How Disagreement Regarding Climate Change Affects Federal and State Efforts to Address It

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This paper seeks to empirically answer a fundamental question: which level of government—federal or state—should act to address climate change? To answer this, I develop a spatially and sectorally disaggregated equilibrium model of the US economy that accounts for how heterogeneity in environmental preferences with respect to climate change is likely to impact the distortions that emerge from federal and state decisionmaking. Using an environmental preference parameter that is recovered from my model of federal decisionmaking given the observed cap, permit allocation, and votes for the American Clean Energy and Security Act of 2009 (ACESA), I am able to conduct a positive revealed welfare analysis of federal and state climate policy that reflects policymakers' revealed valuation for emissions reductions. The central result of this analysis is that state policy results in a substantially smaller welfare loss than federal policy, although both policies lead to lower welfare relative to the policy that maximizes national aggregate surplus. Federal policy results from a majority coalition of climate 'believers' who establish an especially stringent cap that reflects their preferences for emissions reductions as well as free permits (green pork), resulting in a cap that is 31.4% lower than the emissions level which maximizes aggregate surplus and a welfare loss of \$67.0 billion. State policy, in contrast, results in a smaller cumulative emissions reduction that is 21.4% below the aggregate surplus maximizing emissions level, and has a corresponding welfare loss of \$27.3 billion. I then complement this analysis taking the policies from the revealed analysis as given but that instead uses a scientific estimate of the external costs of climate change of \$25 per ton CO_2e. From the perspective of scientific welfare, the revealed federal climate policy results in a welfare gain of \$90.4 billion which is greater than the welfare gain from revealed state policy of \$80.1 billion. I also discuss the distributional implications of federal and state policies and show how the choice of allocation rule under federal decisionmaking both critically impacts the likelihood that federal climate policy will pass as well as the distortionary implications of revealed federal policy.

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1 Introduction

Most scientists and economists recognize that anthropogenic climate change requires immediate and consequential action by policymakers. Yet, in the US there remains significant disagreement both between policymakers and those they represent as to whether policies to reduce greenhouse gas (GHG) emissions—the principal driver of climate change—should be enacted, reflecting widespread heterogeneity in environmental preferences for emissions reductions. While various policies have been proposed at the federal and state levels to reduce GHG emissions, given this heterogeneity which level of government should act to reduce GHG emissions is not clear. Wallace E. Oates (1972) seminal work on "fiscal federalism" suggests two divergent answers: federal decisionmaking may be preferred since GHG emissions are a global pollutant (i.e. spillovers are absolute) or state decisionmaking may be preferred when there is great heterogeneity in preferences between states. While Oates (1972) does not provide a clear path forward, the viability of both federal and state action in Oates' framework hinges upon the important assumption that policymakers seek or are able to maximize the welfare of the constituents within their respective jurisdictions. In practice, however, heterogeneity in preferences will interact with the political and fiscal mechanisms which determine federal and state policies, leading to the emergence of distortions which will critically impact the relative optimality of federal and state policy. At the federal level, heterogeneity in preferences determines which legislative coalitions will form which are unlikely to reflect the preferences of all legislators. At the state level, heterogeneity in preferences may lead 'believer' states to reduce their emissions unilaterally which in turn may be undermined by 'skeptic' states who expand production and thus emissions.

The purpose of this paper is to understand how heterogeneity in environmental preferences is likely to impact the welfare implications of federal and state efforts to address climate change. To this end, this paper poses four related questions. How does heterogeneity in environmental preferences determine the climate policies selected by federal and state governments? Secondly, which level of government should act to address climate change? That is, will state efforts to reduce climate change be more or less distortionary than federal efforts? Third, how do the distributional consequences of federal and state decisionmaking differ? Finally, can these efficiency and distributional outcomes provide insights regarding past and future federal and state efforts to address climate change?

To answer these questions I develop a spatially and sectorally disaggregated equilibrium model of the US economy in which emissions are generated and where preferences for emissions are heterogeneous. To evaluate federal decisionmaking, I develop a legislative bargaining model in the tradition of Baron and Ferejohn (1989) that attempts to explain the structure of the caps and permit allocations observed under the American Clean Energy and Security Act (ACESA) of 2009, the only federal climate policy to have passed at least a single chamber of the US Congress, the House of Representatives on June 26$^{\text{th}}$, 2009. In this model, a proposing federal legislator is randomly selected to propose an emissions cap and an allocation of free permits to various sectors, where the total value of free permits, or green pork, is jointly determined along with the cap level.[1] Permits are then distributed to legislative districts from each sectoral pool according to their relative exposure to each sector. Hence permits are not perfectly targeted to legislative districts and no voting legislative districts will also receive a positive allocation of permits relative to their sectoral exposures. In an analytical version of the model in which I restrict heterogeneity between districts solely with respect to their environmental preferences, I am able to show that the coalitions that are most likely to emerge at the federal level will be dominated by climate 'believers' who, because they receive positive utility from emissions reductions, will require a smaller allocation of green pork to secure their vote. This coalition of climate believers will likely choose a cap that is more stringent than that preferred by all legislators for two reasons. First, believers more greatly value emissions reductions than those outside of the coalition, and secondly, because a more stringent cap increases the overall pool of green pork available for redistribution which they also value.

I then develop a numerical version of the model to evaluate the key questions of the paper empirically. This model uses data from numerous spatial datasets to account for other important sources of heterogeneity such as: emissions intensity between districts, endowments, permit allocation, and sectoral composition. To complete the calibration of the legislative bargaining model I use the observed cap and permit allocation for 2021 under ACESA, as well as legislator's observed votes to recover conservative bounds on policymakers' revealed environmental preferences which reflect what policymakers revealed external damages would need to be in order to explain their vote. Given these preference parameters, I perform a positive, revealed welfare analysis of ACESA. I then aggregate these preferences by state, which allows me to perform a revealed

[1] The joint provision of these two public good streams reflects the logic of the "double dividend" long recognized in the environmental economics literature, namely a Pigouvian policy such as an emissions tax or an emissions cap generates tax or permit revenue which itself has value to society and can be used, for example, to reduce pre-existing distortionary taxes or otherwise distributed back to economic agents in society (e.g. Bovenberg and Goulder (1996)). Applying the legislative bargaining model to this context, thus provides a mechanism that explains how this revenue is likely to be recycled which is co-determined with the overall level of emissions reductions.

welfare analysis of state decisionmaking in which states compete in setting caps and distortions emerge as a result of horizontal fiscal competition first identified by Zodrow and Mieszkowski (1986). I compare both models to the policy that maximizes aggregate surplus nationally as well as the business as usual equilibrium of no climate policy. Finally, I complement the revealed welfare analysis with a scientific welfare analysis that takes the federal and state policies from the revealed analysis as given but which assumes that external damages from climate change instead reflect scientific estimates of external costs instead of my revealed estimate. This allows me to evaluate what policies selected as result of revealed preferences will mean for scientific welfare understood as the scientific external damages net of the efficiency loss of the policy.

I highlight four key findings from my analysis. First, with respect to revealed welfare, I find that state policy in which both offsets and trading are allowed is both less stringent and results in a substantially smaller welfare loss than federal policy, although both policies lead to lower welfare relative to the aggregate surplus maximizing policy. Federal policy results from a majority coalition of climate 'believers' who establish an especially stringent cap that reflects their preferences. This results in a cap that is 31.4% lower than the aggregate surplus maximizing emissions level, which is greater than the business as usual level of emissions since average revealed external benefits from reducing GHG emissions are negative \$0.07 per ton CO_2e per congressional district. Thus, federal policy corresponds to a revealed welfare loss of \$67.0 billion relative to the aggregate surplus maximizing level and \$47.1 billion relative to business as usual. In contrast, state policy reflects the actions of a few 'believer' states who unilaterally reduce emissions, which are offset by 'skeptic' states who move to expand their production, and thus expand emissions. State decisionmaking results in a cap that is just 21.4% below the aggregate surplus maximizing emissions level, corresponding to a revealed welfare loss of \$27.3 billion relative to the aggregate surplus maximizing level and \$7.4 billion relative to business as usual. This result is very robust across alternative calibrations of revealed preference parameters.

Second, in sharp contrast to the first result, I find that revealed federal policy is more likely to result in a scientific welfare gain than state policy, with both federal and state policy in which offsets and trading are allowed improving welfare. Federal policy results in a scientific welfare gain of \$90.4 billion relative to the revealed aggregate surplus maximizing level and \$14.7 billion relative to business as usual, whereas state policy results in welfare gains of \$80.1 and \$4.4 billion respectively. This result is less robust across alternative calibrations of revealed preference parameters.

Third, my revealed welfare analysis identifies an important distributional dichotomy between federal and state policy. Although federal climate policy results in a far greater revealed welfare loss than state policy, the welfare of believers is unchanged under federal policy, whereas under state policy the welfare of believers declines. This suggests that believers may prefer federal action all else equal.

Fourth, the way in which permits were allocated under ACESA has very important implications both for the likelihood of federal policy passing as well as the stringency of the cap that 'believers' select. If permits were equally distributed to all legislators, I find that no federal climate policy would pass. The imperfect targeting of permits to certain sectors in which fence-sitting yes voters have high exposure demonstrates how green pork is essential to grease the wheels of climate policy. This mechanism also allows no voters to receive more permits on average than yes voters and helps offset the burden of climate policy on no voters who are likely to be the most polluting districts. If permits could be perfectly targeted to legislators at just the level necessary to secure their vote and no more (with no voters receiving no permits), then the resulting cap would be even more stringent. Relative to business as usual, this amplifies the revealed welfare loss by 89.0% compared to the revealed welfare loss under ACESA and actually results in a 15.2% smaller scientific welfare gain. Better targeting increases the returns from hijacking as the proposer is able to extract ever more green pork for each additional reduction in emissions, but in this case results in overeating. As a consequence, imperfect targeting may actually be preferred to a perfect targeting mechanism for allocating permits. This suggests that the choice of allocation rule has important scientific welfare implications for the revealed cap which are not obvious *a priori* and further demonstrates the value of my revealed approach.

This paper proceeds as follows. Section 2 summarizes the literature that this paper contributes to. Section 3 provides an overview of ACESA. Section 4 introduces the model of the economy and provides details on how legislative bargaining determines a federal climate policy consisting of the joint determination of a cap and a permit allocation. Section 5 introduces the numerical model. There I discuss how heterogeneous preference parameters can be recovered by applying my legislative bargaining model to the ACESA vote and policy. I also discuss how state climate policy is made, how the policy that maximizes national aggregate surplus is determined, and provide the full numerical results. Finally, Section 6 concludes.

2 Review of the Literature

This paper contributes to three literatures. First, this paper contributes to a sizeable literature on "fiscal federalism" that attempts to understand the relative efficiency implications of centralized and decentralized decisionmaking.[2] While the focus of the theoretical literature in this area has been on richly characterizing the conditions and contexts in which centralized or decentralized decisionmaking is likely to be preferred, most empirical efforts have focused on econometrically testing certain model predictions using reduced form models, typically focusing on either decentralized or centralized decisionmaking.[3] To my knowledge, Banzhaf and Chupp (2012) is the only other attempt to use calibrated simulation models to empirically evaluate the welfare benefits of federal and state level decisionmaking with respect to environmental policy, although the context they examine is policies to address ambient air pollution generated by the electricity sector. This work differs from theirs in two important respects. First, my models of state and federal decisionmaking were chosen to capture realistic aspects of past efforts to address climate change and allow for the possibility for distortionary decisionmaking to result whereas Banzhaf and Chupp (2012) adopt an approach which abstracts from distortionary decisionmaking. Second, Banzhaf and Chupp (2012) assume that policymakers internalize estimates of the scientific external damages of air pollution when setting policy. In contrast, I exploit the ACESA vote and climate policy to infer what policymakers revealed environmental preferences would need to be to justify their vote which allows me to endogenously identify revealed policies and perform both revealed and scientific welfare analyses of those policies.

Second, my work contributes to the legislative bargaining literature. The bargaining model I develop differs from previous work in two ways. First, the joint determination of the cap and permit allocation explicitly links expansions in the global public good (emissions reductions) with expansions in the amount of local public goods (green pork or free permits) available for distribution. This differs from prior work that examined the allocation of purely local public goods (e.g. Baron and Ferejohn, 1989; Knight, 2005; Merlo and Tang, 2012), the allocation of local public goods with varying degrees of cross-border spillovers (Besley and Coate, 2003), or the allocation of purely local public goods

[2]For a review of the fiscal federalism literature see Oates (2005, 2008) and for the related 'environmental federalism' literature see Oates (2002) and Dijkstra and Fredriksson (2010). Finally, a closely related literature examines the welfare implications of political failure; see Battaglini and Coate (2007), for some useful references.

[3]Most recently, Boskovic (2013) evaluates whether decentralization under the US Clean Air Act of 1970 led to unintended emissions spillovers, finding evidence that sizable spillovers did emerge. Outside the context of environmental policy, a few papers have used calibrated simulation models to provide empirical estimates of the welfare impacts of decentralized fiscal competition (Parry, 2003; Wildasin, 1989; Sorensen, 2000, 2004). With respect to federal decisionmaking, Azzimonti et al. (2010) develop a calibrated dynamic model of legislative bargaining in the US that reflects the distortionary implications of deficit spending, and Merlo (1997) and Merlo and Tang (2012) have estimated stochastic legislative bargaining models to explain delays in coalition formation.

or a global public good (e.g. Volden and Wiseman, 2007 and 2008; Battaglini and Coate, 2007). In contrast, in my model legislators have two reasons for supporting a cap: they value emissions reductions, and/or they value the green pork generated from reducing emissions. As a result, the *ex post* coalition that forms in my model will almost always consist of members that highly value emissions reductions since they will require less green pork to secure their vote, and even if a proposer is a skeptic they may still propose a stringent cap since they still value pork. Because of this the amount of the global public good provided (emissions reduced) is more likely to be excessive both *ex post* and *ex ante* relative to the policy that maximizes national aggregate surplus. *Ex post* deviations from the aggregate surplus maximizing policy will thus reflect this additional 'hijacking' mechanism as well as the more conventional majoritarian bias discussed in Fredrikkson et al. (2010).[4] Second, in my model green pork can only be imperfectly targeted to districts. This is similar in spirit to Knight (2005) in that the ability for the proposer to perfectly target yes voters is restricted, although the mechanism differs in my model. In my model a proposer is allowed to jointly select a cap and an allocation of the cap to various sectors, such as oil refineries. Permits are then distributed to districts conditional on their exposure to those sectors. Fence-sitting legislators (moderates who vote for ACESA) may request a slice of permits to assist the industry which is most vulnerable in their district. Since fence-sitters have sectoral exposures that are similar to those of no voters, substantial permits may be allocated to no voters. This inability to perfectly target precisely the amount of permits needed to secure a minimum winning coalition of voters limits proposer power in the model and reduces the distortion caused by hijacking.

A third literature this paper contributes to is the literature that attempts to understand how political economy factors impact the allocation of emissions permits under cap and trade. Joskow and Schmalensee (1998) provide a captivating analysis of how political economy factors impacted the allocation of permits under the Acid Rain Program of the 1990 Clean Air Act Amendments. Similar to my analysis of alternate allocation rules, they consider several hypothetical permit allocations and demonstrate their limitations relative to the allocation rule that was actually adopted. However, by recovering the preference parameters of legislators, I am also able to evaluate how alternate allocation rules can impact the distortionary implications of the resulting cap.

[4]While the environmental context is a compelling one, the model developed here can be used to inform decisionmaking in other areas. For example, the Affordable Care Act of 2010 internalizes externalities in health insurance markets by mandating individual coverage through threat of penalty, but then uses those funds to finance other aspects of the program such as subsidies for low-income individuals. Curiously, there appears to be sharp heterogeneity in preferences with respect to this law as well, as reflected in the shutdown of the federal government in late 2013.

3 The American Clean Energy and Security Act of 2009

HR 2454, the American Clean Energy and Security Act of 2009 (ACESA)—more commonly known as the "Waxman-Markey" climate bill because of its proposers Rep. Henry Waxman (D–California) and Rep. Ed Markey (D–Massachusetts)—was the first and so far the only federal climate bill to pass at least a single chamber of Congress, the US House of Representatives on June 26th, 2009. Previous attempts to address climate legislation took place through the Senate, with all attempts ultimately failing to come up for a vote.[5] Serious discussions to address climate change under Barack Obama's presidency, on the other hand, began in the Democratic controlled House of Representatives. The desire to move climate legislation forward in the House was partially predicated on the existence of a simple majority threshold required there as opposed to the Senate, which according to procedural rules effectively requires a super-majority of 60% of its members. The vote for ACESA of 219 to 212 was tight and largely fell on party lines with 211 Democrats joining 8 Republicans in voting yes and 169 Republicans joining 43 Democrats in voting against.

ACESA is a cap and trade policy consisting of two main components. First, ACESA sets national caps on emissions for each year between 2012 and 2050, covering 84% of all emissions produced in the United States by 2050. Second, each annual cap provides a pool of emissions permits. This pool of "green pork" was largely allocated freely to various sectors such as electricity generators and low-income consumers. Table 1 reports the caps and division of each cap as free permits across sectors for select years. Until 2025, roughly 99% of the cap was to be freely allocated. This declines each year between 2026 and 2050 with only about 46% of allowances freely distributed by 2050.[6]

Both the caps and these permit shares were negotiated jointly as ACESA made its way to the House floor. Starting in the House Energy and Commerce Committee in May 2009, critical early negotiations occurred with a bloc of moderate Democratic representatives in industrial districts led by Representative Rick Boucher (D–Virginia), an ally of the coal industry and whose own district was heavily dependent on coal for electricity generation purposes (Holly, 2009). Several important concessions were made in this first round of negotiations. Waxman, the committee chairman, advocated a cap on 2020 emissions set 20% below 2005 levels. Boucher's starting offer was a 2020 cap that was 6% below 2005

[5]These attempts include: the Clean Air Planning Act of 2003, the Climate Stewardship and Innovation Act of 2007, the Low Carbon Economy Act of 2007, and the Lieberman-Warner Climate Security Act of 2008.

[6]These percentages included permits directly allocated to sectors as well as permits auctioned off on their behalf. The remainder was to be auctioned off by the government with proceeds used to finance deficit reduction and/or a Climate Change Consumer Refund (Environmental Protection Agency, 2009).

levels, with final agreement attained on a reduction in emissions of 17% of 2005 levels by 2020. This 17% was higher than the 14% reduction proposed under President Obama's fiscal year 2010 budget (Holly, 2009).[7]

In exchange, Boucher secured allowances totalling 35% of the cap to the electricity industry, accounting for roughly 90% of the emissions from that sector. This includes a carve-out of allowances of 5% of the cap to merchant coal generators, which was used to attract House members from Texas and the Midwest, who had a larger share of merchant coal-fired power plants (Behr, 2009). Allowances for an additional 9% of the cap would go to LDCs for natural gas, and a further 5% of the cap for carbon, capture and storage (CCS). As part of a deal worked out with Representative Mike Doyle (D–Pennsylvania) and other legislators from manufacturing districts, allowances comprising 15% of the cap would be allocated to vulnerable industries such as steel, aluminum, and chemical producers. To secure support of Representative Gene Green (D–Texas), oil refiners were assured an additional 2% of the total allowance pool.[8] These allowances would continue at this level until 2025, gradually decline until 2030, at which point they would be fully eliminated (Holly, 2009). Given these negotiations ACESA passed the House Energy and Commerce Committee by a vote of 33 to 25 on May 21st, 2009.

A second obstacle to securing passage in the House, emerged when Representative Collin Peterson (D–Minnesota), chairman of the House Agriculture Committee, threatened to send the bill to his committee for a full mark-up unless additional concessions were made on behalf of US agriculture. Peterson was brought on board (and a contingent of 45 legislators, largely from the Midwest, who were siding with him) on June 22nd, after Waxman agreed to USDA oversight of offsets, as well as additional concessions. Finally, on the day ACESA went up for a full House vote, Waxman continued to cut deals on the floor until the bill passed, adding an additional 300 pages to its already considerable 1,200 pages (Tankersley, 2009).

[7] Although, Obama offered a lower reduction of 14% based on earlier efforts in this area, he also offered a 100% auction of permits, which industry groups opposed, largely because details on how auction proceeds would be distributed were never fully articulated and were assumed to consist of per-capita rebates to consumers (Pooley, 2010). The linkage between the stringency of the cap and the permit allocation has even been recognized in the popular press; as Eric Pooley notes, "Basically more allowances and offsets meant [coal-fired utilities] could agree to more aggressive 2020 reductions" (Pooley, 2010).

