy Innovation Portal are implemented through federal programs with non-governmental funding. Even though these programs operate out of the federal government, their participation is never funded by this government. In theoretical perspective, non-government funding's participation, provided by external entities like non-government organization, corporations or foundations, is recognized as important strategies to expend their effectiveness into broader trends associated with the energy policy innovation era (Carley, 2011; Conlan et al., 2017). However, although it has been shown that the success of energy innovation policies increasingly depend on cooperative activities (agreements) rather than the expansion of power of the federal government, the effectiveness of the decentralized

fiscal funds in the implementation stages of policy have not been investigated empirically (Carley, 2011).

Therefore, this research separately considered each category of expenditure allocated by the federal government and non-government sources on innovation activities toward new energy technologies. Accordingly, this research hypothesized that state governments with larger expenditures allocated by federal government are more likely to have higher levels of innovation activities toward new energy technologies. Also, this study expected that state governments with larger magnitudes of non-government expenditures are more likely to have higher levels of innovation activities toward new energy technologies.

ARRA Funding

In 2008 and 2009, the United States was in the midst of the Great Recession, possibly the worst economic situation the nation had faced since the Great Depression. One of the first priorities of the new Obama administration was to implement policies and programs to turn the economy around. In particular, one of the major economic initiatives made by the Obama Administration was the implementation of the American Recovery Reinvestment Act (ARRA). The ARRA provided a wide array of policy instruments to stimulate the U.S. economy and establish a robust technological infrastructure for long-term economic growth (Aldy, 2013). In one important respect, the ARRA was designed to emphasize 'sustainable energy' or 'green energy.' Depending on the definition of 'green,' these instruments tended to focus on technology innovation toward alternative energy and energy conservation. Within the government's ARRA investments, they focused on economic activities that improve environmental quality through energy

efficiency, savings and conservation utilizing energy technologies. Approximately $840 billion of the U.S. economy was spent on technological advancements, job creation, and infrastructure development in the energy sector (Goldman et al., 2011). Specifically, nearly 30 percent was allocated toward renewable energy generation. Approximately 22 percent was spent towards investments in energy efficiency. Also, 30 percent of budget allocations were earmarked for increasing the reliability and sustainability of electricity systems. The remaining investments were allocated toward vehicle and fuel advancements, improved carbon capture, including storage, and clean energy manufacturing.

Currently, the energy policy literature contains few analyses that explore the effects or effectiveness of the new ARRA funds on the innovative energy technology produced during the era of the American Recovery and Reinvestment Act. According to the Executive Office of the President's report (2016), the ARRA funding reached nearly every aspect of the value chain, for numerous key clean energy technologies, including advanced vehicles, batteries, carbon capture and sequestration, and technologies to enhance energy efficiency. Also, the literature contains analyses of how ARRA investments in the deployment of clean energy technologies helped contribute to dramatic cost reductions for those same technologies, as part of a virtuous cycle. Mundaca and Richter (2015) provided a comprehensive assessment of the impact of ARRA funding on green technologies within resource-intensive approach. They suggested that stimulus programs incentivizing research and development in the renewable energy sector led to growth in the number of green energy technology patents issued by the United States Patent and Trademark Office (USPTO) from 2009 to 2012. They suggested that growth

regarding clean energy patents and green technology patents can be attributed to the federal renewable stimulus program. In terms of the environmental dimensions of these expenditures, the U.S. Energy Information Administration's Monthly Energy Review analyzed their effects in terms of reductions in carbon dioxide emissions (EIA, 2013). Emissions were allegedly reduced in 2012 due to ARRA's impacts on technological renewable energy deployment. Recently, the National Academies of Sciences (2017) conducted an assessment and technical evaluation of ARPA-E under the ARRA. They suggested that ARPA-E awardees, under the ARRA funds, produced patents and scientific publications in greater numbers for various technologies. They concluded that the flexible management approach should be preserved in technological advances.

However, most assessments on the relationship between ARRA expenditures and its actual effects have focused on the general effects inferred from all federal ARRA funds rather than expenditures specifically designed for energy. Empirical assessments of specific programs intended to focus upon innovation in new energy technologies in the body of relevant research are all anecdotal. Thus, in order to fill this gap, this research addressed the actual effects of the innovation activities in energy technologies, vis-à-vis federal ARRA expenditures intended to stimulate innovation in alternative energy and energy conservation. Specifically, the effects of the ARRA expenditures allocated in grant programs aimed to promote upgraded energy technologies under the Office of Energy Efficiency and Renewable Energy (EERE). Therefore, this research hypothesized that state governments with greater ARRA expenditures allocated for innovation to upgrade energy technologies are more likely to have higher levels of innovation activities toward new energy technologies.

Electricity Price

Previous studies have identified energy price as a determinant of levels of innovation in alternative energy resource technologies. Several studies have empirically tested the effects of energy prices on innovation in induced technologies. Popp (2002) tested the effects of energy prices on energy efficiency innovation and found a strong effect of energy price on energy efficient innovation, as measured by patent counts. Popp, Newell and Jaffe (2009) explained that the direction of innovation likely responds positively in the direction of increased relative prices. Johnstone et al (2009) investigated the effects of both price-based and quantity-based policies on energy innovation from 25 Organization for Economic Cooperation and Development (OECD) countries. They found that an increase in the price of electricity is associated with increased incentives for innovation and energy demand, which in turn create incentives for energy technology innovation. Another study examined the effect of natural gas prices on renewable energy technology development, and the statistical results confirmed that increased prices increase levels of innovation (Kneifel et al., 2008).

Perhaps the most prominent view of researchers in this area is that advances in electricity have allowed the implementation of many technological solutions that can be impacted by the variations in energy consumption. Liang and Fiorino (2013) stated that technological capacity can be associated with increased electricity prices. They demonstrated how electricity prices were positively related to patent applications, suggesting that a higher level of demand contributed to more innovation activities. Johnstone, Hascic, and Popp (2010) also indicated that electricity market conditions have had little effect on energy innovation. They explained the role of both electricity prices

and growth in electricity consumption. Although one might expect more innovation in alternative sources when prices are high and consumption is growing (thus signaling a need for greater generation capacity), neither variable has had a statistically significant effect on patents. Thus, this research expected to find that states with higher electricity prices are more likely to have higher levels of innovation activities toward new energy technologies.

Structure of Electricity Market

Since the late 1990s, quite a few state governments in the United States have relaxed the traditional regime of monopolistic regulation in electricity generating markets to allow for the existence of competition. The adoption of electricity competition from restructured deregulation had been expected to achieve lower energy costs, diversifying energy supply options, ensuring a reliable, encouraging innovation in power supply technologies, and affordable supply (Joskow, 2008). Previous research on the effects of deregulated electricity markets have concluded that prices are higher in deregulated market, but the changes in prices had been greater in the regulated markets (Ardoin & Grady, 2006; Joskow, 2006). The effect of market competition on electricity rates is still the subject of debated in some restructured states. However, with perspective of generation technology, few studies have addressed that competition can foster technological innovation activities. Competition in deregulated electricity markets enable the electricity generating industry to invest innew and highly efficient generation capacity (Joskow, 2006). In addition to the utility restructuring could accelerate new technological innovation in the transmission and distribution grid, it could serve as more cost-effective substitutes for transmission upgrades (Carley, 2009; Thomas et al., 2016). Therefore, this

research expected to find that states with de-monopolized electricity markets are more likely to have higher level of innovation activities in toward new energy technologies.

Knowledge Stock

It is generally argued that knowledge is one of the key factors for creating new value. Some studies have attempted to evaluate the effect of variation in knowledge stock on variation of innovation in upgraded energy resources. Many researchers have shown that higher educational attainment was positively associated with the increase of innovative technology in the United States (Yi, 2014; Yi, 2013; Inglehart & Abramson, 1994). Empirically, Simons and Choi (2009) demonstrated that more educated people can better accept green energy technologies in the building sector. They added that more highly educated individuals believe going green is the right thing to do. Internationally, Hobmand and Ashworth (2013) confirmed that educational level was positive and significant as an explanatory variable for the diffusion and development of technologies related to renewable energy sources, within a sample of 1,907 Australians. Given these considerations, I expected to find that states with greater knowledge stocks are positively related to the growth of energy technology innovations. Therefore, this research expected to find that states with higher knowledge stock are more likely to have higher level of innovation activities toward new energy technologies.

