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Essays in Policy Analysis

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To the Graduate Council:

I am submitting herewith a dissertation written by Michael Philip Craig entitled "Essays in Policy Analysis." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

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Do not climb mountains so the world can see you, but so you can see the world - David McCullough Jr.

Abstract

My dissertation consists of three essays related to policy analysis. In the first essay we ask, how can developing nations who face revenue mobilization issues and large informal sectors use taxation as a means of nation building? To answer this, we design a dynamic general equilibrium model that accounts for a large informal sector. Contrary to previous studies that model the informal economy, we focus on the importance of the government maintaining its social fiscal contract with its constituents by including the provision of productive public goods in the model. By doing so, we show that increasing taxes can be used to encourage formal sector activity and increase revenue simultaneously. In the second essay, I develop a theoretical outline explaining why treatment effects may lag the treatment event in the context of local labor shocks, and examine the impact properly identifying of treatment date. Using the Clean Air Act Amendments (CAAA) of 1990 as a case study for a negative labor demand shock in the Appalachian coal mining industry, I find lags in treatment effects on the mining industry relative to policy implementation, as well as secondary lags in the multiplier effects on the aggregate economy relative to the labor shock. Building on this, the third essay tests the predictions of the theory in the case of a positive labor demand shock and explores the timing of multiplier effects at the sector level. Using the CAAA as the source of a positive labor demand shock in the Western United States coal industry, I again find lags in the treatment effect on the mining sector, but find variety in the timing of responses of individual sectors. I also discuss the implications these findings have for local policy makers whose communities may experience such shocks, as well as national policy makers concerned with future policy initiatives such as the Clean Power Plan.

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Chapter 1

Introduction

In this dissertation, I present three essays on policy analysis. The first is a theoretical model of tax and enforcement policies in developing nations with large informal sectors. The latter two are empirical investigations on Title IV of the Clean Air Act Amendments of 1990, which established the sulfur dioxide cap and trade system.

In the first essay, I address the issue of revenue mobilization in developing economies who are also plagued by large informal sectors. Specifically I look at how policy changes in taxes and enforcement can help increase the amount of formal sector activity to grow the tax base. I run policy experiments in a small open economy dynamic general equilibrium model to determine how changes to enforcement and tax policy affect the relative size of the formal and informal sectors, as well as the overall economy. Contrary to predictions in the literature, our simulations suggest that tax increases can lead to higher rates of formal sector activity when government revenue is used to provide productive public goods. This result is consistent with the developmental literature that focuses on the importance of governments' maintaining a healthy fiscal social contract with its constituents. I also identify "tipping points" in the proportion of government revenue dedicated to the provision of productive public goods where this result holds.

In the second essay, I study the proper assignment of treatment date in the context of local labor demand shocks. I develop a theoretical analysis for explaining why treatment effects and potential multiplier effects may lag or lead the event that is credited with causing the labor shock based on characteristics of the shock. This issue is not addressed in the literature. Furthermore, treatment is viewed as one event that affects both the extraction sector and other sectors of the economy at the same date. I argue that this assumption is not valid and could introduce bias into the estimates. I instead view it as a series of separate treatment events. The event that affects the extraction sector is the first treatment event, and then the change in behavior of the extraction sector is the second treatment event that affects the broader economy. The date of treatment can be verified using a test for structural breaks with an unknown break point, a method common in the program evaluation literature. To test the predictions of my theoretical framework, I examine the impact of the Title IV of the Clean Air Act Amendments of 1990, which caused a negative labor demand shock in the coal mining industry of Appalachia. I find lags do exist from the time the policy went into effect and when treatment occurred. The structural break in the mining behavior, i.e. treatment date, occurs 4 years after the policy becomes effective. I also find that there is a lag in the treatment effect on the broader economy, which differs with various measurements of economic output. I then discuss the implications this has for local policy makers.

In the third essay, I study employment spillover effects of the Clean Air Act Amendments of 1990 and consider the implications for future potential cap and trade policies. Building on the results of the second essay, the third essay tests the predictions of the theoretical analysis in the case of a positive labor demand shock and also explores the timing of multiplier effects at the sector level. I use the Title IV amendments as the source of a positive labor demand shock in the Western United States coal industry, whose low-sulfur coal was a substitute for Appalachian high-sulfur coal. I find lags in the treatment effect on the mining sector, but find variety in the timing of responses of individual sectors. My results indicate weak

evidence of agglomeration effects as a result of the positive labor shock in the mining sector, with the traded sectors of manufacturing and agriculture experiencing gains in employment and total sectoral income. However, I find mixed evidence on the impact on locally consumed sectors, with the retail sector gaining jobs while the construction sector loses jobs. I also discuss the implications these findings have for local policy makers whose communities may experience such shocks, as well as national policy makers concerned with future policy initiatives such as the Clean Power Plan.

Chapter 2

Developing Nations and the Shadow Economy: Addressing the Recursive Fiscal Dilemma

2.1 Introduction

Developing nations rely heavily on public expenditures for state building activities. Public investments in infrastructure and social overhead capital, such as education, health care, well regulated and efficient credit markets, legal systems, and enforcement of property rights, are necessary for any economy to develop and maintain a sustainable level of growth (Brautigam et al 2008). This is particularly true in developing economies where private consumption and investment are inadequate. Attention in the literature is increasingly focused on mechanisms to promote growth and development through infrastructure and social overhead capital. For example, one study shows that public investment in developing nations can lead to crowding-in of private investment, where \$1 of public investment can lead to an additional \$2 of private investment and \$1.5 of additional output (Eden and Kray working paper), while empirical studies have found government spending multipliers to be between .4 (Kray 2014) and .5 (Kray 2015). Public sector investments require a large and stable public revenue source, which developing nations lack due to their undeveloped private sectors, large informal sectors, and competing uses for government funds.

Increasing taxes can be politically difficult given the fragile nature of the "fiscal social contract" (Everest-Philips 2008) between a government and its citizenry. The challenge is more daunting in the presence of large informal sectors that provide a well established outlet for evasion. This flight to the informal sector shrinks the tax base, and may reduce revenue, a phenomenon referred to as the recursive fiscal dilemma (Schneider and Enst 2000; Fleming et al. 2000; Johnson et al. 1998). This in turn reduces the government's ability to provide services, such as education, health care, and infrastructure, further constraining the human capital development and lowering total factor productivity. As the cycle continues, domestic revenue capacity may be further eroded. This negative feedback loop is the so called recursive fiscal dilemma. Poor quality service delivery compromises the visible benefit to business and citizens of paying taxes, which has been shown to be an important factor in tax compliance

(Westat 1980; Yankelovich et al 1984). This damages the fiscal social contract and hurts tax morale, which can lead to greater non-compliance (Everest-Philips 2008). Considering the important role that citizen involvement in the decision-making process plays in maintaining a proper fiscal exchange, cutbacks in the provision of public services without explicit consent of the public also risks raising non-compliance (Alm et al. 92). Despite the potential for negative reactions from tax payers, revenue mobilization as a means of state building is being seen as an increasingly important component of effective social and economic development.

In addition to raising revenue for state building purposes, bringing micro and small sized enterprises (MSEs) into the formal sector also provides many benefits to the newly-formal firms. First, the informal sector is less productive than the formal (Palmade 2005). Second, informal firms are extremely sensitive to the business climate, which is often less stable in developing nations. Furthermore, informal firms are often market constrained (lack access to government contracts and spending programs), resource constrained (lack access to formal credit markets economic development grants) and capital constrained (unable to increase capacity without risking detection) compared to their formal counterparts (Palmade 2005). Therefore understanding the effects fiscal policy actions have on the formal-informal choice is critical for developing nations. However, the informal sector has a pragmatic motivation to pay taxes to participate in the formal sector when doing so offers tangible benefits (Baross 1990). For instance, in Mauritius the government was able to successfully encourage MSEs participation in the formal sector by offering targeted access to finance. In China, larger firms reported increased willingness to pay higher rates of local taxation in return for more secure property rights. These examples demonstrate the importance of maintaining the fiscal social contract in order to promote tax compliance in developing nations.

We investigate two issues common to developing countries concerned with state building: weak central government revenue capacity and the presence of large informal sectors. Specifically, we ask how temporary changes in tax rates and enforcement

rates can be used to address both of these issues simultaneously. [1] Second, we ask how does including different uses of government spending in the model affect the best policy? This second question addresses the means in which the government maintains its fiscal social contact as well as the overly simplified treatment of the government's role in the existing informal sector literature. To answer these questions, we develop a dynamic general equilibrium (DGE) model, for a small, open, developing economy, which we parameterize to Sri Lanka[2]. The model accounts for the provision of different government services, e.g. a public consumption good, a labor augmenting service, and an informal sector that produces a non-traded good and does not have access to government provided services. We then run simulations for different mixes of government spending, which is funded from taxes on formal output and on penalties assessed to detected informal activity.

Our investigation into the role that different spending mixes plays is an important contribution to the informal economy literature, answering the question of, "what is the best use of an increase in government resources?" An important limitation in the literature is to refine government spending to a lump sum transfer back to the taxpayer. In our simulations, we not only differentiate between government spending as purchases of goods and services and government provision of goods and services, but also between the types of goods and services provided by the government. In the model, the government can provide a specific human capital good and a productivity enhancing services good, both of which factor into the formal sector's production function. Additionally, the government can provide a public consumption good, which factors directly into the agent's utility function. The different uses of government spending differ fundamentally in their purpose, the first two providing a productive benefit and the latter providing a strictly utilitarian benefit. The inclusion of public

[1] We choose to focus on temporary policy changes to reflect the uncertainty of tax and enforcement policies in developing countries

[2] We choose to study Sri Lanka because it fits the profile of a small developing country with a large informal sector. Additionally, Sri Lanka has been the subject of previous studies which provide useful information in parameterizing our model.

goods in the model allows us to address the government's attempt to maintain its fiscal social contract with its citizens.

We first set a benchmark case where government revenue is used strictly as a lump sum transfer back to the household, mimicking the models of existing studies. Our simulations align with the literature where increased enforcement reduces informality and decreased tax rates increase formal sector activity. We then model the case of the public good, which allows for different uses of government revenue spent on a mix of transfers and the provision of public goods. We vary the proportion of government revenue spent on each use, which we incorporate in the model as exogenous spending parameters, and run a variety of simulations to identify how different apportionments of government revenues might affect the best policy.

The key result emerging from these analyses is that we are able to identify tipping points in the proportion of government revenue dedicated to the provision of productive public goods for which a tax increase is an effective policy. Above this point, increased taxation leads to the desired outcome of expanded formal sector output and decreased informal sector activity, but below this point we see the opposite effects. This result contradicts our benchmark case and the predictions of the literature, but is consistent with the story told by emerging literature focusing on using revenue mobilization as a means of state building, a quid pro quo relationship that providing visible and tangible benefits to taxpayers can increase compliance and participation in the formal sector.

The rest of the paper is laid out as follows. Section 2 briefly discusses the informal sector literature. Section 3 describes the model and the policy experiments to be carried out. Sections 4 and 5 discuss the simulations for the two cases described above. Section 6 provides an alternative specification of productive public goods. Section 7 conducts sensitivity analysis, while section 8 discusses the issue of government credibility. Section 9 concludes.

2.2 The Informal Economy

Two facets of the informal economy literature are especially important to our application. First is measurement of the size of the informal sector and second are theoretical causes of informality.

Measuring the size of the shadow economy is problematic because the shadow economy is not directly observable and there are no good proxies to enable measurement. Schneider and his coauthors have published several studies estimating the size of the shadow economy for large sets of countries using a structured modeling system that relies on several explanatory variables identified in the literature as affecting the size of the shadow economy (Schneider et al. 2010). Other methods for measuring the size of the shadow economy include using voluntary surveys and tax audit data (Isachsem et al. 1982; Morgensen et al. 1995; Alm, Bahl, and Murray 1991), using discrepancies between reported income and expenditures (Franz 1983; MacAfee 1980; O'Higgins 1989; Smith 1985; Yoo & Nyun 1998), the transactions approach (Feige 1986), and the currency demand approach (Cagan 1958; Tanzi 1980, 1983).

While there is no way to validate the estimation results against true values, there are some descriptive trends that emerge from the estimation literature that can be useful, such as poorer countries like Sri Lanka and Bolivia should have higher estimated shadow economies. Table 2.1 provides a list of the 11 largest shadow economies relative to the size of officially reported GDP, according to Schneider et al. (2010).

A vast literature seeks to identify factors that affect the size of the shadow economy. High barriers to formal sector entry, such as excessive regulatory burden, high administrative costs and high tax rates, increase the size of the informal sector (Loyaza 1996; Schneider and Neck 1993; Fortin 1997; Rauch 1991; Sarte 2000; Straub 2003). On the other hand, higher enforcement rates and higher penalties decrease the size of the informal sector (Turnovsky and Basher 2009; Loyoza 1996; Prado 2011.

Table 2.1: Countries With Large Shadow Economies

Country	Relative Size of Informal Sector	Rank
Bolivia	66.9%	1
Peru	59.0%	2
Thailand	51.9%	3
Guatemala	51.3%	4
Uruguay	50.0 %	5
Honduras	49.7 %	6
Benin	49.6%	7
El Salvador	46%	8
Nicaragua	44.9%	9
Sri Lanka	43.9 %	10
Cote d'Ivoire	43.3%	11

Source: Schneider et al. 2010

Increased government corruption, less efficient formal credit markets (Straub 2003), and simplified tax codes, i.e. fewer legal loopholes, (Schneider and Enst 1993) also increase the size of the informal sector. While the result that simplified tax codes encourage informality may seem counterintuitive, it is important to keep in mind that tax avoidance, which complicated tax systems allow more opportunities for, is legal, while tax evasion is not. When these legal tax loopholes are closed, firms are more likely to seek out illegal means to escape taxation, joining the shadow economy (Alm et al. 1992). In addition, the presence of non-pecuniary benefits increases household participation in the formal sector for primary workers, but secondary workers are less likely to do so (Saracoglu 2008; Galiani and Weinschelbaum 2007).

That increasing taxes would decrease informality is consistent with the recursive fiscal dilemma, highlighting the importance of finding a way to raise taxes without discouraging formality. In an attempt to do so, Turnovsky and Basher (2009) investigate the effect of decoupling tax rates in a general equilibrium model calibrated to a small open economy. In a baseline model with only output taxes, the authors' first two results support the previously discussed conclusions regarding taxes and enforcement. But when decoupling the tax rates on wages from tax rates on capital, they find that under the right combination of labor tax and probability of audit

increases and capital tax decreases, the government can still raise revenue without a consumption loss. Despite the breadth of the literature examining the fiscal social contract, emphasis of the informal sector literature has been on taxes and enforcement. Surprisingly little has been given to the role that strengthening the fiscal social contract via increased provision of public services and investment may have on how to best increase formal sector activity. Our paper differs from the existing literature by considering different uses of government revenue in our model and explores the possibility that increasing taxes can actually increase formality.

2.3 The Model

The absence of observable data on the informal sector motivates our strategy. We develop a two sector, small, developing, open economy model with formal and informal sectors. The household has access to foreign capital (debt). We assume imperfect capital mobility and the economy is subject to an upward sloping supply curve of debt. This means that the agent can not borrow at the fixed world interest rate, r^*, but is subject to a country specific risk premium. The effective interest rate is thus

$$r_t = r^* + R(e^{d_t - \bar{d}}) \tag{2.1}$$

The representative agent consumes both formal and informal goods, as well as a publicly-provided good (discussed more fully below), and optimizes over a formal/informal-labor/leisure choice. The agent maximizes lifetime expected utility over consumption and labor according to

$$U = E\left\{ \Sigma_{t=0}^{\infty} \beta^t \left[\frac{\left[C_t - (1-\omega)^{-1}(H_t)^{1-\omega}\right]^{1-\sigma} - 1}{1-\sigma} \right] \right\}$$

where C represents total consumption and H represents total labor. Total consumption, C, and total labor, H, are given by

$$C_t = (c_t^f)^{\alpha_1}(c_t^i)^{\alpha_2}(c_t^g)^{1-\alpha_1-\alpha_2} \tag{2.2}$$

$$H_t = h_t^f + h_t^i \tag{2.3}$$

where superscripts f and i denote formal and informal sectors, respectively, and superscript g denotes the publicly provided good. Equation 2.3 shows that the representative agent divides his time between formal and informal activity. This way of modeling addresses the issue of when firms are neither fully formal nor fully informal, but they comply with some aspects of regulation or taxation. The representative agent's time spent working in the formal sector, h^f, represents the fully compliant activities of his business, while his time working informally, h^i, represents the part of the business in which he isn't meeting tax obligations.

The representative agent owns all production. Formal production and informal production are given by

$$Y_t^f = (e^{L_t} h_t^f)^{\theta}(Z_t)^{\psi}(K_t)^{1-\theta-\psi} \tag{2.4}$$

$$Y_t^f = e^{A_t^i}(h_t^i)^{\gamma} \tag{2.5}$$

K_t is the stock of privately provided physical capital and Z_t is the publicly provided productivity enhancing good. This good can be thought of as the provision of an efficient credit market, enforcement of property rights, and a well functioning legal system, all aspects that are critical for formal business to grow and encourage private investment. The formal sector makes use of the specific human capital, private capital and the productivity enhancing good, while the informal sector only has access to labor.

The private capital stock evolves according to the standard capital accumulation equation

$$K_t = X_t + (1-\delta)K_{t-1} \tag{2.6}$$

The budget constraint of the representative agent is given by

$$\begin{aligned} d_t =& (1+r_{t-1})d_{t-1} - (1-\tau_t)Y_t^f - [1-(b+\tau_t)\kappa_t]p_t Y_t^i \\ &+ c_t^f + p_t c_t^i + x_t + \Phi(k_{t+1}-k_t) - T \end{aligned} \tag{2.7}$$

where d_t is the debt level in period t and $(1+r_{t-1})d_{t-1}$ are the interest payments on last periods debt. $(1-\tau_t)Y_t^f$ and $[1-(b+\tau_t)\kappa_t]p_t Y_t^i$ are the after tax income from formal sector production and expected income from informal production, respectively. c_t^f and $p_t c_t^i$ represent the agent's consumption of formal and informal goods, while $x_t + \Phi(k_{t+1}-k_t)$ represents the total cost of investment. $\Phi(\cdot)$ is the capital adjustment cost function given by

$$\Phi(k_t - k_{t-1}) = \frac{\phi}{2}(k_t - k_{t-1})^2$$

Lastly, T is the government's purchase of goods and services which factors back into the agent's income as a lump sum transfer.

The government enters the model through taxation of the formal market, collection of penalties assessed on detected informal activity, and the spending of government revenue. Government revenue is spent in four ways. It can be used for the purchase of formal sector goods and services, T. Second, it can be used for the production of a pure public consumption good, c^g, which enters the utility function. This can be thought of us the provision of things like national parks. Third, it can be used for the provision of productivity enhancing services, Z_t, which enters into the formal sector's production function. These services, which exclusively benefit the formal sector, include well functioning legal systems, access to efficient credit

markets, and enforcement of property rights. Lastly, government revenue can be used for the provision of human capital enhancing services, L_t. Because general human capital, such as reading and writing, is fully transferable from the formal sector to the informal, this refers to human capital enhancing services that apply to a specific occupation or production process, for instance training to use or service equipment that is part of a large scale production process being used by a multinational corporation that has opened a facility in the developing nation. The collection and use of government revenue are given by:

$$G_t = \tau_t Y_t^f + [(b + \tau_t)\kappa_t] p_t Y_t^i \tag{2.8}$$

$$Z_t = \eta_1 G_t \tag{2.9}$$

$$c_t^g = \eta_2 G_t \tag{2.10}$$

$$L_t = \eta_3 G_t \tag{2.11}$$

$$T_t = (1 - \eta_1 - \eta_2 - \eta_3) G_t \tag{2.12}$$

where τ is the tax rate on income, b is the penalty rate, and κ is the detection rate of informal sector activity[3]. p_t is the price of informal goods relative to formal goods, which act as the numeraire good. Government revenue equals government expenditure, and η_1 is the proportion of government revenue spent on the productivity enhancing service, η_2 is the proportion used in provision of the public good and η_3 is the proportion spent on the specific human capital good. The remainder is spent on the Government's consumption of formal sector goods and services, T.