[8] Green reportedly said: "I can't vote for a bill unless my refineries [are protected] because of the nature of my district, it's a job base and a tax base" (eNewsUSA, 2009).

4 Model

4.1 The Economy

Consider a model of the national economy consisting of $d = 1,\ldots,D$ legislative districts. Economic behavior is characterized by agents aggregated at the district level and is denoted by subscript d. Goods in the economy include two primary inputs, labor, L_d, and capital, K_d; $s = 1,\ldots,S$ intermediate capital goods, k_{sd}; a composite of the intermediate capital goods, y_d; and one final good, x_d, which I assume is the numeraire. Labor, intermediate goods, and the composite are assumed to be immobile whereas all other goods are assumed to be perfectly mobile.

4.1.1 Emissions

I distinguish between emissions produced in a district, E_d, and emissions facing consumers located within a district, e_d. Emissions are generated in each district by final good producers according to:

$$E_d = \sum_{s=1}^{S} \alpha_s k_{ds}, \tag{4.1}$$

where $\alpha_s > 0$ simply states the amount of emissions produced per unit of k_{sd}, which is assumed to be constant between districts. Accordingly, the total amount of emissions generated in the economy is simply: $E_0 = \sum_d^D E_d$.

4.1.2 Preferences

Consumers located in each district have preferences over the final good and emissions. They elect a representative to the national legislature who has preferences given by:

$$u_d(x_d, e_d) = x_d - \phi_d E_0, \tag{4.2}$$

where ϕ_d reflects the marginal external damages from GHG emissions to all consumers in the district or the environmental preference parameter of the legislator, which can be positive (climate 'believers') or negative (climate 'skeptics').[9]

[9]Given a few additional assumptions, (4.2) can be understood in two ways: as a monotonic transformation of the preferences of the median voter, or as the utilitarian sum of the utility of all consumers in the district. To see this, define the preferences of consumers $c(d)$ located in district d as: $u_{c(d)} = x_{c(d)} - \phi_{c(d)} E_0$, where $\phi_{c(d)}$ is assumed to be distributed given a symmetric discrete probability distribution function with median (mean) $\phi_{\mu(d)} = \frac{\phi_d}{P_d}$, P_d is the number of consumers who are all assumed to be voters, and $\phi_d = \sum_{c(d)}^{P_d} \phi_{c(d)}$. Then the preferences of the median voter is given by: $\frac{x_d}{P_d} - \phi_{\mu(d)} E_0$, where $x_d = \sum_{c(d)}^{P_d} x_{c(d)}$, which after multiplying across by P_d (a monotonic transformation), is simply (4.2). Alternately, the utilitarian sum of the preferences of all consumers is given by: $\sum_{c(d)}^{P_d} x_{c(d)} - \phi_{c(d)} E_0 = x_d - \phi_d E_0$.

Given a rate of return to capital, r, each district supplies capital, K_d, according to:

$$K_d = K_d(r) = \zeta_d^{-\eta_d} r^{\eta_d}, \tag{4.3}$$

where ζ_d is a scaling parameter and η_d is the elasticity of capital supply. Since I assume that capital is elastically supplied, and emissions are assumed to vary with the amount intermediate capital used in production, total emissions in the economy will vary given the rate of return to capital.

In addition to supplying capital, consumers also possess a fixed labor endowment, $\bar{L}_d$. Thus, the private budget constraint facing the consumer is given by: $x_d = \pi_d + rK_d$ where π_d is the net returns from producing the final good. When there is no federal climate bill, π_d simply equals the returns to the labor endowment, $\hat{\pi}_d(r)$. Under a climate bill, π_d equals the returns to the labor endowment, $\hat{\pi}_d(r, P)$, plus the value of permits freely allocated to the district, $P\xi_d$, where P is the price of permits and ξ_d is the number of permits freely allocated to the district. Consumer's choose x_d to maximize (4.2) subject to this budget constraint. Emissions are exogenous to consumers and thus in the absence of government intervention they do not consider the impact of their choices on emissions. This provides the Walrasian demand for the final good which is given by: $x_d(r)$ when there is no climate bill and $x_d(r, P, \xi_d)$ when there is a climate bill.

Legislators consider aggregate surplus when making decisions, which is given by:

$$U_d(x_d, E_0, r) = u_d(x_d, E_0) - \kappa_d(r), \tag{4.4}$$

where $\kappa_d(r) = rK_d(r) - \int_0^r K_d(x)\,dx = \zeta_d^{-\eta_d}\left(\frac{\eta_d}{1+\eta_d}\right)\left(r^{(1+\eta_d)}\right)$ is the cost of supplying capital. Legislators optimize over (4.4) and not (4.2) to account for the change in welfare from supplying capital to their district given the upward sloping capital supply curves.

4.1.3 Production

The final good is produced by a representative firm under perfect competition according to the following constant-returns-to-scale production function:

$$X_d = f_d(y_d, l_d), \tag{4.5}$$

where X_d is the amount of the private good supplied, y_d is the amount of capital composite demanded, and l_d is labor demanded.

The capital composite is produced according to the following constant-returns-to-scale Leontief production function:

$$y_d = \min\left\{\frac{k_{ds}}{\omega_{ds}}\right\}_{s=1}^{S}, \tag{4.6}$$

where k_{ds} is the amount of sector s capital used to produce the capital composite, and ω_{ds} is a parameter specifying the amount of capital intermediate, k_{ds}, demanded per unit of y_d.[10] Given this, note that the emissions generated by a district can instead be written as: $E_d = \alpha_d y_d$, where $\alpha_d = \sum_{s=1}^{S} \alpha_s \omega_{ds}$ is the amount of emissions produced per unit of the capital composite which differs by district. Thus the Leontief production function assumed above allows us to capture differences in emissions intensity by district in their production of the composite good and which is an additional source of heterogeneity in the model.

Under a national cap, producers must have enough permits—either freely allocated according to the federal climate bill, ξ_d, or purchased/sold from a perfectly competitive permit market, N_d—to at least equal the emissions they generate, E_d. As such, given (4.5) and (4.6), the representative firm located in each district maximizes profits according to:

$$\begin{aligned}
\max_{y_d \geq 0, \{k_{ds}\}_{s=1}^{S} \geq 0, N_d \lesseqgtr 0} \quad & f_d\left(y_d, \bar{L}_d\right) - r y_d - P N_d \\
\text{subject to:} \quad & E_d \leq \xi_d + N_d, \\
& y_d = \min\left\{\frac{k_{ds}}{\omega_{ds}}\right\}_{s=1}^{S}.
\end{aligned}$$

where P is the market clearing price of permits, and I have imposed market clearing in the local labor market, i.e. $l_d = \bar{L}_d$. Under constant returns, production according to (4.5) results in no pure profits. Thus for simplicity I define $\hat{\pi}_d$ as the returns to the labor endowment instead of explicitly tracking local wages. This is simply the value function to (4.7) less the value of free permits.

The first constraint in (4.7) forces firms to internalize their own emissions on their production decision when $P > 0$, which is determined by the emissions cap established under the federal climate bill, $\bar{E}_0$. Summing this constraint across all districts and imposing the national cap I have: $\sum_{d=1}^{D} E_d \leq \sum_{d=1}^{D} (\xi_d + N_d) \leq \bar{E}_0$.[11] In the absence of a

[10] Since y_d is a composite of capital and I wish to keep things in consistent units of capital throughout, I restrict $y_d = \sum_{s=1}^{s} k_{ds}$, which is the same as requiring that $\sum_{s=1}^{S} \omega_{ds} = 1$ since (4.6) implies that $k_{ds} = \omega_{ds} y_d$. The Leontief specification allows me to greatly simplify the solution for the economic equilibrium which in this model is conditional on the model of policy formation, and so must be solved for repeatedly.

[11] Note that for $P > 0$, permits have value to legislators and so they will maximize the allocation of free permits which occurs when $\sum_{d=1}^{D} \xi_d = \bar{E}_0$. Thus total emissions will be less than or equal to the national

national climate policy, firms instead maximize $f_d\left(y_d,\bar{L}_d\right)-ry_d$ subject to (4.6).

Given (4.7), the unconditional factor demands for the capital composite and intermediate capital goods are given, respectively, by: $y_d(r,P)$ and $k_{sd}(r,P)$ for all $s=1,...,S$. Likewise, permits are demanded or supplied according to $N_d(r,P,\xi_d)$, where a positive value denotes demand and a negative value denotes supply; the supply of the final good is given by $X_d(r,P)$; and the returns to the labor endowment is given by $\pi_d(r,P)$. Total firm profits equal the returns to the labor endowment plus the value of free permits provided to the firm under the federal climate bill: $\hat{\pi}_d(r,P,\xi_d)=\pi_d(r,P)+P\xi_d$. When there is no climate bill these expressions are instead simply a function of r, hence $\hat{\pi}_d(r)=\pi_d(r)$.

4.1.4 Equilibrium

An *economic equilibrium* is a price pair r,P such that markets clear:[12]

$$\begin{aligned}
&\sum_{d=1}^{D}K_d(r)=\sum_{d=1}^{D}y_d(r,P),\\
&\sum_{d=1}^{D}x_d(r,P,\xi_d)=\sum_{d=1}^{D}X_d(r,P),\\
&\sum_{d=1}^{D}\left(\xi_d+N_d(r,P,\xi_d)\right)=\bar{E}_0.
\end{aligned}\tag{4.7}$$

I note that the economic equilibrium is conditional on the federal climate policy selected as a result of the legislative process.

4.2 Legislative Bargaining With Imperfect Targeting

Federal climate policy is determined through legislative bargaining using a novel legislative bargaining model in the spirit of Baron and Ferejohn (1989) and Volden and Wiseman (2007, 2008).[13] The legislative bargaining model that I develop mirrors

cap so long as the permit market clear according to: $\sum_{d=1}^{D}N_d\leq 0$. We abstract from issues related to market power in permit markets as Montero (2009) finds no evidence that this has been a concern in other permit regimes.

[12] According to Walras' Law, only two of these three equations need be satisfied.

[13] Fredrikkson et al. (2010) is also related to my effort here in that they examine the role of majority bias in the choice of an emissions tax by a central government. They are able to show that when there is heterogeneity in incidence as well as heterogeneity in emissions spillovers between districts that a simple majority of legislators will select either a vector of district level taxes or a uniform tax that places a greater burden on those districts not in the majority. Their approach, however, assumes homogeneity in preferences for the environmental good, ignores the endogeneity of coalition formation in the presence of heterogeneity, and takes the allocation of tax revenue as exogenous. All of these assumptions are relaxed in the framework I develop here, and thus the majority bias I identify is likely to be even more distortionary.

the logic of the ACESA climate bill in that permits are allocated to legislative districts indirectly by first allocating shares of the national cap to various sectors and then to legislators conditional on their exposure to those sectors. The inability to directly target permits to districts is what is meant by imperfect targeting. Imperfect targeting implies that a proposing legislator is forced to use a blunt instrument to assign the green pork necessary to get his/her bill passed. The determinants of imprecision may reflect a desire to obscure blatant pork barrel spending from constituents, or may reflect a desire to pad minority excesses should legislators one day find themselves in the minority instead of the majority (Diermeier and Fong, 2011).

Imperfect targeting restricts a proposing legislator from being able to explicitly target the distributional component of the policy to those who end up in the voting majority.[14] This raises the costs to building a legislative majority and diminishes the space in which a proposing legislator is able to get a bill passed. In addition, imperfect targeting weakens the ability of the proposing legislator to funnel residual distributional benefits (those remaining after a majority coalition has been bought out) to their own district. Put in terms of the literature in this area, imperfect targeting reduces proposer power (Knight, 2005).[15] In the context of climate policy, legislators who vote against the legislation may still receive some positive allocation of free permits because of imperfect targeting.[16] Imperfect targeting allows us to capture important empirical realities that a model with perfect targeting (i.e. the classical models of Baron and Ferejohn (1989), Volden and Wiseman (2007, 2008)) would not allow us to capture. Similar realities persist in other contexts in which legislative bargaining models have been applied to observed votes, such

[14]The joint determination of the cap and permit allocation is not a violation of the "independence property" between the cap and the allocation detailed by Hahn and Stavins (2011), but, rather, reflects the connectedness between the cap and permit allocation through the political mechanism; as they note: "The choice of an environmental goal and the choice of a particular policy instrument for achieving that goal may be connected, and similarly it is possible that the choice of the cap-and-trade system may be connected with the choice of a specific allocation."

[15]In Knight's model a non-majoritarian gate-keeping committee decides how to split a fixed budget (the Highway Trust Fund surplus) into two, a portion that is equally divided to everyone in the gate-keeping committee and another portion that is equally divided to everyone else. Since the gatekeeping committee lacks a majority on its own, it must allocate some portion of funds to those outside of the committee such that the policy passes under a majority vote. Since permits allocated outside of the committee cannot be targeted, super-majoritarian committees are not uncommon, which reflects historical legislative votes in the area Knight examines. This model is not well suited to the context of climate policy, however. While the Highway Trust Fund is consistently allocated by the House Committee on Transportation and Infrastructure, major policy initiatives, such as climate change policies like ACESA, can originate from several committees, and once leaving the originating committee may still be held up by other committees. As Section 3 shows this in fact occurred in the negotiations over ACESA.

[16]In spite of receiving permits, these legislators still vote against the policy and so this will have implications for these districts revealed environmental preferences; that is, they must be especially skeptical.

as the allocation of the Highway Trust Fund in which even no voting legislators receive a positive allocation of the fund (Knight, 2005). Thus, although I apply my model to an environmental context, imperfect targeting may provide insights that are relevant to other contexts as well.

A federal climate policy consists of a national cap on emissions, $\bar{E}_0$, as well as a vector of shares of the cap that are to be allocated to various sectors $\boldsymbol{\theta} = \{\theta_s\}_{s=1}^{S}$. Given a federal climate policy, $\left(\bar{E}_0, \boldsymbol{\theta}\right)$, the total number of free permits allocated to a sector equals: $\theta_s \bar{E}_0$. Since the total number of permits freely allocated to sectors must be less than or equal to the national cap, I require that $\sum_{s=1}^{S} \theta_s \leq 1$.

A district's *exposure* to a given sector, δ_{ds}, determines the proportion of a sectoral permit allocation that a district will receive. Consequently, the number of permits going to each district, ξ_s, equals:

$$\xi_d = \sum_{s=1}^{S} \delta_{ds} \theta_s \bar{E}_0, \tag{4.8}$$

where $\sum_{d=1}^{D} \delta_{ds} = 1$. For economic sectors, a district's exposure equals the proportion of capital demanded by that district for that sector to the total amount of capital demanded by that sector across all districts: $\delta_{ds}\left(\bar{E}_0, \boldsymbol{\theta}\right) = \left(\frac{k_{ds}\left(\bar{E}_0, \boldsymbol{\theta}\right)}{\sum_{d=1}^{D} k_{ds}\left(\bar{E}_0, \boldsymbol{\theta}\right)}\right)$.[17] Note that both the numerator and denominator are functions of $\left(\bar{E}_0, \boldsymbol{\theta}\right)$, which is to say that exposure to economic sectors will depend upon how firms alter production in response to a national emissions cap.

The legislative process is represented as a one-shot noncooperative bargaining game. In the first stage, a proposing legislator denoted by subscript p is randomly drawn from all D representatives. Under a closed rule, the proposer can offer a policy that cannot be later amended. Given a proposal, all legislators vote on whether or not to accept the climate policy. A legislator will vote for the climate policy ($v_d\left(\bar{E}_0, \boldsymbol{\theta}\right) = 1$) if its aggregate surplus under the climate policy equals or exceeds its aggregate surplus under no policy, that is if $U_d\left(\bar{E}_0, \boldsymbol{\theta}\right) \geq U_d^{BAU}$, where the superscript BAU reflects the solution to the economic model under business as usual or no policy. If the reverse inequality holds then the legislator will vote against the policy ($v_d\left(\bar{E}_0, \boldsymbol{\theta}\right) = 0$). If at least a simple majority (D_M) of legislators vote in favor, i.e. if $\sum_{d=1}^{D} v_d\left(\bar{E}_0, \boldsymbol{\theta}\right) \geq D_M$, then the climate policy is implemented at the beginning of the next period. Thus, the proposer selects the $\left(\bar{E}_0, \boldsymbol{\theta}\right)$ that will maximize their aggregate surplus, $U_p\left(\bar{E}_0, \boldsymbol{\theta}\right)$, subject to the majority

[17] Note the price pair that characterizes the economic equilibrium, (r, P), is itself a function of the federal climate policy, $\left(\bar{E}_0, \boldsymbol{\theta}\right)$. So instead of writing $k_{ds}(r, P)$ I can now write $k_{ds}\left(\bar{E}_0, \boldsymbol{\theta}\right)$.

voting constraint:

$$\begin{aligned} \max_{\bar{E}_0,\boldsymbol{\theta}} \quad & U_p\left(\bar{E}_0,\boldsymbol{\theta}\right) \\ \text{subject to:} \quad & \sum_{d=1}^{D} v_d\left(\bar{E}_0,\boldsymbol{\theta}\right) \geq D_M, \\ & U_p\left(\bar{E}_0,\boldsymbol{\theta}\right) \geq U_p^{BAU}, \\ & \sum_{s=1}^{S} \theta_s \leq 1. \end{aligned}$$

where $D_M = \frac{D+2}{2}$ ($D_M = \frac{D+1}{2}$) if D is even (odd).

4.2.1 Equilibrium Characterization

Following Baron and Ferejohn (1989), I restrict my attention to the unique pure strategies equilibrium. Unlike many other legislative bargaining models, my proposer solves equation (4.9) taking into account the impact of their policy choices on the economic equilibrium and thus a general analytical solution to equation (4.9) is not possible.

However, in the next section I consider a restricted version of the model for which an analytical solution is possible in order to provide intuition regarding how heterogeneity in environmental preferences impacts the solution to my legislative bargaining model with imperfect targeting.

4.2.2 Implications of Legislative Bargaining Model with Imperfect Targeting

Consider a model consisting of one sector, i.e. $S = 1$. Ignore labor in the model and define equation (4.5) as $X_d = \gamma y_d$. Assume that districts are identical in every way except with respect to their environmental preferences, that is restrict $\zeta = \zeta_d$, $\eta = \eta_d$, $\rho = \rho_d$, and $\omega = \omega_d$ for all districts $d = 1,...,D$. Assume that $\gamma \geq \left(\frac{1+\eta}{\eta}\right)$. Given $\omega = \omega_d$, it is also the case that $\alpha = \alpha_d$ for all $d = 1,...,D$.

For simplicity also assume that ϕ_d is distributed uniformly on the interval $[\phi_L, \phi_H]$, where $\frac{\gamma}{D\alpha(1+\eta)} > \phi_H > \phi_L > 0$.[18] Let district subscripts be sorted such that $\phi_1 > ... > \phi_D$.

[18] The restriction that $\frac{\gamma}{D\alpha(1+\eta)} > \phi_H$ is for analytical tractability. This emerges from the requirement that the cap selected under indirect targeting, $\bar{E}_0^{IT}$, be greater than the cap that generates the greatest amount of permit revenue, $\bar{E}_0^{RM}$, that is to say, that proposed caps are assumed to lie on the right side of the 'Laffer curve' with respect to permits where a tighter cap always implies more permit revenue. The requirement that $\phi_L > 0$ means climate beliefs cannot be negative, and thus all possible proposers $p = 1,...,D$ will choose an imperfect cap that results in emissions reductions. Were $\phi_L < 0$ then some proposers may seek to achieve an imperfect cap (a mandate) that is greater than emissions under no policy. In that case the cheapest districts to bring into an electoral coalition will be the $d = D_M + 1,...,D$ group of skeptics, and given the previous assumption emissions increases are substitutes for green pork.

Given this $\phi_1 = \phi_H$ is the greatest climate believer and $\phi_D = \phi_L$ is the greatest climate skeptic. All those districts in between will be believers if $\phi_d > 0$ or skeptics if $\phi_d \leq 0$. An important implication of this assumption is that: $U_1\left(\bar{E}_0\right) - U_1^{BAU} < ... < U_D\left(\bar{E}_0\right) - U_D^{BAU}$ for all $\bar{E}_0 \leq E_0^{BAU}$. Effectively, this means that the districts $d = 1, ..., D_M$ will be the cheapest to bring into any electoral coalition.