Circumstances that Use Renewable Energy Sources

Following other local environmental policy research (Ong, 2012; Krause et al., 2015), a greater presence of firms that use renewable energy is likely to have the effect embedding green technologies for encouraging environmental actions. In other words,

machines with new technologies may have been more likely to be owned by firms with a higher propensity to switch technology toward renewable energy resources. The variations of innovation in new energy technologies may thus be affected by the expressed the willingness of previously existing firms to pay for greener products. Therefore, this research expected that all else held equal, states in circumstances that use more renewable energy resources in electric power generation are more likely to have higher levels of innovation activities toward new energy technologies.

Circumstances of State-Energy Policies

State governments in the U.S. have adopted various clean, renewable, and efficient energy policies to achieve sustainable energy objectives. State-level energy policy initiatives have promoted the energy innovation in homes, business, industries, electricity, and transportation sectors. States differ by existing energy policies circumstances. Some states responded with minimal efforts towards energy policies, other states have implemented energy programs actively to provide renewable and efficiency energy resources. All states started renewable and energy efficiency policies in different years. For example, 26 states had implemented the Energy Efficiency Resources Standards (EERE) by 2016. Some of them, like California, started implementation in as early as 2004. Also, Renewable Portfolio Standards (RPS) that established requirements for the adoption of renewable energy technologies in state electricity markets were enacted in Nevada in 1997. Michigan enacted an RPS in 2008 (DSIRE, 2017). Longer duration of relevant policies was indicative of more time for the planning and implementation process as well as knowledge to influence on innovation in the area of energy (Bowen et al., 2013). Therefore, this study expected that all else held equal, states

with longer accumulated policies implementation experiences related to renewable and energy efficiency are more likely to have higher levels of innovation activities toward new energy technologies.

Political Circumstances

It is generally argued that liberal political ideology is associated with green energy policies and renewable energy programs (Yi & Feiock, 2012). The ideological propensity of the governor and the legislators not only shape the support of green energy laws (Coley & Hess, 2012), but also influence the innovative green energy technologies' development and diffusion. As shown in the literature of policy termination, a stable and predictable political environment is essential for the deployment and development of green energy (DeLeon, 1983). Previous studies have analyzed the relationship between states with a democratic governor and energy policy outcomes (Carley & Nicholson-Crotty, 2015). Republican legislators tend to limit diffusion of the state green energy policies (Coley & Hess, 2012). This is also consistent with recent efforts made by Republican legislators in a dozen states to repeal the renewable portfolio standard (RPS). Previous evidence also shows that Democratic governors are associated with a higher likelihood of adopting environmental programs (Ringquist, 1993). Having a Democratic governor could result in better green energy policy design, which could be more effective in achieving the pre-design policy goals. Based on the above literature, the research focus of this article was in examining the relationship between the political orientation of the governor and policy outcomes for innovations in energy electrical technologies. This research tested the effects of political circumstances, as it pertains to Democratic governors and their effect on innovative activities new energy technologies, from 2005 to

2015, in the United States. Thus, this study expected to find that states with a more legislature seats occupied by Democrats are more likely to have higher levels of innovation activities in new energy technologies, when compared to states with a Republican governor.

Economic Characteristics

Following previous studies, state-specific economic characteristics are always relevant in the growth of innovative technology. The first such factor is the overall level of state economic activities, as characterized by greater per capita gross domestic product (GDP). A recent study found that the higher a state's per capita GDP, the larger the market size in the state, which creates a sufficiently large market to achieve economies of scale for innovative technology and for related industries to develop and grow (Yi, 2013). Porter and Stern (2001) showed a positive relationship between innovative capacity and per capita GDP, which was a main determinant for patterns of technological performance. Thus, this study expected to find that states with vibrant economies are more likely to have higher level of innovation activities toward new energy activities.

Secondly, in the literature on the relationship between population and technology development, previous evidence has shown that greater population stimulates technological change because it increases the number of potential inventors (Kremer, 1993). Previously published empirical research also demonstrated that greater population sizes tend to present more opportunities for developing new technologies. They argued that if a state has a larger population it may have a greater chance of creating new innovative technologies (Sadorsky, 2013). More highly populated states with greater concentrations of human resources also tend to have a correspondingly higher likelihood

of creating new technologies (Madlener & Sunak, 2011). This study expected to find that states with larger populations are more likely to have higher level of innovation activities toward new energy technologies.

Research Methods

Conceptual Model

The major purpose of this research was to evaluate the effectiveness of the ARRA funds on innovative activities in energy technologies. The focus was upon the intergovernmental grants allocated for state and local governments through the Office of Energy Efficiency and Renewable Energy of the DOE, since they were where the funds were dispersed. Under the ARRA funds, each program design, on the intergovernmental grants, was heterogeneous across states. The different program designs across states may lead to variation in outcomes. Thus, this study focused on state level analysis. This research included years both before and after ARRA from 2005 to 2015 to observe the impact of the ARRA funds. The analysis was directed toward whether these one-time shot ARRA grants led to a spike in innovation activities and whether it has had any long-term impact. All of the previously mentioned factors had to be statistically considered.

This study used a first differenced analysis with instrumental variables to consider the endogeneity of the ARRA funds. This was accomplished using a first-differenced two-stage least squares (FD2SLS) estimation routine. The idea was to control correlations between lagged ARRA variables and the modeling error term. This was done allowing for fixed effects.

The analysis was limited to 49 states and excluded Hawaii and Washington D.C[15]. The analysis assumed an underlying process with two stages. The first stage generated whether or not the ARRA funds (endogenous variable) were associated with instrumental variables and the second generated the model that captured the two effects including the direct effect from the explanatory variables, and the proxy effect from the omitted variables:

$$ARRA\_Energy_{st} = \pi_0 + \pi_1 ARRA\_Block_{st} + \pi_2 unemployment_{st} + \pi_3 X'_{st} + \pi_4 * T + \pi_5 * S + \vartheta_{st} \quad (1)$$

$$Innovation_{st} = \beta_0 + \beta_1 ARRA\_Energy_{st} + \beta_2 ARRA\_Funds_{s(t-i)} + \beta_3 X'_{st} + \beta_4 * T + \beta_5 * S + \vartheta_{st} \quad (2)$$

In the first stage equation (1), $ARRA\_Energy_{st}$ represents the total amount of federal ARRA expenditures allocated in seven grant programs (See Table 14) under the Office of Energy Efficiency and Renewable Energy (EERE) by the Department of Energy, under the ARRA, in state *s*, and individual year *t*. This research included two instrumental variables that did not statistically relate to energy technologies' innovation or promotion, but were correlated with the level of the allocated ARRA funds. As instrumental variables, this study used the $Unemployment_{st}$ which means the unemployment rates in state *s*, and individual year *t*, and the $ARRA\_Block_{st}$ which means the amount of ARRA funds spent under the non-energy block grant program in state *s*, and individual year *t*. I expected that two instrumental variables are highly correlated with the $ARRA\_Energy_{st}$ which means total amount of ARRA expenditures allocated in

[15] There are no complete data sets on energy expenses and policies for the state of Hawaii; Washington DC is excluded because the analysis is limited to states.

seven grant programs for promoting energy innovation activities under the decentralized networks.