We implement one time changes to the policy variables κ and τ which we allow to propagate through the economy according to the following stochastic processes:

$$\tau_t - \tau_{ss} = \rho_\tau (\tau_{t-1} - \tau_{ss}) - \epsilon_\tau \tag{2.13}$$

[3] While some models include an enforcement function (Ordonez 2014), we choose not to for simplicity. Thus the term $(b + \tau_t)\kappa_t$ is the expected effective penalty rate. Results from previous work by Ordonez (2014) suggest that costs of enforcement are outweighed by potential gains under a model calibrated to the Mexican economy.

$$\kappa_t - \kappa_{ss} = \rho_\kappa(\kappa_{t-1} - \kappa_{ss}) - \epsilon_\kappa \tag{2.14}$$

The stochastic nature of the tax change can be thought of intuitively as the announcement of an initial tax increase/decrease that is systematically reduced overtime until the rate reaches the original level. The stochastic nature of the enforcement increase can be thought of as a new innovation in enforcement, such as mobile tax collection units sent by the World Bank combing through a local market and auditing vendors to see if they were registered for the VAT. Although the policy is a one-time sweep, a threat effect persists that may affect behavior due to the uncertainty regarding another sweep.

Informal producers do not have access to international transportation networks, such as sea ports, because of the presence of government officials, prohibiting from selling their goods internationally. Thus informal output cannot be traded and must be consumed domestically. This yields an additional market clearing condition:

$$Y_t^i = c_t^i \tag{2.15}$$

Equations for the current account, ca, and trade balance, tb, are given by the following:

$$ca_t = -(d_t - d_{t-1}) \tag{2.16}$$

$$tb_t = Y_t^f - c_t^f - T_t - x_t - \phi(.) \tag{2.17}$$

Thus, the agent's maximization problem can be solved with the following Lagrangian

$$maxE[\Sigma_{t=0}^{\infty}\beta^t\{U(C_t, H_t) + \lambda_t[(1-\tau_t)Y_t^f + (1-(b+\tau_t)\kappa_t)p_tY_t^i + d_t$$
$$-(1+r_{t-1})d_{t-1} - c_t^f - p_tc_t^i - k_{t+1} + (1-\delta k_t) - \Phi(k_{t+1} - k_t)] + T\}]$$

The first order conditions (FOCs) of the household's optimization problem are given by

$$\alpha_1 \frac{C_t}{c_t^f}\left[C_t - \frac{H_t^\omega}{\omega}\right]^{-\sigma} = \lambda_t \tag{2.18}$$

$$\alpha_2 \frac{C_t}{c_t^i}\left[C_t - \frac{H_t^\omega}{\omega}\right]^{-\sigma} = p_t\lambda_t \tag{2.19}$$

$$H_t^{\omega-1}\left[C_t - \frac{H_t^\omega}{\omega}\right]^{-\sigma} = (1-\tau_t)\theta\frac{Y_t^f}{h_t^f}\lambda_t \tag{2.20}$$

$$H_t^{\omega-1}\left[C_t - \frac{H_t^\omega}{\omega}\right]^{-\sigma} = (1-(b+\tau_t)*\kappa_t)\gamma p_t\frac{Y_t^i}{h_t^i}\lambda_t \tag{2.21}$$

$$\lambda_t(1+\phi(K_t - K_{t-1}) = \lambda_{t+1}\beta\big[(1-\tau_t)(1-\theta-\psi)\frac{Y_{t+1}^f}{K_t} + 1 - \delta + \phi(K_{t+2} - K_{t+1})\big] \tag{2.22}$$

Equation 2.18 tells us that the marginal utility of one unit of formal consumption equals the shadow price of labor (λ_t), while Equation 2.19 tells us the marginal utility of one unit of informal consumption equals the shadow price of labor adjusted by the relative price (p_t). Equation 2.20 and Equation 2.21 provide the marginal disutility of one more unit of formal and informal labor, respectively. Equation 2.22 is the Euler equation which relates the utility of one more unit of consumption today versus saving it for tomorrow. The dynamic competitive equilibrium is characterized by the set

$$\{y_t^f, y_t^i, H_t, h_t^f, h_t^i, C_t, c_t^f, c_t^i, c_t^g, X_t, k_{t-1},$$
$$G_t, T_t, Z_t, L_t, r_t, d_t, ca_t, tb_t, \tau_t, \kappa_t, p_t, \lambda_t\}$$

that satisfies equations 2.1-2.22 and the initial conditions $\{K_0, d_0\}$.

2.3.1 Model Calibration and Policy Experiments

We parameterize the model to represent Sri Lanka, a small, developing, open economy with a large informal sector. To do so, we take parameter values used in the previous literature. These values and their descriptions are given in Table 2.2.

Table 2.2: Model Parametrization

Parameter	Value	Description
α_1	.55	Formal consumption preference parameter
α_2	.30	Informal consumption preference parameter
β	.96	Discount rate
θ	.33	Labor share of production, formal sector
ψ	0 or .25	Public capital share of production, formal sector
η_1	[0, .25, .33, .5]	Proportion of government revenue spent on investment
η_2	[0, .25, .33, .5]	Proportion of government revenue spent on public good
γ	.495	Labor share of production, informal sector
σ	1.5	Coefficient of relative risk aversion
r^*	.04	World interest rate
R	.108	Debt elastic interest rate premium
σ_κ	.1	Standard error, stochastic enforcement shock
σ_τ	.1	Standard error, stochastic tax shock
ϕ	.028	Coefficient of capital adjustment
δ	.08	Rate of capital deprecation
ω	3	Intertemporal elasticity of substitution of labor
ρ_κ	.8	Persistence parameter, stochastic enforcement shock
ρ_τ	.8	Persistence parameter, stochastic tax shock
$\bar{d}$	.0074	Steady state level of debt

Source: Schneider et al. 2010

Values for β, θ, and δ are taken from Ihrig and Moe (2004) and are also commonly used elsewhere in the literature. This value of β leads to a world interest rate of 4%. We therefore set the country specific interest rate premium $R = 10.8\%$, which is high, but sets a steady state rate of 14.8%, which is the average of the period from 2006-2010 based on World Bank data. We set the elasticity of labor supply $\omega = 3$, following Mitra (2013), who parameterizes his model to an average developing economy. We face some difficulty with regards to assigning values for certain parameters, as there

are no reliable data for developing economies. To account for this, we run sensitivity analysis over a range of values for α_1 and α_2, and the government spending parameters η_1 and η_2 to determine how robust our results are to these parameters.

Several key findings have emerged from the existing theoretical literature on the determinants of the size of the shadow economy. We choose two of these for the focus of our policy experiments. First, lower costs to formality, such as weaker labor regulations, lower compliance costs, and lower tax rates will encourage firms to operate formally. Second, increased enforcement will increase the costs of operating informally, causing some firms to switch from the informal sector to the formal while causing others to shut down.

The goal of government policy isn't to eliminate informal sector activity for the sake of doing so, but to increase formal sector activity and to be able to use revenue mobilization as a means of nation building. In the following two sections, we apply one time changes to the policy parameters of κ and τ. In Section 4, government spending is used on the consumption of formal goods and services and is considered to be "wasteful," in that it does not contribute productivity or utility. In Section 5, the government now spends some of its revenue on providing public goods in addition to the wasteful spending. We present results for different spending mixes to compare the effect of different government spending behaviors.

2.4 Benchmark Case: The Model with Lump Sum Transfer

We first consider the case where government revenue is simply returned to the household in the form of the lump sum transfer, as in previous literature. We use this as a benchmark to compare our model innovations to. To model this, η_1, η_2, η_3 and ψ are set equal to zero and household preferences are set such that $\alpha_1 + \alpha_2 = 1$. Doing so means that all government revenue will be spent on consumption of goods and

services and there is no provision of public goods. In this case, the government does not provide any tangible benefit to the taxpayer in the form of public goods, thus does not keep its end of the fiscal social contract. The contract can be viewed as a continuum; the benchmark case is thus a myopic form of the contract - the government is doing nothing that is productive or constructive. As a result, we would not expect simple transfers to play an important role in shaping the degree of informality. In the following two subsections we allow for a one-time policy change in each of the parameters mentioned above.

2.4.1 One Period Enforcement Increase

Intuitively, an enforcement increase causes the marginal benefit of informal labor to decrease in absolute terms and also relative to the marginal benefit of operating formally. This drives informal firms on the margin of shutting down to do so and encourages informal firms on the margin of formality to move into the formal sector, as relative costs have adjusted favorably for formal activity. Therefore we expect to see a decrease in informal labor, output, and consumption accompanied by a possible increase in formal output and labor. In the benchmark, there is no public good provided to the household to support a healthy fiscal social contract between the taxpayers and the state. The increase in enforcement can be viewed by the household as an effective increase in taxation. Without offering some increased public good, this could be viewed by the household as a breach of this contract, possibly discouraging compliance and participation in the formal sector.

Looking at the top right panel of Figure 2.1, which plots the Impulse Response Functions (IRFs) of a one period increase in enforcement, it is clear that informal output responds negatively, as expected. The top left panel shows a decrease in formal sector activity, contrary to our expected results of an increase or zero effect. However, this effect is nearly zero, only reaching .175% at its peak deviation from steady state. Government revenue increases, jumping 1.2% at the onset of the policy,

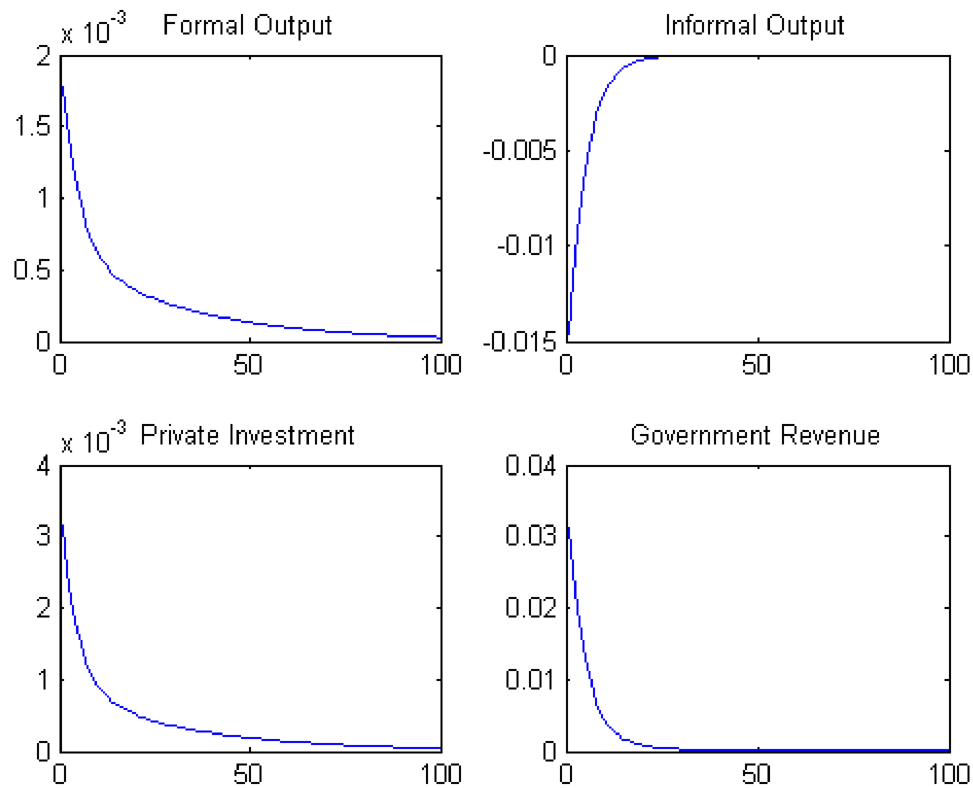

Figure 2.1: Response to one period enforcement increase. All responses are percentage deviations from the steady state values.

and then declining quickly and even becoming slightly negative around the 20th period. This reaction follows the same pattern as the decline of the enforcement rate (not pictured). Given the prolonged decrease in formal activity as well, it is not surprising that government revenue (bottom right) dips negative for those periods where formal activity is recovering.

2.4.2 One Period Tax Decrease

The intuition behind a one period tax decrease is that lowering the cost of formality encourages firms operating informally to switch to the formal sector. This should then increase formal employment and formal output. However, the lower tax rate also results in a lower effective penalty. This lower effective penalty will

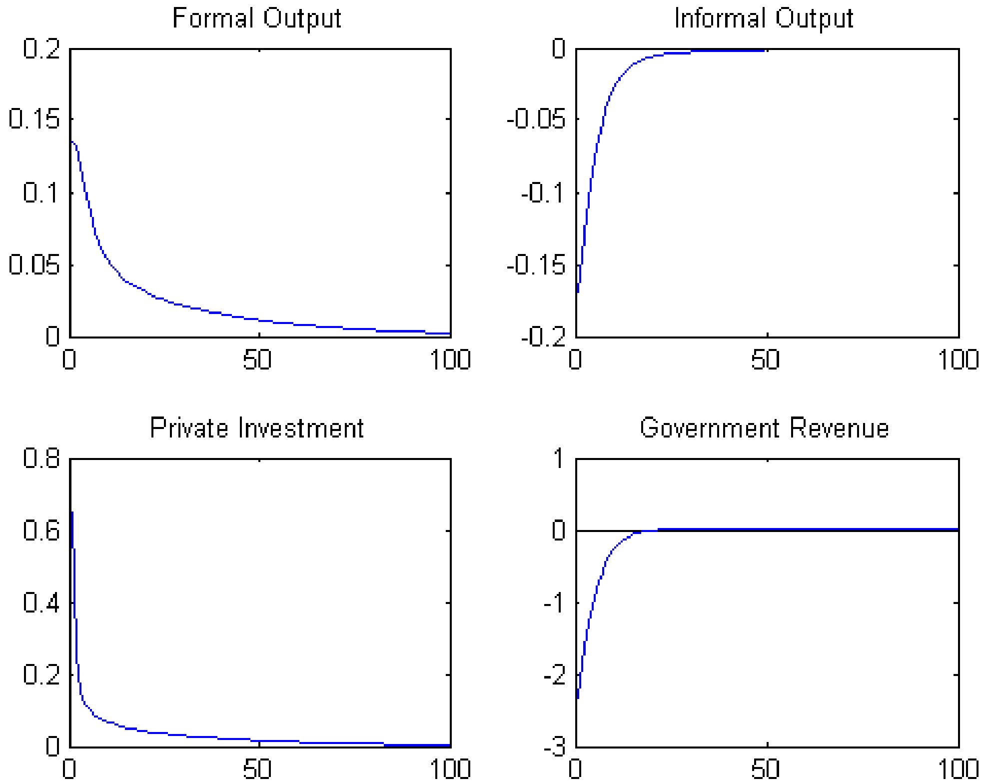

Figure 2.2: Response to a one period tax. All responses are percentage deviations from the steady state values.

encourage additional informal activity. By examining Figure 2.2, we see that formal employment, output, and consumption all increase, as do their informal counterparts[4]

We can see from Figure 2.2 that the tax decrease causes larger magnitude responses in terms of percentage deviations from the steady state than those caused by an increase in enforcement, which will have policy implications to be discussed later. The

[4]When the value added tax (VAT) is used and informal firms use other inputs in addition to labor, that the VAT provides an extra benefit to formality by reducing the cost of inputs. This is not explicitly included in our model, as we choose to model informal production with labor as the only input. This can be justified by previous work of de Paula and Schenkman (2006), where they model an economy with formal and informal intermediate goods, formal and informal final goods, and a VAT. They find that informal firms are more likely to conduct business with other informal firms, and formal similarly trading with other formal firms. This suggests that informal firms do not stand to gain much in reduced input costs via VAT rebates by switching to the formal sector as they primarily deal with other informal firms and already avoid taxes on their inputs.

increase in formal sector output, seen in the top-left panel of Figure 2.2, compared to the increase in total consumption (not pictured), suggests the representative agent's saving habits have changed. This can be verified by examining the investment (bottom left) and trade balance (not pictured), respectively. Although the decrease leads to an initial drop in the trade balance, it immediately swings positive before beginning its gradual trend back towards steady state levels. Likewise, the debt level initially responds to the tax shock with a large positive jump, but begins decreasing immediately, reaching levels .25% below the steady state level before beginning its trends back towards steady state. Another indicator of the change in savings habits is the large increase in capital stock (not pictured). As expected, informal labor and output rise as well due to the lower effective penalty.

As before, we are interested in what happens to government revenue. The negative effects of the lower rates outweigh the positive effects of the increase in the tax base, suggesting that this policy is inferior to an enforcement increase if the ultimate goal is to increase government resources. While this policy can be seen as the government maintaining its fiscal social contract in the sense that it is lowering the tax burden to make up for the fact that it provides no productive of utilitarian benefit to the household, the reduction in government revenue is counterproductive to the goal of nation building.

2.5 Case 2: The Model with Public Goods

In the benchmark case, the model was parameterized such that the additional government revenue raised from an increased tax base is not directed anywhere productive, but simply returned to the household as a lump sum transfer. This myopic specification means there is no mechanism for the government to provide productive goods or services to the public in exchange for its taxes. If the purpose of increasing formality is to expand the tax base so the government may carry out more nation building activities, then the model should account for this. We extend

the model to allow the government to divide its resources into alternative uses by providing public goods. Furthermore, we differentiate between three different forms of the public good. There is a pure public consumption good, c^g, which factors into the agent's utility function, a productivity enhancing good, Z_t, which factors into the formal sector's production function, and a specific human capital good, L_t, which acts as a scalar on formal labor in the production function.

Intuitively, the presence of the public good should alter the economy's response to temporary tax and enforcement changes. For instance, the pure public consumption good may encourage the agent to continue to operate formally in the face of increased taxes. Operating formally, provides a "double dividend," in which the household benefits from income generated by operating formally, and then benefits as well from the public good provided by taxing that formal output. This secondary benefit is the tangible means by which the household sees the benefit from its taxes. If this secondary benefit provided by the public good is stronger than the disincentive to operating formally caused by taxation, then the household could view this as the government creating a healthy fiscal social contract; compliance could improve despite the increase in tax burden. This suggests that increasing taxes would be beneficial.

The presence of productivity enhancing and labor augmenting services, Z_t and L_t, can likewise provide a double dividend to formality in the face of increased taxes resulting in positive impact on formal sector variables. As we observed in the benchmark case, a reduction in taxes leads to lower levels of government revenue despite broadening the tax base. This implies that the lower tax rate could result in less expenditures on maintaining a functional business environment and providing labor augmenting services. This would decrease returns to formal sector inputs, reduce private investment and could outweigh the benefits of decreased taxes, leading to an overall decrease in formal sector activity. On the other hand, a tax increase would have the opposite effect, increasing formal sector activity. The intuition behind the positive enforcement shock remains the same as in the benchmark case, although

we expect more sustained positive impacts in formal sector production as a result of the increased private capital accumulation.

To fully investigate the effects of the provision of the public goods, we consider multiple spending mixes and compare the results. In the main discussion section, I present and discuss the following three combinations:

- ($\eta_1 = \eta_2 = \eta_3 = 0$) Benchmark case
- ($\eta_1 = \eta_2 = \eta_3 = .10$) Below the "joint tipping point"
- ($\eta_1 = \eta_2 = \eta_3 = .11$) At the "joint tipping point"
- ($\eta_1 = \eta_2 = \eta_3 = .12$) Above the "joint tipping point"
- ($\eta_1 = \eta_2 = \eta_3 = .25$) Above the "joint tipping point"

As will be demonstrated in the following subsections, this set of spending mixes demonstrates the existence of a "joint tipping point," where combinations of government spending in excess of this level yield positive responses from formal sector variables in the face of tax increases, and below yields negative. The results of additional spending mixes are presented in the appendix, including each use of government revenue in isolation.