Since any randomly drawn proposer p will wish to maximize the permits they receive by minimizing the permits they allocate to others, the proposer will seek to offer sufficient permits to get $D_M - 1$ of this group of believer stalwarts on board and then round out any majority coalition with themselves. To avoid subscript confusion I will assume the proposer p is selected from $D_M, ..., D$, and so p plus all of those districts from $d = 1$ to $d = D_M - 1$ will be the core of my yes voting electoral coalition. I compare the results of my model with imperfect targeting to a model where perfect targeting or permits is possible. In this case, the proposer's problem is similar to (4.9), except that the proposer chooses a vector of shares to allocate directly to each district, $\boldsymbol{\theta} = \{\theta_d\}_{d=1}^{D}$, instead of a vector of shares to sectors, $\boldsymbol{\theta} = \{\theta_s\}_{s=1}^{S}$, and the final constraint in (4.9) is instead $\sum_{d=1}^{D} \theta_d \leq 1$.

Given these assumptions, I can provide some intuition regarding the mechanics of the model. I note that under imperfect targeting, that the firms in each district all have identical production processes and so exposure is identical for all districts, that is, $\delta = \frac{1}{D}$. Thus, for any share of the cap, θ, (only one since $S = 1$) that determines the total pool of permits $\theta\bar{E}_0$ available, each district will be provided an equal number of the permits generated, that is, $\xi_d = \frac{1}{D}\theta\bar{E}_0$ for all $d = 1, ..., D$. Since aggregate surplus is unbounded in x_d and x_d is linear in the value of permits received, any randomly drawn proposer p will choose $\theta = 1$ since this is when the total value of permits they receive will be maximized, and so $\xi_d = \frac{1}{D}\bar{E}_0$ for all $d = 1, ..., D$, where I omit the superscript p for ease of notation. Note that while ξ_d is identical for all $d = 1, ..., D$ under imperfect targeting, under perfect targeting each permit vector will be unique since $\xi_d = \theta_d\bar{E}_0$.

Implications for the Distribution of Permits and Proposer Power

Imperfect targeting provides a blunt instrument for getting legislators on board to pass a climate policy. While the proposer will always select $\theta = 1$, the share of permits needed to secure the coalition, $\hat{\theta} = \hat{\theta}\left(\bar{E}_0\right)$ will be determined by the aggregate surplus of the $D_M - 1$ yes voter such that: $U_{D_M - 1}\left(\hat{\theta}, \bar{E}_0\right) = U_{D_M - 1}^{BAU}$. For all other yes voting districts $d = 1, ..., D_M - 2$ it must be the case that $U_d\left(\hat{\theta}, \bar{E}_0\right) > U_d^{BAU}$, given my assumptions. Thus imperfect targeting will increase the aggregate surplus of most yes voters above and beyond their aggregate surplus under no policy. In addition, $\frac{D - D_M}{D}$ of permits will be allocated to voters who will vote against the policy. From the perspective of the proposer both overcompensating yes voters and compensating no voters is a waste as it implies fewer permits that the proposer will be able to sequester to their own district.

Excess permits available to the proposer—the pool of permits over and above those necessary to secure a majority coalition—under imperfect targeting can be defined as $\frac{1}{D}\left(1-\hat{\theta}\right)$. In sharp contrast, under perfect targeting the proposer would choose $\hat{\hat{\theta}}_d = 0$ for all no voters, and exactly the number of permits needed to obtain the vote of yes voters, that is $\hat{\hat{\theta}}_d = \hat{\hat{\theta}}_d\left(\bar{E}_0\right)$ will be chosen such that: $U_d\left(\hat{\hat{\theta}}_d, \bar{E}_0\right) = U_d^{BAU}$ for all $d = 1, ..., D_M - 1$.[19] Thus, excess permits under perfect targeting will be defined as $1 - \sum_{d=1}^{D} \hat{\hat{\theta}}_d$, which I note is greater than $\frac{1}{D}\left(1-\hat{\theta}\right)$ for any $\bar{E}_0$.

Imperfect targeting, in addition to forcing the proposer to overcompensate yes voters and compensate no voters, also restricts the ability of the proposer to sequester the pool of excess permits directly to their district. For the $\frac{1}{D}\left(1-\hat{\theta}\right)$ of additional permits that the proposer is able to sequester to their district as a result of having proposer power, imperfect targeting forces them to distribute permits to all other districts equal to $\frac{D-1}{D}\left(1-\hat{\theta}\right)$. In contrast, under perfect targeting all of the $1 - \sum_{d=1}^{D} \hat{\hat{\theta}}_d$ total excess permits are provided solely to the proposer. Since the proposer must obtain aggregate surplus under a climate policy at least equal to its aggregate surplus under no policy, $U_p\left(\bar{E}_0\right) \geq U_p^{BAU}$, the inability to perfectly target excess permits to the proposer limits the parameter space in which a proposer is willing to choose a climate policy that will result in emissions reductions. Thus the inability to target green pork decreases the likelihood of climate policy getting passed.

Implications for the Optimal Cap

So far this analysis has simply considered how permits are allocated conditional on the cap level chosen by proposer p, $\bar{E}_0$. So long as $\bar{E}_0$ is fixed, the analysis is similar to the classical legislative bargaining models which assume a fixed budget to be allocated to different legislative districts (Baron and Ferejohn (1989), Volden and Wiseman (2007, 2008)). In my model, however, the cap is itself endogenous reflecting the fact that emissions reductions themselves are jointly determined alongside the total value of free permits or green pork, available for redistribution. Consequently, my models of perfect and imperfect targeting will yield different cap levels, $\bar{E}_0^{DT}$ and $\bar{E}_0^{IT}$, respectively. Given that I have already characterized the minimum number of permits needed to secure yes

[19]Unless of course $U_d\left(0, \bar{E}_0\right) > U_d^{BAU}$. In this case, the legislator will vote yes even when it receives no permits, as may be the case for the strongest believers. For those districts then, $\hat{\hat{\theta}}_d = 0$.

votes conditional on every possible cap in the preceding paragraphs, the cap that solves:

$$\begin{aligned} \max_{\bar{E}_0^{IT}} \quad & U_p\left(\bar{E}_0^{IT}\right) \\ \text{subject to:} \quad & U_p\left(\bar{E}_0^{IT}\right) \geq U_p^{BAU}, \\ & \hat{\theta}\left(\bar{E}_0^{IT}\right) \leq 1. \end{aligned}$$

will be my solution to the legislative bargaining model with imperfect targeting, and the cap that solves:

$$\begin{aligned} \max_{\bar{E}_0^{DT}} \quad & U_p\left(\bar{E}_0^{DT}\right) \\ \text{subject to:} \quad & U_p\left(\bar{E}_0^{DT}\right) \geq U_p^{BAU}, \\ & \sum_{d=1}^{D} \hat{\hat{\theta}}_d\left(\bar{E}_0^{DT}\right) \leq 1. \end{aligned}$$

will be my solution to the legislative bargaining model under perfect targeting.

The solutions to (4.9) and (4.9) suggest the following proposition:[20]

Proposition 1: *Under perfect targeting, the optimal cap selected by a proposer, $\bar{E}_0^{DT}$, maximizes the aggregate surplus of those districts that form the yes voting coalition. This will reflect a cap that is more stringent then the cap that maximizes national aggregate surplus. Under imperfect targeting, the optimal cap selected by a proposer, $\bar{E}_0^{IT}$ will be less stringent (e.g. $\bar{E}_0^{DT} \leq \bar{E}_0^{IT}$) then both the cap selected under perfect targeting as well as the cap that maximizes the aggregate surplus of those that form the yes voting coalition. This may be more or less stringent than the cap that maximizes national aggregate surplus.*

The first part flows from the observation that $\theta_d^{DT}\left(\bar{E}_0^{DT}\right)$ is such that $U_d\left(\theta_d^{DT}\left(\bar{E}_0^{DT}\right)\right) = U_d^{BAU}$ for all $d = 1, ..., D_M - 1$, which forces the proposer to internalize the aggregate surplus of all yes voters when determining the optimal cap level $\bar{E}_0^{DT}$ since doing so maximizes the permits that the proposer is able to receive.[21] The second claim follows

[20] See Appendix, Section B for proofs of all propositions.

[21] For this to be true, I require the additional assumption that $\hat{\hat{\theta}}_d\left(\bar{E}_0^{DT}\right) > 0$ for all districts that form the yes voting coalition. Given the restrictions on the parameters assumed here this indeed holds. As such, the only coalition that is possible is a minimum winning coalition of size D_M. If some legislators would have voted for the cap even if they received zero permits, then that legislator's preferences would not be internalized by the proposer, and thus $\bar{E}_0^{DT}$ may not maximize the aggregate surplus of those districts that form the yes voting coalition in that case. Instead, it would only maximize the sum of aggregate surplus for those districts for whom $\hat{\hat{\theta}}_d\left(\bar{E}_0^{DT}\right) > 0$ (in the yes voting electoral coalition). A super-majoritarian or unanimous (i.e. non-minimum winning) coalition is possible only if $\hat{\hat{\theta}}_d\left(\bar{E}_0^{DT}\right) = 0$ for *all* legislators in the electoral coalition (if one were to require positive permits to vote yes, then the proposer would just drop them from the coalition). In such a case the proposer will simply select a cap that maximizes their own aggregate surplus.

from the fact that the yes electoral coalition is comprised of climate believers which have stronger preferences for emissions reductions than does the national average of all legislators.[22] The third sentence flows from the observation that imperfect targeting limits the ability of the proposer to sequester green pork to those within the electoral coalition. Consequently, the cap a proposer would select under the imperfect model will be less stringent than the cap they would select under the perfect model. The final part reflects the fact because the imperfect model results in a cap that is less restrictive than that which maximizes the aggregate surplus of the yes electoral coalition, then it is more likely to be closer to the cap that maximizes national aggregate surplus since that cap itself is less stringent than the cap that maximizes the aggregate surplus of those in the yes electoral coalition.

While Proposition 1, speaks to the relative cap levels of individual proposers, the next proposition speaks to the average of all proposers' caps:

Proposition 2: *Under perfect targeting, the average of all possible proposers' caps will be more stringent than the cap that maximizes national aggregate surplus, e.g* $\sum_{p=1}^{D} \bar{E}_0^{DT}(p) < \bar{E}_0^{NAS}$. *In contrast, under imperfect targeting the average of all caps will be less stringent when* $\eta > 1$ *and may be more or less stringent when* $\eta \leq 1$. *The average cap under perfect targeting will always be more stringent than the average cap under imperfect targeting.*

The first and third claims follow from Proposition 1. If each proposer's cap under the perfect model is more stringent than the policy that maximizes national aggregate surplus or the imperfect cap, then so too must the average of those caps. The second statement reflects the fact that because the imperfect cap is likely to be less stringent than the perfect cap, then it is more likely to be closer to the policy that maximizes aggregate national surplus. However, unlike the perfect case, the imperfect cap may actually end up being too slack relative to the policy that maximizes aggregate national surplus. To the extent that legislators have beliefs with respect to climate change that are more skeptical than those of scientists, what this in effect means is that perfect targeting of green pork is preferred to imperfect targeting since a more stringent cap is likely to emerge when perfect targeting is permitted. However, to the extent that legislators preferences coincide with those of the general public, imperfect targeting is more likely to result in a cap that is

[22]This result stands in contrast to those bargaining models that examine a more classical policy space in which a global public good can be provided only by reducing the amount of the pork provided. In those models, coalitions can form around those that value the private good or those that value the public good, depending upon the distribution of the marginal utility of the public good relative to the private good across districts, the total number of districts, and the vote threshold (Volden and Wiseman (2007) and (2008), Christiansen (2013)). In these models, the *ex post* policy (conditional on a particular proposer) may deviate from the aggregate surplus maximizing policy, but whether the *ex ante* policy (averaged across all possible proposers) results in a deviation is much less clear.

closer to the policy that maximizes national aggregate surplus. The leakage in green pork implied by imperfect targeting in this sense increases the likelihood that the imperfect cap will reflect such a policy.

5 Numerical Model

I supplement the analytical model developed above with a numerical model that I use to evaluate the welfare implications of the ACESA climate bill for the year 2021. I assess the welfare effects of the ACESA federal climate bill against three alternative regimes: business as usual or no climate policy, the climate policy that maximizes national aggregate surplus, and the climate policy that would emerge from state-level or decentralized decisionmaking.

My numerical model of national decisionmaking closely follows the analytical model detailed above, with a few exceptions. First, I expand my definition of sectors to include both *economic sectors* which follow the earlier economic model and are subscripted $s = 1, ..., S$, as well as *civic sectors* which I denote as $s = S+1, ..., \bar{S}$. Exposure to civic sectors does not depend upon the resulting economic equilibrium induced by the policy, but instead exogenous characteristics of districts. For example, one civic sector is defined as 'low-income consumers' under ACESA. In this case, exposure is simply the proportion of low-income individuals located in a particular district to the total number of low-income individuals in the nation which is not endogenous to the economic model but instead reflects exogenous data. Second, I also allow for the provision of offsets following the offset supply curves from the EPA's IGEM analysis of ACESA, which accounts for international offsets, domestic offsets, and additional domestic abatement from CCS, bio-electricity, and non-CO_2e sources.[23] Third, I assume a CES production function for equation (4.5). Fourth, I assume that the elasticity of substitution for these functions as well as the elasticity of capital supply are identical across districts.

My welfare assessment occurs in three stages. First, using data from multiple sources, I calibrate the business as usual baseline. It should be noted that since GHG emissions are exogenous at this stage that this calibrated baseline is not a function of the vector of environmental damages, $\boldsymbol{\phi} = \{\phi_d\}_{d=1}^{D}$, although I am able to track all emissions produced in the economy. Second, given data provided in the ACESA climate bill on the cap in 2021, $\bar{E}_0^{WM}$, and the vector of shares of the cap allocated across sectors, $\boldsymbol{\theta}^{WM}$, I am able to determine what $\boldsymbol{\phi}$ would need to be such that the solution to the legislative bargaining model with imperfect targeting outlined above replicates the observed ACESA cap and

[23] The EPA's analysis of ACESA used both the Intertemporal General Equilibrium Model (IGEM) and the Applied Dynamic Analysis of the Global Economy (ADAGE) model and was widely circulated two months prior to ACESA's passage.

vector of cap shares. Third, the ϕ that is identified in this way concludes the calibration of the model and allows us to perform a welfare consistent evaluation of the ACESA climate bill to the three alternate regimes I evaluate.

This section proceeds as follows. In Section 5.1 I more concretely categorize the three alternate regimes I use for my welfare assessment. Section 5.2 presents an overview of the datasets used in my numerical analysis and the assumptions underlying my calibration of the vector of environmental preference parameters, ϕ. Finally, Section 5.3 presents the results of my welfare assessment.

5.1 Alternative Regimes

The business as usual of no climate policy is simply the solution to the numerical model when there is no policy.

The climate policy that maximizes aggregate surplus is the cap that solves:

$$\begin{aligned} \max_{\bar{E}_d \geq 0 \, \forall \, d=1,\dots,D} \quad & \sum_{d=1}^{D} U_d\left(\left\{\bar{E}_d\right\}_{d=1}^{D}\right) \\ \text{subject to:} \quad & \sum_{d=1}^{D} K_d\left(\left\{\bar{E}_d\right\}_{d=1}^{D}\right) = \sum_{d=1}^{D} \frac{\bar{E}_d}{\alpha_d}, \end{aligned}$$

where the constraint accounts for the way in which capital is accounted for in the model.

For the model of state decisionmaking I aggregate congressional districts by state which I denote $\hat{d} = 1, \dots, \hat{D}$,[24] and consider two cases: state decisionmaking when neither offsets nor trading are allowed and state decisionmaking when offsets and trading are allowed. In both cases, the representative producer and consumer in each state follows the earlier model with a few exceptions. First, the representative producer located in state $\hat{d}$ instead maximizes profits according to:

$$\begin{aligned} \max_{y_{\hat{d}} \geq 0, \left\{k_{\hat{d}s}\right\}_{s=1}^{S} \geq 0} \quad & f_{\hat{d}}\left(y_{\hat{d}}, \bar{L}_{\hat{d}}\right) - r y_{\hat{d}} \\ \text{subject to:} \quad & E_{\hat{d}} \leq \bar{E}_{\hat{d}}, \\ & y_{\hat{d}} = \min\left\{\frac{k_{\hat{d}s}}{\omega_{\hat{d}s}}\right\}_{s=1}^{S}, \end{aligned}$$

for the case in which neither offsets nor trading are allowed and where $\bar{E}_{\hat{d}}$ is the state cap chosen by state policy-makers. When offsets and trading are allowed the objective

[24] Letting $d(\hat{d})$ denote the legislators located in state $\hat{d}$, then preferences are now $\phi_{\hat{d}} = \sum_{d(\hat{d})} \phi_{d(\hat{d})}$, $x_{\hat{d}} = \sum_{d(\hat{d})} x_{d(\hat{d})}$, and similarly for $\bar{L}_{\hat{d}}$, $K_{\hat{d}}$, and $\kappa_{\hat{d}}$.

function is instead $f_{\hat{d}}\left(y_{\hat{d}}, \bar{L}_{\hat{d}}\right) - ry_{\hat{d}} - PN_{\hat{d}}$ and the number of permits bought or sold by the representative producer, $N_{\hat{d}} \gtreqless 0$, also enters as a choice variable. In addition, the first constraint is instead $E_{\hat{d}} - N_{\hat{d}} \leq \bar{E}_{\hat{d}}$.

Second, state policymaker's located in state $\hat{d}$ select a state cap, $\bar{E}_{\hat{d}}$, conditional on the caps chosen by all other states, $\left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}$, according to:

$$\begin{aligned}
\max_{\bar{E}_{\hat{d}} \geq 0} \quad & U_{\hat{d}}\left(\bar{E}_{\hat{d}}, \left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right) \\
\text{subject to:} \quad & E_{\hat{d}}\left(\bar{E}_{\hat{d}}, \left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right) \leq \bar{E}_{\hat{d}}, \\
& U_{\hat{d}}\left(\bar{E}_{\hat{d}}, \left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right) \geq U_{\hat{d}}^{BAU}\left(\left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right)
\end{aligned}$$

for the case in which neither offsets nor trading are allowed. When offsets and trading are allowed, the first constraint is instead $E_{\hat{d}}\left(\bar{E}_{\hat{d}}, \left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right) - N_{\hat{d}}\left(\bar{E}_{\hat{d}}, \left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right) \leq \bar{E}_{\hat{d}}$. The Nash equilibrium which solves (5.1) for all $\hat{d} = 1, \ldots, \hat{D}$ is the climate policy that emerges from state-level or decentralized decisionmaking. Note that the final constraint in (5.1) differs from the aggregate surplus constraint given in (4.9) for the federal problem. $U_{\hat{d}}^{BAU}\left(\left\{\bar{E}_s\right\}_{s \neq \hat{d}=1}^{\hat{D}}\right)$ is the business-as-usual equilibrium from the perspective of a state that decides not to set a cap, but which still reflects their aggregate surplus conditional on all other states choosing caps as they please. In contrast, $U_{\hat{d}}^{BAU}$ with no argument results when all states jointly set non-binding caps, which is the same as when there is no federal climate policy.[25]

Oates and Schwab (1988) were the first to show that decentralized decision-making may achieve the first-best reduction in emissions. They also show, however, that the ability for decentralization to achieve the first-best falls apart with emissions reductions being under-provided when a non-distortionary lump-sum tax instrument is not available, a result which extends the classic inefficiency of horizontal fiscal competition result of Zodrow and Mieszkowski (1986) to the environmental setting. More recent work by Ogawa and Wildasin (2009) considers a model of decentralization in the tradition of Oates and Schwab (1988) but where districts are heterogeneous with respect to environmental preferences, endowments, and production technology.

[25]This is not a model of conditional decisionmaking; either the federal government acts in my model or states act, but not both. Conditional decisionmaking complicates things considerably and is beyond the scope of this paper. For a model that tackles this issue in a classical public finance setting, see Janeba and Wilson (2011).

When emissions spillovers are uniform, both lump-sum and capital taxes are available, emissions are generated uniformly (per unit of capital), and policymakers assume their choices have no impact on the price of capital, they re-establish the result that decentralization can achieve the first-best. My model of decentralization is close to that of Ogawa and Wildasin (2009) except that I relax the last three assumptions. I abstract from interactions with state fiscal systems and the provision of local public goods. Instead, state governments compete in emissions caps and not capital (emissions) taxes. I choose caps instead of taxes as my instrument of choice because this appears to be the preferred instrument used across many states and for consistency with my federal model.[26] I allow states to differ in all the dimensions that Ogawa and Wildasin (2009) consider, except I also allow states to differ in their emissions intensity (given equations (4.1) and (4.6)) between states. Finally, I assume states are aware that their policy choices can impact the equilibrium price of capital. Consequently, inefficiency in decentralized provision again emerges.