In the second stage equation (2), $Innovation_{st}$ is the total number of patent applications at individual level counted in the classification identified in the Alternative Energy Production and the Energy Conservation of the Green Technology Classification within the U.S. Patent and Trademark Office (USPTO)' Green Technology Pilot Program in state *s* and year *t*. In all equations, $ARRA\_Energy_{s(t-i)}$ represents the total amount of federal ARRA expenditures allocated in seven grant programs under the EERE, under the ARRA, in state *s*, and individual year *t* with lag length of *i*. This captured the lagged effects of the total amount spent by EERE under the ARRA. The lag length of *i* was used from one year to three years. The appropriate lag length was determined by the Akaike Information Criterion (AIC) (Popp, 2016). Where X'_{st} was a vector of independent variables including financial capacity, electricity price, structure of electricity market, knowledge stock, and influence of industries that use renewable sources, circumstances of state-energy policies, political circumstances and economic circumstances in state *s* and year *t*. ϑ was error term into identically distributed state-effect term.

Data

Dependent variable

The dependent variable reflected the total number of patent applications in classification identified in the Alternative Energy Production and the Energy Conservation of the Green Technology within the USPTO's Green Technology Pilot Program. The Classification of Green Technology was used to isolate alternative energy

(Model 1), energy conservation (Model 2) and combined categories (Model 3) regarding the labeling of patent applications. These particular classifications were used in order to take into account the impact of the ARRA funds on innovation activities related to alternative energy and energy conservation. The count of patent application was used as proxy for innovative activities instead of patent publication, which would have reflected innovation output. Although patent applications may not translate into practice, their counts have the potential for most accurately representing the outcomes for technological innovative activities (Johnstone et al., 2009). Relevant patent applications were counted in the data at the individual patent level, with using codes issued by the USPTO's Green Technology Pilot Program. The concept of the Green Technologies covers a broad range of fundamentally different types of innovation including 1) Alternative Energy Production 2) Energy Conservation 3) Environmentally Friendly Faming 4) Environmental Purification, Protection, or Remediation (See Table 12).

Table 12. Classification of the Green Technology

	Classification of the Green Technology under Green Technology Piot Program
1	**Alternative Energy Production**
2	**Energy Conservation**
3	Environmentally Friendly Farming
4	Environmental Purification, Protection, or Remediation

Source: U.S. Patent and Trademarks Office. USPTO Green Technology Pilot Program, Retrieved from http://www.waybetterpatents.com/green_tech_pilot_program.html

This research was focused on innovative activities of the energy technologies to improve energy conservation, and develop alternative sources of energy. This idea was to examine the effectiveness of the ARRA funds' in terms of their rationales regarding developing advanced energy as part of the larger U.S. energy policy. Thus, the dependent variable contained observations only for the number of patent applications in Alternative

Energy Production and Energy Conservation classifications (See Appendix A and Appendix B). The number of patent applications included in the definition of Alternative Energy Production and the Energy Conservation were derived from the Public PAIR dataset provided by the United States Patent and Trademark Office (USPTO).[16]

Independent variables

The empirical model included factors that, on the basis of previous research, could be expected to influence levels of innovation activities in the energy technology field. See Table 13 for a description and the source of each of the independent variables. These include (1) ARRA expenditure, (2) financial capacity, (3) electricity prices, (4) structure of electricity market, (5) knowledge stock, (6) circumstances that use renewable energy sources, (7) circumstances of state-energy policies, (8) political circumstances, and (9) economic characteristics

[16] The data are available at (https://pairbulkdata.uspto.gov/).

Table 13. Variable Measurements

Variables	Measurements	Data Source
Dependent variable Innovation Activities in Energy Technologies	1) Total number of patent applications counted in the Alternative Energy Production (Model 1) 2) Total number of patent applications counted in the Energy Conservation (Model 2) 3) Total number of patent applications (at individual level) counted in the classification identified in 1) Alternative Energy Production and 2) Energy Conservation of the Green Technology Classification (Model 3)	United States Patent and Trademark Office(USPTO)'s Public PAIR Dataset
Independent variable ARRA Funds	Total amount of federal ARRA expenditures spent in 7 grant programs under the Office of Energy Efficiency and Renewable Energy (EERE), the lag length was used from one year to three years.	Department of Energy Data Reported by the American Recovery and Reinvestment Act (www.recovery.gov)
Financial Capacity	1) Total amount of federal expenditures annually allocated by the Department of Energy 2) Total amount spent under the federal DOE program through non-government funding participation	USASPENDING. GOV (www.usasspending.gov)
Electricity Price	State's average annual retail electricity price in residential, and industrial sectors (cents/KWH)	U.S. Energy Information Administration (EIA)
Structure of Electricity Market	The presence of de-monopolized electricity market (1= presence, 0=otherwise)	EIA
Knowledge Stock	Percentage of population over the age of 25 with BA or higher	U.S. Census Bureau
Circumstances that Use RE Sources	Number of establishments that use renewable energy resources (See Appendix C)	U.S. Census Bureau
Circumstances of State-Energy Policies	Duration of policy on the RPS, EERS, and EERPB	DSIRE
Political Circumstance	1) Percentage of House seats occupied by Democrat at state level 2) Percentage of Senate seats occupied by Democrat at the state level	Multistate Associates Incorporated (MAI)
Economic Characteristics Per Capita GDP Population	1) Per Capita Real GDP adjusted in 2015 dollars 2) Number of whole population (1,000)	Bureau of Economic Analysis (BEA)
Instrumental Variable ARRA Funds in Block Grant Unemployment Rate	8) Total amount of federal ARRA expenditures spent under the CCDBG, CSBG and CDBG 9) Number of percentage of unemployed from the sum of the employed and unemployed.	Data Reported by the American Recovery and Reinvestment Act (www.recovery.gov), Bureau of Labor Statistics (https://www.bls.gov/)

This study used federal government ARRA expenditures invested for motivating innovation of energy technologies. The variable contained observations of the total amount spent in seven grant programs aimed to promote upgraded energy technologies under the Office of Energy Efficiency and Renewable Energy (EERE) (See Table 14).

Table 14. Fiscal Decentralization Tools in the ARRA: Intergovernmental Grants

DOE Office	Grant Provision	Grant Purpose
Office of Energy Efficiency and Renewable Energy (EERE)	1) Energy Efficiency and Conservation Block Grants	Grant for supporting energy conservation in the transportation, building, and other sectors and renewable energy development
	2) Weatherization Assistance Grant Program	Grant for purchase of the energy efficient equipment for low income household
	3) State Energy Grant Program	Grant for state-led energy initiatives. It was aimed to promote the energy efficiency and energy conservation.
	4) State Energy Efficient Appliance Rebate Grant	Grant for the purchase of energy-efficiency Energy Star products
	5) Advanced Battery Manufacturing Grants	Grant for developing advanced battery and battery system
	6) Transportation Electrification Grants	Grant for conducting demonstration (evaluation) on advanced electric drive vehicles technologies.
	7) Alternative-Fueled Vehicles Grants	Grant for the purchase of alternative fuel and advance technology vehicles

Source: Energy Provisions in the American Recovery and Reinvestment Act of 2009, Retrieved from http://nationalaglawcenter.org/wp-content/uploads/assets/crs/R40412.pdf

The overarching hypotheses was that the ARRA expenditures spent in intergovernmental grant programs and intended to support the energy technologies would be associated with increases in innovative activities in energy technologies. Indeed, this research employed ARRA expenditure's lagged variables with length of three years to address the short-run and long-run effects of ARRA expenditures. It was represented in terms of the cumulative effects of the ARRA expenditures for the past three years. The database related to the American Recovery and Reinvestment Act (ARRA) funds was

collected from Department of Energy Data Reported by the American Recovery and Reinvestment Act (www.recovery.gov).