2.5.1 Enforcement Increase

Figure 2.3 shows consistent responses to increases in enforcement across the different spending mixes with very little variation. In the baseline case, the response of formal output (top left) and private investment (bottom right) are slightly below the other various specifications of spending mixes. However, the overall behavior of each variable is consistent in shape. The relatively lower formal output and private investment can be explained by the household's response to the changes in marginal benefits from additional capital. As government revenue increases from increased penalty collection, the government can now spend more on the specific human

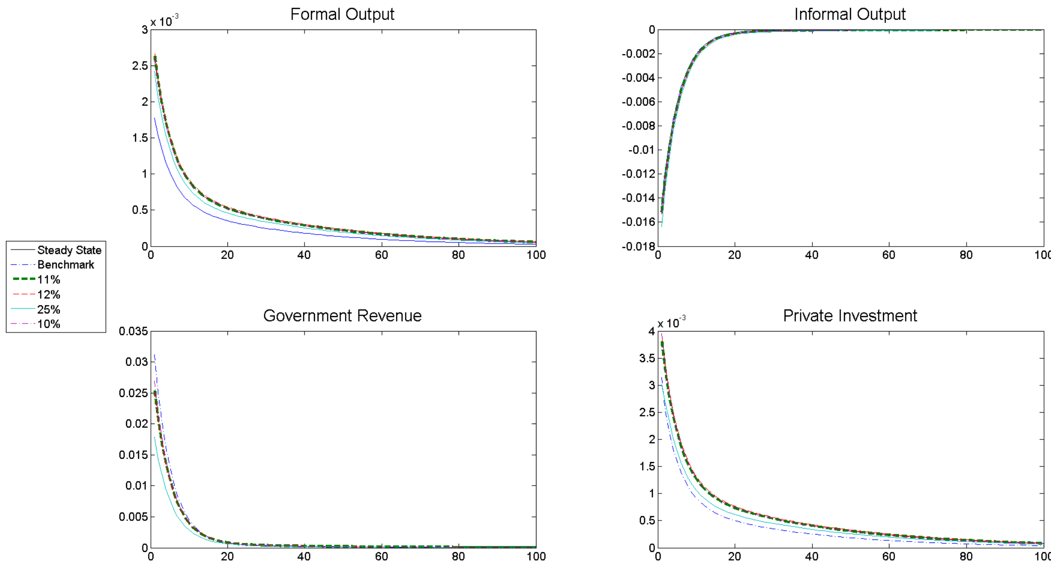

Figure 2.3: Response to one time tax increase for different values of η_1, η_2 and η_3 . All responses are percentage deviations from the steady state values.

capital good and productivity enhancing services, increasing the marginal productivity of labor and capital. Increased marginal productivity of these inputs results in the household choosing to allocate more time and resources to them. As expected, informal output (top right) decreases in response to the increase in the effective penalty rate.

2.5.2 Tax Increase

Figure 2.4 shows that responses to a tax increase are consistent across spending mixes for informal output and government revenue. However, the behavior of formal output and investment both change as more government revenue is directed towards public goods rather than the lump sum transfer. The top left panel shows that formal output can respond positively in the face of a tax increase, indicating that when the government spends its revenue on productive means that the incentive to operate formally outweighs the increased burden of higher taxes. There exists a tipping point in the amount of revenue dedicated to maintaining the social fiscal contract. Considering the case where government revenue is spent equally across the different public good, this occurs when that proportion is 11%, such that if the government spends more than 11% on the specific human capital, the labor augmenting services, and the public consumption good each, that raising taxes produces the positive effects on output that are the goal of policy. This same tipping point exists for private investment as well. In the benchmark case, private investment responds with a sharp initial decrease and makes a concave approach towards steady state. However, when other uses of government spending are added to the model, private investment recovers to positive deviations from steady state, with the effect amplified the higher the proportion of government revenue devoted to productive uses. This change in household savings behavior can be explained by the increased marginal returns to capital as other complimentary inputs into formal production are increased as well.

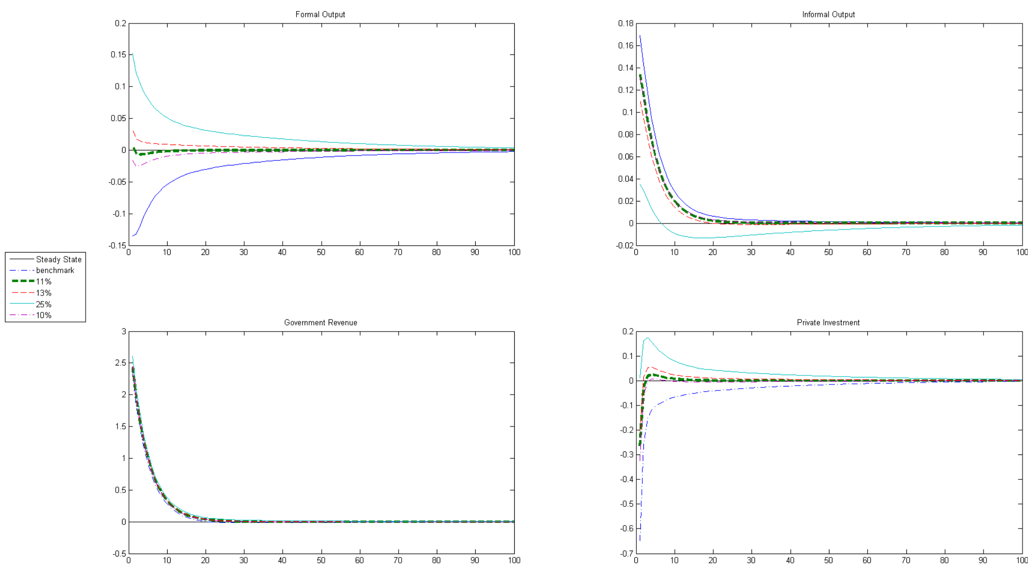

Figure 2.4: Response to one time tax increase for different values of η_1, η_2 and η_3 . All responses are percentage deviations from the steady state values.

When introducing each of these public goods in isolation, tipping points can be found that produce the same positive effects for both the specific human capital good and the productivity augmenting services. However, these tipping points are at 29% of revenue when only used on the specific human capital good and 35% for the productivity augmenting good only. While there are numerous combinations of spending that can produce the tipping point, the key take away from the "joint tipping point" found with all capital goods provided, is that when the different types of capital goods are used jointly this tipping point can be achieved at a lower level than each of these goods in isolation. It is also worth noting, that while introducing the public consumption good into the model in isolation does dampen the negative effect seen in the benchmark as the proportion spent on it increases, there is no level such that formal output responds positively to a tax increase.[5]

2.6 Alternative Specification of Productivity Enhancing Good

To this point, the formal sector productivity enhancing public good has been described in the context of services that are exclusive to the formal sector, such as protection of property rights, well functioning legal systems, and efficient credit markets. Another useful way to think about this would be as a publicly provided capital good, most easily thought of as infrastructure. Examples of infrastructure that are exclusive to the formal sector include access to major sea ports and air terminals, which are essential if a firm wishes to trade internationally. Infrastructure exclusive to the formal sector could also be thought of as the legal and financial infrastructure required to provide the aforementioned productivity enhancing services, like well functioning legal systems and credit markets. Maintaining the infrastructure that supports these

[5]Furthermore, a very similar joint tipping point of 12% is found when only including the specific human capital and productivity augmenting goods without the presence of the public consumption good

systems requires a continuous government investment and the quality of these services would decline without doing so, much the same way physical capital stock declines without continuous investment. To include this in the model, the additional equations are added:

$$X_t^g = \eta_4 G_t \tag{2.23}$$

$$K_t^g = X_t^g - (1-\delta)K_{t-1}^g \tag{2.24}$$

Equation 2.13 rewritten as

$$T_t = (1 - \eta_1 - \eta_2 - \eta_4)G_t \tag{2.25}$$

And the formal sector production function now becomes

$$Y_t^f = (e^{L_t} h_t^f)^{\theta} (K_t^g)^{\psi} (K_t)^{1-\theta-\psi} \tag{2.26}$$

The impulse response functions for one time increases in enforcement and tax rates are given by Figure 2.5 and Figure 2.6, respectively. Like the specific human capital good and the productivity augmenting good, the publicly provided capital good is also able to generate a double dividend to working formally, allowing the government to achieve both of its goals of increased revenue and increased formal sector output with a tax increase. Also similar to the other productive public goods, there is a tipping point for which this result holds, although at 12%, this tipping point is lower than the tipping point of the other two goods when introduced in isolation.

To investigate the effects of the provision of the public capital good, we first consider several spending mixes and compare the results. For simplicity, the other productive uses of government revenue are not included so that we may focus on the effect of productive government capital in isolation. The four spending mixes are:

- ($\eta_4 = .33$, $\eta_2 = .33$) to represent equal spending across all three uses
- ($\eta_4 = .50$, $\eta_2 = 0$) to represent the case where only the public capital good and lump sum transfer
- ($\eta_4 = 0$, $\eta_2 = .50$) to represent most half of revenue being diverted towards the lump sum transfer and half towards the public consumption good
- ($\eta_4 = .50$, $\eta_2 = .50$) to represent the case where half of revenue is diverted to public capital good and half towards the public consumption good.

2.6.1 Tax Increase

Figure 2.5 shows that responses to a tax increase are consistent across spending mixes with one exception - the case where no public productive capital good is provided. In the spending mixes where public capital is provided, we see the positive effects on formal sector variables (top left and bottom right panels). Despite an initial drop at the onset of the policy change, both formal output and formal labor (not pictured) recover to positive deviations from steady state, peaking around the 10th period before beginning to steadily decline back towards their steady state levels. In the case where the government does not provide the capital good, formal sector variables behave as they did in benchmark case. This suggests the existence of a tipping point in this specification as well.

We identify this tipping point at around 12% ($\eta_4 = .12$). Below this tipping point, we see results similar to that of the benchmark case, where increasing tax rates decreases formal sector activity, but increases government revenue. Above this point, increasing tax rates increases both government revenue and formal sector output, which is the desired effect. There is a second, upper tipping point for η_4, such that after passing $\eta_4 = .4$, further increases in η_4 lead to a dampened response in formal sector variables. For the IRFs when $\eta_4 = .50$, the positive response in formal output and private investment is less than that of $\eta_4 = .33$ and $\eta_4 = .25$.

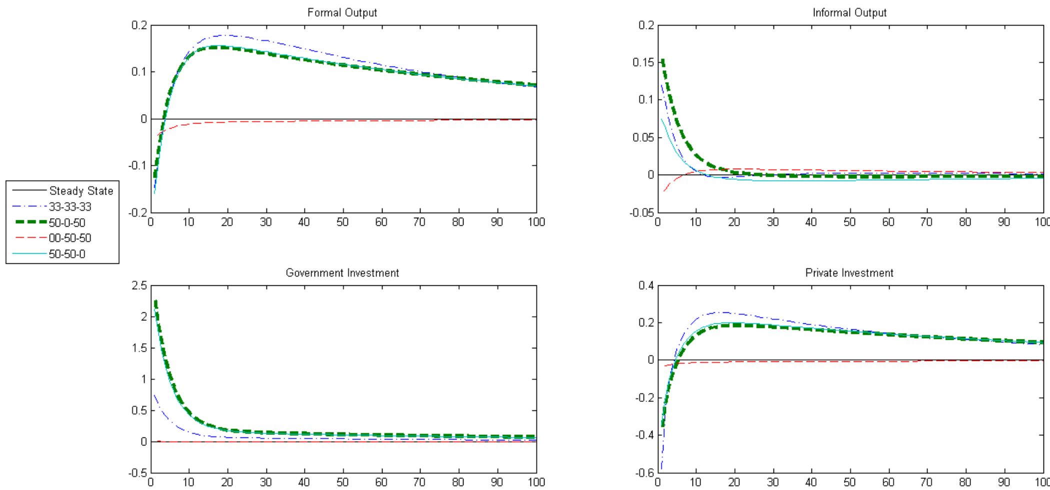

Figure 2.5: Response to one time tax increase for different values of η_4 and η_2 . All responses are percentage deviations from the steady state values.

The lower tipping point for η_4 in response to the tax increase has greater implications for policy for two reasons. First, the magnitude of the changes brought by the tax changes are greater than that of the enforcement increase, so regardless of the side of the tipping point a country is on, tax policy remains more effective than enforcement in terms increasing the size of the formal sector. The second reason is that the upper tipping point for η_4 under an enforcement shock is a much higher proportion than a developing nation would reasonably be devoting to public provision of productive capital.

Focusing on the instances where a proportion of government revenue above this 12% tipping point is dedicated towards the productive public good, this result highlights the relationship between providing a productive return on the taxes paid by the household and compliance. This is particularly true given in the way we have described our public capital good as social overhead capital, including enforcement of property rights, legal protection, and access to well functioning credit markets. As discussed earlier, these social capital “goods” have been shown in China and Mauritius to encourage compliance because they allow firms to grow more. The results from our policy experiments confirm these findings.

Another important finding is the relationship between government investment and private investment. Our simulations find a positive relationship, providing theoretical support for the “crowding-in” effect discussed by Eden and Kray (2014).

2.6.2 Enforcement Increase

Again we see consistent responses to positive enforcement shocks across the different spending mixes with the same exception as before - that in the case of zero public capital provision. From the top left panel of Figure 2.6, we see that when public capital is provided, there is an almost immediate and sustained increase in formal output. As with the benchmark case, the increase in the enforcement rate results in an increase in the effective tax rate.

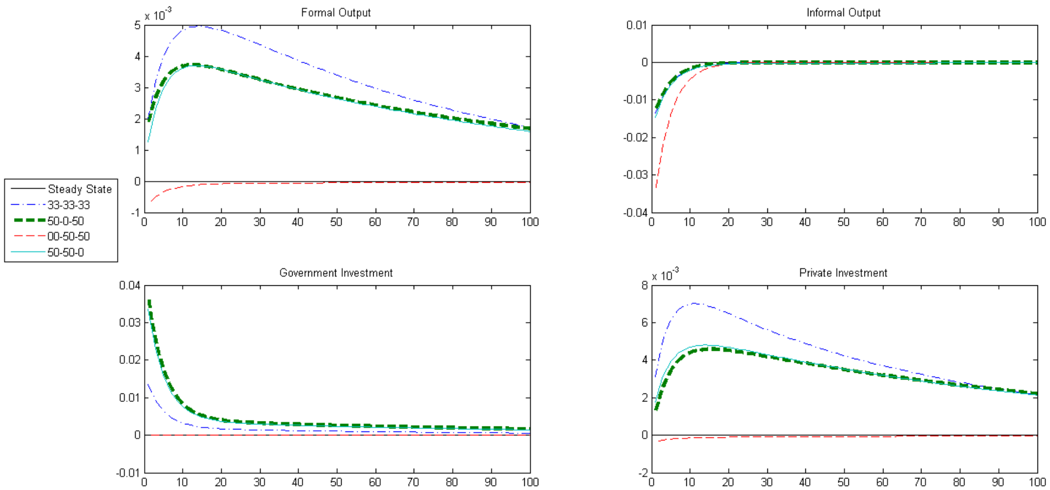

Figure 2.6: Response to one time increase in enforcement for different values of η_1 and η_2. All responses are percentage deviations from the steady state values.

But in the case of the public good, the government is able to maintain its credibility and its responsibility to the fiscal social contract through the provision of public capital, thus allowing it to improve compliance and increase participation in the formal sector, similar to the tax increase. Also similar to the tax increase, accounting for the public consumption good in the model has little effect when considered without the provision of public capital. The same tipping points in the proportion of government resources devoted to the provision of the public good are present under an enforcement shock as well.

2.7 Sensitivity Analysis

We now conduct sensitivity analysis to determine to what extent our specification of the agent's consumption preferences might affect the outcome of the model. These parameters are not directly observable and no reliable estimates exist in the literature. For this analysis, we set $\eta_4 = \eta_2 = .33$, to represent equal proportions of government resources allocated to each use.

As can be seen in Figure 2.7, the IRFs for our variables of interest, formal sector output and government revenue, the results are not dependent on the specification of household preferences under a tax increase. There are however, some differences in the way informal output (top right) and labor (not pictured) respond. As α_1 decreases from the top of the range at $\alpha_1 = .55$ to the bottom at $\alpha_1 = .15$, the IRFs for informal labor and output shift down, to the point where the initial negative shock in informal sector variables is unable to recover to positive values until near period 30. For $\alpha_1 = .55$ and $\alpha_1 = .33$ these variables return to a positive response almost immediately. The preference specification of $\alpha_1 = .15$ is consistent with the notion of having low tax morale or a general distrust of the government, which means that rather than participating in the regulated and taxed formal sectors, most households prefer to participate it in the informal sector.

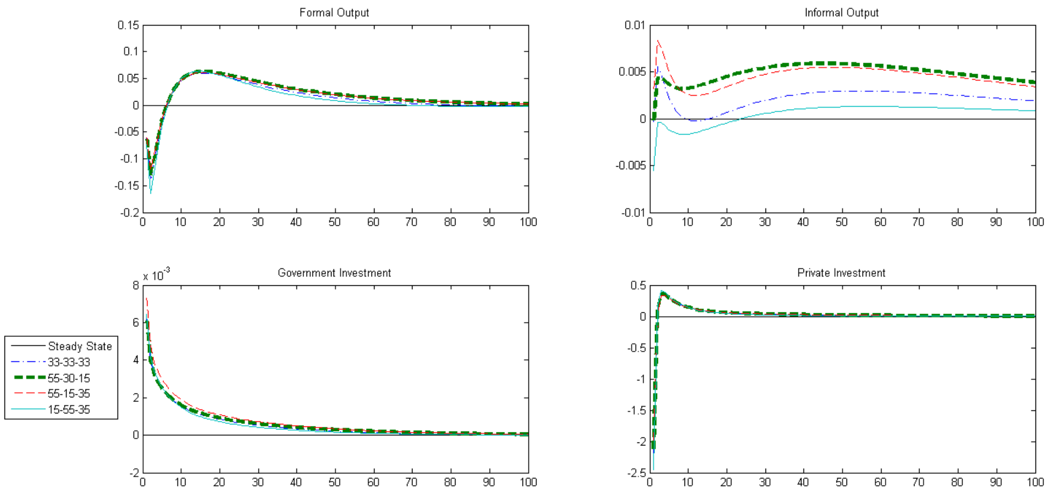

Figure 2.7: Response to one time tax increase for different values of α_1 and α_2 and fixed η_2 and η_4. All responses are percentage deviations from the steady state values.

This explains the relatively smaller response of the informal sector in the face of a higher tax rate (and therefore higher effective penalty) than to the situation in which higher preference weights are placed on the formal sector, indicating higher tax morale and a greater desire to participate in formal markets. However, more important for policy, is that different combinations seem to have little to no effect on formal sector variables or government revenue in response to a tax shock.

The responses to increased enforcement are also largely the same regardless of household preference specification (Figure 2.10), with one notable exception. Again the case of $\alpha_1 = .15$ results in a markedly different IRF than for other values tested, this time also in formal sector variables. In the case of $\alpha_1 = .15$, formal labor (not pictured) and output (top left) IRFs follow the same pattern as other specifications of α_1, the effects are just larger in magnitude. This amplified response in the case of higher relative preferences for the informal good can also be explained by vertical reciprocity. This concept in behavioral tax compliance refers to similar individuals receiving different tax treatment, in this case, some firms not paying their taxes. When social attitudes reflect a high preference for participation in the informal economy, this may discourage others from wanting to participate in the formal sector who otherwise would (Bazart & Bonein 2014). When the government increases enforcement, the positive effects seen at other specifications of household preferences are amplified because even more firms are choosing to operate formally due to the increased fairness of the system. The attitude of "other firms aren't paying their taxes so why should I?" is lessened.

2.8 Government Credibility

If an unannounced one time policy change, such as a tax or an enforcement increase, can cause positive effects that persist for longer than the duration of the policy change, then it should follow that an announced permanent policy change should cause a permanent shift in behavior.