5.2 Data and Model Calibration

I calibrate the model to the year 2021. While the ACESA climate bill provides a sequence of emissions caps and share vectors for every year between 2012 and 2050,[27] I select the year 2021 for my welfare analysis as the emissions reduction of 18.8% achieved by the cap in 2021 is closest to the average annual discounted emissions reduction achieved under ACESA across all 38 years (20.1%), when future emissions reductions are discounted at an annual rate of 2.9%.[28] To calibrate the numerical model I use data from multiple sources which are summarized in Table 2. In general the model is calibrated to reflect national outcomes in terms of observed permit price, share of offsets to industry abatement, and economy-wide efficiency cost that are reported in the EPA's IGEM assessment of ACESA. While ACESA allows for banking of permits and the EPA's IGEM analysis of ACESA assumes that significant amounts of offsets are added to the bank until 2029, I adjust the offset supply curves to reflect the average contribution of offsets to total abatement across all years of the policy, which is the amount of offsets that I assume are supplied in 2021. I treat six abstaining voters as no-voters for the purposes of my calibration and welfare analysis. Additional details on model calibration are provided

[26] Twenty states have state-wide GHG emissions targets. Ten states have state-wide GHG caps on the electricity sector. There are also several regional GHG emission reduction initiatives that are based on cap and trade systems in various stages of development (the Regional Greenhouse Gas Initiative, the Midwest Greenhouse Gas Reduction Accord, and the Western Climate Initiative). In addition, 29 states have Renewable Portfolio Standards (RPS) and eight states have renewable portfolio goals, which mandate/target that certain quantities of renewables be used in electricity generation.

[27] See Table 1 in the Appendix for a detailed summary of the caps and share vectors for other years.

[28] This is a simple mean of the Stern Review estimate and Nordhaus' preferred estimate.

in the Appendix, Section A.

Following the ACESA climate policy outlined in Table 1, I consider seven economic sectors ($S = 7$): electricity, heating oil, petroleum refineries, automobiles, trade vulnerable industries, and other economic which are $s = 1, \ldots, 7$, respectively. In addition, I consider seven civic sectors ($\bar{S} = 14$) which reflect the seven broad categories of permits otherwise distributed by ACESA. These are: low income, carbon capture and storage (CCS), renewables, adaptation, workers, buildings, and other civic which are $s = 8, \ldots, 14$, respectively.

Table 3 provides a summary of the national economy in the absence of ACESA. As reported in the first panel, total GDP is 19.5 trillion dollars in 2021, with labor comprising 32% of total output. 91.6% of all capital in the economy is used by other economic sectors. After this, the most capital intensive economic sector is automobiles, followed by trade vulnerable industries, electricity, petroleum refineries, natural gas, and heating oil at 2.7%, 2.4%, 1.5%, 1.2%, 0.6%, and 0.1% of all capital, respectively. The first panel of Table 4 reports emissions broken down by economic sector while the second panel reports emissions intensity which is simply emissions from panel two divided by the total value of capital in panel one. Total emissions in 2021 are 7,448.8 Tg CO_2e. Emissions from other economic sectors comprise 58.8% of total emissions, of which only roughly one third are covered by the 2021 cap. Emissions from electricity are by far the next largest contributor at roughly one-third of total emissions, followed by natural gas, trade vulnerable industries, heating oil, petroleum refineries, and automobiles.[29] The electricity and heating oil sectors have by far the largest emissions intensity, followed by natural gas trade vulnerable industries, other economic sectors, petroleum refineries, and automobiles.

5.2.1 Calibration of Policymakers' Revealed Environmental Preference Parameters

Given the no policy baseline, I am able to identify all the model parameters except the vector of environmental preferences, $\boldsymbol{\phi}$. Using the climate policy for 2021, $\left(\bar{E}_0^{WM}, \boldsymbol{\theta}^{WM}\right)$ as reported in Table 1, I can numerically compute the resulting economic equilibrium under the climate policy in 2021. Finally, using the observed vector of votes in the House of Representatives that took place on June 26$^{\text{th}}$, 2009, bounds on $\boldsymbol{\phi}$ can be identified.

In order to vote yes, legislator's preferences must satisfy the vote constraint in (4.9).

[29]With respect to automobiles, it should be noted that I am unable to attribute emissions to automobile production from the *US EPA Inventory of Greenhouse Gas Emissions and Sinks: 1990-2010* and so emissions from automobile use are embedded in emissions from other economic sectors.

That is:

$$
\begin{aligned}
&U_d^{WM} \geq U_d^{BAU} \Leftrightarrow \\
&\pi_d^{WM} + P^{WM}\xi_d^{WM} + r^{WM}K_d^{WM} - \phi_d \bar{E}_0^{WM} - \kappa_d^{WM} \geq \\
&\qquad \pi_d^{BAU} + r^{BAU}K_d^{BAU} - \phi_d E_0^{BAU} - \kappa_d^{BAU} \Leftrightarrow \\
&\phi_d \geq \left[\frac{\pi_d^{BAU} - \pi_d^{WM} + r^{BAU}K_d^{BAU} - r^{WM}K_d^{WM} - P^{WM}\xi_d^{WM} - \left(\kappa_d^{BAU} - \kappa_d^{WM}\right)}{\left(E_0^{BAU} - \bar{E}_0^{WM}\right)}\right],
\end{aligned} \tag{5.1}
$$

where $\left(\pi_d^{BAU}, r^{BAU}, K_d^{BAU}, E_0^{BAU}, \kappa_d^{BAU}\right)$ reflects the no policy equilibrium and $\left(\pi_d^{WM}, r^{WM}, K_d^{WM}, \bar{E}_0^{WM}, P^{WM}, \xi_d^{WM}, \kappa_d^{WM}\right)$ reflects the equilibrium under ACESA.

Assuming equality in (5.1), provides an estimate of environmental preferences, $\hat{\phi}_d$, where it must be the case that:

$$\phi_d \geq \hat{\phi}_d, \tag{5.2}$$

which is to say that, for yes voters, $\hat{\phi}_d$ is a lower bound on the true environmental preferences of a yes voting legislator. I note that for at least twelve districts, (5.2) must bind with equality in order for the observed $\boldsymbol{\theta}^{WM}$ to reflect the optimal policy.[30]

Similarly, no voters must satisfy $U_d^{WM} \leq U_d^{BAU}$. However, while the calibrated $\hat{\phi}_d$ for all non-proposing yes voters will satisfy (5.1) at equality, the $\hat{\phi}_d$ calibrated for no voters must be calibrated such that they are more expensive to add to the coalition than all non-proposing yes voters that are already in the coalition. If this is not the case for a no voter, than that no voter could replace a yes voter in the coalition since they would be cheaper to buy out with permits and thus the observed ACESA vote coalition could not be sustained as an optimum. Consequently, $\hat{\phi}_d$ for no voters is calibrated such that:

$$\hat{\phi}_d = \left[\frac{\pi_d^{BAU} - \pi_d^{WM} + r^{BAU}K_d^{BAU} - r^{WM}K_d^{WM} - P^{WM}\left(\max\left\{\xi_d^{WM}, \hat{\xi}_p^{WM}\right\}\right) - \left(\kappa_d^{BAU} - \kappa_d^{WM}\right)}{\left(E_0^{BAU} - \bar{E}_0^{WM}\right)}\right], \tag{5.3}$$

where $\hat{\xi}_p^{WM} = \max\left\{\xi_d^{WM}\right\}_{d \neq p \in \mathbb{D}^{WM}}$ is the maximum number of permits provided to non-proposing yes voters in the observed vote coalition $\mathbb{D}^{WM}$. Given the reversal in inequality

[30] There are 14 sectors, of which I only allow permit shares to be allocated to 13 sectors. The proposer would prefer to assign a maximum share of permits to the sector in which s/he has the greatest exposure. Thus, the fact that I observe positive shares for the twelve remaining sectors is only possible if some voters require those permits in order to obtain their votes for whom (5.2) must bind at equality. I note that this logic coincides with the way in which the coalition was incrementally formed as discussed in Section 3.

in the voting constraint, for no voters $\hat{\phi}_d$ is such that:

$$\hat{\phi}_d \geq \phi_d, \tag{5.4}$$

which is to say that, for no voters, $\hat{\phi}_d$ is an upper bound on the true environmental preferences of a no voting legislator.

Once $\hat{\phi}_d$ has been calibrated for all non-proposing yes and no voters, I identify the environmental preferences for the proposer, $\hat{\phi}_p$, numerically such that the proposer's aggregate surplus is maximized at the observed ACESA climate policy, $\left(\bar{E}_0^{WM}, \boldsymbol{\theta}^{WM}\right)$.

The welfare analysis I conduct assumes that $\hat{\phi}_d = \phi_d$ for all legislators. Given that this upper bounds no voters and lower bounds yes voters the estimate this provides is conservative in that it under-predicts the beliefs of yes voters as well as the skepticism of no voters. The vector of all legislator's revealed environmental preferences is denoted $\hat{\boldsymbol{\phi}}$ and reflects the revealed preferences of legislators conditional on the observed ACESA vote.

My recovery of these revealed environmental preference parameters is in the spirit of McFadden (1975). Whether $\hat{\phi}_d$ reflects the preferences of the median voter in each district is much less clear as the current analysis abstracts from several important aspects which may imply a divergence between the preferences of citizens and their elected representatives.[31] Given the way in which these preference parameters are recovered from the structural model, they undoubtedly reflect other unobservables which reflect observed vote behavior but not necessarily actual environmental preferences. These unobservables may bias the revealed welfare analysis that uses these recovered parameters to estimate the revealed external damages from climate change. In general, however, I find that these estimated preference parameters largely mirror survey responses to the question of whether climate change should be addressed. I also try to account for several ways in which bias is likely to emerge through sensitivity analysis and find that the central results of the revealed welfare analysis are quite robust. That said, even if one is not satisfied with the revealed welfare analysis, these preference parameters do explain observed choices and thus are reasonable predictors of policies which can then be evaluated using a scientific welfare analysis that relies on scientific estimates of the external damages from climate change, and which complements the revealed welfare analysis performed in this paper.

[31] To be precise, I abstract from the ability of interest groups to divert the preferences of legislators, the ability of voters to strategically delegate representatives with views that diverge from their own, the ability of legislators to horse trade across votes or engage in other strategic voting behavior, as well as more complex models that explain legislators' observed choices.

5.3 Results

5.3.1 Implied Environmental Preferences

The first panel in Table 5 reports the average revealed environmental preferences of legislators broken down by vote on ACESA. Average environmental preferences imply revealed external benefits from reducing GHG emissions of negative \$0.07 per ton CO_2e. Since average preferences are negative, it should be noted that the sum of all preferences which determines the aggregate surplus maximizing equilibrium will correspond to emissions that are greater than the business as usual or the competitive equilibrium under no climate policy.[32] Relative to scientific estimates of the social costs of GHG emissions of \$25.00 per ton CO_2e, my revealed estimate is considerably smaller. However, the scientific estimate reflects planet-wide damages from climate change whereas our revealed estimate should be thought as reflecting the revealed estimate of damages to that district from climate change which may reflect a welfare benefit, plus, perhaps, legislators' regard for damages to others outside of one's district. Moreover, the negative valuation is not a concern in this context, since the revealed estimate reflects skepticism with respect to scientific assessments of both climate change or the damages it is likely to cause, the ability for policy to remedy the problem, moral choices as to whether anything should be done to address climate change, and a host of other explanations.

Yes voters are on average climate believers with mean environmental preferences equivalent to revealed external damages of climate change of \$0.02 per ton CO_2e. No voters have average revealed environmental preferences equivalent to negative \$0.16 per ton CO_2e. This is roughly eight times larger in magnitude then my estimate for yes voters. The reason for this is fairly intuitive given the way these estimates were recovered from the model. Yes voters receive both permits and emissions reductions. Since permits provide positive utility to members of the electoral coalition, the positive utility that yes voters need to receive from emissions reductions through $\hat{\phi}^{WM}$ is less than if yes voters received zero permits. In contrast, no voters receive positive permits and in spite of this still vote against the policy, and so the negative utility they receive from emissions reductions through $\hat{\phi}^{WM}$ must be greater than if no voters received zero permits.

Figure 1 compares my calibrated estimate of ϕ^{WM} to an estimate of climate preferences using Pew survey data, after standardizing both estimates to have mean

[32] Note that the no climate policy equilibrium is also the policy that maximizes aggregate surplus when all districts have environmental preferences that are equal to zero. The aggregate surplus maximizing equilibrium when all legislators' preferences sum to zero is the same solution as that which results when all legislators preferences jointly equal zero. This is due to the fact that emissions are global in the model and so only the national level of emissions matters for welfare.

zero and standard deviation of one across all legislative districts. The Pew estimate was constructed using three years of pooled Pew survey results from 2008-2010 in which survey respondents were asked the following question: "In your view, is global warming a very serious problem, somewhat serious, not too serious, or not a problem?," where a value of 1 denotes "very serious" and 4 denotes "not a problem."[33] The Pew data reports party identification by state, and so after first fitting a truncated extreme value distribution of survey responses by party by state using Maximum Likelihood Estimation, I construct a mixture distribution for each congressional district using the party vote shares for each legislative district from the 2008 election and the 100 state by party estimated truncated extreme value distributions.[34] The median of each mixture distribution for each congressional district is my Pew estimate. The standardization simply allows us to reconcile the fact that two data sources have different natural scales. For yes voters, the center of mass for my structural estimate of ϕ^{WM} is very close to that for the Pew estimate, although my structural estimate has a tighter spread. For no voters, the center of mass for my structural estimate skews slightly to the left of that of the Pew estimate, although the spread is closer between the two estimates for no voters than for yes voters. That said, t-tests between the means of the two estimates for either yes or no voters find no statistically significant difference between the means of both mass pairs. Individually for both estimates, I also perform within estimate t-tests of the null hypothesis of no difference in means between yes and no voters. For both the structural and Pew estimates, I do find a strong statistically significant difference (at the 1% level) between yes and no voters. Since the Pew estimates are recovered from polling data of the climate beliefs of US citizens, these results suggest that my structural estimates reflect the heterogeneity in the climate preferences of voters through their legislators.

The second panel in Table 5 reports the average environmental preferences of state policymakers given the preference parameters calibrated for federal legislators. For each state this is simply the sum of the preference parameters for all the legislators located within that state. This is broken down by those states that set caps lower than their business as usual state emissions level, cap 'reducers,' as well as states that set caps equal to their conditional competitive equilibrium emissions levels (given the cap reductions of others), which are larger than their competitive equilibrium emissions level without any state policy, or cap 'increasers.' I report estimates for two permutations of state policy,

[33] The three surveys used are the *Pew Research Center April 2008 Political Survey*, *October 2009 Political Survey*, and *October 2010 Political Survey*.

[34] For districts that were uncontested in 2008, I use the split from the 2006 elections instead. A few districts were uncontested in both 2006 and 2008 (always for candidates of the same party). For those districts, I allow shares to equal 1 and 0.

one in which permits cannot be traded between states and offsets are not permitted, and a second case when permits can be traded and offsets purchased. Since ACESA allows for offsets, my preferred state policy is the latter as is this is a more fair comparison between federal and state decisionmaking and so are the results I emphasize in the analysis that follows although I note that either state policy regime results in the same final emissions change. Average environmental preferences are negative at \$0.58 per ton CO_2e. States that decide to reduce their emissions have implied external benefits from reducing GHG emissions of \$0.39 per ton CO_2e. States that emit more have an implied external benefit from reducing GHG emissions of negative \$0.96 per ton CO_2e.

5.3.2 The Emissions Implications of Federal and State Climate Policy

Table 6 reports that ACESA would have reduced emissions by 1,142.7 $TgCO_2$e, relative to business as usual. The bulk of these emissions reductions, 654.6 $TgCO_2$e, come from offsets which is consistent with the EPA's IGEM analysis of ACESA. No voters account for 382.9 $TgCO_2$e of emissions reductions and yes voters for the remaining 105.2 $TgCO_2$e. As ACESA requires that all districts reduce their emissions by 15.2% relative to business as usual, the fact that no voters account for at least two-thirds of industry abatement reflects the fact that those districts were dis-proportionally larger emitters to begin with. This reflects the fact that, unsurprisingly, heterogeneity in emissions incidence across districts is strongly correlated with vote for ACESA. Since environmental preferences are likely to be strongly correlated with emissions, this demonstrates the value of my structural approach as it allows me to disentangle this component from my estimate of environmental preferences. The level of emissions that maximizes aggregate surplus exceeds the business as usual emissions level since the average preferences of all legislators is negative. Relative to this, ACESA significantly lowers emissions by 31.4% or 2,912.3 $TgCO_2$e.

In sharp contrast, state climate policy results in a very slight emissions reduction of just 2.9% or 217.6 $TgCO_2$e, relative to business as usual. 14 climate 'believing' states cumulatively reduce emissions by 72.7 $TgCO_2$e, whereas 36 climate 'skeptic' states that do not choose binding caps reduce cumulative emissions by 4.5 $TgCO_2$e and offsets account for additional emissions reductions of 140.7 $TgCO_2$e. Some climate 'skeptic' states reduce emissions because they can abate more cheaply than climate believing states, and so can make greater profits by reducing emissions and selling permits. If offsets and trading are not allowed the same emissions reductions by state policy emerges as when trading and offsets are allowed. This reflects the fact that emissions are global and thus believing states bid down their caps to the same Nash equilibrium in either case.

Emissions under state policy are closer to the emissions level which maximizes aggregate surplus than federal policy, consisting of a reduction of 21.4% or 1,987.5 $TgCO_2e$.

5.3.3 Welfare Implications of Federal and State Climate Policy

As reported in the top panel of Table 8, ACESA leads to a revealed welfare loss of $47.1 billion relative to business as usual and $67.0 billion relative to the aggregate surplus maximizing policy. In sharp contrast, state policy with offsets and trading results in a revealed welfare loss of $7.4 billion relative to business as usual and $27.3 billion relative to the aggregate surplus maximizing policy. This is a key result of this paper. In terms of revealed welfare, state policy is less costly than federal policy, although both policies result in less welfare.

Under ACESA, the welfare of yes voters is unchanged relative to business as usual with the full welfare loss absorbed by no voters, which reflects the calibration of the environmental preference parameters. This welfare discrepancy reflects the logic of the legislative bargaining equilibrium in the context of climate policy; namely, that the climate bill provides an opportunity for those within the electoral coalition to maximize their own welfare irrespective of their impact on those outside the coalition. While believers are indifferent under federal policy, under state policy believers fare considerably worse. States that reduce their emissions experience a welfare loss of $3.2 billion relative to business as usual, whereas the welfare of states that increase their emissions falls by $3.2 billion.[35] Interestingly, this reveals an important dichotomy between federal and state policy. Although federal climate policy results in a far greater revealed welfare loss than state policy, the welfare of believers increases under federal policy, whereas under state policy the welfare of believers declines. This suggests that believers may prefer federal action all else equal.

State policy without offsets or trading results in revealed welfare costs that are an order of magnitude greater than the welfare costs of state policy with offsets and trading amounting to a loss of $30.1 and $50.1 billion relative to business and usual and the aggregate surplus maximizing policy respectively. Correspondingly, while the revealed

[35]This is consistent with the logic of horizontal competition in emissions caps. A state reduces their emissions because their welfare from choosing a non-binding cap (the competitive equilibrium emissions level conditional on the emissions levels chosen by all other states) is less than choosing a binding cap conditional on the emissions levels chosen by all other states. It does not reflect the fact that a state will only set a cap if its welfare improves relative to the no policy equilibrium. If a believer state decides to act unilaterally to improve its welfare by setting a binding cap, skeptic states will expand production to undermine the believer's cap. This will lower the believer's welfare from their original cap choice, but this will still reflect greater welfare than moving back to their original no policy equilibrium conditional on the skeptic's elevated production level. Thus the Nash equilibrium results in a situation where believer states cannot help themselves and in so doing end up worse off than where they began.

welfare loss under ACESA far exceeds that of either of the two state policies, per ton CO_2e of emissions reduced state policy without offsets or trading is far more distortionary than ACESA. As reported in Table 9 state policy without offsets or trading results in a revealed welfare loss of $25.2 per ton CO_2e of emissions reduced relative to the aggregate surplus maximizing policy which compares to welfare costs of $23.0 per ton CO_2e of emissions reduced under ACESA and $13.8 per ton CO_2e of emissions reduced under state policy with offsets and trading.[36] Thus while both state policies result in a smaller absolute welfare loss relative to ACESA, only state policy with offsets and trading results achieves a smaller welfare loss per unit of emissions reduced than federal policy. My finding of significant cost savings from allowing trading and offsets, thus coincides with the classical result that trading and offsets can substantially lower compliance costs of achieving emissions reductions. This also suggests that

The bottom panel of Table 8 provides the results of a welfare analysis which uses scientific external damage estimates rather than the revealed external damage estimates from above, but which takes as given the policies selected as result of revealed preferences. This allows me to evaluate the implications of revealed policy from a basis of the scientific estimates of the external damages from climate change. With respect to scientific welfare, I find that both federal and state policy with offsets and trading both improve welfare, with federal policy resulting in a substantially greater gain in scientific welfare.