This research also included other explanatory variables: financial capacity, electricity circumstances, knowledge stock, circumstances that use renewable energy sources, circumstances of state-energy policies, political circumstance, and economic characteristics. The financial capacity of government was indicated by two types of annual expenditures by the federal government and non-government sources: (1) the total amount of federal expenditures allocated annually by the Department of Energy (DOE); and (2) the total amount of expenditures came from non-government sources. Federal DOE expenditure has been obligated annually under a rationale about stimulating innovative activities toward the sustainable energy resources (Executive Office of the President, 2016). It was implemented as a mandatory spending regimen over the long time regardless of enacting of Recovery Act funds. In this regard, this expenditures could be characterized as stable, and predictable funds of government. In the other hand, total amount from non-government resources was collected from total amount implemented within federal DOE program with non-government funding participation. Non-government expenditures were made based upon temporal contracts with provision of funds from the non-government sector over the short term. These expenditures can be characterized as non-stable, unpredictable investments (Nemet & Kamman, 2007). To determine determinants of innovation activities in energy technologies, these two different categories of expenditures were used to proxy for government financial capacity because there is reason to expect that they would lead to increases in innovation activities toward new energy technologies. The analysis assumed each effectiveness between

federal expenditure and non-government expenditures. The related data are gathered from an online database, USAspending.gov (www.usaspending.gov)[17].

Previous research has shown that the determinants of innovative activity in energy technologies broadly include electricity circumstances. Thus, more specifically, electricity circumstances were observed with two attributes. Firstly, the states' average annual electricity price in the residential and industrial sector was applied. This reflected the average annual retail electricity price. The data were collected by form EIA-861, which is the Annual Electric Power Industry Report of the U.S. Energy Information Administration (EIA) at the state level. Each observation was measured annually over the period of 2005 to 2015, and the units used were cents/kilowatt-hour. All values were adjusted to 2015 values. Secondly, the analysis assumed that competition in electricity market may lead to more technological innovation related to energy. In order to account for the electricity circumstance, this research used a variable reflecting the electricity market structure. Structure of electricity market was categorized within two groups: (1) group included both states with monopolized electricity market and states with suspended de-monopolized electricity market even if electricity restructuring law was enacted; (2) group included only states with de-monopolized electricity market. States with the form of de-monopolized electricity market were coded '1', States with the form of monopolized electricity market were coded '0'. States with suspended de-monopolized electricity market were also coded '0'.

[17] www.usaspending.gov is established based on the Federal Funding Accountability and Transparency Act (FFATA) of 2006. Usaspending.gov is the most comprehensive database on government expenditures.

The analysis assumed that the size of a state's higher knowledge stock would influence its level of innovation activities. To measure the knowledge stock, this study used an indicator of educational attainment. The proportion of 25 year olds and older with at least a bachelor's degree was applied. Educational attainment data is available in the annual Current Population Survey at U.S. Census of Governments (https://www.census.gov/govs/).

In addition, this study expected that states with circumstances in which they used more renewable energy resources are more likely to have higher levels of innovation activities in energy technologies. The model included the number of establishments that used renewable energy resources in the electric power generation industries. The industries that use wind, geothermal, biomass, and solar electric power generation were defined by the Economic Census under the North American Industry Classification System (NAICS). This was recorded at the six digit NAICS level within six sub-categories (See Appendix C); (1) Hydroelectric power generation (NACIS 221111), (2) Solar electric power generation (NACIS 221114), (3) Wind industries (NACIS 221115), (4) Geothermal (NACIS 221116), (5) Biomass (NACIS 221117). Data was retrieved from the Census Bureau Economic.

Furthermore, this research expected that states with longer accumulated experience with policy implementation related to renewable and energy efficiency would be more likely to have higher levels of innovation activities in energy technologies. The model included three of the most important state-energy policies: Renewable Energy Portfolio Standards (RPS), Energy Efficiency Resources Standards (EERS) and Energy Efficiency Requirements for Public Buildings (EERPB). I included the difference

between the current year and the year of adoption. Data was retrieved from the Database of State Incentives for Renewable & Efficiency (DSIRE).

Next, previous research has shown that the presence of a political orientation of the Democratic are more likely to support to green technologies that are associated with the effect on the quality of the environment (Clark & Whitfor, 2011; Krause et al., 2014). Therefore, I expected states with higher percentages of House and Senate seats occupied by Democrats were more likely to have higher levels of technological innovation related to the energy. The independent variable related to political circumstances was measured in terms of percentages of House and Senate seats occupied by Democrats.

Finally, this study specifically used state economic characteristics, including the per capita Gross Domestic Product (GDP), and population. All relevant numbers were adjusted for inflation and listed in 2015 dollars using the GDP deflator.

Instrumental variables

The first instrumental variable was the unemployment rate. ARRA was intended to stimulate growth in economic performance and employment. Unemployment rates can be correlated with the level of ARRA funds allocated at the state level. However, unemployment rates are not directly related to innovation activities that foster new energy technologies. This research assumed that states with high unemployment rates would have spent more ARRA dollars to create more jobs.

The second instrumental variable was the total amount of federal ARRA funds spent in block grant programs aimed to provide federal grants to state or local governments. Under the ARRA, block grant programs were designed to stimulate

innovation at the state and local levels (Conlan et al., 2017). The ARRA funding, through the block grant programs, increased rapidly over the time period of the ARRA (Dilger & Boyd, 2014). State and local governments received $52.9 billion in the form of grant-in-aid funds under the ARRA (Conlan et al., 2017, p.33). This funding was intended to reform federalism relationships as well as to reduce bureaucratic redundancy and cost (Terman & Feiock, 2014). What this research proposes is that the funding of the ARRA block grants was analogous to that of ARRA energy grants implemented through the EERE. Governments tend to pursue similar reforms (Urpelainem & Yang, 2017); therefore, when the ARRA energy funds were allocated under the decentralized framework for simulating energy innovation, they were so allocated as to mirror the funding of the block grants. Finally, also included in the second instrumental variable was the total amount spent under the Child Care and Development Block Grant (CCDBG) program[18], the Community Services Block Grant (CSBG)[19] program and Community Development Block Grant (CDBG) program.[20]

For the instrument to be valid, I confirmed that the total amount of ARRA expenditures spent in the form of block grants, through the CCDBG, CSBG and CDBG, were highly correlated with the total amount of ARRA expenditures allocated within the decentralized networks under the DOE's Office of EERE and Office, but not directly related to outcome of the innovation activities in energy technologies. The rate of unemployment was also correlated with the total amount of ARRA expenditures spent for

[18] The program's purpose was to provide for child care assistance for low-income families, it was implemented under the Department of Health and Human Services.

[19] The program's purpose was to help to alleviate the causes and conditions of poverty in communities, it was implemented under the Department of Health and Human Services.

[20] The program's purpose was to provide community development for affordable housing and anti-poverty, it was implemented under the Department of Housing.

energy innovation (See Appendix E). According to the results of the first stage with the instrumental variables, there was a strong positive association between the ARRA funds spent in the form of block grant and ARRA funds spent for energy technologies innovation within the decentralized networks. When ARRA energy funds were spent for energy innovation, there was a significant difference between states with higher rates of unemployment and those with lower rates of unemployment. Those states with higher unemployment had higher rates of ARRA funding for energy innovation. Thus, this research discovered that the potential drivers behind ARRA energy investment were the amount of ARRA funds spent in the form of block grants and the rate of unemployment.

In order to suggest validity of the instrumental variables, the week identification test was used based on the F-statistic (Staiger and Stock, 1997). The results of this test showed that the instrumental variables were strong. The F-statistic for the first-stage regression analysis was consistently much larger than 10 (Table 15). A test of overidentifying restrictions was performed in order to verify the validity of instrumental variables. The null hypothesis that the instrumental variables are valid was not rejected.