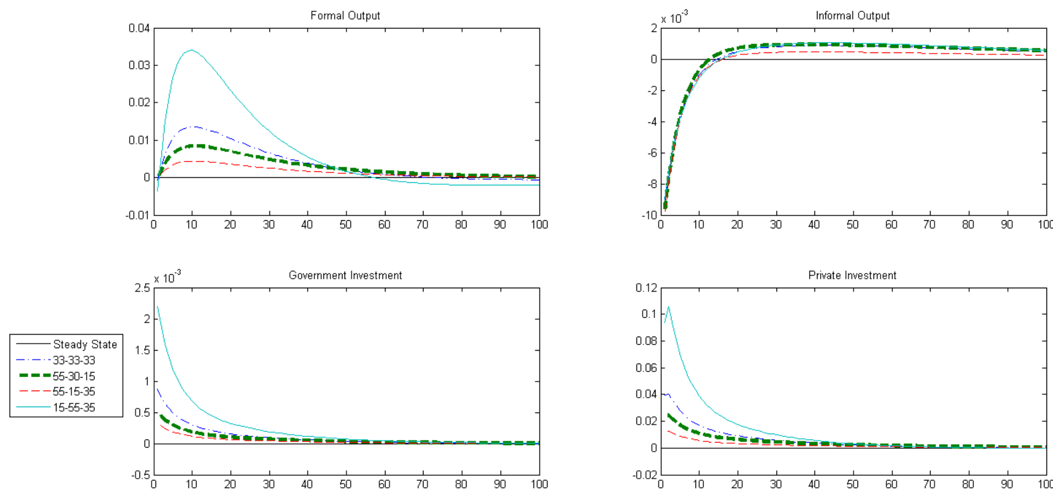

Figure 2.8: Response to one time enforcement increase for different values of α_1 and α_2 and fixed η_2 and η_4 . All responses are percentage deviations from the steady state values.

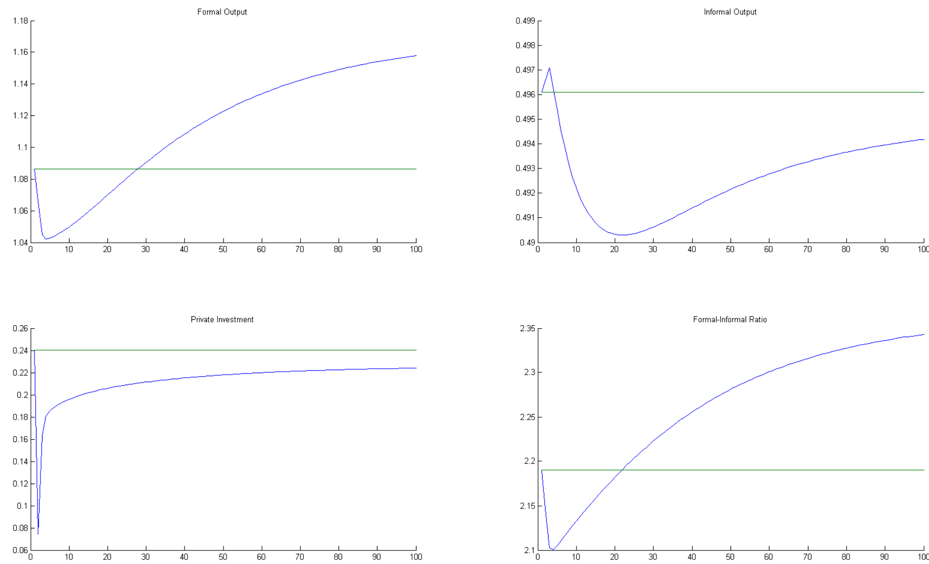

Figure 2.9: Response to a permanent tax increase known with certainty . All responses are in levels of the variable.

Indeed, this is what we see in Figure 2.9, which plots the behavior of selected variables in response to an expected permanent tax increase when government capital is provided in the model. The top left panel, shows that formal output immediately decreases, as the costs of operating formally increase. However, formal output begins increasing and surpasses its original steady state level by period 30. This can be explained by increases in tax revenue, which in turn leads to higher levels of government investment, as depicted in the lower left panel. This increase in government investment then leads to higher marginal productivity of formal labor, increasing the marginal returns of formal labor and private capital accumulation. This effectively increases the marginal benefit of operating formally to the point of offsetting the increase in taxes. The effect is not immediate because it takes time for the public capital good to accumulate.

Yet a permanent policy change is not a realistic option, particularly for developing nations, which may have credibility issues. If the household does not believe the government's commitment to a policy change is credible, it will act as if the change

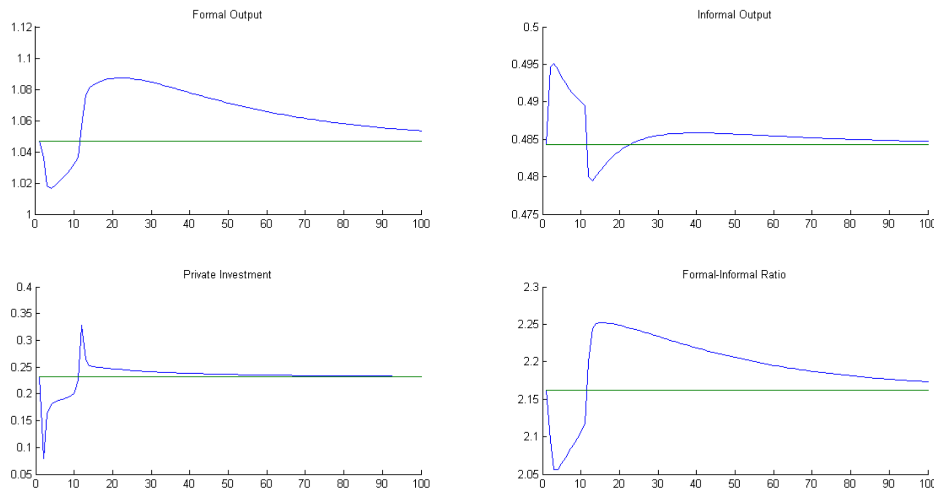

Figure 2.10: Response to a 10 period tax increase known with certainty . All responses are in levels of the variable.

is temporary. Developing nations are much more likely to face credibility issues than developed nations due to their relatively less stable political nature. Regime and party changes are frequent, and new leaders may be quick to undo an unpopular move such as a tax increase to separate themselves politically from the previous ruling party. Furthermore, the household may not trust the government's commitment to a policy. Figure 2.10 depicts the responses of the economy in the case of an announced temporary shock, that is, one that the household believes to be from a non-credible government.

The policy is announced in period 1 and lasts for 10 periods, which is known to the household. Therefore, the household can begin adjusting behavior in response to the shock right from beginning, during the shock, and in anticipation of when the shock ends. The top left panel shows formal output begins to fall slightly in anticipation of the shock, and drops sharply in period 1. However, in period 5, output begins to rise, even before the tax increase returns to normal. This follows the same explanation as in the permanent shock that government investment increases marginal returns to formal labor and private capital, thus producing more formal

sector output. Unlike the permanent case, however, the response of the formal sector is convex rather than concave. This is because after the tax rate declines back to its original level, government revenues fall as well. The response is not immediate because the increased level of output still produces higher tax revenue and therefore more government investment than the original steady state level, but it is declining. The behavior of the formal sector in this case closely follows the behavior of formal sector output in the case of the stochastic simulations. Given that this is how the household will behave when the central government faces a credibility issue, even an announced permanent policy change will produce similar results as the one time policy changes presented in our stochastic model.

2.9 Conclusion

Revenue mobilization is a serious issue for developing nations. A complicating factor is the recursive fiscal dilemma, brought on by the presence of large informal sectors of the economy. Bringing informal firms into the formal sector while using tax as state building is thus a critical issue for these nations. Existing compliance literature has assumed a simplified treatment of the government's role in development, despite studies in other lines of literature that show its importance. We address this gap by investigating policy actions in a small developing DGE model that accounts for a large informal sector and productive public expenditures.

We find that when government revenue is used for the provision of productivity enhancing public goods that only the formal sector has access to, increasing taxes is actually the best policy for achieving the goals of increased revenue and increased formal sector output. We focus on a specific human capital good, such as job specific training that would only benefit workers in a large formal firm, and productivity enhancing government services, such as well functioning legal systems and credit markets. Furthermore, there is a tipping point in the proportion of government revenue used for the provision of public goods in which raising taxes is the best policy

for achieving the governments dual objective of increasing revenue and increasing formal sector output.

In our model, which is parameterized to Sri Lanka, we find that if the government dedicates below the joint tipping point of 12% of total expenditures (i.e. 11% dedicated towards the specific human capital and 11% dedicated towards the productivity enhancing service), easing the burdens of formality through reducing taxes is the best policy. This aligns with the existing informal sector economy literature. However, for countries above this tipping point, our model suggests that increasing taxes is actually the most effective policy, contrary to the existing literature. This 11% joint tipping point is lower than the individual tipping points for each of these services when introduced in isolation: 29% of revenue when only used on the specific human capital good and 35% for the productivity augmenting good only. This suggests that a diversified mix of productivity enhancing services offered to the formal business owner will be more cost effective than committing more resources to a single program.

The identification of tipping points shows that as long as enough revenue is dedicated to the provision of productive services, the increased returns to operating formally now outweigh the increased costs to informality brought by increased taxes. This result is consistent with a growing body of literature focused on developing nations using tax revenue as a means of state building. Many of these studies focus on the central government's obligation to maintain an unofficial fiscal social contract with its constituents through providing them with tangible benefits in exchange for their tax dollars and maintaining their participation in the fiscal exchange. This is a key result with potential to change how developing nations look to address the fiscal issues caused by large informal sectors.

The results of our analysis have strong implications for the best practices in dealing with the negative effect informality can have on a developing nation. It is important to keep in mind that the goal of policy is not necessarily to decrease informality for the sake of doing so, but rather to increase formality so that the tax base can

be increased and the increased government revenues can be used for nation building activities. Given this and the assumption that government resources are directed effectively to increase formal sector activity, the use of one time increases to tax rates and enforcement on the informal sector both lead to the desired effects of increased government revenue and increased formal sector activity, with the former having longer lasting and more pronounced effects.

Chapter 3

Resource Extraction Booms and the Proper Identification of Treatment

3.1 Introduction

Labor demand shocks occur at various levels, from national to local. These shocks can be driven by changes to product demand or the production function, each affecting the derived demand for labor. At the local level, shocks can be the result of an industry-specific event, such as the discovery of a natural resource or a firm's decision to open or close a large facility. In the case of an export sector's positive shock, it is often thought that the new economic activity generated will have positive spillover effects on the existing local businesses and, therefore, other industries' labor markets, resulting in a multiplier effect. Politicians often vocalize the importance of bringing new firms to a region to stimulate economic growth. Negative shocks are feared to have the opposite effect, and policy makers fight to oppose such events. However, it is difficult to determine the true effects that such economic shocks have on the local economy because there is no way to know for certain how the local market would have progressed otherwise. It is plausible that an observed increase in employment in one industry crowded out expansion in other industries.

Labor demand shocks in natural resource-extraction sectors serve as an excellent example to study localized shocks' effects. Whether the change in an extraction sector's activity results from an innovation, the discovery of new reserves, price changes, or a policy-driven demand change, these events can provide a natural experiment in which to study local labor shocks' effects. Within the resource-extraction literature, two different lines of thinking offer competing predictions about the impact of large endowments of natural resources. On the one hand, trade models predict that these regions can benefit from positive shocks in the resource extraction sector, while concerns of a natural resource curse driven by Dutch Disease-type effects are also valid. This study attempts to analyze the effects of a resource extraction sector's labor demand shock by examining the effects of the Clean Air Act Amendments (CAAA) of 1990, and contributes to the existing literature by identifying the effects of booms/busts in local resource extraction sectors.

The SO_2 cap-and-trade permit system implemented by Title IV of the CAAA acts as a tax on the higher-sulfur bituminous coal mined throughout central Appalachia. The resulting decrease in demand for this coal led to stark drop offs in mining production throughout the region. As in many other studies in the literature (Black et al., 2005; Weber, 2013; Feryer et al., 2015), this study used a Difference-in-Differences (DID) framework in which a control group of non-mining counties acted as the counterfactual to the mining counties comprising the treatment group. In addition to further analyzing an issue that has implications for both local and regional policy initiatives, my study also focused on the importance of properly selecting treatment dates, an issue not thoroughly explored in the literature. For instance, Black et al. (2005) selected treatment dates based on coal prices' behavior. However, that may not be the best selection strategy. First, while coal prices are certainly a major factor in determining the coal industry's behavior, measures of the industry's activity, such as employment and wages, may not fall exactly in line with prices.

Additionally, in studies concerned with spillover effects into other sectors and multiplier effects, it is important to note that it is the change in employment, earnings, and non-payroll spending in the extraction sector that generates these effects, not the event that affects the resource extraction sector. This also has implications for selecting the proper treatment date concerning spillover effects. If there is a significant lag or lead in the mining sector's response, the timing of the response of the local economy's other sectors will also be affected relative to the event, thus causing the labor shock in the extraction sector. Furthermore, there may be lags or leads in the non-mining sectors' response to the change in mining employment and wages, and these lags may differ both across and within sectors for different variables of interest.

Understanding these lags is critical to local policy makers, particularly in the case of an expected negative shock such as the CAAA. Although these policy makers might be powerless to prevent the policy from being implemented, they are still in a position to best prepare their community for the economy's potential negative downturn. Policy makers in communities experiencing similar booms, such as fracking

towns in the American West, might also find this information useful as historically busts inevitably follow resource extraction booms. This study's results could help policy makers better position their communities while times are good in preparation for potential bust periods. For these reasons, I propose an alternative method for examining a resource extraction boom's effects. This method identifies the proper treatment date by borrowing techniques from the program- evaluation literature.

First, I devised a theoretical framework to predict whether the resource extraction sector should lag or lead an exogenous shock based on the shock's characteristics, and conducted an empirical examination to test my theory's prediction using the CAAA. I used the test for structural change with an unknown breakpoint that Andrews (1993) proposed to properly identify the treatment date in the mining sector before using a simple trend break analysis approach to identify the CAAA's effects on the industry. Then, having identified the proper treatment date and confirming that negative effects did exist in the industry, I used the test for structural change on aggregate measures of economic output, including county-level employment, annual payroll, and the number of establishments. As I expected, the timing of the data's structural change occurred after treatment occurred in the mining sector. Additionally, the structural break for my three measures of interest all occurred at different times. From this finding, I conclude that incorporating this step in the process for measuring potential spillover effects from local resource extraction booms is critical in producing more accurate estimates and provides improved understanding of the timing of events. This information can be useful to local policy makers who may have some say in whether or not to allow new operations or expansions in existing resource extraction operations. They may also use this information when considering long-term financing of public expenditures, which may become more difficult with large reductions in tax revenue from decreased mining activity.

The rest of the essay proceeds as follows. Section 2 discusses the previous literature and describes the theoretical reasons lags or leads may exist in response to the events that actually cause the labor shocks. Section 3 details the CAAA's background and

my data. Section 4 discusses my empirical strategy. Section 5 discusses the results. Section 6 is the conclusion.

3.2 Previous Literature and Theoretical Framework

A diverse body of literature has emerged that investigates labor shocks arising for a variety of reasons, including large plant openings (Fox and Murray 2004; Greenstone and Moretti 2004), the creation of government-designated enterprise zones (O'Keefe 2004; Busso and Kline 2007; Kolko and Neumark 2010; Hansen 2009), and military base closings as a result of the Base Realignment and Closure Commission recommendations of the late 1980s (Dardia et al. 1996; Krizan 1998; Hooker and Knetter 1999). The studies which have found modest effects as a result of base closings, are particularly interesting because those closings represent a negative labor shock, similar to that of a contraction in the natural resource extraction sector that I studied. These results suggest that the contraction of an industry thought to be providing vital economic support to the local economy might not be as important as perceived because the lost economic activity is made up for elsewhere.

Michaels (2010) conducted a study of the long-term economic impact on counties located over significant oil fields. Rather than finding inhibited growth seen with resource-based national economies (often referred to as the resource curse, Sala-i-Martin et al. 2004; Sachs and Warner 1997; Sachs and Warner 2001) and in some instances at the county level (Douglas and Walker 2013), Michaels found positive effects on population growth, education, and manufacturing. However, my study focused on the short-term effects of a boom in local resource extraction. Several particularly relevant studies have explored these effects.

Matheis (2015) examined county-level outcomes in coal mining counties for population, median family income, as well as employment levels in several other

sectors during 1870-1970. In his study, identification came from county variation in three different measures of lagged coal production, where each accounted for different time frames, allowing him to assess short-term and long-term impacts. He found evidence of short-run positive spillover effects on employment levels of locally-consumed sectors but found negative long-run effects, in contrast to Michaels' (2010) results. He also found negative short-run and long-run impacts on manufacturing employment, providing evidence supporting the crowding out effect. In a study examining the local employment effects of a boom in natural gas fracking in the Western United States, Weber (2012) shows that total employment increased by 1.5% on average for boom counties and that incomes increased an average of 2.6%. These findings are in line with theoretical predictions.

Black et al. (2005) and Marchland (2012) examined a cycle of boom and bust in resource extraction. Identifying treatment areas as counties or census division tracts deriving 10% of total income from resource extraction, they used DID estimators to examine booming resource sectors' spillover effects. Black et al. found that a boom resulted in a 2% annual increase in total employment in treatment counties and contracted 2.7% annually during the bust. Job multipliers were also calculated, finding that every 10 jobs created in the mining sector led to approximately 2 jobs for the local sectors of construction, retail, and services. Again, the bust seemed to have stronger effects than the boom because for every 10 coal jobs lost, 3 jobs across other sectors were lost. Marchalnd (2012) also found booms had positive impacts on total personal income at the county level; but contrary to Black et al., he found no evidence of contraction during the bust. The bust's lack of effect compared to the boom suggests the presence of more permanent benefits through agglomeration effects as Michaels (2010) discussed. Marchland also calculated jobs multipliers, finding that every 10 jobs created in the energy extraction sector created 1.2 jobs, 1.7 jobs, and 3.6 jobs in the construction, retail, and services sectors, respectively.

A common element throughout the literature is how the treatment date was selected. While dates were reasonably selected within the range of the various price

appreciations or surges in extraction visible in the data, appropriate lags have not been considered to maximize the estimate's accuracy. Marchland (2012) and Black et al. (2005) adopted similar strategies by identifying periods with increasing resource prices as boom periods and decreasing prices as bust periods, while not accounting directly for mining sector behavior. Focusing on the fracking boom in the American West, Weber (2012) discussed the fact that the treatment's timing is unclear during the boom. He noted that the construction of wells is labor intensive up front and that the influx of construction crews during well installation could be the labor shock associated with the fracking boom. He also considered the effect of royalties paid to land owners and the increased tax revenues in addition to the crews operating the wells (relatively small compared to the construction crews) as being the driver of the non-extraction sector demand boom. He used the number of new wells drilled as a proxy for the influx of construction workers, though he lacked any empirical confirmation of this choice.

Furthermore, the treatment date was assumed to be the same between the extraction sector and the non-extraction sectors. I view this assumption as a second potential source of bias in the estimates. This essay contributes to the resource extraction literature by addressing both of these issues. The following subsection discusses these assertions' theoretical underpinnings.

3.2.1 Theoretical Framework

The goal of this section is to describe the economy as it transitions from an initial equilibrium to a "boom" period equilibrium, and from the boom period equilibrium to a "bust" equilibrium. I build on the analytical framework provided by Parker and Jacobsen (2014) and Corden and Neary (1982), but focus more on the theoretical underpinnings of the timing of the local economy's response. Consider a local economy with a natural resource endowment. For simplicity and to remain in context with this study, assume this resource is coal. Now consider three sectors within the local

community: the coal sector; the locally consumed sector (construction, retail and services); and the traded sector (manufacturing and agriculture). In equilibrium, firms operate in competitive markets.

Booms

Beginning in equilibrium, an unanticipated positive shock to the demand for coal raises the coal mining's profitability in the endowed communities. To increase output, coal companies look to expand production in existing mines by increasing the number of shifts, as well as opening new mines, thus increasing land rent payments to local landowners in the form of leasing rights, royalties, and land purchases. The increased labor demand from the mining sector drives up total employment and total income. If labor markets are already tight, then this will also drive up wages and encourage immigration. Some of this new income is then spent in the local economy, increasing demand in the non-tradeable sectors of retail, services, and construction, thus generating multiplier effects. The increased business-to-business spending as the mining companies increase their demand for local services also contributes to this effect. As demand increases, existing firms are able to experience positive economic profits in the short run. However, these profits induce new firms to enter the market until profits are competed away to the point that potential proprietors' expectations of the boom's length no longer justify the investment of opening a new business. It is also possible that non-mining sectors, both tradeable and non-tradeable, could benefit in the long run from new infrastructure, technology spillovers, and agglomeration effects, as well as improvements in public services financed through increased government revenue from an enlarged tax base.