This is a sharp reversal of our earlier finding that state policy revealed welfare dominates federal policy and both policies achieve a revealed welfare loss and is the second central finding of this paper. ACESA achieves a scientific welfare gain of $14.7 billion relative to business as usual and $90.4 billion relative to the revealed aggregate surplus maximizing policy, whereas state policy with offsets and trading results in a scientific welfare gain of $4.4 billion and $80.1 billion with respect to the same two counterfactuals. State policy without offsets and trading, however, results in welfare loss relative to business as usual of $18.4 and a smaller welfare gain of $57.3 billion relative to

[36] While state policy with trading and offsets is the more natural comparison to ACESA which assumes a large role in the ability of offsets to contribute to emissions reductions, some may find this characterization of state policy as unrealistic. In reality, state policy is somewhere in between the two. Many states have passed Renewable Portfolio Standards (RPS) which establish consumption mandates which specify the share of renewable electricity to be blended into electricity generation. RPS's hope to achieve emissions reductions without specifying that polluting industries must emit less, but instead target a sector that under ACESA would supply offsets. While there is significant heterogeneity in RPS schemes between states, some states permit trading of renewable credits in order to comply with the RPS. In addition, some states have formed regional trading bodies with the end objective of establishing a regionally consistent climate policy, where trading would be permitted. Voluntary offsets markets exist that can be used to supply offsets to some of these regional climate initiatives without intervention by the federal government.

the aggregate surplus maximizing policy. Thus, from the perspective of business as usual state policy without offsets and trading leads to a consistent welfare loss in terms of both revealed and scientific welfare. Per ton CO_2e of emissions reduced, ACESA achieves a welfare gain of \$31.0 per ton relative to the aggregate surplus maximizing policy which is below the welfare gain of \$40.3 per ton achieved under state policy with offsets and trading. What this demonstrates is that although revealed decisionmaking emerges as a result of different distortionary mechanisms at the federal and state levels, the resulting policy outcomes can have very different implications for scientific welfare. In order to properly assess the latter, however, recovering the revealed preference parameters is essential as it allows me to endogenously model policy selection in a realistic way, so long as the models of federal and state decisionmaking I have chosen sufficiently reflect the first-order mechanisms that determine how climate policy is selected and so long as the revealed preference parameters I have recovered are sufficiently good predictors of that decisionmaking.

5.3.4 Sensitivity Analysis of Key Welfare Results

Figures 2 and 3 consider three alternative parameterizations of revealed preferences across three outcomes relative to business as usual and the aggregate surplus maximizing policy, respectively. Recall, in my central calibration of $\boldsymbol{\phi}$ that we assumed $\boldsymbol{\phi} = \hat{\boldsymbol{\phi}}$ despite the fact that $\phi_d \geq \hat{\phi}_d$ for yes voters and $\phi_d \leq \hat{\phi}_d$ for no voters. In row A in both tables I suppose instead that $\phi_d = \hat{\phi}_d + \varepsilon$ for yes voters and $\phi_d = \hat{\phi}_d$ for no voters, where ε is a shifter term that is strictly positive and is plotted on the x-axis in all figures. What this in effect allows us to examine is what happens when true environmental preferences for yes voters $\phi_d > \hat{\phi}_d$ with the distance between the two estimate increasing as ε gets larger. Row B performs a similar analysis but with respect to no voters where $\phi_d = \hat{\phi}_d - \varepsilon$ for no voters and $\phi_d = \hat{\phi}_d$ for yes voters, and row C allows $\phi_d = \hat{\phi}_d + \varepsilon$ for yes voters and $\phi_d = \hat{\phi}_d - \varepsilon$ for no voters. Column i examines the change in emissions, column ii the change in aggregate surplus from the revealed welfare analysis, and column iii the change in aggregate surplus from the scientific welfare analysis. Relative to both the business as usual and the aggregate surplus maximizing policy, my central revealed result is quite robust. In all three cases, both federal and state policy result in lower revealed welfare, with federal policy resulting in a larger revealed welfare loss than state policy.

With respect to scientific welfare the results are considerably more mixed, although I focus on the implications for the business as usual case since the counterfactual policy is fixed in this case. Increasing the preference parameters of yes voters (row A) results in federal policy that achieves ever greater emissions reductions whereas state policy results in more emissions reductions but in a step-wise fashion as the preference parameters increase to such a extent to tip states from skeptic states to believer states. This corresponds to a scientific welfare gain until the point where revealed external damages of yes voters are roughly four times greater than my central estimate after which state policy results in greater welfare gain, and shortly thereafter federal policy results in excessive emissions reductions that actually result in lower scientific welfare. In contrast, when I shift the parameters of no voters (row B), federal policy is unchanged since the unaltered believers determine federal policy, whereas state policy results in greater emissions increases. This corresponds to consistent scientific welfare gains from federal policy and greater welfare losses for state policy as emissions increase. Finally, when I allow the preferences of both voters to adjust (row C) the result is a combination of the two results, with federal policy resulting greater scientific welfare gains until the point in which the revealed external damages of yes voters are roughly five times greater than the central estimate. State policy is not consistent as it depends upon which states are flipping from net believers to net skeptics and thus scientific welfare flips repeatedly around the zero axis.

5.3.5 Distributional Implications of ACESA Under Alternative Allocation Rules

Table 10 examine the emissions and welfare implications when the ACESA cap and the proposer are held fixed, but when permits are allocated to districts using alternative allocation rules. The top panel examines the implications if the proposer were able to perfectly target permits to districts, whereas the bottom panel examines the implications if permits were forced to be allocated to all districts equally.

Under perfect targeting, the proposer would shed one yes voter from the coalition, since passage of the bill would only require a majority of 218 votes. The legislator that is dropped received the largest amount of permits of all yes voters under ACESA equal to 23.4 $TgCO_2e$. This voter joins the coalition of no voters who receive an average of 12.4 $TgCO_2e$ under imperfect targeting and who now all receive zero permits. The average permits to yes voters under the original ACESA more than doubles owing solely to gains to the proposer.[37] The permits that went to no voters are all returned to the proposer, who now receives an enormous sum of 2,716.4 $TgCO_2e$ of permits compared to just 9.2 $TgCO_2e$ of permits under imperfect targeting. This reveals the critical difference in proposer power between the two models, and also reveals how far off my welfare estimates would be if I fit ACESA using a model of perfect targeting rather than my

[37] The proposer continues to offer roughly the same number of permits to yes voters remaining in the coalition, since the ϕ_d's for a the fixed cap were determined such that aggregate surplus under ACESA just equaled the aggregate surplus of these voters under business as usual.

correct model of imperfect targeting.

Under equal (or, rather, no) targeting, all districts receive the exact same number of permits worth 11.3 $TgCO_2e$.[38] 156 yes voters under ACESA with imperfect targeting would continue to support the ACESA cap under equal targeting. In fact, those voters would receive an average increase in permits of 2.9 $TgCO_2e$ under equal targeting. In sharp contrast, 63 voters that voted for ACESA under imperfect targeting would not vote for ACESA under equal targeting.[39] Consequently, the ACESA cap would have failed the House by 62 votes (since only 218 votes are needed for passage). These voters would lose on average 3.8 $TgCO_2e$ worth of permits under equal targeting. In addition, no voters who voted against ACESA with imperfect targeting would continue to vote but receive on average 1.0 $TgCO_2e$ fewer permits under equal targeting. Imperfect targeting, because it targets some industries that are vital to secure passage of the original cap, allows permits to be boosted to a critical segment of yes voters but in so doing also boosts the average permits of no voters. Critically, this occurs because the exposure of this segment of yes voters under the cap is correlated with the exposure of no voters. Since changes in welfare again follow changes in the permit allocation, imperfect targeting improves the welfare of all no voters relative to equal targeting while lowering the welfare of consistent yes voters.

5.3.6 Emissions and Welfare Implications of Federal Climate Policy Under Alternative Allocation Rules

The prior analysis has examined how alternative allocation rules impact the distribution of permits across districts as well the implications for votes for a fixed ACESA cap. However, as shown in Proposition 1, the choice of allocation rule will also have important efficiency implications for the level of the cap itself.

With respect to an allocation rule in which permits are equally distributed, I find that there is actually no cap that would be able to pass the House. Thus, the resulting federal policy is no climate policy. From a revealed welfare perspective this would actually be preferred to both ACESA and the state policy which result in greater revealed welfare losses relative to the aggregate surplus maximizing level.[40] From the perspective of

[38]While the analysis that follows compares imperfect targeting under ACESA to an equal allocation of permits, it should be noted that similar distributional dynamics would likely emerge even if 100% of allowances were auctioned off, or if a carbon tax was used in lieu of a cap. As Pooley (2010) notes: "Any [carbon tax bill] would be shaped by the same regional forces that shaped ACESA. A carbon tax that failed to address them would never pass." This point is also acknowledged by Hahn and Stavins (2011).

[39]These "fence-sitters" are skewed geographically. 71.4% of these fence-sitters are from states that are not located in either the northeast or the west coast. Comparatively, yes voters from states not located in either the northeast of the west coast accounted for only 49.3% of all yes votes cast for ACESA.

[40]This can be seen from comparing the business as usual baseline to the aggregate surplus maximizing

scientific welfare, however, no policy would imply a smaller welfare gain relative to both policies.

Table 11 reports the results for the allocation rule in which the proposer can perfectly target just the amount of permits needed to secure the minimum winning coalition, holding the proposer fixed. In this case, the proposer would select a considerably more stringent cap than the ACESA cap, resulting in an additional 64.2% reduction in emissions. This result is consistent with Proposition 1, which showed that the cap selected under perfect targeting would result in a significantly more stringent cap than under imperfect targeting allocation rule of ACESA, although that analytical observation assumed that there was only heterogeniety in environmental preferences and the numerical model permits heterogeneity across multiple dimensions. From the perspective of revealed welfare, the cap selected under perfect targeting results in a 89.0% greater welfare loss than that achieved by the ACESA cap relative to business as usual and 62.5% greater welfare loss relative to the aggregate surplus maximizing emissions level. In effect, better targeting increases the returns from hijacking as the proposer is able to extract ever more permits for each additional reduction in emissions.

Even more interesting is what perfect targeting means for the scientific welfare analysis. Under perfect targeting the scientific welfare gain is 15.2% smaller than the welfare gain under the imperfect targeting allocation rule of ACESA relative to business as usual and 2.5% smaller relative to the aggregate surplus maximizing emissions level. In effect, the determinants of revealed policy lead to too stringent a cap under perfect targeting from the perspective of both revealed and scientific welfare. This highlights the value of my empirical approach as it demonstrates how revealed policy choices can lead to different scientific welfare results depending upon how the allocation rule impacts decisionmaking. In addition, this result suggests that imperfect targeting may actually be preferred to a perfect targeting mechanism for allocating permits. In this case, the improved ability to consume green pork under perfect targeting results in overeating, from the perspective of scientific welfare.

5.3.7 Would ACESA Have Passed the US Senate?

The state environmental preference parameters provided in Table 5 reflect the preferences of Senators given that Senators are elected at large in each state. One implication of this is that the preferences of believers in a state partially wash out the preferences of skeptics. The result is that extreme preferences are tamped down by aggregating at the state level. Since the ACESA coalition in the House consisted

baseline in the first panel of Table 8.

predominantly of climate believers, this dilution will have important implications for the ability of ACESA to pass the Senate. I can evaluate this by passing the observed ACESA climate policy into my state model and counting the number of yes votes that result. I find that only 12 states or 24 senators would have voted for ACESA.

6 Conclusion

This paper developed a spatially and sectorally disaggregated model of the US economy where heterogeneous preferences for emissions critically determine both federal and state decisionmaking with respect to climate change. At the federal level, heterogeneity in environmental preferences encourages the selection of a federal climate policy that reflects the preferences of climate 'believers' who, since they value emissions reductions, require fewer free permits or green pork to secure their vote. At the state level, heterogeneity in environmental preferences encourages 'believer' states to unilaterally reduce their emissions which are offset by 'skeptic' states who expand production in response to a lower rate of return to capital, and thus emissions.

Using the observed vote, cap, and permit allocation for ACESA, I was able to recover bounds on the revealed preferences of legislators which allowed me to perform a welfare consistent comparison of federal and state policy relative to both business as usual and the aggregate surplus maximizing policy. I find that revealed federal policy is likely to result in substantially greater emissions reductions than revealed state policies. This has important implications for welfare, providing the two central results of this paper.

First, with respect to revealed welfare, I find that state policy in which both offsets and trading are allowed is both less stringent and results in a substantially smaller welfare loss than federal policy, although both policies lead to lower welfare relative to the aggregate surplus maximizing policy. This finding is very robust across alternative calibrations of revealed preference parameters. Federal policy results from a majority coalition of climate 'believers' who establish an especially stringent cap. This occurs because yes voters in the coalition have revealed external damages of \$0.02 per ton CO_2e which are considerably greater than the mean negative external damages of \$0.07 per ton CO_2e which determine the aggregate surplus maximizing level of emissions. ACESA thus implies a cap that is 15.2% lower than business as usual emissions. Thus, federal policy corresponds to a revealed welfare loss of \$67.0 billion relative to the aggregate surplus maximizing level and \$47.1 billion relative to business as usual. In contrast, state policy results in a cumulative emissions reduction that is just 2.9% below the business as usual emissions level, corresponding to a revealed welfare loss of \$27.3 billion relative to the aggregate surplus maximizing level and \$7.4 billion relative to business as usual.

Second, in sharp contrast to the first result, I find that revealed federal policy is more likely to result in a scientific welfare gain than state policy, with both federal and state policy in which offsets and trading are allowed improving welfare. Federal policy results in a scientific welfare gain of $90.4 billion relative to the revealed aggregate surplus maximizing level and $14.7 billion relative to business as usual, whereas state policy results in welfare gains of $80.1 and $4.4 billion, respectively. This result is less robust across alternative calibrations of revealed preference parameters.

In addition, my revealed welfare analysis identifies an important distributional dichotomy between federal and state policy. Although federal climate policy results in a far greater revealed welfare loss than state policy, the welfare of believers is unchanged under federal policy, whereas under state policy the welfare of believers declines. This suggests that believers may prefer federal action all else equal.

Finally, the way in which permits were allocated under ACESA has very important implications both for the likelihood of federal policy passing as well as the welfare implications of the cap that 'believers' select. If permits were equally distributed to all legislators, I find that no federal climate policy would pass. The imperfect targeting of permits to certain sectors in which fence-sitting yes voters have high exposure demonstrates how green pork is essential to grease the wheels of climate policy. This mechanism also allows no voters to receive more permits on average than yes voters and helps offset the burden of climate policy on no voters who are likely to be the most polluting districts. If permits could be perfectly targeted to legislators at just the level necessary to secure their vote and no more (with no voters receiving no permits), then the resulting cap would be even more stringent. Relative to business as usual, this amplifies the revealed welfare loss by 89.0% compared to the revealed welfare loss under ACESA and actually results in a 15.2% smaller scientific welfare gain. Better targeting increases the returns from hijacking as the proposer is able to extract ever more green pork for each additional reduction in emissions, but in this case results in overeating. As a consequence, imperfect targeting may actually be preferred to a perfect targeting mechanism for allocating permits. This suggests that the choice of allocation rule has important scientific welfare implications for the revealed cap which are not obvious *a priori* and further demonstrates the value of my revealed approach.

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Table 1: ACESA Cap and Permit Allocation Schedules, 2012 to 2050

	2012	2015	2020	2025	2030	2035	2050	2021
Emissions Cap ($TgCO_2e$)	4,627.3	5,003.3	5,055.5	4,294.2	3,532.8	2,908.5	1,035.5	4,903.3
Share of Cap Going to Permits, Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Share to Economic Sectors	0.506	0.606	0.620	0.620	0.068	0.000	0.000	0.620
Electricity	0.438	0.389	0.350	0.350	0.000	0.000	0.000	0.350
Natural Gas	0.000	0.000	0.090	0.090	0.000	0.000	0.000	0.090
Heating Oil	0.019	0.017	0.015	0.015	0.000	0.000	0.000	0.015
Oil Refineries	0.000	0.020	0.020	0.020	0.000	0.000	0.000	0.020
Automobiles	0.030	0.030	0.010	0.010	0.000	0.000	0.000	0.010
Trade Vulnerable Industries	0.020	0.150	0.135	0.135	0.068	0.000	0.000	0.135
Share to Civic Sectors	0.494	0.394	0.380	0.380	0.933	1.000	1.000	0.380
Low Income Consumers	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
CCS Bonus Allowances	0.000	0.018	0.050	0.050	0.050	0.050	0.050	0.050
Renewable Energy	0.110	0.110	0.070	0.025	0.060	0.060	0.060	0.070
Domestic Adaptation	0.010	0.010	0.010	0.020	0.040	0.040	0.040	0.010
Investment in Workers	0.005	0.005	0.005	0.010	0.010	0.010	0.010	0.005
Building Codes	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
All Others	0.214	0.097	0.090	0.120	0.618	0.685	0.685	0.090

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Table 2: Datasets Used to Calibrate the Model

Variable/Parameter	Description	Data Source
$\bar{E}_0^{WM}$, θ^{WM}	WM Climate Policy	*US EPA IGEM Analysis of WM*
$\bar{L}_d$	Labor Endowment by District	*US Census American Community Survey 2007*
π_0, K_0, r	National Returns to Labor, Capital Supplied, and Rate of Return to Capital	*US BEA GDP 2007*; *US BEA 2002 Input-Output Tables 2002*
π_d	Returns to Labor by District	*US Census American Community Survey 2007*
k_s	Capital Demand by Sector	*US BEA 2002 Input-Output Tables 2002*
E_0, E_s	Total Emissions and Emissions by Sector	*US EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2010*; *US EPA IGEM Analysis of WM*
ω_{ds}, k_{ds}, y_d, K_d	Capital Demand and Shares by District and Sector, Capital Demand and Supplied by District by Sector,	*US Census County Business Patterns 2007*; *US EIA Annual Energy Review 2012*; *US EIA Fuel Oil and Kerosene Sales 2009*
δ_{ds} for $s = 8$	Poor Exposure	*US Census American Community Survey 2007*
δ_{ds} for $s = 9$	CCS Exposure	*US NREL NATCARB Saline 2012*; *Coal 2012*; and *Oil and Gas 2012 Datasets*
δ_{ds} for $s = 10$	Renewables Exposure	*US EIA Annual Energy Review 2012*; *US NREL Wind 25km 2011*; *Geothermal 2009*; *Urban Wood and Secondary Mill Residues 2012*; *Crop Residues 2008*; *Forest and Primary Mill Residues 2008*; *PV 10km Resolution 2012 Datasets*
δ_{ds} for $s = 11$	Adaptation Exposure	*USGS National Elevation Dataset 2012*; *US National Atlas Coastline One Million-Scale 2012*
δ_{ds} for $s = 12$	Workers Exposure	*US Census American Community Survey 2007*
δ_{ds} for $s = 13$	Building Exposure	*US EIA Residential Energy Consumption Survey 2009*
δ_{ds} for $s = 14$	Other Exposure	*US Census American Community Survey 2007*
P	Permit Price	*US EPA IGEM Analysis of WM*

Table 3: Characteristics of the Baseline Economy

	National	Congressional Districts
Economy		
Real GDP (billion 2009 dollars)	19,519.5	44.77
		(9.54)
Total Value of Labor	9,327.8	21.39
		(3.53)
Total Value of Capital	10,191.7	23.38
		(7.98)
Electricity	154.4	0.35
		(0.23)
Natural Gas	57.4	0.13
		(0.13)
Heating Oil	9.6	0.02
		(0.02)
Petroleum Refineries	118.2	0.27
		(0.74)
Automobiles	272.3	0.62
		(1.08)
Trade Vulnerable Industries	249.1	0.57
		(0.65)
All Other Economic Sectors	9,330.7	21.40
		(7.83)
Total Labor (million persons)	152.2	0.35
		(0.04)

Notes: Mean reported for congressional districts with standard deviation in parentheses. The seven sectors listed above are the economic sectors included in the model.