Table 15. First-Stage Results with Instrumental Variables (IVs)

Model 1	Coef.	Std. Err	P-value
ARRA Funds Spent under the Block Grant Types	0.713***	0.178	0.000
Unemployment Rate	1.554***	0.571	0.007
ARRA Funds under the EERE			
One-year lag	0.860***	0.042	0.000
Two-year lag	-0.128*	0.066	0.055
Three-year lag	-0.246***	0.055	0.000
Financial Capacity			
Federal DOE Expenditures	0.000	0.002	0.945
Non-Government Expenditures	-0.022	0.022	0.314
Electricity Price			
Electricity Price in Residential Sector	0.892	0.643	0.166
Electricity Price in Industrial Sector	-1.231*	0.684	0.073
De-Monopolized Electricity Market	-0.058	1.634	0.972
Knowledge Stock	0.098	0.150	0.515
Circumstances that Use RE Sources	1.56e+04	1.28e+05	0.903
Circumstances of State-Energy Policies			
RPS	0.190	0.164	0.248
EERS	0.199	0.385	0.605
EERPB	-0.577	0.402	0.153
Political Circumstance			
%House Seats occupied by Democrats	0.051	0.092	0.583
% Senates occupied by Democrats	-0.107	0.080	0.183
Economic Characteristics			
Per Capita Real GDP	0.000	0.000	0.593
Population (1,000)	0.001***	0.000	0.000
Under-identification Test p-value	0.000		
Weak-identification Test (F-statistic)	32.102		
Over-identification Test of instruments Test p-value	0.297		
Year FE	YES		
Observation	539		

Note: * p<0.10, ** p<0.05, p<0.01*** Dependent variable was total amount of ARRA expenditures spent in seven grant programs under the Office of Energy Efficiency and Renewable Energy.

Results

Table 16 presents the relevant descriptive statistics for the states, excluding D.C. and Hawaii from 2005 to 2015. The number of patent applications combined in the Alternative Energy Production and the Energy Conservation ranged from 0 to 5535 with a mean of 200.063 and standard deviation of 494.352. The number of patent applications in the Alternative Energy Production ranged from 0 to 2184 with a mean of 82.033 and standard deviation of 239.755. The number of patent applications in Energy Conservation ranged from 0 to 3351 with a mean of 118.029 and standard deviation of 276.347. The ARRA grants spent in the seven grant programs administered by the Office of Energy Efficiency and Renewable Energy (EERE) ranged from $0 to $2,109,441,787 with an average of $1,851,895 over the period. Next, the amount of federal expenditures allocated annually by the Department of Energy (DOE) ranged from $258,824 to $42,601,587,316 with an average of $805,128,732 aggregated over the period of the study. The total amount spent within state DOE programs through non-governmental funding ranged from $0 to $3,405,072,313 with an average of $70,658,346 over the period of the study.

In terms of electricity price, states' average annual retail electricity price in the residential sector ranged from 6.21 cent/kwh to 20.94cent/kwh with an average of 11.353 cent/kwh. States' average annual retail electricity price in the industrial sector ranged from 3.60 cent/kwh to 16.82 cent/kwh with an average of 7.17 cent/kwh. Also, 29% of the states had a de-monopolized electricity market. The percentage of the state's population over age 25 with a BA degree or higher ranged from 15% to 40%, with a mean of 27.44%. The influence of industries that use renewable energy resources in electric power generation varied considerably, in the range of 0 to 348, with a mean of

30.15. In terms of circumstances of State-energy policies, the duration of the Renewable Portfolio Standards policy ranged from 0 to 19 with a mean of 3.363 year. The duration of Energy Efficiency Resource Standard policy ranged from 0 to14 with a mean of 1.196 years, the duration of policy on Energy Efficiency Requirements for Public Buildings ranged from 0 to 12 with mean of 1.948 years. In regards to political support circumstances, the percentage of House seats occupied by Democrats ranged from 13% to 92% and the percentage of Senate seats occupied by Democrats from 7% to 96%, both with means of close to 50%. Finally, in regards to economic characteristics, per capita GDP ranged from $$31,169 to $78,835 with a mean of $49,579; and population ranged from 514,157 to 39,288,180 with a mean of 6,273,252. As instrumental variables, the amount of ARRA grants spent through the CCDBG, CSBG, and CDBG ranged $0 to $674,560,200 with an average of $15,514,690 over the period. The rate of unemployment ranged from 2.4% to 13.7% with an average of 6.3%.

Table 16. Descriptive Statistics

	Variable	Mean	SD	Min	Max
Innovation Activities	Patent Applications counted in Alternative Energy Production and Energy Conservation	200.063	494.352	0	5535
	Patent Applications counted in Alternative Energy Production	82.033	239.755	0	2184
	Patent Applications counted in Energy Conservation	118.029	276.347	0	3351
ARRA Funds	Total amount of federal ARRA expenditures spent in 7 grant programs under the Office of Energy Efficiency and Renewable Energy (EERE) ($10,000,000)	18.518	36.167	0	210.9442
Financial Capacity	Federal Expenditures allocated by the DOE ($10,000,000)	80.512	218.920	0.025	4260.159
	Total amount spent under the federal DOE program through non-government funding participation ($10,000,000)	7.065	26.007	0	340.5072
Electricity Price	Electricity Price in Residential Sector (cents/kwh)	11.353	3.032	6.21	20.94
	Electricity Price in Industrial Sector (cents/kwh)	7.175	2.540	3.6	16.82
Structure of Electricity Market	Status of De-Monopolized Electricity Market	0.293	0.455	0	1
Knowledge Stock	Percentage of BA or higher	27.440	4.963	15.1	40.4
Circumstances that Use RE Sources	Number of establishments that use renewable energy resources	30.153	44.873	0	348
Circumstances of State-Energy Policies	Duration of RPS	3.363	5.039	0	19
	Duration of EERS	1.196	2.457	0	14
	Duration of EERPB	1.948	2.636	0	12
Political Circumstances	% House occupied by Democrats	48.399	17.371	13.333	92
	% Senates occupied by Democrats	47.251	18.755	7.096	96.65
Economic Characteristics	Per Capita Real GDP ($)	49579.61	9672.184	31169	78835.42
	Number of Population (1,000)	6273.252	6862.072	514.157	39288.18
ARRA Funds in Block Grants	Total amount of federal ARRA expenditures spent under the CCDBG, CSBG and CDBG ($10,000,000)	1.551	5.298	0	67.456
Unemployment Rate	Number of percentage of unemployed from the sum of the employed and unemployed.	6.318	2.168	2.4	13.7

Note: N = 539

Table 17 presented the results of the first difference model with instrumental variables allowing fixed effects. In the results of the test of endogeneity, this research presented the p-value of the endogeneity test, these results indicate that the error term in each model did not correlate with the ARRA funds. (Woolridge, 2003; Popp, 2016).

Table 17 presents the highly significant results of Model 2 (energy conservation) and Model 3 (alternative energy production and energy conservation) after an individual year of the ARRA funding. After a three-year period of ARRA expenses, these figures increased significantly, thereby suggesting the effectiveness of such funding. However, a negative impact occurred after two years because innovation does require a long time period for implementation. Thus, this research showed that innovative activities in energy technologies do bear fruit, but over time.

Table 17 also presented Model 1 (alternative energy production) as a weak trend toward significant in the first individual year; however, after three years, the ARRA funds had a highly significant impact, signaling that time is required for alternative energy production.

In the results of first differenced models, the ARRA funds had the largest cumulative effects on the innovative activities in the technologies of the alternative energy and the energy conservation, as well as combined categories, over the period of the ARRA. These results indicate that ten million dollars of additional government ARRA funds led to development in slightly more than 815,993 new energy technologies over five years.

In addition, in Table 17, the second column for each model includes results assuming all variables are exogenous. These results were similar to those from the main first difference models. Also, in all of the statistical models, the year dummy variables for year specific effects showed that more energy technologies were generated in 2009 and 2013 since the American Recovery and Reinvestment Act was enacted in 2009. These results give us evidence of the effectiveness of Federal stimulus package under the ARRA of 2009.[21]

[21] Autocorrelation had been checked through the Durbin-Watson statistic and did not find any problem in three different models.