However, there are some potential downsides. First, increased inward migration and business expansion may make provision of public services less efficient or may lower the overall quality as they become subject to congestion, despite increased government revenue. Second is the potential increase in wages and other locally sourced input factor prices. If the market for factor inputs is already tight, a sudden increase in demand causes prices to rise as well. Migration into the booming region

could mitigate this effect on wages; but other factor inputs with fixed supplies (such as land) or upward sloping supply curves (such as raw materials and energy) would face increasing costs. These increased costs could deter expansion of existing firms or entry of new firms. As traded goods sector's output price is determined by the national economy, rather than locally, the sudden rise of factor input prices could lead to contraction in the size of traded sectors competing for locally supplied factor inputs, in turn leading to crowding out. This price effect is analogous to the Dutch Disease models' exchange-rate effect at the national level. Particularly true for Appalachian coal mining is the land use story, in which agricultural and productive timber tracts are destroyed to create new mines. This is in contrast to other types of resource extraction such as oil and natural gas wells, which simply require a vertically placed drill in a small plot of land and do not diminish the surrounding area's productivity as much compared to coal mines. The unrecoverable change in land use associated with coal mines is also consistent with the Dutch Disease's de-industrialization story.

Busts

On the other hand, an exogenous event may also cause in the demand for coal to unexpectedly decrease, thus causing a sharp decline in mining activity, which is manifested as a negative labor shock and a negative business input shock as the mining sector demands fewer services. This effect could result from the boom event ending or an unrelated event like regulation or a competing product entering the market. The immediate effect corresponding to a sharp decline in production is lowered employment and income for the mining sector, as well as decreased royalty payments to and land purchases from landowners. As demand for local goods and services decreases, these sectors experience layoffs and firm closures, generating negative multiplier effects. As unemployment increases and labor demand decreases, wages also fall to their original levels. Furthermore, there are a few reasons the new bust equilibrium may be worse off than the original pre-boom equilibrium (Jacobsen and Parker 2014), at least in a "per-laborer" or "per unit of capital" basis.

The first reason refers to the aforementioned non-booming traded sectors' de-industrialization. If de-industrialization occurs, the manufacturing and agriculture sector activity cannot simply pick up where it left off, but requires heavy capital investments and time to restore these sectors' pre-boom capital stock. In the case of land reclamation, many mining sites are unsuitable for their original agricultural and forestry uses for years after a mine closes, resulting in an irreversible level of de-industrialization. A second reason is that some mining operations and locally consumed sector firms still remain active at substantially lower profit levels, for sunk capital cost consideration. This results in overcapitalized sectors with low earnings per unit of capital and fewer employees or fewer shifts for employees, thus leading to underemployment. A third reason is constrained outward migration. Workers who came in during the boom period may have been mobile at that stage in their lives, but have since become tied to the region. Additionally, some laborers who would otherwise be mobile find their skill set is mismatched to other labor markets' needs; thus, moving would not improve their situation.

Timing Issues

While previous studies focus primarily on price or the "increase in the value of extracted resources" (Weber 2012) to identify when treatment should occur, the timing of the extraction companies' behavior may not mimic price behavior perfectly. Several factors may influence the time frame the actual effects are felt relative to the event that causes them: whether the shock was anticipated, expectations of whether the shock is temporary or permanent, whether the shock comes from the supply side of the resource market (i.e., the mining companies) or the demand side (i.e., the resource's end users), and whether the shock is positive or negative. Appendix A provides a hierarchical flow chart of how the extraction firm might consider the shock's characteristics.

The first characteristic to consider is the expectation of the shock's duration. A temporary shock, perhaps a supply chain disruption caused by a hurricane in the Gulf of Mexico, would not incentivize mine operators to expand much, knowing that

oil prices would likely drop within a few months. Likewise, the product's consumers would likely find that the costs of switching to an alternative fuel in the short run outweigh the costs of temporarily higher prices in the disrupted market, thus causing little change in demand conditions as well. Furthermore, whether the shock affects the supply side or demand side or if the shock is positive or negative would not likely alter the timing responses in the case of a temporary shock. On the other hand, a permanent shock, such as the passage of environmental regulation like the CAAA (despite years of individual states suing the EPA over the act's provisions), would generate different timing effects. The timing of mining firm responses to permanent shocks further depends on the hierarchy's next levels.

Whether the shock was anticipated or not is the second level. An unexpected shock to the resource extraction sector, such as the discovery of new reserves (positive) or worsening conflict in the Middle East (negative), cannot be prepared for; therefore, employment and wages in the mining sector could lag behind coal prices as demand rises more quickly than the firms can act. Expanding or opening new mines is often a time and capital-intensive process and could take months, extending lags further if current mines are already operating at full capacity. On the other hand, in the case of an expected shock, such as in response to an announced policy like the CAAA, the employment and wages could lead coal prices, as mining operations begin to scale up (down) in anticipation of the price increase (decrease). However, a mining firm's behavior ultimately depends on the event's other characteristics.

The hierarchy's third level is which side of the market, supply or demand, is directly affected. For instance, innovations in extraction technology (such as hydraulic fracturing drilling technology or mountain-top removal excavation techniques) or the discovery of new proven reserves (such as the North Sea oil fields) act as supply side shocks. On the other hand, events like the exogenous price increases driven by the 1970s OPEC oil embargo or the CAAA's implicit tax on sulfur emissions affect the demand side. The timing of the mining firm's response ultimately depends on the hierarchy's fourth level: whether the shock is positive or negative. The

aforementioned supply side examples represent positive shocks. In these cases, mining companies act as quickly as possible to exploit new profits before their competition does, thus minimizing lag times that might occur between the event that prompts the shock and its manifestation in the mining sector's wages and employment outcomes. In the case of negative supply side shocks, lags will increase because the mining firms will want to operate as long as possible to recover as much of their fixed capital expenditures as they can. How long depends on the specific shock. For instance, an immediate moratorium on fracking such as the one implemented in New York state would not allow for any lag in the mining sector's response. On the other hand, a shock that causes operating costs to rise would result in a cutback in production, even resulting in the firm's operating at a loss. If some fixed costs can continue to be recovered in the short run, the mining firm will operate as long as possible to minimize its losses from unrecoverable capital investments. This is true for expected and unexpected shocks as well as for supply-side and demand-side shocks.

Additionally, in the case of demand side shocks, circumstances in the demand side firms may cause delayed responses to the event. For instance, switching to a new fuel may require expensive and time-consuming capital investments, which will cause lags to extend even more. In both cases of negative shocks, mining firms have no incentive to cut production. When considering positive demand shocks, the mining firm may have an incentive to lead the treatment event if it is expected in order to be positioned to exploit new profit opportunities before its competitors do. While leading is not possible in unexpected shocks, the firms still act as quickly as possible for the same reasons, minimizing lags.

3.3 Background of CAAA and Data Selection

The CAAA most notably created the first large-scale emissions cap-and-trade system, designed to limit the amount of sulfur dioxide (SO_2) emissions. It required firms to acquire permits for each ton of SO_2 produced, incenting them to reduce emissions

however they could or to purchase additional permits on the open market. This policy, which was announced in 1990 and went into effect in 1995, became a de facto tax on sulfur emissions. As the largest emitters of SO_2, coal- burning power plants were forced to seek ways to reduce their emissions to avoid this tax. Switching to coal with less sulfur, which was primarily from Wyoming's Powder River Basin, was the primary way this problem was addressed.

Despite the presence of a few mid-grade sulfur coal seams in Appalachia, the region experienced a sharp decline in mining production following the CAAA's passage. These mid-grade sulfur coal seams, located primarily in southern West Virginia and eastern Kentucky, contained "medium-sulfur" coal, producing approximately 1.2 lbs. of SO_2 emissions per million BTUs[1], right at the limit set by the original Clean Air Act of 1970 for new power plants (Schmalansee & Stavins 2012; Chan et al. 2012). While these mid-grade sulfur coal deposits positively affected the demand for the coal from these seams relative to other Appalachian coal seams, raising the relative price (see Figure 3.1), overall demand for coal from the region continued to drop as the West's low-sulfur sub-bituminous coal replaced it (see Figure 3.2).

As shown in Figure 3.1, the trend of relative coal prices broke in 2000, which seems plausible given that this is when the cap became "binding." However, as shown in Figure 3.2, production may have begun to decline prior to the binding cap.

The CAAA, which was passed in 1990 and which went into effect in 1995, represents an expected, permanent, negative, demand side shock to the coal industry. According to the theory presented in Section 3, the mining sector should lag the event. Mines represent significant capital investments; therefore, the firms want to recover as much of those fixed costs as possible, even if operating below-average total costs. As far as the mining firms are concerned, there is certainly no reason to shut down in advance of the law going into effect because doing so would increase losses on their fixed costs. These firms continue producing as long as the market's demand side continues buying their coal.

[1]British Thermal Units (BTUs) are a measure of the quantity of heat

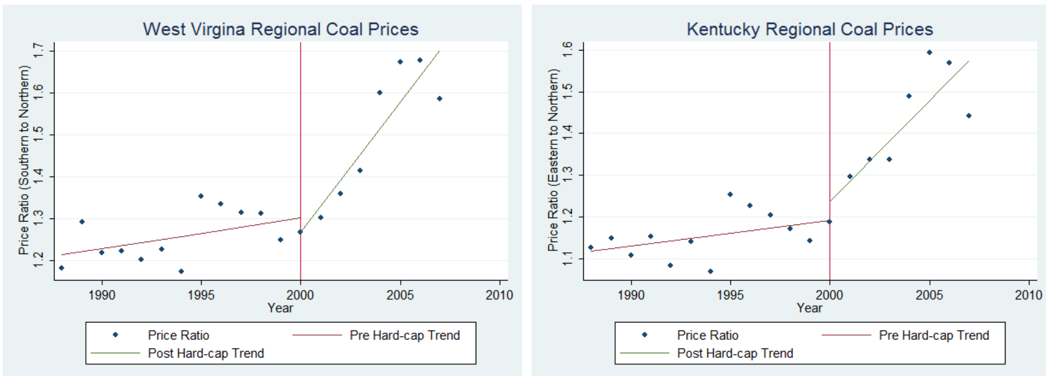

Figure 3.1: Appreciation of Within State Regional Coal Prices

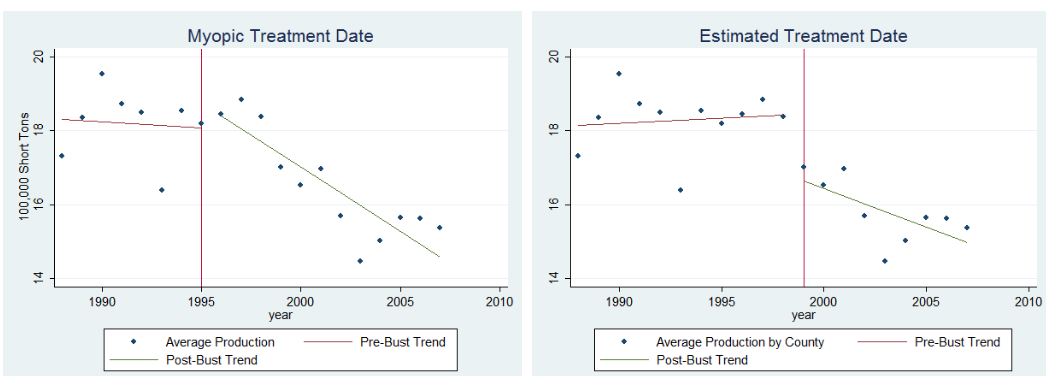

Figure 3.2: Average Coal Production

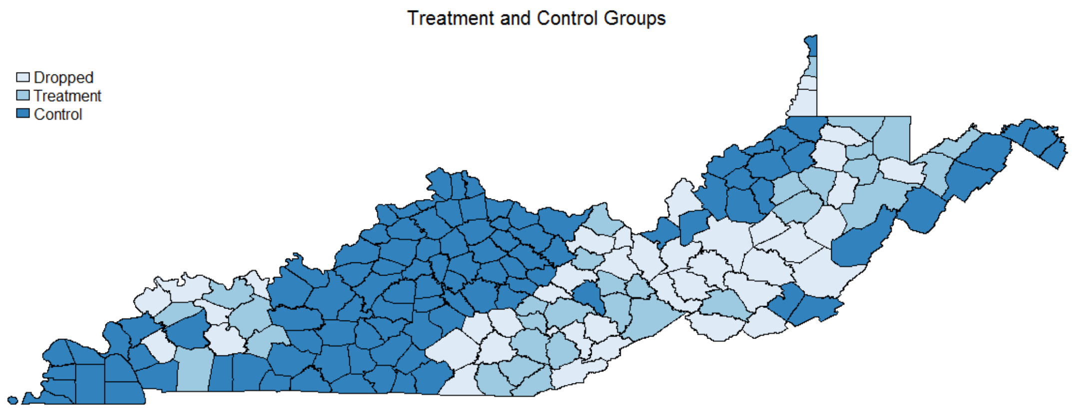

Figure 3.3: Map of Study Region

My study area included counties in Kentucky and West Virginia. I divided this two-state region into three categories. I adopted the same strategy as Black et al. (2005) and Marchland (2013) did in identifying counties most likely to be adversely affected by the policy as those which derive 10% or more of their total earnings from the coal industry. I considered these my treatment counties, which were treated with a large negative demand shock. To successfully carry out my DID estimation of the spillover effects, I had to also identify a proper comparison group, which was my control group and included all non-mining counties in both states. I excluded the counties who had relatively smaller mining sectors because it was plausible that although the CAAA negatively affected these counties' mining sectors, the sectors did not represent a significant enough portion of the economy. Dropping these counties created a "buffer zone" between the treatment group and the control group. In addition, I dropped four counties from my sample because of large differences in urban populations. These dropped counties included the urban areas of Louisville, KY; Lexington, KY; Charleston, WV; and Kenton County, KY (the latter is a suburb of Cincinnati, Ohio). Dropping these counties resulted in a treatment sample of 31 counties (12 from West Virginia and 19 from Kentucky) and a control group of 98 counties (81 from Kentucky and 17 from West Virginia). Figure 3.2 presents a map of the study region identifying the different treatments and control groups.

Despite counties being dropped to create the buffer region, there was still the potential for spatial spillover effects from these counties. Instances of cross-border shopping, commuting and business-to-business transactions, particularly to the extent that they played a role in the regional supply chain, should not be omitted without appropriate consideration. Unfortunately, my data set and strategy did not directly address the issues. However, Fryer et al. (2016 NBER working paper) addressed in detail the issues of geographically dispersing economic shocks in a case study of the fracking boom in the Western United States. They found that the fracking boom's multiplier effects at the county level were actually amplified two to fourfold at the regional level, depending on the dependent variable, in the 100-mile region from a boom county's centroid. This result implies that any multiplier effects I found at the county level would understate the true regional impact of a policy-induced mining bust.

My data consisted of observations at the county-year level, with mining industry variables, population estimates, and variables on county-level payroll, employment, and number of establishments. I used the Energy Information Agency (EIA) Annual Coal Reports to collect mine-level data, containing information on production, labor hours, number of employees, and type of mine (surface or underground). Then I aggregated this data to the county level. Average annual coal-price data also came from the EIA and was calculated by dividing the total Free on Board[2] value of the coal sold by the total amount of coal sold. Aggregate data on employment, annual payroll, and number of establishments from the Census Bureau's County Business Patterns data set. Population figures also came from the Census Bureau. I used 1990 Census data to create a set of socio-economic initial conditions used as controls in the analysis. Table 3.1 provides a comparison of various descriptive statistics for my control and treatment groups, five years before and after the policy was implented.

[2]Free on Board price is the price paid for a good at the beginning point of transportation rail/barge

Table 3.1: Descriptive Statistics

	Treatment 1990	**Control 1990**	**Treatment 2000**	**Control 2000**
Population	27,400	30,980	27,970	34,570
Coal Production (1,000s short tons)	45,000	0	28,600	0
Annual Payroll (1000s of dollars)	$177,600	$270,600	$191,000	$423,000
Total Employment	7,400	10,400	6,700	13,600
Establishments	520	680 550 790		
Land Area (square miles)	430	320	430	320
N	31	68	30	68

As can be seen in Table 3.1, there were clear differences between the treatment and control counties in 1990 despite their similar population sizes. Control counties averaged about $93 million more in annual payroll, employed approximately 300 more people, and had an average of 160 more business establishments than their treatment counterparts. In 2000, 10 years after the policy went into effect, the gaps widened, suggesting that control counties grew more during that time than treatment counties.

3.4 Empirical Strategy

The primary questions asked in this essay are whether the SO_2 permit-trading system that took effect in 1995 resulted in a bust in central Appalachia's coal mining industry and, if so, whether this bust led to negative spillover effects in the local economy's non-mining sectors. Implicit in these questions are two more important questions. First, if there was indeed a structural change in the coefficients on the explanatory variables in the mining sector, when did this change occur? Second, assuming there were measurable spillover effects, did they occur at the same time as the changes in the mining sector?

3.4.1 Direct Effects

To measure the CAAA's direct effects on the mining sector, I employed a simple trend break analysis. Because there was no control group for comparison, only the mining-intensive counties were considered. This approach is common in the literature when examining direct effects of a boom/bust in demand (Black et al 2005, Marchland 2012, Weber 2012, Jacobsen and Parker forthcoming). I ran the regression given by Equation 4.1:

$$Y_{i,t} = \beta + \beta_1 * Post_t + \beta_2 * T_t + \beta_3 * Post * T_t + \beta_4 * KY_i + B * X_{i,1990} + e_{i,t} \quad (3.1)$$

Where $Y_{i,t}$ is the dependent variable, either employment, annual payroll, or number of establishments. $Post_{i,t}$ is a binary indicator equal to 1 if year is after the treatment date. T_t is a linear time trend, and $Post * T_{i,t}$ is the interaction of treatment and the linear time trend. The coefficient of interest is β_1, which is the average difference in the dependent variable after the policy went into effect from before. This "jump" in the dependent variable is the short term impact of the policy. β_3 is the change in slope after the policy goes into effect, and, while informative, is more important in determining medium and long term effects. KY_i is a state fixed effect and $X_{i,1990}$ is a vector of county- specific socioeconomic controls from the 1990 census, which control for the county's characteristics at the time of the policy's announcement.

Because it is unclear when the mining industry responded to the policy, I used the test for structural change with an unknown breakpoint proposed by Andrews (1993). The test is similar to a Chow test; but rather than using t-tests, Wald Statistics with augmented critical values are used. This strategy has been implemented where the structural change is the result of both an expected shock and an unexpected shock. Cozad and LaRiviere (2012) used the technique when examining total vehicle emissions and emissions per-vehicle-mile traveled in response to the unexpected spike in oil prices in the 1970s. Similarly, Piehl et al. (2003) also used this strategy in examining the expected policy aimed at reducing youth homicide rates in Boston during the 1990s. In that study, implementation lags justified the use of this procedure. In both cases, as in my study, there was not a comparison group to perform a DID estimator in examining the effects' timing. I varied the treatment date from 1994 to 2003, one year before the policy began(1995) to three years after the emissions cap became binding (2000). This exercise's results are discussed in Section 5.

3.4.2 Spillover Effects

To test for the presence of spillover effects, I employed a DID estimator of the form:

$$\begin{aligned} Y_{i,t} =& \alpha + \alpha_1 * Bust_i + \alpha_2 * Post_t + \alpha_3 * Bust_{i,t} * Post_t \\ &+ \alpha_4 * T_t + \alpha_5 * KY_i + A * X_{i,1990} + e_{i,t} \end{aligned} \tag{3.2}$$

$Bust_i$ is a binary indicator variable equal to one if county i is a bust county. The interaction term $Bust_i * Post_t$ is the treatment, thus α_3 is the coefficient of interest. α_3 is the effect that being a bust county after treatment occurs has on the dependent variable. The variables $Y_{i,t}$, $Post_t$, T_t , KY_i and $X_{i,1990}$ have the same meaning as before.