Table 4: Emissions in the Baseline Economy

	National	Congressional Districts
Total Emissions (Tg CO_2e)	7,448.8	17.21
		(16.00)
Electricity	2,118.4	4.86
		(3.18)
Natural Gas	1,171.7	2.69
		(2.75)
Heating Oil	95.3	0.22
		(0.25)
Petroleum Refineries	2,367.7	5.43
		(14.84)
Automobiles	0.0	0.00
		(0.00)
Trade Vulnerable Industries	337.9	0.77
		(0.89)
All Other Economic Sectors	1,413.2	3.24
		(0.00)
Covered By Cap	0.0	0.00
		(0.00)
Uncovered By Cap	1,413.2	3.24
		(0.00)

Notes: Mean reported for congressional districts with standard deviation in parentheses. The seven sectors listed above are the economic sectors included in the model.

Table 5: Revealed Environmental Preferences

	Number of States/ Districts	Average	Standard Deviation	Minimum	Maximum
Congressional Districts					
Revealed External Damages ($ per tonCO_2e)	436	-0.07	0.23	-1.20	1.25
For Yes Voters	219	0.02	0.15	-0.16	0.86
For No Voters	217	-0.16	0.27	-1.20	1.25
States					
Revealed External Damages ($ per tonCO_2e)	50	-0.58	1.10	-5.32	2.14
For Cap Reducers, With Offsets	14	0.39	0.70	0.01	2.14
For Cap Increasers, With Offsets	36	-0.96	0.97	-5.32	-0.02
For Cap Reducers, No Offsets	14	0.39	0.70	0.01	2.14
For Cap Increasers, No Offsets	36	-0.96	0.97	-5.32	-0.02

Notes: Revealed external damages is the calibrated $\hat{\phi}$ times 1,000.

Table 6: Emissions Impacts of Federal and State Climate Policy

	Federal (ACESA)	State With Offsets	State No Offsets
Emissions Under BAU (Tg CO_2e)	7,504.2	7,504.2	7,504.2
Emissions Under Climate Policy	6,361.5	7,286.3	7,286.3
Difference	-1,142.7	-217.9	-217.9
Difference, From Offsets	-654.6	-140.7	–
Difference, From Firm Reductions	-488.1	-77.2	-217.9
Difference, Yes Voters/Cap Reducers	-105.2	-72.7	-619.1
Difference, No Voters/Cap Increasers	-382.9	-4.5	401.1
% Difference	-15.2%	-2.9%	-2.9%
Emissions Under ASM (Tg CO_2e)	9,273.8	9,273.8	9,273.8
Emissions Under Climate Policy	6,361.5	7,286.3	7,286.3
Difference	-2,912.3	-1,987.5	-1,987.5
% Difference	-31.4%	-21.4%	-21.4%

Notes: BAU denotes the outcome under business as usual or no climate policy. ASM denotes the outcome that maximizes national aggregate surplus.

Table 7: External Damages of Federal and State Climate Policy

	Federal (ACESA)		State With Offsets		State No Offsets	
	Revealed	Scientific	Revealed	Scientific	Revealed	Scientific
Ext. Damages Under BAU (billion $)	218.0	-187.6	218.0	-187.6	218.0	-187.6
Ext. Damages Under Climate Policy	184.8	-159.0	211.6	-182.2	211.6	-182.2
Difference	-33.2	28.6	-6.3	5.4	-6.3	5.4
Yes Voters/Cap Reducers	5.9	–	1.2	–	1.2	–
No Voters/Cap Increasers	-39.1	–	-7.5	–	-7.5	–
% Difference	-15.2%	-15.2%	-2.9%	-2.9%	-2.9%	-2.9%
Ext. Damages Under ASM (billion $)	269.4	-231.8	269.4	-231.8	269.4	-231.8
Ext. Damages Under Climate Policy	184.8	-159.0	211.6	-182.2	211.6	-182.2
Difference	-84.6	72.8	-57.7	49.7	-57.7	49.7
% Difference	-31.4%	-31.4%	-21.4%	-21.4%	-21.4%	-21.4%

Notes: BAU denotes the outcome under business as usual or no climate policy. ASM denotes the outcome that maximizes national aggregate surplus.

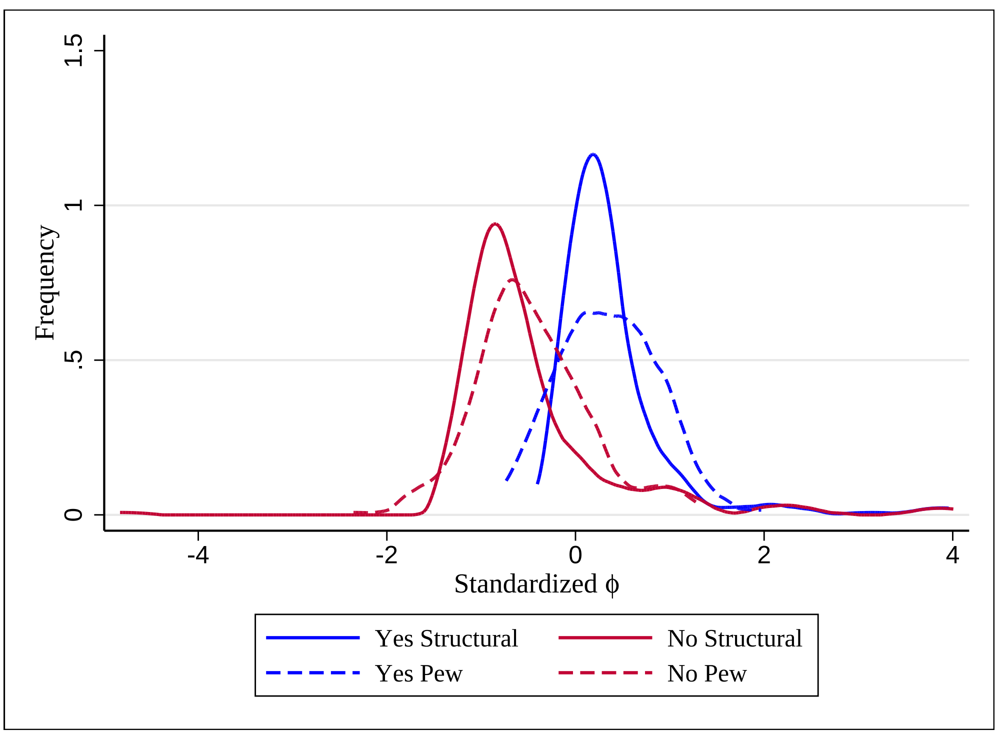


Figure 1: Comparison of Standardized $\hat{\phi}$ Structural Estimate to Pew Estimate

Table 8: Welfare Impacts of Federal and State Climate Policy

	Federal (ACESA)	State With Offsets	State No Offsets
Using Revealed Estimate of External Damages			
Agg. Surplus Under BAU (billion $)	13,647.4	13,647.4	13,647.4
Agg. Surplus Under Climate Policy	13,600.4	13,640.1	13,617.3
Difference	-47.1	-7.4	-30.1
Difference, Yes Voters/Cap Reducers	0.0	-3.2	-0.9
Difference, No Voters/Cap Increasers	-47.1	-4.1	-29.3
% Difference	-0.3%	-0.1%	-0.2%
Agg. Surplus Under ASM (billion $)	13,667.4	13,667.4	13,667.4
Agg. Surplus Under Climate Policy	13,600.4	13,640.1	13,617.3
Difference	-67.0	-27.3	-50.1
% Difference	-0.5%	-0.2%	-0.4%
Using Scientific Estimate of External Damages			
Agg. Surplus Under BAU (billion $)	13,241.8	13,241.8	13,241.8
Agg. Surplus Under Climate Policy	13,256.5	13,246.3	13,223.5
Difference	14.7	4.4	-18.4
Difference, Yes Voters/Cap Reducers	8.5	-2.9	-0.5
Difference, No Voters/Cap Increasers	6.2	7.3	-17.8
% Difference	0.1%	0.0%	-0.1%
Agg. Surplus Under ASM (billion $)	13,166.2	13,166.2	13,166.2
Agg. Surplus Under Climate Policy	13,256.5	13,246.3	13,223.5
Difference	90.4	80.1	57.3
% Difference	0.7%	0.6%	0.4%

Notes: BAU denotes the outcome under business as usual or no climate policy. ASM denotes the outcome that maximizes national aggregate surplus.

Table 9: Change in Aggregate Surplus Per Tg CO_2e of Emissions Reduced

	Federal (ACESA)	State With Offsets	State No Offsets
Climate Policy Relative to BAU			
Change Using Revealed Estimate of Ext. Damages (\$ per TgCO_2e)	41.2	33.7	138.2
For Yes Voters/Cap Reducers	0.0	14.8	4.0
For No Voters/Cap Increasers	41.2	18.9	134.2
Change Using Scientific Estimate of Ext. Damages	-12.9	-20.3	84.2
For Yes Voters/Cap Reducers	-7.4	13.3	2.4
For No Voters/Cap Increasers	-5.5	-33.6	81.8
Climate Policy Relative to ASM			
Change Using Revealed Estimate of Ext. Damages (\$ per TgCO_2e)	23.0	13.8	25.2
Change Using Scientific Estimate of Ext. Damages	-31.0	-40.3	-28.8

Notes: BAU denotes the outcome under business as usual or no climate policy. ASM denotes the outcome that maximizes national aggregate surplus.

Table 10: Comparison of Alternate Allocation Rules Given ACESA Cap

Comparison of Imperfect Targeting to Perfect Targeting

	Imperfect Targeting	Perfect Targeting	Difference	% Difference	Votes
Average Permits Allocated, All Voters ($TgCO_2e$)	11.3	11.3	0.0	0.0%	436
Average Permits Allocated, Yes Voters	10.3	22.6	12.3	118.5%	219
That Voted For PT	10.3	22.7	12.4	120.8%	218
To Proposer	9.2	2,716.4	2,707.2	29,467.5%	1
To Other Yes Voters	10.3	10.3	0.0	0.0%	217
That Voted Against PT	23.4	0.0	-23.4	-100.0%	1
Average Permits Allocated, No Voters	12.4	0.0	-12.4	-100.0%	217

Comparison of Imperfect Targeting to Equal Targeting

	Imperfect Targeting	Equal Targeting	Difference	% Difference	Votes
Average Permits Allocated, All Voters ($TgCO_2e$)	11.3	11.3	0.0	0.0%	436
Average Permits Allocated, Yes Voters	10.3	11.3	1.0	9.8%	219
That Would Have Also Voted for ET	8.4	11.3	2.9	34.8%	156
That Would Not Have Voted for ET	15.1	11.3	-3.8	-24.9%	63
Average Permits Allocated, No Voters	12.4	11.3	-1.0	-8.2%	217

Notes: Imperfect Targeting (IT) reflects the allocation rule under ACESA in which permits are directly allocated to sectors, and then indirectly to legislators. Perfect Targeting (PT) assumes that the proposer can directly allocate permits to legislators. Equal Targeting (ET) assumes that all legislators receive an equal proportion of the total permit pool.

Table 11: Comparison of Optimal Policy Under Imperfect Targeting to Optimal Policy Under Perfect and Equal Targeting

	ACESA	Optimal With Perfect Targeting	Difference	% Difference
Change in Emissions and Permit Allocations				
Change in Emissions, Climate Policy to BAU ($TgCO_2e$)	-1,142.7	-1,876.2	-733.5	64.2%
Change in Emissions, Climate Policy to ASM ($TgCO_2e$)	-2,912.3	-3,645.8	-733.5	25.2%
Average Permits Allocated ($TgCO_2e$)	11.3	9.7	-1.7	-14.8%
To Yes Voters	10.3	19.3	9.0	87.0%
To Proposer	9.2	2,168.7	2,159.5	–
All Others	10.3	9.4	-0.9	-8.9%
To No Voters	12.9	0.0	-12.9	-100.0%

Change in Agg. Surplus, Using Revealed Estimate of External Damages				
Change in Agg. Surplus Climate Policy to BAU (billion $)	-47.1	-88.9	-41.9	89.0%
To Yes Voters	0.0	56.1	56.1	–
To Proposer	0.0	55.9	55.9	–
All Others	0.0	0.2	0.2	–
To No Voters	-47.1	-145.0	-98.0	–
Change in Agg. Surplus Climate Policy to ASM (billion $)	-67.0	-108.9	-41.9	62.5%

Change in Agg. Surplus, Using Scientific Estimate of External Damages				
Change in Agg. Surplus Climate Policy to BAU (billion $)	14.7	12.5	-2.2	-15.2%
To Yes Voters	8.5	55.4	47.0	–
To Proposer	-0.1	55.7	55.8	–
All Others	8.6	-0.3	-8.9	–
To No Voters	6.2	-43.0	-49.2	–
Change in Agg. Surplus Climate Policy to ASM (billion $)	90.4	88.1	-2.2	-2.5%

Notes: BAU denotes the outcome under business as usual or no climate policy. There is no solution when permits are distributed according to equal targeting. "Difference" column may not add up due to changes in the number of voters between policies.

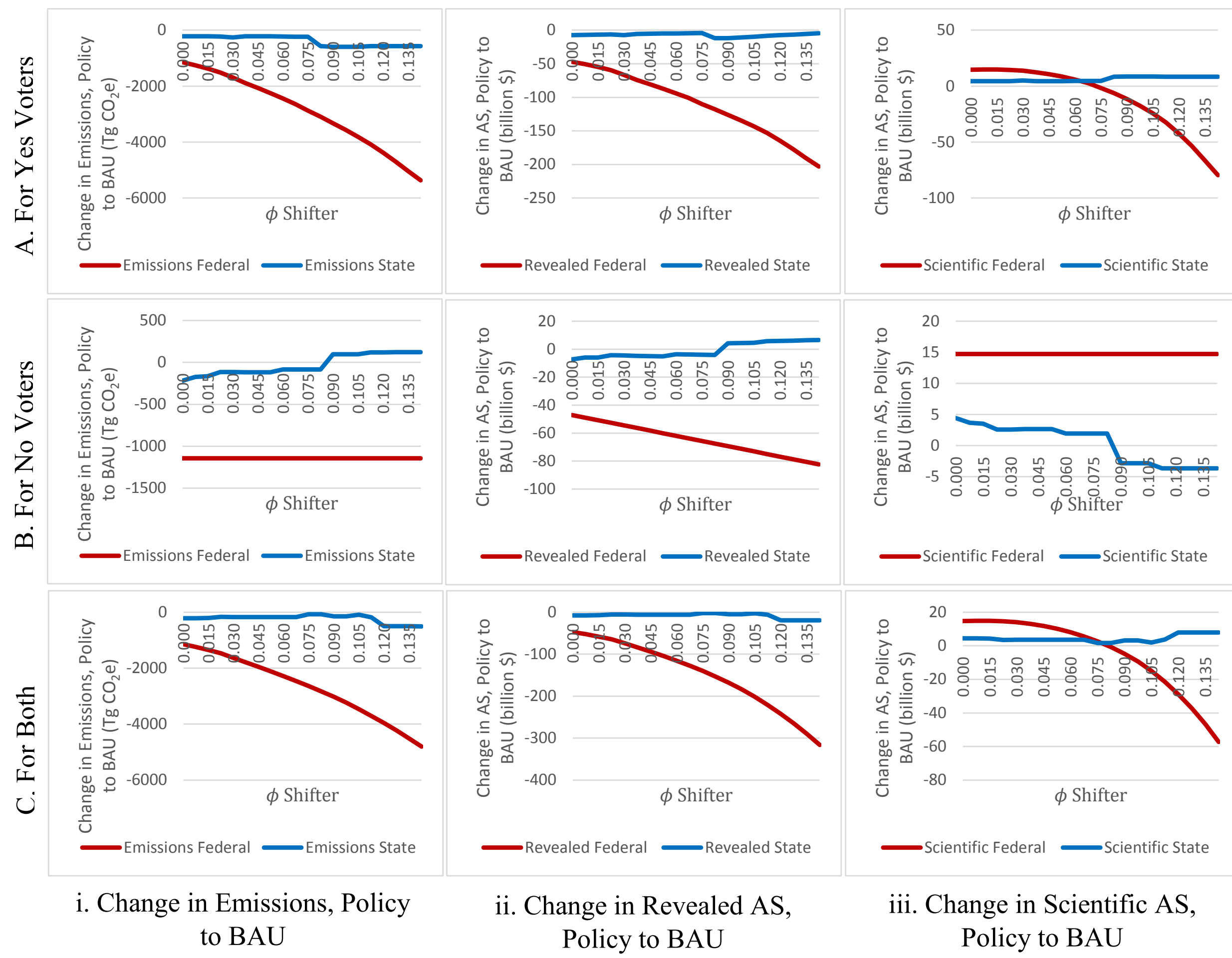
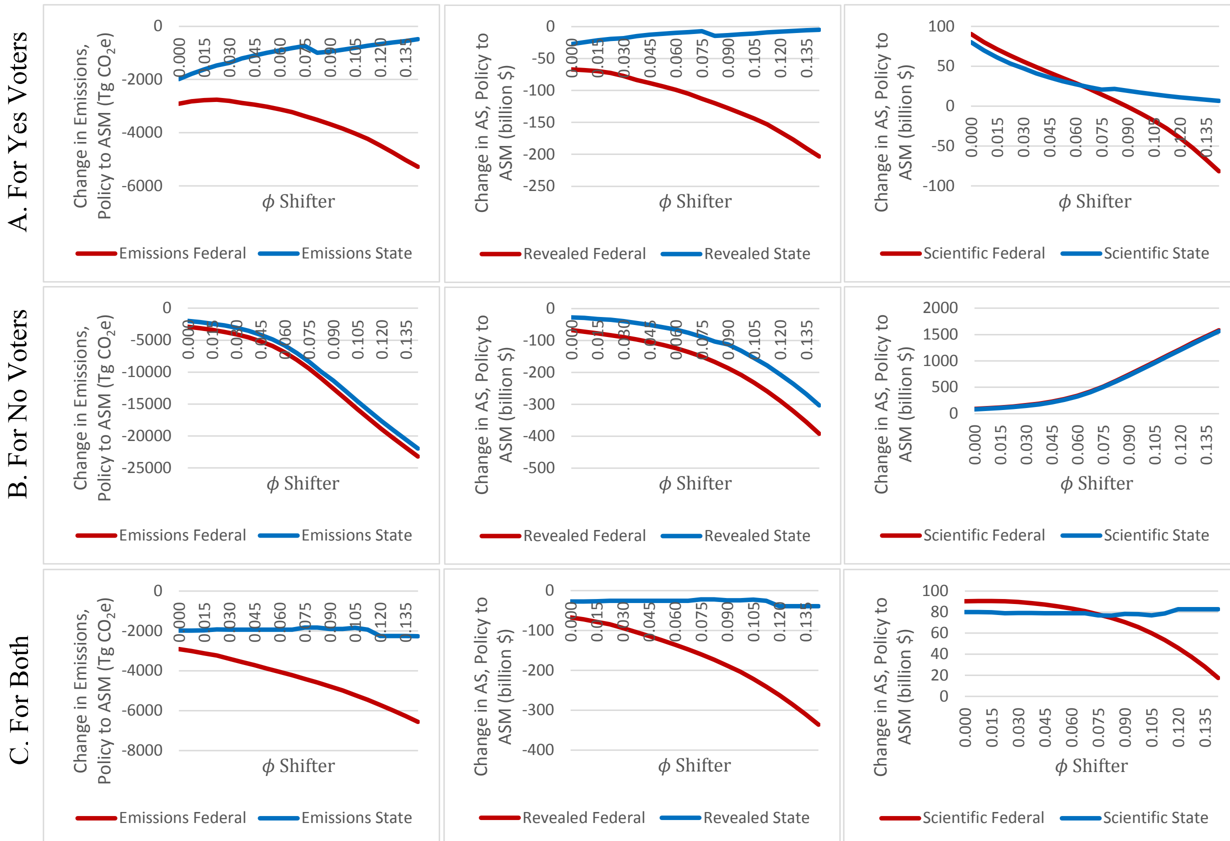


Figure 2: Comparison of Federal and State Policy to BAU Under Alternate ϕ



i. Change in Emissions, Policy to ASM

ii. Change in Revealed AS, Policy to ASM

iii. Change in Scientific AS, Policy to ASM

Figure 3: Comparison of Federal and State Policy to ASM Under Alternate ϕ

Appendix

How Disagreement Regarding Climate Change Affects Federal and State Efforts to Address It

Joel R. Landry

For reference only and not for publication.

A Model Calibration

I calibrate the model to analyze the welfare impacts of ACESA for the year 2021. Although I calibrate the model for 2021, much of the data used to calibrate the economic model reflects the year 2007 economy which is then extrapolated forward to the year 2021 using data from the EPA's IGEM assessment of the ACESA climate bill and GDP projections from the US BEA.[41]

A.1 Economy

A.1.1 Economic Sector Definitions

I consider seven economic sectors: electricity, natural gas, heating oil, petroleum refineries, automotive, trade vulnerable industries, and other. These correspond to subscripts $s = 1, ..., 7$, respectively.