Table 17. Determinants of the Innovative Activities in Energy Technologies

	Model 1		Model 2		Model 3	
	IV	exog	IV	exog	IV	exog
ARRA Funds under the EERE						
Individual year	1.428*	0.305	2.532***	3.009***	3.960***	3.314***
	(0.777)	(0.275)	(0.928)	(0.333)	(1.480)	(0.532)
One-year lag	1.213***	1.492***	1.114***	0.995***	2.326***	2.487***
	(0.343)	(0.295)	(0.410)	(0.358)	(0.654)	(0.571)
Two-year lag	0.284	0.099	-2.849***	-2.770***	-2.565***	-2.671***
	(0.421)	(0.408)	(0.502)	(0.495)	(0.801)	(0.490)
Three-year lag	1.685***	1.667***	6.849***	6.856***	8.534***	8.524***
	(0.419)	(0.424)	(0.500)	(0.514)	(0.798)	(0.820)
Financial Capacity						
Federal DOE Expenditures	0.002	-0.001	0.009	0.010	0.011	0.010
	(0.012)	(0.012)	(0.014)	(0.014)	(0.023)	(0.023)
Non-Government Expenditures	-0.043	-0.067	-0.268*	-0.258	-0.311	-0.325
	(0.130)	(0.131)	(0.156)	(0.159)	(0.249)	(0.254)
Electricity Price						
Electricity Price in Residential Sector	-7.194	-5.181	13.701	12.846	6.507	7.664
	(11.498)	(11.558)	(13.726)	(14.014)	(21.893)	(22.365)
Electricity Price in Industrial Sector	-1.419	-4.460	-5.400	-4.108	-6.819	-8.568
	(11.586)	(11.551)	(13.831)	(14.005)	(22.060)	(22.351)
De-Monopolized Electricity Market	-12.072	-12.496	-19.782	-19.602	-31.854	-32.098
	(10.762)	(10.885)	(12.848)	(13.198)	(20.491)	(21.063)
Knowledge Stock	-1.492	-1.408	0.594	0.558	-0.899	-0.850
	(0.978)	(0.988)	(1.168)	(1.19)	(1.863)	(1.913)
Circumstances that Use RE Sources	1.46e+05	4.20e+05	1.37e+06	1.25e+05	1.51e+06	1.67e+06
	(1.98e+06)	(1.99e+06)	(2.36e+06)	(2.42e+06)	(3.77e+06)	(3.86e+06)
Circumstances of State-Energy Policies						
RPS	3.886	5.135	3.640	3.109	7.526	8.244
	(11.630)	(11.739)	(13.884)	(14.233)	(22.145)	(22.715)
EERS	-8.340	-10.224	-19.161	-18.360	-27.501	-28.585
	(13.569)	(13.673)	(16.199)	(16.578)	(25.837)	(26.458)
EERPB	5.544	5.882	5.787	5.644	11.331	11.244
	(12.858)	(13.007)	(15.350)	(15.771)	(24.482)	(25.169)
Political Circumstance						
%House Seats by Democrats	-0.322	-0.247	-1.870	-1.902	-2.192	-2.149
	(1.187)	(1.200)	(1.417)	(1.455)	(2.261)	(2.323)
% Senates by Democrats	-0.005	-0.117	0.264	0.312	0.259	0.195
	(0.980)	(0.989)	(1.170)	(1.199)	(1.867)	(1.914)
Economic Characteristics						
Per Capita Real GDP	0.000	-0.001	-0.002	-0.002	-0.002	-0.002
	(0.003)	(0.003)	(0.004)	(0.004)	(0.007)	(0.007)
Population (1,000)	-0.036	-0.033	-0.017	-0.018	-0.053	-0.051
	(0.056)	(0.056)	(0.067)	(0.068)	(0.107)	(0.110)
Cumulative Effects of ARRA	4.609***	3.562***	7.645***	8.090***	12.255***	11.653***
	(0.907)	(0.608)	(0.848)	(0.738)	(1.727)	(1.177)
Endogeneity Test P-Value	0.1477		0.1842		0.1574	
Observation	490		490		490	
Country FE	Yes		Yes		Yes	

Note: * p<0.10, ** p<0.05, p<0.01*

Discussion

During 2008 and 2009 recession, the Obama administration used ARRA funds for macroeconomic purposes of helping to recover from the recession. A substantial amount of expenditure occurred at the state level, and was designed to stimulate green growth, create jobs and support energy technologies (Conlan et al., 2017). This research has focused that whether federal ARRA investments, designed to spur new technologies, toward alternative energy and energy conservation, effectively achieved their stated objectives. Specifically, the third essay focused on the evaluation of the cumulative effects of government ARRA funding as well as year by year spending. This research confirmed that cumulated ARRA expenditures made in grants through the Office of Energy Efficiency and Renewable Energy (EERE) led to higher levels of innovation activities in alternative energy and energy conservation. The results showed that the ARRA spending had a negative impact in the short-term (two-year after), but three years after, it led to positive impact on more innovation, in delayed returns toward technological energy activities. These results also support the proposition that technological innovation activities takes time.

As another notable finding, the results showed that innovation activities were strongly associated with lagged delayed effects of government investments. It is very noteworthy that temporary government funding evidently played a determinative role in directly stimulating more energy technology-related innovative activities, in cumulated returns, at the state level. The technology innovation process is complex and nonlinear, which occurs between the various stages of the process. It is also made up of many

institutions, including universities, start-ups, the federal government, and extra-national institutions, including the relationships between them. In this perspective, this research's empirical evidence indicates that innovative activities may require extended timeframes for more productive return on government investment.

Also, one of the expectations was that state governments with larger magnitudes of non-government expenditures are more likely to have higher levels of innovation activities in energy technologies. Inconsistent with this expectation, this research found that states with greater amounts spent within government projects with non-government funding participation were associated with decreasing in innovation activities in energy technologies. Although it was a weak evidence toward significant in Model 1 (alternative energy production), these results lead readers to infer that technological innovation may be vulnerable to investments from temporal contracts with non-stable provision (Liang & Fiorino, 2013).

The statistically insignificant coefficients on several of the variables were unexpected on the basis of previous research, including financial capacity, electricity price, presence of de-monopolized electricity market, knowledge stock, the circumstances that use renewable resources, and the circumstance of state-energy policy, economic characteristics, and the impact of political ideology occupied by Democrats.

In regards to Federal DOE expenditures, empirical evidence indicates that the level of expenditures allocated by federal government did not have any relationship at all levels of innovation activities toward new energy technologies. However, it was estimated with the whole federal DOE budget. The whole federal DOE budget might not be enough as proxy for the expenditures, intended for energy technologies development.

Early, the present study looked at higher electricity prices under the belief that they would lead to increases in research and patenting activities in energy area (Popp, 2015)[22]. Stated differently, empirical evidence indicated that higher retail electricity prices were not associated with higher levels of innovation activities in energy technologies. Also, although the law enactment for the deregulating of the electricity market had been expected to accelerate technological innovation, this research's finding showed that the presence of competitive electricity market did not have any relationship with innovation activities in energy technologies. Although the law enactment for the deregulating of the electricity market had been expected to accelerate technological innovation, this research showed that the presence of retail competition does not encourage innovation in the technologies of alternative energy and energy conservation.

In addition, another of expectations was that state governments with longer accumulated policies implementation experiences related to renewable and energy efficiency are more likely to have higher levels of innovation activities toward new energy technologies. Empirical result from this study has shown that the circumstances of state level-energy policies such as RPS, EERE, and EERPB did not have any relationship with innovation activities in energy technologies. From the two perspectives of demand pull and technology push, state level-energy policies such as RPS, EERE, and EERPB are more closely related to demand-pull strategies than technology-push strategies. Thus, the experience of RPS, EERE, and EERPB, that are targeted to renewable power's generation or efficient equipment installation, might not be

[22] In the long run, a 10 percent increase in energy prices leads to a 3.5 percent rise in the number of energy patents. Most of the response occurs quickly after a change in energy prices (http://www.nber.org/reporter/2015number4/popp.html).

associated with the outcome of technology push strategies to boost the launch (or development) of new energy technologies.