As in the case for testing for effects on the mining sector, it is unclear when treatment should have occurred. In the case of spillover effects, I define treatment as being in a mining-intensive county after the mining sector experienced a negative shock. Even though the analysis above indicates that treatment occurred in the mining sector in 1999, the spillover effects could lag the mining sector. To address this issue, I conducted the same test for structural changes to identify the exact treatment date for the dependent variables of employment, annual payroll, and number of establishments. The results are displayed in Section 5.

3.5 Results

3.5.1 Direct Effects

Figure 3.3 displays the test results for structural change for the mining sector's dependent variables of employment, annual payroll, and number of establishments. As shown in Figure 3.3, the strongest structural break for each dependent variable occurred in 1999. Wald Statistics of 22.52, 13.15, and 14.25 were found for

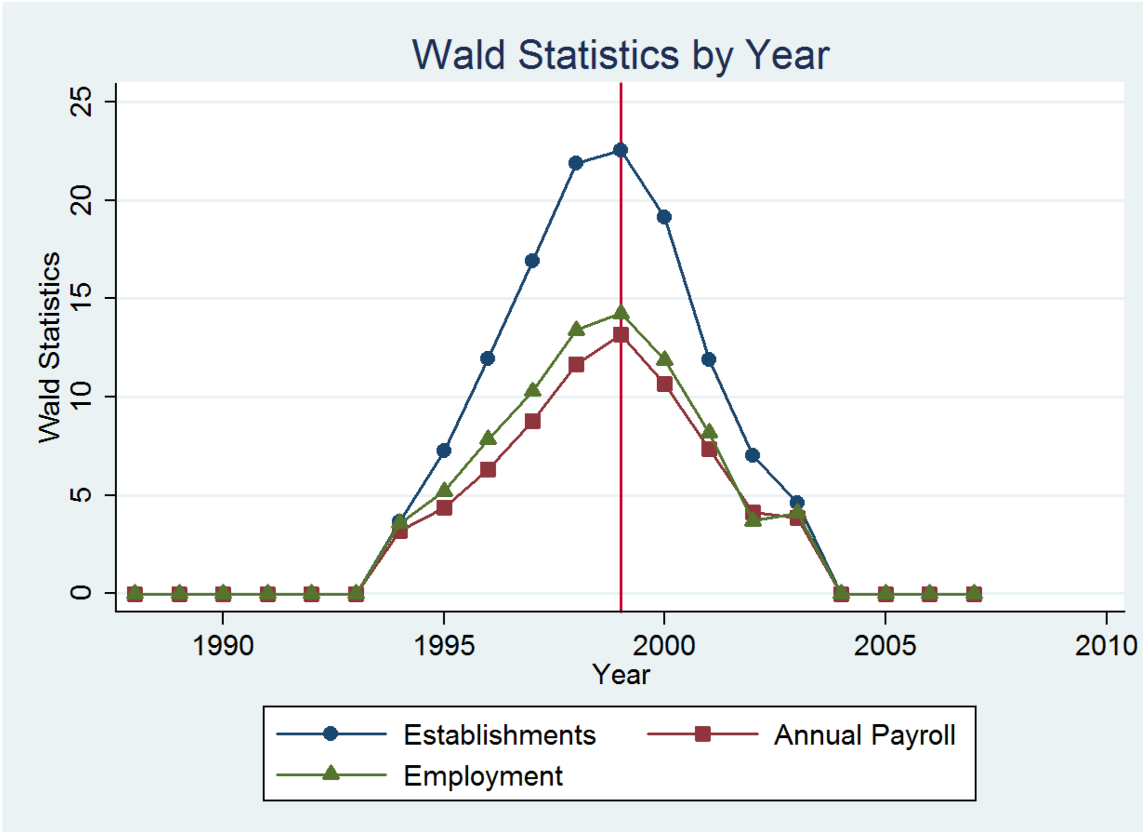

Figure 3.4: Wald Statistics by Year, Mining Sector

establishments, annual payroll, and employment, respectively. Each of these statistics is well above the necessary augmented critical value at the 1% level, as Andrews (1993) tabulated. This was the fifth year the permit trading system was in place but one year before it became binding.

The lag in the mining companies' response to the policy supports the theory's predictions. As mentioned earlier, if reasons exist for the demand side firms to postpone responding, lag times for the mining sector's response would increase. This was likely a contributing factor in this scenario. The electricity-generation companies that purchase coal hold on to this inexpensive source of fuel as long as possible. At the initial policy-implementation date of 1995, the emissions cap was not binding. That is to say, the cap was set higher than the existing emissions' level. The electricity companies had no immediate reason to act. Yet as the date the

cap was to be lowered in 2000 approached, power plants could no longer postpone their mitigation efforts. For some, the mitigation costs involved installing scrubbers that helped remove SO_2 particulates from plant emissions, allowing some demand for the high-sulfur coal to remain. However, most had invested in more costly and time-consuming improvements in their facilities to accommodate different fuel blends, resulting in sharp declines in demand for the bituminous coal from the region.

Using 1999 as the treatment date, I ran the regression given in Equation 3.1 for employment, annual payroll, and the number of establishments. The results are displayed in Table 3.2.

Table 3.2: Direct Effects on Mining Sector in Bust Counties

	Employment	Establishments	Payroll ($1,000s)
Post	-366**	-18***	-$19,556**
	(173)	(5.4)	(8794)
T	-26**	-1.5***	-$1,190**
	(11)	(.37)	(537)
T*Post	26*	1.6***	$1,472*
	(15)	(.48)	(760)
N	566	566	566
adj. R^2	0.684	0.660	0.648

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The variable of interest here is *Post*, the indicator variable equal to 1 after the treatment date determined by the calculated Wald statistics' supremum. As shown in Table 3.2, there was a clear and statistically significant drop in mining employment, payroll, and the number of active mines as a result of the CAAA. Employment decreased by nearly 1200 workers in the mining sector, accompanied by a $64 million decrease in total sectoral income. Given an average economy-wide payroll between $240 and $280 million for treatment counties, a decrease in $64 million is a significant loss to total county spending power. These results clearly demonstrate a negative labor shock in the treatment region's mining sector.

3.5.2 Spillover Effects-Aggregate Level

As with the policy's direct effects, I ran a test for structural changes in the parameters for the model describing the spillover effects. The results are shown in Figure 3.4. The most significant structural break for each dependent variable occurred at different times from one another, as well as from the break identified in the mining sector. This finding indicates a lag in the treatment date for each measurement in the aggregate economy relative to the mining sector. The structural break occurred in 2001 for the number of establishments, reporting a Wald statistic of 8.17. The break point for employment was 2002, reporting a Wald statistic of 12.43; and for annual payroll it was 2003, reporting a Wald statistics of 7.82. Figures depicting breaks in the data are in Appendix A. While these breaks are not as strongly significant as those detected in the mining sector, they too were above the augmented critical values at the 1% level. This result has critical implications for the resource-extraction literature, showing that the treatment date on the broader economy may not be the same or the mining sector, which could impact the results.

Furthermore, I consider these results to be even more informative than the identified lag in response to the mining sector for two reasons. First, they supports my view of the existence of two distinct treatment events. The first event is the policy affecting the mining sector. The second event is the mining sector's response affecting the overall economy. The second reason is that these results provide some insight into how a slumping resource-extraction sector's effects play out in the rest of the economy. The number of establishments was first to respond in 2001, two years after the shock to the mining sector. Employment was second in 2002, and payroll followed in 2003.

These results raise two questions. First, why did these different economic indicators respond at different times? Second, what are the lessons for local/regional policy makers? The behavioral story behind establishments is likely driven by future expectations. A business would want to open a new location only when expectations

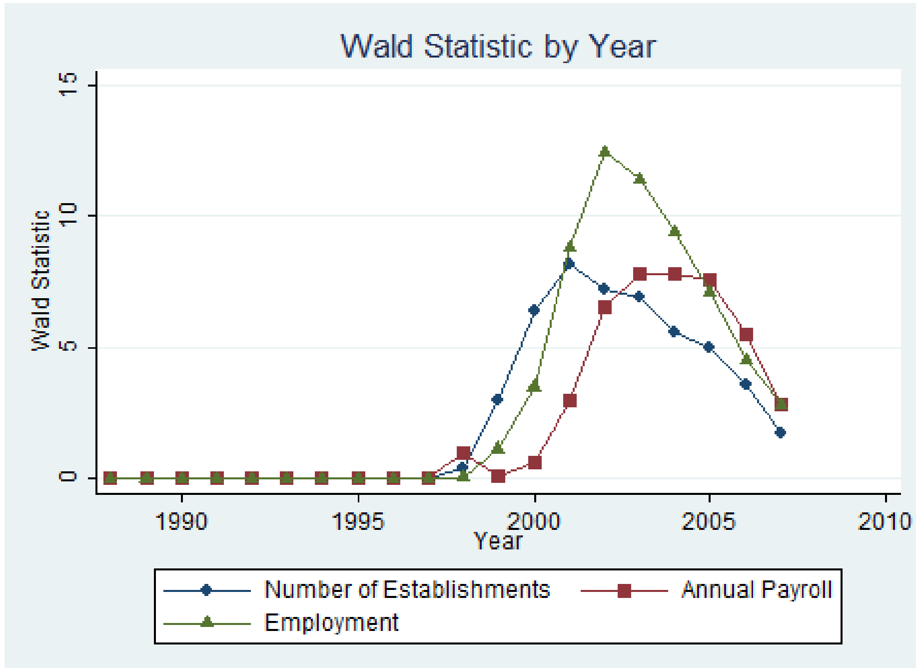

Figure 3.5: Wald Statistics by Year, Aggregate Economy

are consistent with a stronger economy because opening a new location involves a larger investment with more fixed costs than hiring new workers at an existing location. New businesses are less likely to open locations in a town where potential economic downturn is right around the corner. On the other hand, payroll and employment decisions have less fixed cost than opening or closing new establishments; therefore, they require a less forward-looking approach. Because of the decision-making process's more flexible nature, existing firms can wait longer for conditions to change before making payroll and personnel decisions. Assuming they were already operating at a profit-maximizing level of employment and payroll, firms would have no reason to adjust before any changes in consumer demands and demand for business-to-business services. Additionally, many workers would qualify for unemployment and would be able to maintain at least a partial level of their spending for the next two years; thus, demand for local goods and services could be expected to have a longer lag.

Therefore, what do these findings mean for local policy makers? In the case of many negative demand shocks, local politicians can do little to counteract federal policy that is hurting their local industry. However, understanding the shocks' time lines may give them a window within which to work to begin programs dealing with anticipated negative effects. For instance, such programs include applying for federal funding for displaced workers' job training programs and properly staffing unemployment and disability insurance offices to assist with the influx of claims accompanying such negative labor shocks (Black, Daniels, Sanders 2002). In terms of maintaining employment opportunities, politicians can also become actively engaged in industrial recruitment to facilitate economic diversification, and they can establish assistance programs for small businesses.

Table 3.3 presents the results for the key explanatory variables. Being a bust county negatively affected employment, annual payroll, and the number of establishments in a statistically significant way, consistent with the story the descriptive statistics told. The coefficient on $Bust * Post$ shows that the negative labor shock in the mining sector created negative spillover effects on the broader local economy.

Table 3.3: Aggregate Spillover Effects

	(1) Employment	(2) Establishments	(3) Annual Payroll
Bust	-865**	-3.8	-$24,174
	(348)	(14)	(15849)
Post	-700	-14	-$18,197
	(434)	(17)	(19825)
Bust*Post	-1055*	-73***	-$61,262**
	(548)	(21)	(26863)
T	260***	10***	$11,475***
	(34)	(1.4)	(1493)
N	2460	2460	2460
adj. R^2	0.977	0.987	0.955

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The number of establishments decreased by 73, significant at the 1% level, while the number of employed persons and annual payroll decreased by 1055 and $61,262,000, respectively, both significant at the 5% level. These results are consistent with my expectations of a negative labor shock's effects.

I also ran trend break analysis regressions on the control group for the calculated treatment dates to test if the control group experienced a similar change in behavior. If the mining sector was truly driving these results in the treatment group, then there is no reason why the control group should have experienced a shock at the same time. My results from this analysis conclude that there was no statistically significant change in the control county's behavior for any of the dependent variables.

3.5.3 Comparison to the Standard Approach

In this subsection, I compare the results of my analysis conducted at the true treatment date vs the "standard" treatment date, set to take place in 1995. Table 3.4 presents a comparison of the direct effects, and Table 3.5 presents a comparison of the indirect effects.

Table 3.4: Comparison of Standard and Estimated Treatment Effects for Mining Sector

	Employment	Establishments	Payroll
"Standard" Treatment	-102	-5.9*	-$5,135
	(96)	(3.2)	(4631)
Treatment	-366**	-18***	-$19,556**
	(173)	(5.4)	(8794)
Difference	264	12.1	$14,421
	(197.85)	(6.27)	(9,938)
N	566	566	566
adj. R^2	0.683	0.658	0.646

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The first row of Table 3.4 gives the results of the regression with treatment occurring in 1995, while the second row gives the results with treatment occurring

in 1999. Giving the difference in the estimates, the third row indicates that the myopic treatment date underestimated the effect on the mining sector and also produced statistically insignificant results with the exception of the coefficient on establishments, which was only weakly significant.

Table 3.5 provides the same analysis for the estimates of the spillover effects into the aggregate economy. In this case, the myopic estimates tended to overestimate the spillover effects compared to my calculated treatment date. This finding suggests not only that testing for the true treatment date was beneficial in terms of understanding the timing issues related to how an economy responded to a shock, but also that neglecting to do so could produce incorrect results. The results here indicate that the myopic treatment date's results produced larger negative multiplier effects than the results from my estimated treatment date.

Table 3.5: Comparison of Myopic and Estimated Treatment Effects for Aggregate Economy

	Employment	Establishments	Payroll
"Myopic" Treatment	-1756***	-79***	-$101,586***
	(548)	(21)	(25,756)
Treatment	-1055*	-73***	-$61,262**
	(548)	(21)	(26,863)
Difference	-701	-6	-$40,324
	(774.98)	(29.69)	(37,215)

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

3.6 Conclusion

Examining the effect of booms and busts in natural resource extraction is nothing new, and many studies have done so at both the national and subnational level. However, many of these studies have failed to identify the proper timing of treatment. While identifying the event that caused the boom may be straightforward, this identification does not necessarily indicate when treatment occurred. To my knowledge, this

study is the first to address this issue by providing a theoretical construct describing why resource-extraction sectors might actually respond (i.e., receive treatment at times other than when the event driving treatment occurs). To test my theory's predictions, I incorporated a technique proposed by Andrews (1993) that is common in the program-evaluation literature to test for a break in structural parameters to identify the treatment date. Testing my theory using the shock to the Appalachian coal industry induced by the CAAA's passage, I found that the industry's response indeed lagged the implementation of the policy by four years.

Also critical in this study was that the way in which I considered spillover effects' nature differs from the methods discussed in the existing literature. Rather than viewing the event that drives the surge in resource extraction as the single event determining treatment for the extraction sector and the non-extraction sectors, I examined it as a series of separate treatment events. In this study, the passage of Title IV of the CAAA of 1990 was the event that induced treatment on the extraction sector, but the extraction sector's response induced treatment on the non-mining sectors. Therefore, I consider this a separate treatment event, which is also subject to "implementation lags."

Again using the test for structural change in parameters, I found that treatment for the broader economy occurred after treatment for the resource extraction sector. Additionally, different economic variables responded at different times. This finding has two important implications. First, studies missing this step in the resource-extraction literature could be introducing a source of bias into their estimates. Second, it not only provides a more accurate measure of the effects of labor shocks in resource-extraction sectors to the broader local economy, but also gives insight into these spillover effects' timing. This information is pertinent to local policymakers when considering their own resource extraction sectors' future. For example, when an impending regulation that might make an existing resource-extraction method prohibitively expensive, such as a carbon tax, local policy makers who may be powerless to prevent the policy from happening may instead focus on encouraging

other industries to take its place. Having insight into the time line of how these shocks play out in the broader economy would be beneficial in making these decisions. Furthermore, communities and regions currently experiencing resource-extraction booms can take these findings regarding the negative multiplier effects of busts in the extraction sector as impetus to prepare for the future. The following are two possibilities: (1) creating rainy day funds to protect local government-funding priorities (such as education, health, and other public services), (2) or using high government revenue to encourage the establishment and growth of other industries not reliant on the extraction sector.

Chapter 4

The Clean Air Act Amendments and the Low Sulfur Coal Boom

4.1 Introduction

Despite the overwhelming scientific consensus on the existence of climate change and its potential for disastrous environmental effects, the political arena still disagrees on if or how the issue should be addressed. Proponents of action have suggested various forms of regulation, such as a carbon tax or a cap-and-trade system, citing the success of Title IV of the Clean Air Act Amendments (CAAA) of 1990. Opponents warn of the disastrous effects environmental regulation will have on the economy, arguing that increased energy costs will hurt the industry and cost jobs. Several studies examining the CAAA of 1970 and 1977, which established the National Ambient Air Quality Standards, have found negative consequences for regulated industry employment in counties failing to meet the established emissions and air quality criteria (Henderson 1996; Greenstone 2002; Walker 2012). Likewise, the previous chapter in this dissertation discussed negative employment effects in the Appalachian coal mining region because of Title IV of the Clean Air Act Amendments of 1990.

Furthermore, environmental regulations, such as the CAAA and the 2015 Clean Power Plan (CPP), will increase energy costs for all electricity users, whether in an industry directly regulated or otherwise. Given that electricity prices are major determinants for manufacturing firms' decisions (Carlton 1983; Mansur 2012), such increases have the potential to affect a wide range of industries. The literature examining regulation beyond the CAAA also discusses environmental regulation's negative consequences. For example, Curtis (2014) found that for each additional 1 percentage point of energy intensity in an industry, employment levels decreased by 1.3% as a result of the Nitrous Oxide Budget Trading Program introduced in 2004. Negative effects on other manufacturing sector indicators, such as the frequency of plant openings and the productivity levels in regulated industries, are also discussed throughout the literature (Becker and Henderson 2000; Dean et al. 2000; List et al. 2003; Henderson 1996; Hanna 2010; Greenstone et al. 2012).

The literature focuses overwhelmingly on the effects of manufacturing and electricity-generating sectors, but this focus represents only one side of the story. As with any industry, when costs for one product rise, existing substitutes increase their market share and new ones enter the market. The increased demand for these substitutes generate job growth in these industries; and rather than being job killers, as environmental regulations are often called by their opponents, they are job shifters. In the context of Title IV of the CAAA, the SO_2 cap-and-trade system implemented under Title IV resulted in an implicit tax on high-sulfur bituminous coal. The most readily available substitute for Appalachia's high-sulfur bituminous coal was the American West's low-sulfur sub-bituminous coal. The flexibility in choice of abatement method offered by Title IV resulted in many coal-burning power plants' changing their fuel blends to incorporate low-sulfur coal. The ensuing increased demand for sub-bituminous coal led to a positive labor demand shock for the region's mining industry. This positive demand shock led to a potential for positive employment effects on not only the coal sector, but also other sectors of the local economies where coal was extracted through spillover effects.

Previous studies have examined spillover effects from locally booming resource extraction sectors, and two competing theories have emerged for predicting such booms' effects. One theory involves the resource curse and Dutch disease, pointing to crowding out, local institutions' misappropriating revenues, and controlling outside interests as the causes of many resource rich economies' poor economic conditions. In contrast, the agglomeration theory points to increased investment, population influxes, and technology spillovers as the causes of positive spillover effects seen in other resource-rich regions. Marchland (2012) and Matheis (2014) found negative effects on traded sectors, while Michaels (2010) found positive effects .

This essay contributes to the literature examining environmental regulation's effects on employment as well as to the literature on local labor demand shocks. I first asked if the mining industry experienced a positive shock from the passage of the CAAA of 1990. After finding that it did, I tested for local multiplier effects. I also

have built on the analysis of the previous chapter of this dissertation, which describes why there may be lags or leads in treatment effects relative to policy implementation, as well as lags or leads in the spillover effects relative to demand shock in the resource extraction sector. I do so by decomposing the multiplier effects into sector-specific shocks to test if different sectors of the economy respond at different times.