Electric power generation, transmission and distribution is listed as NAICS=221100. I define this as $s = 1$, *Electricity*.

Natural gas distribution is listed as NAICS=221200. I define this as $s = 2$, *Natural Gas*.

Heating Oil dealers is listed as NAICS=454311. Liquefied Petroleum Gas (Bottled Gas) Dealers is listed as NAICS=454312. Other Fuel Dealers is listed as NAICS=454319. I define this as $s = 3$, *Heating Oil*.

Petroleum refineries is listed as NAICS=324110. I define this as $s = 4$, *Petroleum Refineries*.

Automobile manufacturing is listed as NAICS=336111. Light truck and utility vehicle manufacturing is listed as NAICS=336112. Heavy duty truck manufacturing is listed as NAICS=336120. Motor vehicle body manufacturing is listed as NAICS=336211. Motor vehicle parts manufacturing is listed as NAICS=336300. I define this as $s = 5$, *Automotive*.

Alkalies and chlorine manufacturing is listed as NAICS=325181. All other basic inorganic chemical manufacturing is listed as NAICS=325188. All other basic

[41] While 2008 or 2009 are closer to the ACESA vote, 2007 precedes the recent recession.

organic chemical manufacturing is listed as NAICS=325199. Alumina refining is listed as NAICS=331311. Carbon and graphite product manufacturing is listed as NAICS=335991. Carbon black manufacturing is listed as NAICS=325182. Cellulosic organic fiber manufacturing is listed as NAICS=325221. Cement manufacturing is listed as NAICS=327310. Ceramic wall and floor tile manufacturing is listed as NAICS=327122. Clay refractory manufacturing is listed as NAICS=327124. Copper, nickel, lead, and zinc mining is listed as NAICS=21223. Cyclic crude and intermediate manufacturing is listed as NAICS=325192. Electrometallurgical ferroalloy product manufacturing is listed as NAICS=331112. Ethyl alcohol manufacturing is listed as NAICS=325193. Flat glass manufacturing is listed as NAICS=327211. Glass container manufacturing is listed as NAICS=327213. Ground or treated mineral and earth manufacturing is listed as NAICS=327992. Gum and wood chemical manufacturing is listed as NAICS=325191. Inorganic dye and pigment manufacturing is listed as NAICS=325131. Iron and steel mills is listed as NAICS=331111. Iron and steel pipe and tube manufacturing from purchased steel is listed as NAICS=331210. Iron ore mining is listed as NAICS=212210. Lime manufacturing is listed as NAICS=327410. Mineral wool manufacturing is listed as NAICS=327993. Newsprint mills is listed as NAICS=322122. Nitrogenous fertilizer manufacturing is listed as NAICS=325311. Noncellulosic organic fiber manufacturing is listed as NAICS=325222. Nonclay refractory manufacturing is listed as NAICS=327125. Other pressed and blown glass and glassware manufacturing is listed as NAICS=327212. Other structural clay product manufacturing is listed as NAICS=327123. Paper (except newsprint) mills is listed as NAICS=322121. Petrochemical manufacturing is listed as NAICS=325110. Phosphate rock mining is listed as NAICS=212392. Phosphatic fertilizer manufacturing is listed as NAICS=325312. Plastics material and resin manufacturing is listed as NAICS=325211. Porcelain electrical supply manufacturing is listed as NAICS=327113. Primary aluminum production is listed as NAICS=331312. Primary smelting and refining of copper is listed as NAICS=331411. Primary smelting and refining of nonferrous metal (except cooper and aluminum) is listed as NAICS=331419. Pulp mills is listed as NAICS=322110. Reconstituted wood product manufacturing is listed as NAICS=321219. Synthetic organic dye and pigment manufacturing is listed as NAICS=325132. Synthetic rubber manufacturing is listed as NAICS=325212. Tire cord and tire fabric mills is listed as NAICS=314992. Vitreous china plumbing fixture and china and earthenware bathroom accessories manufacturing is listed as NAICS=327111. Vitreous china, fine earthenware, and other pottery product manufacturing is listed as NAICS=327112. Wet corn milling is listed as NAICS=311221. I define this as $s = 6$, *Trade*

Vulnerable Industries. This characterization of Trade Vulnerable Industries is taken from Schneck et al 2009.

Non-differentiated capital is the total amount of capital less capital from these six sectors. I define this as $s = 7$, *Other Economic*.

A.1.2 Civic Sector Definitions

I permit seven categories of civic 'sectors' to reflect the seven broad categories of permits otherwise distributed by ACESA after those provided to the economic sectors I have defined above. *Low Income* reflects permits going to low-income consumers, or $s = 8$. *CCS* reflects permits going to Carbon Capture and Storage (CCS) beneficiaries, or $s = 9$. *Renewables* reflects permits going to areas with high potential for renewable energy development, or $s = 10$. *Adaptation* reflects permits going for domestic adaptation, or $s = 11$. *Workers* reflects permits going for job re-training and other worker investments, or $s = 12$. *Building* reflects permits going for building codes, or $s = 13$. *Other Civic* reflects permits going for international forestry set-asides, wildlife and natural resource adaptation, international adaptation, international clean technology deployment, and for deficit reduction and climate change consumer refund, or $s = 14$.

A.1.3 Size of the Economy

I assume total US Real GDP equal to $19,519.5 billion (2009 dollars) in 2021. This is computed after first calculating an average annual growth Real GDP rate over the past 20 years (2012-1992) of 2.62% from the *US BEA Real GDP, Table 1.1.6* dataset and extrapolating this from the total real GDP reported in 2012 of $15,470.7 billion. I note that the EPA's IGEM Analysis of ACESA reports GDP equal to $19,173.0 billion (after adjusting to 2009 dollars) in 2020. The EPA estimate is roughly 0.8% higher than the same calculation performed for the year 2020. The US CBO's *The Budget and Economic Outlook: Fiscal Years 2011-2021* reports a GDP estimate of $23,333.8 in 2021 (after adjusting to 2009 dollars), which is 19.5% greater than my estimate.

To determine the share of capital and labor in the economy I use the US BEA *2002 Input-Output Table, The Use of Commodities by Industries after Redefinitions*. I compute a share of labor income to total output, $share_{\pi_0}$, equal to 0.3179 which equals 'Compensation of employees' divided by 'Total industry output'. I assume the share of capital to total output equal to $1 - share_{\pi_0}$. Using this the total value of labor nationally, π_0, is $6,204.5 billion in 2021 ($GDP_{2021} share_{\pi_0}$). Likewise, the total value of capital nationally, rK_0, is $13,315.0 billion ($GDP_{2021}\left(1 - share_{\pi_0}\right)$). Normalizing $r = 1$, then K_0 is 13,315.0.

A.1.4 Labor

$\bar{L}_d$ is the sum of persons sixteen or older who are in the civilian labor force as reported by the *US Census 2007 American Community Survey, DP-03 Selected Economic Characteristics, 1-Year Estimates* by congressional district.

Total returns to labor by congressional district, π_d, is computed by combining employment data by two digit NAICS code provided in the *US Census 2007 American Community Survey, DP-03 Selected Economic Characteristics, 1-Year Estimates* by congressional district with national data on compensation to employees by three digit NAICS code provided in the *US BEA 2002 Input-Output Table After Redefinitions, Use File*. Formally, π_d equals:

$$\pi_d = \pi_0 \sum_{\hat{s}=1}^{13} comp_{\hat{s}} \sigma_{d\hat{s}}, \tag{A.1}$$

where $comp_{\hat{s}}$ is "compensation to employees" by two-digit NAICS code $\hat{s} = 1, \ldots, 13$ aggregated from data by three digit NAICS codes reported in the BEA dataset, and $\sigma_{d\hat{s}}$ is the share of employees in sector $\hat{s}$ in congressional district d to the total number of employees in sector $\hat{s}$ nationally which is computed from the Census dataset. Formally, this is:

$$\sigma_{d\hat{s}} = \frac{emp_{d\hat{s}}}{\sum_{\hat{s}=1}^{13} emp_{d\hat{s}}}, \tag{A.2}$$

where $emp_{d\hat{s}}$ is the total number of employees in congressional district d employed in two-digit NAICS sector $\hat{s}$.

A.1.5 Capital

Detailed capital data by congressional district and sector does not exist. I approximate capital demanded by district d for sector s according to:

$$k_{ds} = \varrho_{ds} k_s, \tag{A.3}$$

where k_s is total amount of capital nationally in sector s, and ϱ_{ds} is the share of capital in district d and sector s to the total amount of capital in sector s nationally.

δ_{ds} is given by:

$$\varrho_{ds} = \frac{x_{ds}}{\sum_{d=1}^{D} x_{ds}}, \tag{A.4}$$

where x_{ds} equals the estimated total number of employees in congressional district d and economic sector s.

x_{ds} is computed using the *US Census 2007 County Business Patterns* dataset which has data at the county level on employment, total annual payroll, and number of establishments by employment size class broken down by six-digit NAICS codes. Out of a dataset of 2,216,770 counties by NAICS sectors, data on employment (mid-March) exists for only 741,178 county by NAICS classes and total annual payroll for only 930,409 county by NAICS classes. The missing datapoints in this series are those that are withheld to avoid disclosing confidential firm data, and both the employment and total annual payroll variables separately provide a noise flag denoting this fact ($nf = D$), with the value for the respective variable set to 0 when that this is the case. That said, the number of establishments by employment size class is not confidentially protected and appears to be complete (see below). Thus I impute x_{ds} using an estimate of total employment by county and economic sector, $e\hat{m}p_{cs}$, using the number of establishments by size class dataseries, and the share of area of county c in congressional district d, s_{cd}. Thus x_{ds} is given by:

$$x_{ds} = \sum_{c} s_{cd} e\hat{m}p_{cs}. \tag{A.5}$$

My estimate of the total number of employees by county, $e\hat{m}p_{cs}$ is given by:

$$\begin{aligned}
e\hat{m}p_{cs} = {} & n_{(1-4)}2.5 + n_{(5-9)}7 + n_{(10-19)}15 + n_{(20-49)}35 + n_{(50-99)}75 + n_{(100-249)}175 \\
& + n_{(250-499)}375 + n_{(500-999)}750 + n_{(1000-1499)}1250 + n_{(1500-2499)}2000 + n_{(2500-4999)}3750 \\
& + n_{(5000+)} * 6000,
\end{aligned} \tag{A.6}$$

where $n_{(1-4)}$ is the number of establishments with $1-4$ employees, and the other n_x are likewise defined with $n_{(5000+)}$ being the number of establishments with 5,000 plus employees. I note that unlike my estimate of the number of employees by county-NAICS combination, emp_{cs}, $e\hat{m}p_{cs}$ appears to be complete. That is, for all county-NAICS combinations $e\hat{m}p_{cs}$ does not equal zero. I can validate this estimate of the number of employees by county-NAICS combination by comparing $e\hat{m}p_{cs}$ with emp_{cs} for those datapoints that do not have a confidentiality noiseflag (e.g. $nf \neq D$). For this subset I find that $e\hat{m}p_{cs}$ has a mean of 954.4 and a standard deviation of 11,210.0 and emp_{cs} a mean of 848.6 and a standard deviation of 10,259.9, with the average difference between the two equal to 105.8, or $e\hat{m}p_{cs}$ is on average 12.5% greater than emp_{cs}. Although there is some error in $e\hat{m}p_{cs}$, this error is not excessive and the correlation coefficient between $e\hat{m}p_{cs}$ and emp_{cs} equals 0.9913, suggesting that $e\hat{m}p_{cs}$ should be a decent proxy for emp_{cs}. I note that across all counties in the US the sum of $e\hat{m}p_{cs}$ for the NAICS code representing the economy-wide total number of employed in the US is 135.0 million, whereas according to the national *2007 County Business Patterns* dataset the total number employed in the

US economy in 2007 was 120.6 million. Finally, since I do not have all county-NAICS combinations in the data, those combinations that are not present are assumed to have zero employees for the NAICS sector for that respective county.

The share of county c in district d is given by:

$$s_{cd} = \frac{\text{area of county } c \text{ in district } d}{\text{area of county } c}, \tag{A.7}$$

where areas are computed using ESRI's ArcGIS software using shapefiles for congressional districts and counties provided by the US Census.

Capital going to sector s nationally is given by:

$$k_s = \chi_s K_0, \tag{A.8}$$

where χ_s is the share of the value of all commodities sold by sector s nationally to the total value of all commodities in the economy.

χ_s is computed using data from the *US BEA 2002 Input-Output Tables, Detailed Make File* which provides data on the total value of commodities produced nationally by six digit NAICS sector. That is:

$$\chi_s = \frac{\text{Total Commodity Value}_s}{\sum_{s=1}^{7} \text{Total Commodity Value}_s}. \tag{A.9}$$

where Total Commodity Value$_s$ is the total value of the commodity produced by economic sector s in producers' prices. The BEA dataset does not report the annual sales of heating oil dealers, LPG dealers, or other fuel dealers, which I have defined as my third economic sector, *Heating Oil*. As a result, I impute the share of Home Heating Oil, $\chi_{s=3}$, using the size of the electricity sector from the *US BEA 2002 Input-Output Tables*, $\chi_{s=1}$, data from the EIA on the share of BTU's used for home heating oil relative to those used for electricity generation, $BTUshare_{HHOtoElect}$. In 2007, the electric power sector consumed 40,068 trillion BTUs according to the *US EIA 2012 Annual Energy Review Table 8.4b*. The *US EIA 2012 Annual Energy Review Table 5.12* reports that 8,921 trillion BTUs, 67 trillion BTUs, and 1,729 trillion BTUs of distillate fuel oil, kerosene, and propane were supplied in 2007. According to the *US EIA Fuel Oil and Kerosene Sales 2009* the share of distillate fuel oils sales to the residential sector was 0.081 in 2007. This reflects the proportion of total distillate fuel that is going for home heating oil, i.e. distillate fuel oil #2. Likewise, the same report shows that 0.66 of kerosene sales went for residential use in 2007. Using these shares and the information on BTUs supplied I calculate

$BTUshare_{HHOtoElect} = \frac{(8921*0.081+67*0.66+1729)}{40068} = 0.0623$. Consequently, $\chi_{s=3}$ is given by:

$$\chi_{s=3} = BTUshare_{HHOtoElect}\chi_{s=1}. \tag{A.10}$$

Finally, $\chi_{s=7} = 1 - \sum_{s=1}^{6} \chi_s$. Together, these calculations imply: $\chi = [0.0151359, 0.0056347, 0.000943, 0.0115895, 0.0267711, 0.0243214, 0.9156044]$.

Given k_{ds} total capital demanded by congressional district is simply: $y_d = \sum_{s=1}^{7} k_{ds}$.

A.1.6 Private Good Production Parameters

Under no policy, representative firms located in each district solve:

$$\begin{bmatrix} \max_{y_d \geq 0, \{k_{ds}\}_{s=1}^{S} \geq 0} \gamma_d y_d^{\rho_d} \bar{L}_d^{1-\rho_d} - r y_d \\ \textit{subject to:} \\ y_d = \min \left\{ \frac{k_{ds}}{\omega_{ds}} \right\}_{s=1}^{S} \end{bmatrix}. \tag{A.11}$$

The solution to (A.11) provides the unconditional factor demands, $y_d\left(r; \gamma_d, \rho_d, \bar{L}_d\right)$, and the value function is the total returns to labor, $\pi_d\left(r; \gamma_d, \rho_d, \bar{L}_d\right)$. Inverting the closed form solutions corresponding to $y_d\left(r; \gamma_d, \rho_d, \bar{L}_d\right)$ and $\pi_d\left(r; \gamma_d, \rho_d, \bar{L}_d\right)$, given my calibration year data, r, π_d, y_d, the capital share parameter for the Cobb-Douglas production function, ρ_d, has a closed form solution that is given by:

$$\rho_d = \left(\frac{r y_d}{r y_d + \pi_d} \right). \tag{A.12}$$

Given ρ_d, $y_d\left(r; \gamma_d, \rho_d, \bar{L}_d\right)$, and calibration year data, $r, y_d, \bar{L}_d$, I can obtain the closed form solution for the Cobb-Douglas scaling parameter:

$$\gamma_d = \left(\frac{r}{\rho_d} \right) \left(\frac{y_d}{\bar{L}_d} \right)^{1-\rho_d}. \tag{A.13}$$

Finally, given k_{ds} and y_d, I can compute the Leontief share parameters: $\omega_{ds} = \frac{k_{ds}}{y_d}$.

A.1.7 Capital Supply Parameters

I assume capital supply is equal to capital demand by congressional district, $K_s = y_d$. I assume that the capital supply elasticities are identical across all districts, that is: $\eta_d = \eta$ for all $d = 1, ..., D$.

I select η such that the permit price predicted by my model under the 2021 ACESA cap approximates the estimated permit price reported in the *US EPA IGEM Analysis*, Scenario

2 of $P = \$16.75$ per ton CO_2e. Finally, the capital supply scaling parameter can be solved as a function of the calibrated data:

$$\zeta_j = rK_j^{\left(-\frac{1}{\eta_j}\right)}. \tag{A.14}$$

A.2 Emissions

The data used to calibrate emissions by sector comes from the *US EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2010 Table ES-2* for the year 2007. This provides emissions from various sources which I aggregate to compute emissions by economic sector. I then re-scale these emissions levels to the emissions levels predicted by the *US EPA IGEM Analysis* for the year 2021.

Total net emissions in the US in 2007 were 7,263.2 Tg CO_2e. Total predicted emissions under the EPA analysis are 7,448.8 Tg CO_2e. Of these 1,413.2 Tg CO_2e or 19.0% of total emissions in 2021 are projected to be outside of the cap, leaving total covered emissions of 6,035.6 Tg CO_2e. If I assume that 19.0% of 2007 emissions are emissions that would not be covered given the 2021 coverage levels, the net emissions in 2007 would be 5,885.2 Tg CO_2e ($= (1 - 0.19)7,263.2$). This allows us to rescale 2007 emissions to 2021 levels according to $share_{emissions} = \frac{6,035.6}{5,885.2} = 1.026$.

Emissions for sector *Electricity* equal CO_2 emissions from fossil fuel combustion for electricity generation plus SF_6 from electrical transmission and distribution = 2,412.8 + 8.8 = 2,421.6 Tg CO_2e, which after rescaling are 2,483.5 Tg CO_2e.

Emissions for sector *Natural Gas* equals CO_2 emissions from natural gas systems, plus CH_4 from natural gas systems = 30.9 + 168.4 = 199.3 Tg CO_2e, which after rescaling are 204.4 Tg CO_2e.

Emissions for sector *Heating Oil* equals CO_2 emissions from non-energy use of fuels = 134.9 Tg CO_2e, which after rescaling are 138.3 Tg CO_2e.

Emissions for sector *Petroleum Refineries* equals CO_2 emissions from petrochemical production and petroleum systems plus CH_4 from petroleum systems and petrochemical production = 4.1+0.3 + 29.8+3.3 = 37.5 Tg CO_2e, which after rescaling are 38.5 Tg CO_2e.

Emissions for sector *Automobiles* is set equal to zero. I note that the EPA's Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2010 does report the emissions from fossil fuel combustion for transportation in the US of 1,904.7 Tg CO_2e. However, this is emissions from non-point sources and so it does not make sense to attribute emissions to automobile production, which is how the sector is categorized here.

Emissions for sector *Trade Vulnerable Industries* equals CO_2 emissions from iron, steel and metallurgical coke production, cement production, lime production, ammonia production, aluminum production, soda ash production and consumption, titanium dioxide production, ferroalloy production, glass production, zinc production, phosphoric acid production, lead production, and silicon carbide production and consumption plus CH_4 from iron, steel, and metallurgical coke production, ferroalloy production, and silicon carbide production and consumption plus N_2O from nitric acid production and adipic acid production plus HFC's from semiconductor manufacture plus PFC's from semiconductor manufacture and aluminum production plus SF_6 from magnesium production and processing and semiconductor manufacture = 71.3 +44.5 +14.6 +9.1 +4.3 +2.9 +1.9 +1.6 +1.5 +1.0 +1.2 +0.6 +0.2 +0.7 +0.05 +0.05 +19.7 +10.7 +0.3 +3.8 +3.8 +2.6 +0.8 = 197.2 Tg CO_2e, which after rescaling are 202.2 Tg CO_2e.

Emissions for *Other Economic Sectors* equals total net emissions of 7,263.2 Tg CO_2e less emissions from the above sectors, so = 7,263.2 - 2,421.6 - 199.3 - 134.9 - 37.5 - 197.2 = 4,272.7 Tg CO_2e. After rescaling to 2021 emissions levels I have 4,381.9 Tg CO_2e. From this I deduct the emissions that are not covered by the cap, 1413.2 Tg CO_2e, leaving 2,968.7 Tg CO_2e. These are the emissions that enter the model.