This research's results also provide empirical confirmation for a number of hypotheses related to state-specific economic characteristics. The fact that per capita GDP and population were insignificant on the innovation activities in three different models. In regard to knowledge stock variables, the results, in three different models, had shown that states with higher knowledge stock did not have any relationship with the higher levels of innovation activities related to energy technologies. Lastly, in all statistical model, the results indicate that state' political circumstances occupied by the Democrats identification was not associated with higher rates of innovation activities in energy technologies. The greater presence of the firms that use renewable energy, also, were not associated with stimulating in innovation activities in energy technologies.

Conclusion

The American Recovery and Reinvestment Act (ARRA) was the largest federal temporary investment as a one-time grant program. The ARRA investment, provided in seven grant programs through Office of energy Efficiency and Renewable Energy, helped to motivate innovation activities in the alternative energy technologies and energy conservation technologies.

This study provides empirical results on the program's effectiveness implemented under the fiscal decentralization framework. The ARRA relied on many programs being implemented quickly at the federal, state, and local levels as well as non-government entities level. These finding have implications that it is important that decentralized delivery system should be able to distribute the federal expenditure more efficiently for

promoting of innovation activities toward energy technologies in the future. This study also notes that the decentralization approach through intergovernmental grants among federal, state, and local level entities is essential as a new effective method in managing energy programs.

This analysis of the ARRA temporary expenditures shows clearly that short-term and temporary funding from the public sectors can provide a cumulative return on innovative energy activities, despite the previous theoretical scholarship that recognized only long-term and stable government funding positively affecting technological innovation. Although discontinuity public sectors' spending might be disruptive to the achievement of longer term impact in the post-ARRA period, the empirical evidence certainly suggests that temporal expenditures, especially in the short-term, could be effective performance in terms of promoting energy innovation activities.

From this viewpoint, future research should include empirical study of whether short-term investment can be important for encouraging innovation technologies outcome distributed into the practical filed as patent publication in the post-ARRA period.

CHAPTER V

CONCLUSION

What lessons can be extracted about the American Recovery Reinvestment Act (ARRA)' funds that shaped the era of energy program and what do these lessons suggest about the role of energy policy toward the U.S. sustainable energy? This three-essay dissertation sought to address these questions and, in doing so, empirically evaluate effectiveness of the energy programs that government had implemented in American Recovery Reinvestment Act (ARRA). Specifically, I first evaluated whether the ARRA energy efficiency expenditures substantially influenced levels of local government energy activities. In the second essay, I tested whether ARRA expenditures that aim to increase jobs were effective at motivating jobs creation in the energy efficiency and renewable energy sectors. In the final essay, I empirically evaluated the effects of the ARRA investments designed to spur new technologies, toward alternative energy and energy conservation, and effectively achieved their stated objectives. All three essays in this dissertation provide answers to the questions whether they effectively achieved their stated objectives in regards energy policy field.

The first essay showed that ARRA funds, expended with the stated intent of improving energy efficiency, actually helped local governments to make countless initiatives toward developing and adopting energy efficiency programs and policies. The competitive process for acquiring ARRA grants at the local level seems to have been an effective mechanism for the diffusion of more energy efficiency programs and policies, at least in the short term.

The second essay found that federal DOE funds allocated under the ARRA, to stimulate the new jobs in the energy efficiency and renewable energy sector, led to successful policy implementation. This research confirmed that cumulated ARRA expenditures allocated through State Energy Office (SEO) from federal EERE led to higher level of job creation in energy efficiency and renewable energy during the ARRA period. Although the results showed that the ARRA spending had a negative impact in the short-term (one-year after), these results had been matched the previous proposition that some states encountered more difficulties to implement ARRA funds which raised several intergovernmental challenges related to communication and administration (Carley & Hyman, 2014). Two years after, the ARRA funds led to positive impact on more job creation. This research's results support that job creation activities require some time. It was strongly associated with delayed effects of government investment.

The third essay confirmed that the ARRA funds, implemented under the decentralized networks, successfully led to stimulate innovative activities in energy technologies within both categories of alternative energy and energy conservation. Another finding in third essay was that ARRA funds led to productive cumulative return on innovation activities toward alternative energy technologies and energy conservation

technologies during the period of ARRA. These findings has implications that it is important to inject a decentralization approach through intergovernmental grants regarding how government expenditures can more efficiently promote innovation activities in energy technologies. These accomplishments has indicated that temporary government investment evidently played a determinative role in directly stimulating more energy technology-related innovative activities.

In light of these findings, how should the national government's energy policies improve with respect to investments in sustainable energy?. This dissertation of the effects of government ARRA investment lends a number of insights into broader trends associated with the policies toward the energy sustainability. First of all, to achieve sustainable energy, implementation of the grants under more competitive selection processes should be considered for an energy policy delivery system for the diffusion of more energy programs. Competing principals can lead to change the behavior of local governments as well as non-governmental entities. These process, in competitive grants, could be contributed to improve program quality and performance in order to provide more message on sustainable energy and services to the local community.

In addition, the implementation process based upon the competitive functions dependent on state and local agencies within the decentralization approach (Conlan et al., 2017, p.7). This dissertation also gave meaningful attention to the ARRA funds implemented under the decentralized framework; these funds had important impact on achieving their stated goals during the period of ARRA. Thus, one can conclude, decentralized delivery system has a greater effect a new method in managing competitive grants to achieve sustainable energy.

A second possible lesson is that the presence of the networked governance structure can be an effective implementation approach to have a higher level of innovation activities toward sustainable energy. The success of the ARRA funds relied on many projects being implemented quickly at the federal, state, and local as well as non-government entities level. The ARRA functioned as a problem-solver that engaged with a wide range of federal, state and local partners. Decisions and implementation regarding energy programs under the networked governance structures had been allowed for greater flexibility and enhanced objectives which depend on some extent on state and local government's perception. The independent authority of state and local governments led to more motivated actions or plans to match their unique circumstances, being more effectiveness toward sustainable energy than had been achieved at the national initiative. Therefore, this dissertation proposes that the effectiveness of federal programs depends on their function of managing through increasingly interdependent networks of federal, state, local nonprofit, and private entities. The collaborative networked governance can deliver significant performance advantages by enhancing the capacity to achieve sustainable energy. Some actors who have no experiences working across boundaries should be required to realize their partnership's potential for national goals (Conlan et al., 2017).

A third possible lesson is that intergovernmental grants can serve as great devices for stimulating job creation and innovative technologies in the energy sector. Intergovernmental grants helped the delivery of complex national initiatives to numerous states, counties, cities, nonprofits, and private entities in energy programs under the ARRA. These implementations promoted the effectiveness of federal programs. The

presence of intergovernmental grants, that assume a bottom-up view of implementation, can provide a valid picture of energy program delivery.

Finally, the focus of this dissertation on the assessment of the rationale, design, implementation, and impacts of the ARRA offers opportunities to evaluate the effectiveness in the ARRA provisions. This dissertation provides empirical evidence of the effectiveness of ARRA funds spent, as one time and temporary expenditures according to their stated objectives. The finding of analyses from three different essays can contribute to the study of local and state government, as well as federal government's role in sustainable energy policies. This dissertation can also contribute to policy adoption, implementation, evaluation literature focused on energy policy. As an extension of my dissertation, I propose empirical study of whether ARRA investment might be important for achieving long-term energy policy goals. I also propose to find the policy instrument to enhance the overall effectiveness of energy policies. In addition, I propose to find how state government under the meta-governance mechanism can be engaged in promoting more energy efficiency continuously. Specifically, it will focus on the impact of the meta-governance mechanism, and whether there is continuation of the energy program after self-participation of sub-national level's government under the ARRA.