As a result of the policy, the mining industry employed an average of 312 more workers, and the total sectoral payroll increased by nearly $50 million at the county level. These findings are consistent with the idea that increased demand for low-sulfur coal created a positive labor demand shock in the mining sector. This would be an increase of $160,000 per new worker, indicating that wages for those already employed in the sector increased as well. This increase could be the effect of individual workers' working more hours or increased wages per hour. I found mixed results regarding the spillover effects on locally-consumed sectors. The retail sector gained almost 500 jobs. However, the retail sector lost $15,000,000 in total sectoral payroll while the construction sector lost $26,740,000. For the traded sectors of agriculture and manufacturing, I again found mixed results. The agriculture sector gained 87 jobs and $1,911,000 in total sectoral payroll, while the manufacturing sector had no statistically significant impact. These findings suggest, at least to a small extent, that there were positive multiplier effects in traded good sectors, consistent with the agglomeration effects model.

These results can be applied to policy makers' decisions at the local, state and national levels. At the local level, policy makers can seize the opportunity to increase local employment by attracting new industries to locate and grow within their districts. In the context of environmental regulation, this is particularly important for policy makers in jurisdictions that will be hurt by new regulations. Rather than fighting to save jobs in a costly, dirty industry, policy makers can begin trying to ease the transition to new industry.

For instance, policy makers could lobby for firms in the new substitute industry that will compete with or replace the old, dirty industry to locate within their district.

Given the transition costs for workers who switch sectors (Walker 2011), policy makers at both levels could also attempt to create policies to help smooth the transition from regulated sectors to cleaner sectors for reallocated laborers, thus reducing these costs. National policy makers can use these findings as evidence that environmental regulation also has the potential to create new jobs to replace jobs lost in the industry it is regulating. This potential for new jobs is particularly important given the heavy focus previous research has given to the negative effects on employment outcomes in regulated sectors.

The rest of this essay proceeds as follows. Section two discusses the existing literature on booming resource extraction sectors. Section three discusses how Title IV of the CAAA of 1990 affected the study region. Section four discusses the data sources and sample selection. Section five outlines the empirical strategy. Section six discusses the results and section seven concludes.

4.2 Conceptual Framework and Previous Literature

A booming sector at a local level affects other local sectors' labor markets in several ways. One immediate effect is that the booming sector increases labor demand, thus driving up employment and total income. This additional income is then spent in the local economy, increasing demand in other sectors such as retail, services, and construction. In addition, as the booming sector expands, it also demands more goods and services, increasing business-to-business transactions. Furthermore, other sectors, both tradeable and non-tradeable, can benefit in the long run from new infrastructure, technology spillovers, and agglomeration effects, as well as from increased government revenue resulting from an enlarged tax base. However, a downside is the potential for increased wages and prices of other locally sourced factor input. If the market for inputs is already tight, a sudden increase in demand will cause prices to rise as

well, in turn deterring expansion of existing firms or entry of new firms. As traded goods sector output price is determined by the national economy and not locally, factor input prices' sudden rise could even lead to a contraction in the size of traded sectors competing for locally supplied factor inputs. If crowding out happens to the extent that industry-specific infrastructure is dismantled, the local economy could experience Dutch Disease-type effects seen in national economies.

The literature examining local labor demand booms covers a variety of causes. For example, large firms' sitings in a community could cause a surge in labor demand at the local level. However, some of the studies offer conflicting results. For example, Fox and Murray (2004) showed that these large plant sitings have no net economic benefits, suggesting that bidding wars to attract such firms may be ill advised. On the other hand, Greenstone and Moretti (2004), who also conducted a study on plant openings by comparing employment outcomes for the various communities that bid for the plant to locate there, found that a successful bid was correlated with a 1.5% earnings increase in that sector.

Another example of a shock to local labor demand is the implementation of government-designated "enterprise zones," areas where local governments encourage economic activity by offering incentives such as tax concessions, infrastructure development, or reduced regulations. Investigations of designated enterprise zones, which should generate similar increases in local labor demand, have also produced mixed results. Some studies found positive effects on short-term employment (O'Keefe 2004; Busso and Kline 2007), while other studies concluded that such designations produce no significant effect on local employment other than reallocated labor (Kolko and Neumark 2010a; Neumark and Neumark 2010; Hanson 2009).

More closely related to my study are studies that investigated the economic effects of increased labor demand stemming from booms in natural resource extraction. Michaels (2010) studied the long-term economic impact on counties located over significant oil fields. Rather than finding inhibited growth seen with resource-based national economies, often referred to as the resource curse (Sala-i-Martin et al. 2004;

Sachs and Warner 1997; Sachs and Warner 2001) and in some instances at the county level (Douglas and Walker 2013), Michaels found positive effects on population growth, education, and manufacturing. This finding is in line with the agglomeration effects theory. However, this essay focused on a boom's effects in local resource extraction in the short-to-medium terms, for which there are several relevant studies.

Matheis (2014) examined not only county-level outcomes in coal mining counties for population and median family income, but also employment levels in several other sectors from 1870 to 1970. In his study, identification came from county variation in three different measures of lagged coal production, with each accounting for different time frames, allowing him to assess short-term and long-term impacts. Although Matheis found evidence of short-run positive spillover effects on employment levels of locally-consumed sectors, he found negative long-run effects, in contrast to Michaels' results (2010). He also found negative short-run and long-run effects on manufacturing employment, providing evidence supporting the crowding out effect symptomatic of Dutch Disease. In a study examining the local employment effects of a boom in natural gas fracking in the Western United States, Weber (2012) found that total employment increased by 1.5% on average for boom counties, while average wage and salary incomes increased 2.6%, in line with theoretical predictions.

Black et al. (2005) and Marchland (2012) examined a boom-bust cycle in resource extraction. Identifying treatment areas as counties or census division tracts that derive 10% of their total income from resource extraction, these researchers used difference-in-differences (DID) estimators to examine spillover effects of booming resource-extraction sectors. Black et al. (2005) found that employment increased 2% annually in treatment counties during a boom and contracted 2.7% annually during the bust. Job multipliers were also calculated, finding that every 10 jobs created in the mining sector led to approximately 2 jobs for the local construction, retail, and services sectors. Again, the bust seemed to have stronger effects than the boom, as Black et al. found that for every 10 coal jobs lost, 3 jobs across other sectors were lost. Marchalnd (2012) found that booms had positive impacts on total personal

income; but contrary to Black et al. (2005), no evidence of contraction during busts was found. Marchland (2012) also calculated job multipliers, finding that every 10 jobs created in the energy extraction sector created 1.2 jobs, 1.7 jobs, and 3.6 jobs in the construction, retail, and services sectors, respectively.

4.3 Background and Study Areas

Title IV of the CAAA decreased the demand for high-sulfur coal and increased it for low-sulfur coal, as coal-burning power plants needed to lower their emissions to avoid being forced to purchase a sulfur dioxide emission permit that the law established.[1]

This policy increased demand for low-sulfur sub-bituminous coal, which was substituted for higher-sulfur bituminous coal in coal-burning power plants. Before the policy was implemented, demand for this coal was relatively lower than coal from the East because of the costs of switching fuel blends in power plants as well as the relatively higher costs involved in transporting coal to the power plants located primarily in the Eastern half of the United States. As low-sulfur coal became more valuable, plant operators became more willing to bear these costs, allowing Western mines to profitably increase their production. The Powder River Basin, which spans Northeast Wyoming and Southeast Montana, accounts for much of the coal mined in the region, as well as for approximately 85% of the nation's accessible low-sulfur coal reserves. Utah, New Mexico, and Colorado also contain sub-bituminous coal-producing counties and are included in the sample. Total coal production from the study region is displayed in Figure 4.1.

[1] Low-sulfur coal is defined as having fewer than .6 lbs. of sulfur per million Btu, medium-sulfur coal as having between .6 and 1.6 lbs. of sulfur per million Btu, and high-sulfur coal as having more than 1.6 lbs. sulfur per million Btu. Medium- and high-sulfur coal still retained some of its value because power plants could adjust their burners to operate on blended-low and medium/high-sulfur coal.

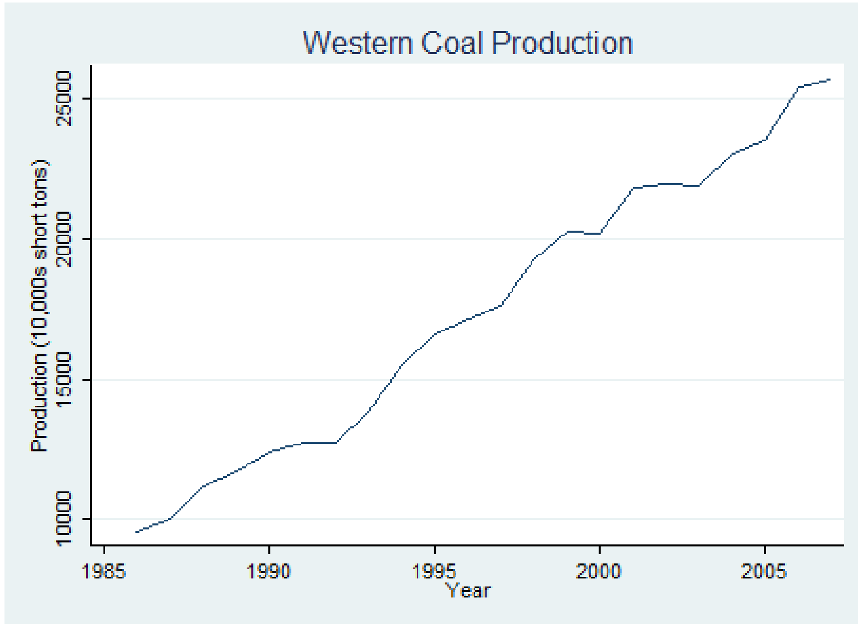

Figure 4.1: Western Coal Production

4.4 Data and Sample Description

The data consists of county-year observations spanning from 1988 until 2007 for population, total annual payroll, and employment by sector. The Energy Information Agency (EIA) Annual Coal Reports were used to collect mine-level data, including information on production, labor hours, number of employees, and type of mine (surface or underground). This data was then aggregated to the county level. Average annual coal prices also came from the EIA and were calculated by dividing the total Free on Board value of the coal sold [2] by the total amount of coal sold. Employment, payroll, and population came from the Census Bureau's County Business Patterns database. Average wages were unavailable and thus were calculated by dividing the total sectoral income by the sectoral employment, a practice consistent with similar studies (Marchland 2012, Black et al. 2005).

The 1990 Census data were used to create a set of socio-economic initial conditions used as controls in the analysis. Unfortunately, in both employment data and payroll

[2] Free on Board price is the price paid for a good at the beginning point of transportation rail/barge

data, some observations were missing for agriculture, construction and manufacturing. Some data were withheld for disclosure reasons, while others were bottom coded as 10 for employment figures and \$50,000 for payroll figures. This could bias estimates upwards. A Heckman two-step estimation process, which is further discussed in Section 5, was used to address the missing data.

Counties lying over low-sulfur coal beds that increased production were designated as "boom counties," representing 22 of the 30 coal mining counties. The eight non-boom mining counties were excluded from the control group because they would probably have experienced negative effects and biased the results upward. Contraction in a resource extraction sector results in decreased employment in the mining sector, thus lowering total employment and total income, and in turn demand for local goods. The newly unemployed would also bid down the price of labor, lowering total income and local demand even further. This reduction in labor costs could improve the traded goods sectors' competiveness. The predicted effects are opposite in this case, and including these counties in the control group would make these effects in boom counties seem larger than they really were. The control group consisted of non-mining counties in five states, thus leaving a sample size of 18 treatment counties and 175 counties for the control group from the Western states. A map of the study region is provided in Appendix B.

Table 4.1 presents some descriptive statistics of the treatment and control regions from 1990 to 2000, thus providing a snapshot comparison of the treatment and control groups five years before and after the policy was implemented. As shown in Table 4.1, treated counties have larger populations on average, but lower levels of employment and income per capita.

4.5 Empirical Strategy

I measure how the passage of Title IV of the CAAA of 1990 affected both the mining and non-mining sectors. The own-industry effects were measured to provide evidence

Table 4.1: Summary Statistics

	Treatment 1990	**Control 1990**	**Treatment 2000**	**Control 2000**
Population	23,350	40,100	27,500	50,400
Coal Production (1,000s short tons)	1,503	0	25,000	0
Income Per Capita (2005 dollars)	\$14,400	\$15,100	\$23,200	\$23,300
Total Employment	11,700	23,000	15,300	32,000
Land Area (square miles)	3880	2640	3880	2640
N	18	175	18	175

of a boom in the mining sector. To measure a booming mining sector's spillover effects on other sectors' total employment and annual payroll, a difference-in-differences strategy was used to obtain estimates for the dependent variable's jump at the time of treatment.

The results from the own-industry analysis were also used to create a simple job multiplier, measuring how many jobs were created/destroyed in a non-mining sector per 10 jobs created in the mining. To ensure the treatment date was measured correctly, the test put forth by Andrews (1993) for changes in structural parameters was employed and is elaborated on in Chapter 2 of this dissertation. The results of this test are provided in the next section.

4.5.1 Own-Industry Effects

Because the control group had no mining sector to compare to, a simple trend break analysis with a binary treatment indicator was used. The estimation equation is given by Equation 4.1:

$$Y_{i,t} = \alpha_0 + \alpha_1 Post_t + \Phi(State * Year) + \beta X_i + \epsilon_{i,t} \tag{4.1}$$

The dependent variable $Y_{i,t}$ represents either mining sector employment or payroll in county i in year t. $Post_t$ is an indicator variable equal to 1 if it is after the treatment date. $State * Year$ is a vector of state-year fixed effects. X_i is a vector of county-specific socio-economic control variables from 1990, the time the policy was announced; these variables include land area, the number of households receiving social security income, county-level federal expenditures, the number of reported violent crimes, the valuation of new housing units, and the number of families in poverty. The coefficient of interest, α_1, estimates the average difference in the dependent variable before and after treatment.

4.5.2 Spillover Effects

To measure spillover effects, a DID estimator was used for the employment and mining outcomes of the retail, construction, manufacturing and agriculture sectors. To address the issue of missing data, the two-step Heckman selection model was employed. The following two-stage regression was estimated. The first stage is a probit model determining the selection's probability and was used to generate the inverse mills ratio, $\lambda\beta$. The first stage is given by Equation 4.2:

$$Prob(D = 1|Z_{it}) = \Phi(Z_{it}\gamma) \tag{4.2}$$

where D is the probability of selection into missing observations; and $Z_{i,t}$ is a vector of explanatory variables determining selection, including population, quantity of coal produced in short tons, the number of open Walmarts, and land area, all for a county in a given year. γ is a vector of unknown parameters, and ϕ is the cumulative distribution function ofthe standard normal distribution.

The second stage is the augmented OLS regression, which uses the probit estimates for γ, $\hat{\gamma}$ from the first stage. Equation 4.3 is a standard DID estimator in which treatment is binary and equal to one in boom counties after the treatment year identified for each dependent variable:

$$\begin{aligned} Y_{it} =& \alpha_0 + \alpha_1 Boom_i + \alpha_2 Post_t + \alpha_3 Treatment \\ &+ \Phi(State * Year) + \beta X_i + \rho\sigma_y \lambda(Z_{it}\hat{\gamma}) + \epsilon_{it} \end{aligned} \tag{4.3}$$

where α_0 is a constant, $Boom_i$ indicates a boom county, $Post_t$ is a binary indicator equal to 1 for years after the CAAA goes into effect. $State * Year$ and X_{it} are the same as in Equation 4.1. α_3, the coefficient of interest, is the difference in the discrete change in control counties and the discrete change in the dependent variable in boom counties at the time of treatment.

4.6 Results

The results are broken down into three sections. First, the results for the test for changes in structural parameters are presented. Then, after the proper treatment date is identified, the CAAA's effects on the mining sector and the spillover effects on other sectors are presented.

4.6.1 Identification of Treatment Date

The analysis provided in the previous chapter of this dissertation's predicts that the mining sector should lag an anticipated, permanent, positive demand-side shock. The key reason for this lag is that it would not be profitable for the mining companies to increase production until demand warrants it, so the lag is largely driven by the electricity-generating firms' behavior. Because it took a few years for power plants to fit their burners to accommodate different fuel blends, the change to the lower-sulfur sub-bituminous coal was not immediate.

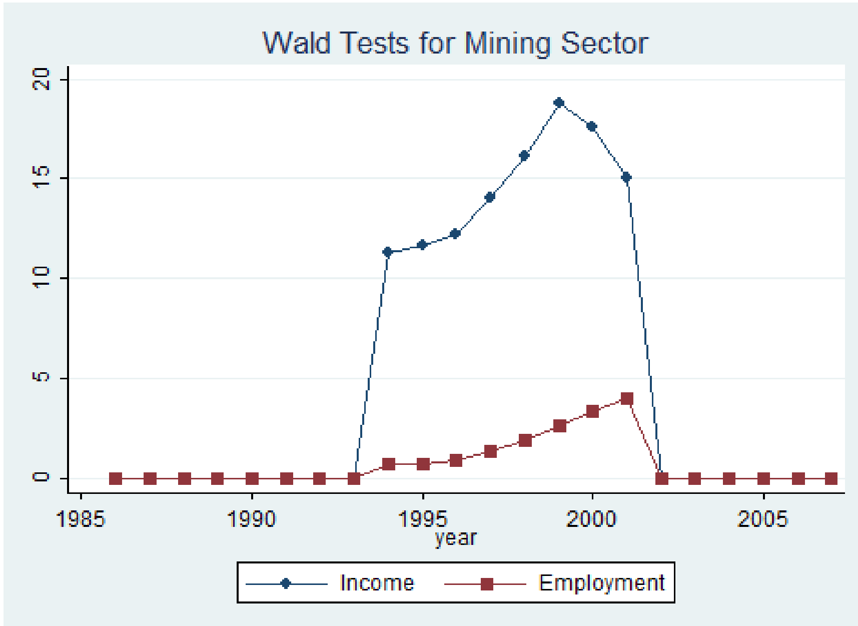

Figure 4.2: Wald Statistics for Mining Sector

Figure 4.2 shows the most significant change in the mining sector occurred in 1999 for payroll and in 2001 for employment. This finding is consistent with the timing of events found in the Appalachian mining industry discussed in the previous chapter. The same technique was applied to the individual sectors to determine the proper treatment date for each. The results are summarized in Table 4.2.

Table 4.2: Summary of Tests for Proper Treatment Date

Sector	Payroll	Employment
Construction	1994	1997
Retail	1994	1998
Manufacturing	2002	2002
Agriculture	1998	1998

Table 4.2 shows that for both the traded goods sectors, payroll and employment, received treatment at the same time. In the locally-consumed goods sectors of

construction and retail, employment lagged behind payroll by three and four years, respectively. Additionally, manufacturing lagged behind all other sectors by four years in payroll. The relatively quicker response of the locally consumed sectors compared to manufacturing could be because the theoretical reason behind the sector's growth is agglomeration effects, which would likely take a few years to accrue. Additionally, the construction, retail, and agriculture sectors all lead the mining sector for payroll and employment.

4.6.2 Direct Effects

Table 4.3: Effects on Mining Sector

	Employment	Payroll
Post	312***	\$47,989***
	(67)	(6827)
N	396	396

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

As seen in Table 4.3, the surge in demand for the West's low-sulfur sub-bituminous coal brought on by the CAAA resulted in a boom in the region's mining industry. The policy caused an increase of over 300 jobs and an increase in total sectoral payroll of nearly \$50 million dollars, both significant at the 1% level. Income increased by approximately \$166,000 per new worker, indicating that average wages rose across the industry for new and existing workers. Both of these results are in line with the predictions of the effects of a surge in demand for the natural resource and provide impetus to investigate the potential for spillover effects into other economic sectors.

4.6.3 Spillover Effects

While two competing theories offer predictions on the direction of spillover effects on traded sectors, both predict positive effects on locally consumed sectors. Table 4.4 shows mixed support for these theories. Concerning the locally consumed sectors of retail and construction, we would expect increased consumption demand from the newly employed mine workers to increase demand in these sectors. As expected, the retail sector gained 491 jobs, significant at the 10% level. However, there was also a statistically significant decrease on total sectoral payroll, opposite of what the theory predicts. The construction sector also showed evidence of a negative spillover effect, losing $26,743,000 in total sectoral income with no statistically significant impact on employment. While the positive effect on retail was expected, the negative effect on the construction sector contradicts both theories. One explanation for this unexpected negative effect is the possibility that the existing stock of housing and commercial space was sufficient enough to meet an increased demand for new building. If people and businesses are moving into existing structures, then construction would not sharply rise.

The effects on the traded sector provide some evidence of agglomeration effects. While there was no statistically significant impact on manufacturing employment or payroll, the agriculture sector increased by 87 jobs and $1,911,000 in total sectoral payroll. These increases are important for the local economy's health given the harmful local environmental effects of coal mining that often destroy agriculture production.

4.6.4 Simple Jobs Multipliers

Using the own-industry and spillover results from the previous two subsections, a simple job multiplier was created showing how many jobs in other sectors were created/lost per 10 mining jobs created. For every 10 jobs created in the mining sector, the traded sectors of agriculture and manufacturing gained 2.8 and 21.9 jobs,

Table 4.4: Spillover Effects

	Agriculture Employment	Agriculture Payroll	Manufacturing Employment	Manufacturing Payroll
Boom	-58**	-$1,415**	-279*	-$10,069
	(28)	(555)	(156)	(7414)
Post	-669***	-$12,253***	-2,409***	-$71,623***
	(37)	(733)	(284)	(13495)
Treatment	87**	$1,911**	401	$13,310
	(40)	(803)	(283)	(13444)
N	3920	3920	3920	3920

	Construction Employment	Construction Payroll	Retail Employment	Retail Payroll
Boom	660***	$32,257**	-154	$15,632**
	(242)	(13215)	(202)	(6557)
Post	4152***	$122,521***	-2455***	$64,066***
	(298)	(12956)	(267)	(6428)
Treatment	-525	-$26,743*	491*	-$15,044*
	(326)	(15768)	(285)	(7824)
N	3920	3920	3920	3920
adj. R^2			0.975	0.964

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

respectively. In the locally consumed sectors of retail and construction, for every 10 jobs created in the mining sector, retail gained 15.8 jobs while construction lost 16.8 jobs.

4.7 Conclusion

This essay contributes to the understanding of environmental regulation's employment effects using the framework of studies examining booms' impact in resource extraction sectors. While many studies on environmental regulation have focused on job loss caused by increasing costs to regulated industries, this study examined the employment effects in communities where substitute industries were located. With Title IV of the CAAA 1990 identified as the cause of a positive labor shock in the American West's mining sectors, this essay asks two questions. Does this environmental regulation also create jobs in industries that compete with the regulated industry? If so, are the effects of these competing industries large enough to cause positive spillover effects in other sectors of the local economy where these industries are growing?

The mining sector gained jobs and increased total sectoral payroll as a result of the policy, indicating that the policy did in fact cause a boom in the region's mining sector. However, the spillover on employment in other industries offers only weak evidence supporting the agglomeration effects theory. In the agriculture sector, statistically significant gains were found in both employment and total sectoral payroll, while in the manufacturing sector gains were also found, but not at any statistically meaningful level.

These results have important implications given the need to address carbon-dioxide (CO_2) emissions, where a cap-and-trade system similar to the one implemented by Title IV of the CAAA is being considered under the Clean Power Plan. The existing literature on environmental regulations consistently shows that regulations have negative employment effects on regulated industries, validating the concerns that

increasing energy prices will have negative effects. However, just as with the CAAA, restrictions lowering the demand for CO_2 intensive processes will increase demand in less CO_2 intensive substitutes, thus shifting jobs away from the former to the latter. It is also useful to consider the coincidental timing of rail freight deregulation in the 1980s that greatly lowered the cost of transporting sub-bituminous coal from the West to the East, where the majority of coal-burning power plants are located. This deregulation helped reduce the costs of switching from Appalachia's high-sulfur coal with shorter transportation distances to the low-sulfur coal that had to travel across the country. This deregulation suggests that similar policies to help ease the transition to substitute industries may increase the job-growth potential in these industries. One example of a complimentary policy in the context of CO_2 regulations would be tax incentives for manufacturing and distributing solar panels.

Regarding local policy makers whose districts may be hurt by such regulations, recruiting new industries to replace lost activity in the regulated sector would be prudent. Policy makers should also focus on training programs and job-placement assistance to help newly displaced workers transition to new jobs and on providing small business development assistance, all activities consistent with the Pareto compensation principle.

Chapter 5

Conclusion

This dissertation is comprised of three essays in policy analysis. The first outlines a dynamic general equilibrium model which is used to study revenue mobilization in developing economies who also have large informal sectors. We ask, how policy changes in tax rates and enforcement can be used to increase the level of formal sector activity while also increasing government revenue. Contrary to much of the existing literature, our simulations show that under certain conditions, increasing taxes can actually achieve the aforementioned goal. The key component of the model that allows the model to produce this result is the ability for the government to provide productive public goods, which also enables the government to maintain its delicate fiscal social contract with its constituents.

In the second essay, I contribute to the literature on resource extraction booms/busts by focusing on the proper selection of treatment date. First, I develop a theoretical framework for explaining why direct treatment effects and spillover effects might lag or lead the event causing the labor shock in the extraction sector. Furthermore, I argue that the assumption that treatment on the resource extraction sector and the adjacent sectors of the economy occur simultaneously does not hold and introduces bias into the estimates. I use the introduction of the SO_2 cap and trade program implemented by Title IV of the Clean Air Act Amendments as a source

of a negative shock to the Appalachian coal mining industry. To test the predictions of my framework, I employ the test for change in structural parameters introduced by Andrews (1993), and find that treatment in the mining sector occurs four years after the policy became effective in 1995. I also find that there is a second lag between the time the mining industry is affected and the spillover effects on the local aggregate economy are felt.

The final essay investigates environmental regulations effect on employment. The existing literature focuses on the negative impact on employment of regulation caused by increased cost of doing business. However, the question of whether the policy also creates jobs in other industries is largely ignored. In addition, this essay tests the predictions of the theoretical analysis in the case of a positive labor demand shock and explores the timing of multiplier effects at the sector level. Using the Clean Air Act Amendments of 1990 as a source of positive labor shock in the Western United States coal industry, whose coal was a substitute for Appalachias high sulfur coal, I find strong evidence of a boom in the regions mining sector. This boom lagged the treatment event by 4 years. I also find mixed evidence of positive spillover effects, with the retail and manufacturing sectors gaining jobs, but construction and retail losing in total sectoral income. I also discuss the implications these findings have for local policy makers whose communities are dependent on natural resource extraction, as well as national policy makers focusing on initiatives like the Clean Power Plan.

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Appendix

Appendix A

Additional Figures for Chapter 3

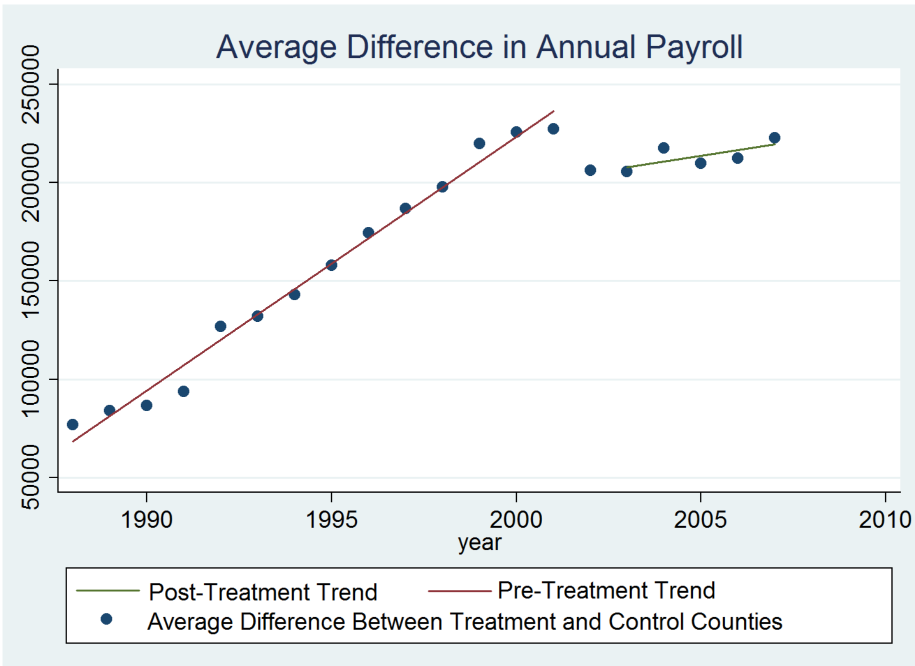

Figure A.1: Time Trends for Aggregate Annual Payroll

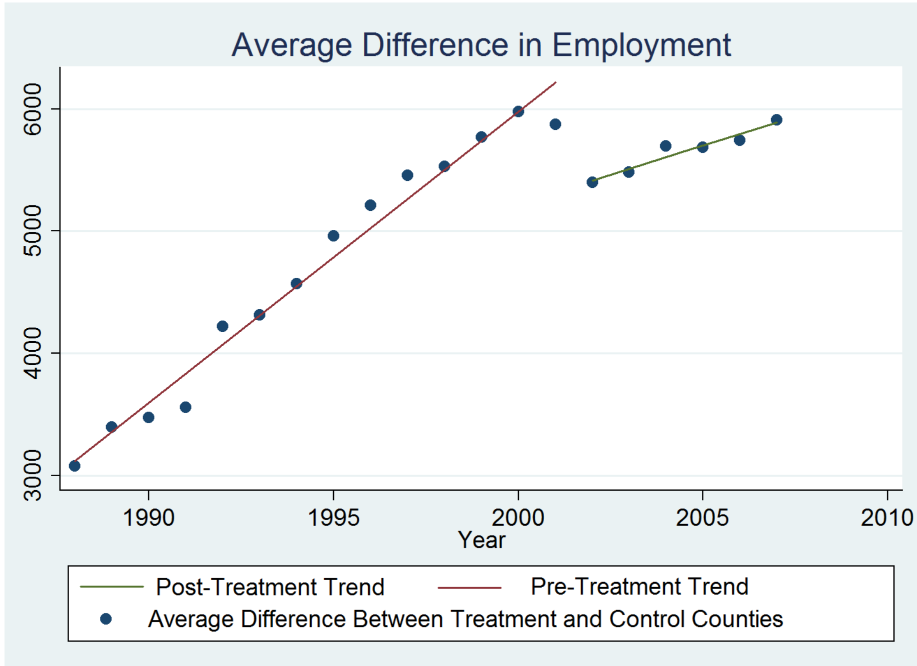

Figure A.2: Time Trends for Aggregate Employment

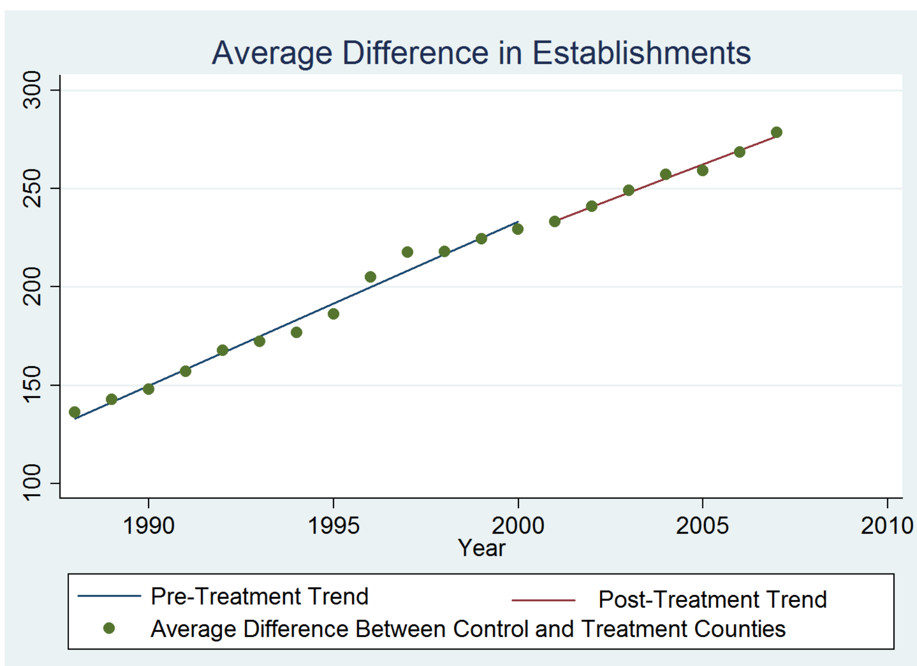

Figure A.3: Time Trends for Aggregate Number of Establishments

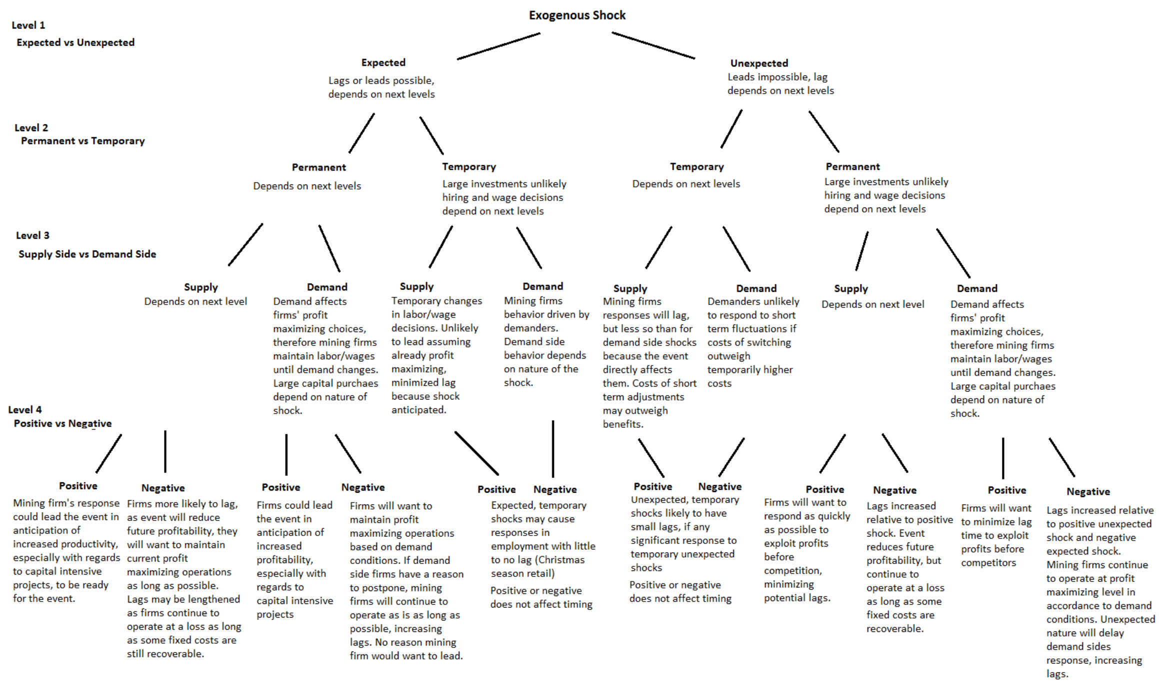

Figure A.4: Hierarchical Flow Chart of Determinants of Resource Extraction Sector Firms Responses to Exogenous Shocks

Appendix B

Additional Figures for Chapter 4

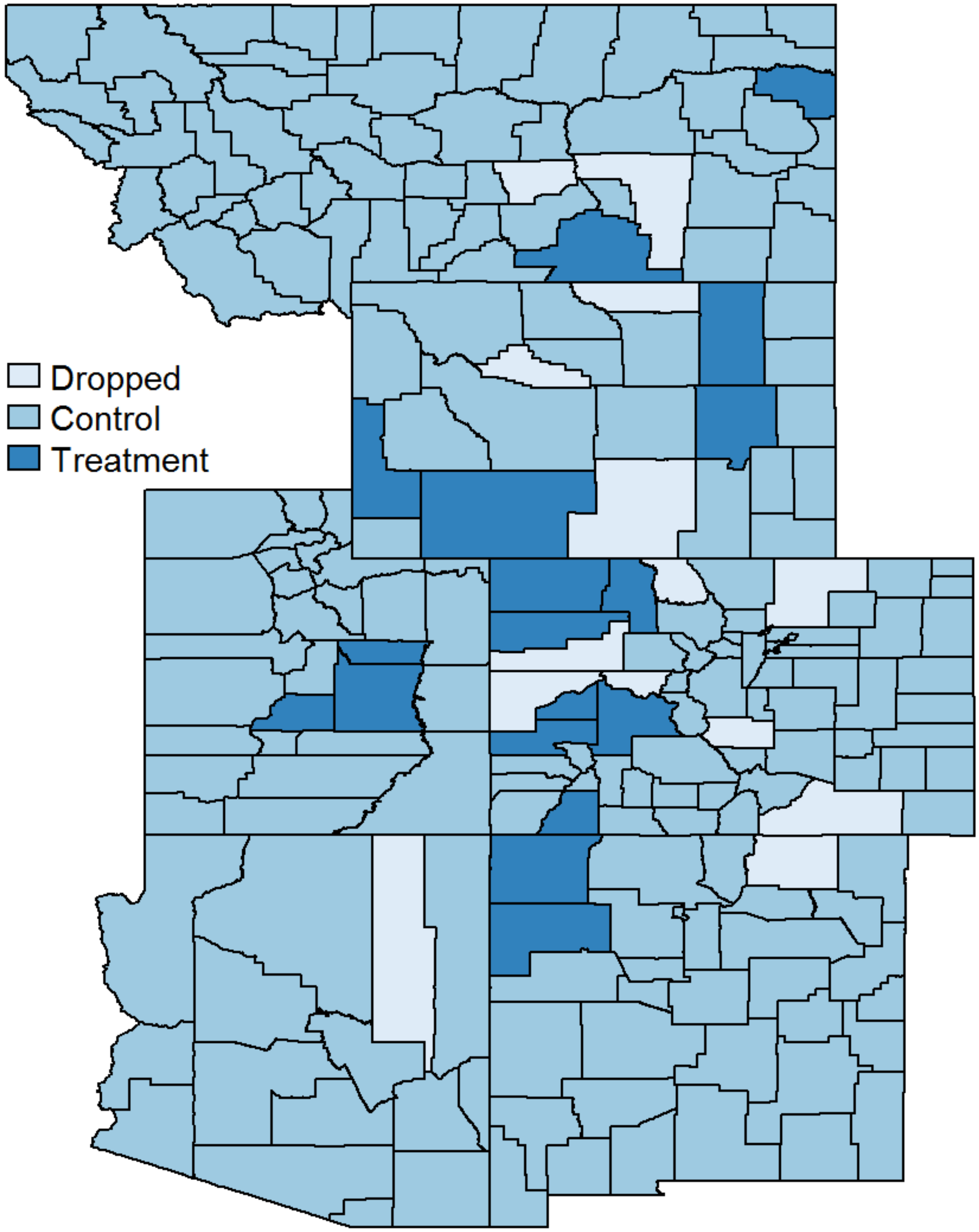

Figure B.1: Map of Treatment and Control Counties

Vita

Michael Craig was born in to Mike and Patti Craig in Houston, Texas on July 24, 1987. He was raised in Friendswood, Texas and graduated from Friendswood High School in 2006. He then moved to Rock Hill, South Carolina where he attended Winthrop University. While at Winthrop, Michael competed for the university's varsity Cross Country and Indoor and Outdoor Track & Field teams. Michael graduated from Winthrop University Cum Laude with a Bachelor of Arts in Economics. The following August, he moved to Knoxville, Tennessee to begin his graduate studies in economics at the University of Tennessee. He received his Master of Arts degree in Economics in August of 2013 and his Doctorate degree in Economics in August of 2016. Upon graduating from the University of Tennessee, he accepted a position at Lynchburg College in Lynchburg, Virginia.