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APPENDICES

Appendix A. Definition of the Patents Related To Alternative Energy Production

Classification of Green Technologies	Description	U.S. Class	U.S. Subclass
Alternative Energy Production	Agricultural Waste	44	589
	Biofuel	44	605, 589
	Chemical Waste	110	235~259, 346
	Domestic Hot Water Systems	126	634~680
	Passive Space Heating	52	173.3
	Swimming Pools	126	561~568
	Fuel Cell	429	12~46
	Fuel from Animal Waste	44	605
	Gasification	48	197A, 197R
	Genetically Engineered Organism	435	252.3, 252.35, 254.9 254.11, 257.2,
		257	325~408, 410~431
	Geothermal	60	641.2~641.5
		436	25~33
	Harnessing Energy from man-made waste	75	958
		431	5
	Hospital Waste	110	235~259, 346
	Hydroelectric	405	76~78
		60	495~507
	Industrial Waste	110	235~259, 346
	Industrial Waste Anaerobic Digestion	210	605
	Industrial Wood Waste	44	589~606
	Inertial (Turbine)	290	51~54
		60	495~507
	Landfill Gas	431	5
	Municipal Waste	44	552
	Nuclear Power : Induced Nuclear Reactions, processes	376	-
	Nuclear Power : Reaction Motor with electric	60	203.1
	Nuclear Power : Heating motive fluid by nuclear energy	60	644.1
	Nuclear Power Photovoltaic	136	243~265
	Refuse derived fuel	44	552
	Solar Cells	438	57,82,84~86,90,93~94, 96, 97
	Solar Energy	126	561~714
		320	101
	Solar Thermal Energy	126	561~713
		60	641.8 ~641.15
	Water Level (Wave or Tide)	405	76~78
		60	495~507
	Wind	290	44, 55
		307	64~66, 82~87
		415	2.1

Source: U.S. Patent and Trademarks Office. USPTO Green Technology Pilot Program, Retrieved from http://www.waybetterpatents.com/green_pilot_classes.html

Appendix B. Definition of the Patents Related To Energy Conservation

Classification of Green Technologies	Description	U.S. Class	U.S. Subclass
Energy Conservation	Alternative-Power Vehicle	180	2.1, 2.2, 54.1
	Cathode Ray Tube Circuits	315	150, 151
	Commuting – HOV, Teleworking	705	13
		105	1.1, 1.3
	Drag Reduction	105	1.1~1.3
		296	180.1~180.5, 181.5
	Electric Lamp & Discharge Devices	313	498~512, 567~643
	Electric Vehicle	180	65.1, 65.21
		320	109
		701	22
		310	1~310
	Emission Trading (Pollution Credits)	705	35~45
	Energy Storage & Distribution	307	38~41
		700	295~298
		713	300~340
	Fuel Cell Powered Vehicles	180	65.21, 65.31
	Human-Powered Vehicle	180	205
		280	200~304.5
	Hybrid-Powered Vehicle	180	65.21
		73	35.01~35.13
		73	112~115
		73	116~119A
		73	121~132
	Incoherent Light Emitter Structure	257	79, 82, 88~90, 93, 99~103
	Land Vehicle – Electric Trains	105	49~71
	Land Vehicle – Electric Cars	180	65.1~65.8
	Optical Systems and Elements	359	591~598
	Roadway – Recycled Surface, All Weather Bikeways	404	32~46
	Static Structure	52	309.1~309.17
		52	404.1~404.5
		52	424~442
		52	783.1~795.1
	Thermal	702	130~136
	Transportation	361	19,20,141,152, 218
	Watercraft Drive (Electric Powered)	440	6~7
	Watercraft Drive (Human Powered)	440	21~32
	Wave-Powered Boat Motors	440	9
	Wind-Powered Boat Motors	440	8
	Wind-Powered Ships	114	102.1~115

Source: U.S. Patent and Trademarks Office. USPTO Green Technology Pilot Program, Retrieved from http://www.waybetterpatents.com/green_pilot_classes.html

Appendix C. Establishment that Use Renewable Energy Resources in Electric Power Generation

NAICS	Description
221111	Hydroelectric power generation
221114	Solar Electric power generation
221115	Wind industries
221116	Geothermal
221117	Biomass

Source: U.S. Census Bureau Economic Data

Appendix D. Cross-Correlation Analysis in Second Essay

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)ARRA_EERE	1.000											
(2)ARRA_EERE (t-1)	0.794	1.000										
(3)ARRA_EERE(t-2)	0.469	0.791	1.000									
(4)ARRA_EERE(t-3)	0.206	0.533	0.875	1.000								
(5)Federal DOE budget	-0.025	-0.028	-0.028	-0.0295	1.000							
(6)Non-Government funds	-0.009	-0.008	-0.030	-0.029	0.028	1.000						
(7)Democratic Governor	-0.032	0.001	0.036	0.033	0.035	0.011	1.000					
(8) RE Sources	0.348	0.224	0.120	0.226	-0.001	-0.028	-0.092	1.000				
(9) Per Capita Real GDP	-0.074	-0.087	-0.081	-0.054	-0.007	-0.020	-0.095	0.050	1.000			
(10) Population Density	0.135	0.139	0.143	0.130	-0.005	0.059	-0.091	0.140	0.327	1.000		
(11)ARRA in the Block Grant	0.505	0.609	0.614	0.485	-0.017	-0.020	-0.006	0.000	-0.041	0.112	1.000	
(12)State Energy Policies	0.235	0.372	0.523	0.538	-0.038	-0.028	-0.078	0.296	-0.040	0.163	0.234	1.000

Appendix E. Cross-Correlation Analysis in Third Essay

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1)ARRA_EERE	1.00																			
(2)ARRA_EERE (t-1)	0.79	1.00																		
(3)ARRA_EERE (t-2)	0.46	0.79	1.00																	
(4)ARRA_EERE (t-3)	0.20	0.53	0.87	1.00																
(5)Federal DOE annual budget	-0.03	-0.03	-0.03	-0.03	1.00															
(6)Non-Government funds	-0.00	-0.01	-0.03	-0.03	0.03	1.00														
(7)Electricity Price in Industrial	0.03	0.04	0.05	0.05	-0.03	-0.05	1.00													
(8)Electricity Price in Residential	0.15	0.19	0.24	0.24	-0.02	-0.06	0.88	1.00												
(9)De-Monopolized Electricity	-0.01	0.01	0.04	0.05	-0.04	0.03	0.17	0.20	1.00											
(10)Knowledge Stock	0.00	0.02	0.07	0.08	-0.00	-0.01	0.23	0.24	0.40	1.00										
(11) RE Sources	0.34	0.22	0.12	0.23	-0.00	-0.03	0.12	0.25	0.02	0.07	1.00									
(12) RPS	0.11	0.19	0.28	0.29	0.03	-0.07	0.27	0.42	0.11	0.14	0.18	1.00								
(13) EERS	0.23	0.37	0.52	0.54	-0.04	-0.03	0.17	0.33	0.04	0.12	0.30	0.39	1.00							
(14) EERPB	0.33	0.43	0.50	0.46	-0.04	0.02	0.18	0.36	-0.01	0.09	0.27	0.44	0.79	1.00						
(15)%House Seats by Democrats	0.08	0.03	-0.03	-0.02	0.02	0.01	0.40	0.42	0.08	0.05	0.17	0.25	0.15	0.23	1.00					
(16)% Senates Seats by Democrats	0.02	-0.01	-0.04	-0.04	0.05	-0.03	0.40	0.37	0.06	0.08	0.10	0.29	0.17	0.24	0.88	1.00				
(17) Per Capita Real GDP	-0.07	-0.09	-0.08	-0.05	-0.01	-0.02	0.43	0.35	0.19	0.26	0.05	0.15	-0.04	-0.03	0.15	0.20	1.00			
(18) Population	0.45	0.46	0.47	0.42	-0.02	0.01	0.09	0.21	0.21	0.07	0.50	0.13	0.42	0.38	0.12	0.05	0.12	1.00		
(19)ARRA in the Block Grant Types	050	0.61	0.61	0.49	-0.02	-0.02	0.05	0.16	-0.05	-0.04	-0.00	0.11	0.23	0.32	0.04	0.02	-0.04	0.34	1.00	
(20)Unemployment Rate	0.59	0.50	0.29	0.14	-0.04	0.04	0.10	0.20	-0.05	-0.07	0.26	0.07	0.13	0.27	0.27	0.16	-0.28	0.23	0.28	1.00