Thus, other emissions is 58.8% of total emissions, and emissions from the other six sectors are 41.2% of total emissions. While the six formal sectors receive 62% of total permits in 2021, it should be noted that given the limited way in which the *Inventory* reports sectoral emissions it is virtually impossible to disentangle the emissions from industrial sources that are generated by the six formal sectors versus those generated by industrial sources embedded with the other sector.

Let E_s denote the emissions levels defined above. Then the sectoral emissions parameters are simply $\alpha_s = \frac{E_s}{k_s}$.

A.2.1 Emissions Validation

Given capital by district and sector, k_{ds} and the sectoral emissions parameters, α_s, I am able to impute total emissions by district, $E_d = \sum_{s=1}^{7} \alpha_s k_{ds}$. To validate this imputation I consider two alternative emissions datasets, the *US Vulcan Emissions*, *Version 2.2* dataset which provides emissions estimates by 10km squares across the US for 2007, and the *US EPA Greenhouse Gas Reporting Program 2010* which began monitoring emissions from direct emitters and suppliers in the US beginning in 2010, which together account for 85% to 90% of total US emissions. Using GIS software I compute estimates of total emissions by congressional district from each dataset.[42] Re-scaling all three estimates

[42]Emissions by congressional district using the *Vulcan* dataset are computed by intersecting the 10km squares with my shapefile of congressional districts, and then summing emissions by 10 km square by the fraction of area overlap in each district. The *Greenhouse Gas Reporting Program* provides the latitude and

by the total emissions predicted in each dataset, respectively, provides the share of total emission by congressional district, which I use for comparison.[43] My imputed emissions estimate exceeds the *Vulcan* estimate on average by 10.4% and under-predicts the *Greenhouse Gas Reporting Program* estimate on average by 3.1%. Standard deviations are considerable at 61.4% and 176.9% for each dataset, respectively. While these standard deviations are considerable, a direct comparison of both validation datasets provides some basis for understanding these magnitudes. The emissions intensity predicted by the *Greenhouse Gas Reporting Program* estimate exceeds the *Vulcan* estimate by 8.1% on average with a standard deviation of 152.4%. Thus, differences in coverage likely explain a great deal of this difference.

A.3 Civil Sector Exposure

A.3.1 Low Income Exposure

Low Income exposure reflects the share of households in a congressional district whose incomes in the last 12 months are below the poverty level to total US households whose incomes in the last 12 months are below the poverty level. This is simply:

$$\delta_{d,s=8} = \frac{poor_d}{\sum_{d=1}^{D} poor_d}, \tag{A.15}$$

where $poor_d$ is the number of households in congressional district d whose income in the past 12 months has been below the poverty level as reported in the *US Census 2007 American Community Survey*.

A.3.2 CCS Exposure

CCS exposure reflects the share of potential carbon, capture and storage available in a congressional district to total US potential for carbon, capture and storage. This is simply:

$$\delta_{d,s=9} = \frac{CCS_d}{\sum_{d=1}^{D} CCS_d}, \tag{A.16}$$

longitude coordinates for 6,232 direct emitters ("facilities that combust fuels or otherwise put GHGs into the atmosphere directly from their facility") and 759 suppliers ("those entities that supply certain fossil fuels or fluorinated gases into the economy which, when combusted, released or oxidized emit greenhouse gases into the atmosphere"). After plotting each facility I join facilities with the congressional district to which they are located, and then sum total emissions across facilities located within each congressional district.

[43] I note that there is significant differences in coverage between the three datasets and in some cases different years of coverage, making direct comparisons difficult. By rescaling by total emissions predicted by each dataset what I am comparing is the share of total emissions by congressional district to the total emissions predicted nationally, or the relative emissions intensity of each congressional district predicted by each dataset.

where CCS_d is the metric tons of CCS potential in congressional district d.

To compute CCS_d I merge data from the three principal datasets that are used by NREL to compute the CCS estimates reported in *US NREL 2012 Carbon Utilization and Storage Atlas*. These three datasets are: *US NREL 2012 National Carbon Sequestration Database and Geographic Information System (NATCARB) Saline 10K*, *US NREL 2012 NATCARB Coal 10K*, and *US NREL 2012 NATCARB Oil and Gas 10K* spatial databases. While the Atlas also discusses the CCS potential of sedimentary basins, basalt formations, and organic-rich shale basins, the *Atlas* does not provide estimates of CCS potential for these geologies. For the three geologies for which I do have CCS potential estimates by congressional district, I sum to compute an estimate of total CCS potential for each congressional district d given by:

$$CCS_d = CCSSaline_d + CCSCoal_d + CCSOil_d. \tag{A.17}$$

To compute $CCSSaline_d$ I intersect the *Saline 10K* spatial database with my shapefile of congressional districts to construct saline formation (subscript n) by congressional district geographies which I denote by the subscript dn. Saline formations are layers of sedimentary porous and permeable rocks saturated with salty water called brine that are suitable for CCS. My estimate of the carbon potential from saline formations by congressional district is given by:

$$CCSSaline_d = \sum_n \left(\frac{CCSSaline_d area_{dn}}{\sum_n area_{dn}} \right), \tag{A.18}$$

where $CCSSaline_d$ is the medium (P50) estimate of carbon storage potential in metric tonnes for each saline geography n if suitability class equals 1, and $area_{dn}$ is the area of intersected geography dn. For those saline geographies with a 0 value for the medium (P50) estimate I impute this variable as the mean of the P10 and P90 estimates for each saline geography n.

I use repeat this technique to acquire $CCSCoal_d$ and $CCSOil_d$, using the *Coal 10K* and *Oil and Gas 10K* spatial databases, respectively. $CCSCoal_d$ reflects the CCS potential from coal that is considered unmineable because of geologic, technological, and economic factors (typically too deep, too thin, or lacking the internal continuity to be economically mined with today's technologies). $CCSOil_d$ reflects the CCS potential of oil and gas reservoirs, that is porous rock formations (usually sandstones or carbonates) containing hydrocarbons (crude oil and/or natural gas) that have been physically trapped.

A.3.3 Renewables Exposure

Renewables exposure reflects a weighted composite of projected renewables by congressional district for the year 2021. Formally, define:

$$\delta_{d,s=10} = \frac{renew_d}{\sum_{d=1}^{D} renew_d}, \tag{A.19}$$

where $renew_d$ is a composite of total renewable potential in congresional district d in 2021. (A.19) reflects a simple normalization of $renew_d$ so that exposure sums to 1 across all congressional districts. Formally, $renew_d$ is given by:

$$renew_d = s_{geo} geo_d + s_{sol} sol_d + s_{wind} wind_d + s_{bio} bio_d, \tag{A.20}$$

where s_{geo}, s_{sol}, s_{wind}, and s_{bio} are the shares of geothermal, solar, wind and biomass, respectively, of total renewables (the sum of all four) anticipated by 2021. The variables geo_d, sol_d, $wind_d$, and bio_d are measures of the geothermal, solar, wind and biomass potential in congressional district d, respectively, to the total amount available in that renewable class available nationally.

The variables s_{geo}, s_{sol}, s_{wind}, and s_{bio} are impute using data from *US EIA 2012 Annual Energy Review, Table 10.1* which provides the amount of geothermal, wind, solar, and total biomass consumed from 1949 to 2010. I use this data to compute the percent annual growth rate for each year between 1990 and 2010. I then take the average annual growth rate over this 20 year period and use this to impute the total amount of biomass, geothermal, wind, and solar produced by 2021, given the most recent 2011 projections also provided in the table. Given these imputations I calculate weights that reflect the share of a particular renewable class to total renewables consumed in 2021 or s_{geo}, s_{sol}, s_{wind}, and s_{bio}. These shares are 0.019, 0.018, 0.581, and 0.383 for geothermal, solar, wind, and biomass respectively.

To compute wind potential by congressional district d, $wind_d$, I first merge *US NREL 2011 Alaska Wind 25 km* shapefile with the *US NREL 2011 Hawaii Wind 25 km* and the *US NREL 2011 Lower 48 Wind 25 km* shapefiles. The geographies n in the combined US shapefile each possess a wind power class that corresponds to the intensity of wind exposure at 25 km height above the surface. Next, I intersect the resulting US Wind 25 km shapefile with my shapefile of congressional districts, resulting in a new shapefile of power class by congressional district geographies dn. Finally $wind_d$ is given by:

$$wind_d = \frac{\sum_n area_{dn}^{pc\geq 3}}{\sum_{d=1}^{D}\sum_n area_{dn}^{pc\geq 3}}, \tag{A.21}$$

where $area_{dn}^{pc\geq 3}$ is the area of geography dn that has a wind powerclass of 3 or greater, which according to NREL reflects areas "are suitable for most utility-scale wind turbine applications" (US National Renewable Energy Laboratory, 2013). The estimate of wind potential by congressional district, $wind_d$, is thus simply the share of total wind potential in a congressional district to the sum of all total wind potential in the US.

To compute biomass potential by congressional district d, bio_d, I first merge *US NREL 2012 Urban Wood and Secondary Mill Residues* shapefile with *US NREL 2008 Crop Residues* shapefile and *US NREL 2008 Forest and Primary Mill Residues* shapefile. I use this to compute the total amount of biomass energy available from crop residues, methane emissions from manure management, methane emissions from landfills and wastewater treatment facilities, forest residues (forest residues include logging residues and other removable material left after carrying out silviculture operations and site conversions), primary and secondary mill residues (primary mill residues include wood materials (coarse and fine) and bark generated at manufacturing plants (primary wood-using mills) when round wood products are processed into primary wood products, such as slabs, edgings, trimmings, sawdust, veneer clippings and cores, and pulp screenings; secondary mill residues include wood scraps and sawdust from woodworking shops - furniture factories, wood container and pallet mills, and wholesale lumberyards), urban wood waste (urban wood waste includes wood residues from MSW (wood chips and pallets), utility tree trimming and/or private tree companies, and construction and demolition sites), and dedicated energy crops (corn, wheat, soybeans, cotton, sorghum, barley, oats, rice, rye, canola, dry edible beans, dry edible peas, peanuts, potatoes, safflower, sunflower, sugarcane, and flaxseed). Intersecting these shapefiles with congressional districts I construct biomass by congressional district geographies dn which I then use to compute an estimate of total biomass, bio_n. Consequently, bio_d is given by:

$$bio_d = \frac{\sum_n \left(\frac{bio_n area_{dn}}{area_d}\right)}{\sum_{d=1}^{D}\sum_n \left(\frac{bio_n area_{dn}}{area_d}\right)}, \tag{A.22}$$

where: $area_{dn}$ is the area of biomass by congressional district geography dn, and $area_d$ is the area of congressional district d. The estimate of biomass potential by congressional district, bio_d, is thus simply the share of total biomass potential in a congressional district to the sum of all total biomass potential in the US.

To compute geothermal potential by congressional district d, geo_d, I use *US NREL 2009 Geothermal* shapefile which provides a qualitative assessment of geothermal potential for the U.S. using the Enhanced Geothermal Systems (EGS) for various geothermal geographies n. EGS is based on the levelized cost of electricity with class 1 being most favorable and class 5 being the least favorable. I intersect this shapefile with my shapefile of congressional districts to construct the area of geothermal by congressional district geography if EGS class is less than or equal to 2, $area_{dn}^{c\leq 2}$. Finally geo_d is given by:

$$geo_d = \frac{\sum_n area_{dn}^{c\leq 2}}{\sum_{d=1}^{D}\sum_n area_{dn}^{c\leq 2}}. \tag{A.23}$$

Thus, my estimate of geothermal potential by congressional district, geo_d, is simply the share of area in a congressional district with geothermal class of 2 or lower to the sum of all area in the US with a geothermal class of 2 or lower.

To compute solar potential by congressional district d, sol_d, I use *US NREL 2012 Lower 48 and Hawaii PV 10km Resolution 1998 to 2009* shapefile which provides monthly average and annual average daily total solar resources averaged over surface cells of 0.1 degrees in both latitude and longitude, or about 10 km in size. I intersect this shapefile of 10km grid squares denoted by subscript n with my congressional district shapefile. sol_d is given by:

$$sol_d = \frac{\sum_n \left(\frac{sol_n area_{dn}}{area_d}\right)}{\sum_{d=1}^{D}\sum_n \left(\frac{sol_n area_{dn}}{area_d}\right)}, \tag{A.24}$$

where: sol_n is the annual average latitude equals tilt irradiance (or AALETI) (for a given latitude and geography this is a measure of the average solar exposure of a tilted plane held perpendicularly to the sun's rays over the course of a day, or a measure of the maximum possible exposure to the sun's rays that is possible for a given latitude; this is measured in kWh/m2/day), $area_n dn$ is the area of grid square n by congressional district d, and $area_d$ is the area of congressional district d. The estimate of solar potential by congressional district, sol_d, is thus simply the share of total solar potential in a congressional district to the sum of all total solar potential in the US.

A.3.4 Adaptation Exposure

Adaptation exposure reflects relative exposure of a congressional district to sea level rise. This is simply:

$$\delta_{d,s=11} = \frac{seaexp_d}{\sum_{d=1}^{D} seaexp_d}, \tag{A.25}$$

where $seaexp_d$ is a measure of congressional district d's exposure to sea-level rise and equals the approximate length of coastline in congressional district d, $coastline_d$, divided by the average elevation of the congressional district, $elevation_d$.

To compute $elevation_d$ I use the *US GS 2012 National Elevation Dataset* which reports mean elevation for geographies defined as a 1/3 Arc second. I intersect this shapefile with my congressional districts shapefile, resulting in 1/3 Arc second by congressional district geographies denoted by the subscript n. The average elevation of a congressional district d is thus:

$$elevation_d = \frac{\sum_n (elevation_n area_{dn})}{\sum_n area_{dn}}, \tag{A.26}$$

where $elevation_n$ is the mean elevation of geography n and $area_{dn}$ is the area of geography n located in congressional district d.

To compute $coastline_d$ I intersect a 100 meter buffer of the *US 2012 National Atlas Coastline One Million-Scale* shapefile with my shapefile of congressional districts. The sum of the areas of the resulting shoreline by congressional district d geographies is a proxy for the length of coastline for congressional district d.

A.3.5 Worker Exposure

Workers exposure reflects the share of employed workers in a congressional district to total employed workers in the US. This is given by:

$$\delta_{d,s=12} = \frac{workers_d}{\sum_{d=1}^{D} workers_d}, \tag{A.27}$$

where $workers_d$ is employed workers in congressional district d, the sum of employed individuals in the civilian labor force plus labor in the armed services taken from the *US Census 2007 American Community Survey*.

A.3.6 Building Exposure

Building rule reflects the exposure of a congressional district to energy inefficient residential housing stock. This exposure assigns permits according to population, weighted by the inverse of the average year in which residential structures were built, which is then normalized so that the sum of all rules equals 1. Formally, building exposure is given by:

$$\delta_{d,s=13} = \frac{building_d}{\sum_{d=1}^{D} building_d}, \tag{A.28}$$

where $building_d$ is the share of population in congressional district d weighted by the inverse of the average year in which residential structures were built in d to the same for the nation. This is given by:

$$building_d = \frac{pop_d}{year_d}, \tag{A.29}$$

where $year_d$ is the mean year in which residential structures were built in congressional district d, and pop_d is the share of population in congressional district d that is 16 years or older to the total national population that is 16 years or older.

To compute $year_d$ I use *US EIA 2009 Residential Energy Consumption Survey, Public Use Microdata File* (RECS) which includes data from 12,083 households selected at random using a complex multistage, area-probability sample design to represent 113.6 million U.S. households, the US Census Bureau's statistical estimate for all occupied housing units in 2009 derived from the *2007 American Community Survey*. The RECS sample was designed to estimate energy characteristics, consumption, and expenditures for the national stock of occupied housing units and the households that live in them. The geographic unit of observation in the sample is 27 reportable domains, which includes 16 individual states and 11 aggregations of states within similar geographic proximity. Each sampled household has a weight reflecting the number of households it reflects in the RECS reportable domain. I compute the weighted mean by reportable domain of the year in which the household's dwelling unit was built (Question A-6 of the Household Questionnaire, *EIA 457-A*), which is self-reported in the sample. I then assign this mean year built to each congressional district located in a reportable domain, which is $year_d$.

A.3.7 Other Civic Sector Exposure

Other Civic Sector exposure reflects the share of population that is 16 years or older in a congressional district to total US population that is 16 years or older. In effect, this simply splits all remaining permits equally to each district on the basis of a proxy for voting population. Other civic sector exposure is given by:

$$\delta_{d,s=14} = \frac{pop_d}{\sum_{d=1}^{D} pop_d}, \tag{A.30}$$

where pop_d is the population in congressional district d that is 16 years or older as taken from the *US Census 2007 American Community Survey*.

A.4 Private Good Production CES Version

I assume the production function in (4.5) is a CES function given by:

$$X_d = \gamma_d \left(\rho_d y_d^{\sigma_d} + (1 - \rho_d) \bar{L}_d^{\sigma_d} \right)^{\left(\frac{1}{\sigma_d} \right)} \tag{A.31}$$

A.5 Offsets Supply

The US EPA's *ADAGE and IGEM v2.3 Data Annex to HR.2454* model output spreadsheet, sheet "Emissions—IGEM Scn02" provides breakdowns of annual emissions reductions, industry abatement, domestic offsets supplied, international offsets supplied, bank balance, and domestic abatement from CCS, bio-electricity, and non-CO_2e sources. Since ACESA allows borrowing and banking of allowances and the caps become tighter over time, in the early years there is expected to be more total abatement than the annual cap to build the bank. In fact, according to the EPA analysis until 2029 allowances are added to bank after which they are drawn down until the bank is fully depleted by 2050.

As shown in Table 13 for all caps from 2012-2050, total reductions from industry comprise only 42.2% of all emissions reductions, with the remaining 57.8% provided by offsets and other abatement, which I refer to as *total offset supply*. *Total offset supply* equals the sum of *international offsets supply* plus *net domestic offset supply*, where net domestic offset supply includes domestic offsets supplied as well as all other domestic abatement from CCS, bio-electricity, and non-CO_2e sources as tracked by the EPA's analysis. International offsets account for 63.8% of total offsets supply after discounting,[44] with net domestic offset supply accounting for the remaining 36.2%. Domestic offsets account for 52.3% of net domestic offset supply with an additional 34.4% coming from CCS, and 7.4% and 5.9% coming from domestic capped bio-electricity abatement and domestic capped non-CO_2e abatement sources, respectively.

Thus *total offsets supply* is given by:

$$A = 0.8A^I + A^H, \tag{A.32}$$

where *international offsets supply* is given by:

$$A^I = A^I(P) = (\zeta^I)^{-\eta^I} P^{\eta^I}, \tag{A.33}$$

and *net domestic offset supply* is given by:

$$A^H = A^H(P) = (\zeta^H)^{-\eta^H} P^{\eta^H}, \tag{A.34}$$

and the 0.8 in (A.32) reflects the fact international offsets are discounted under ACESA to have 80% of the value of domestic abatement.

The US EPA's *Non*-CO_2 *and Offset MAC Data Annex to HR.2454* provides

[44] Under ACESA, international offsets count as only 0.8 of domestic emissions reductions.

supplementary data tables used to to compute the various categories of offsets and abatement discussed above. I select η^I to reflect the total supply elasticity from offsets supplied as a result of international avoided deforestation and afforestation. These are by far the bulk of expected international offsets supplied.

To do this I estimate (A.33) using data on offsets supplied from this channel for a given schedule of carbon prices taken from the 'March 2009 Int'l Forest Carbon Sequestration' data file. The original source of this data is Mendelsohn and Sohngen (2007). Taking the natural log of both sides of (A.33) provides an estimating equation in terms of abatement quantities and prices:

$$\ln A_k^I = \beta_0^I + \eta^I \ln P_k + \epsilon_k^I, \tag{A.35}$$

The resulting OLS regression fits the data very well (adjusted $R^2 = 0.933$), with $\eta^I = 2.19$ and is statistically significant at the 5% level.

Likewise, I select η^H to reflect the total supply elasticity from offsets and abatement supplied from: offsets, bio-electricity abatement, ethanol abatement diesel abatement, domestic afforestation, domestic animal waste (CH_4 and N_2O), domestic other agriculture (CH_4 and N_{20}, domestic forest management, and domestic soil sequestration. I note that this includes basically all of the components included in net domestic supply except CCS.

To do this I estimate (A.34) using data on offsets supplied from this channel for a given schedule of carbon prices taken from the 'March 2009 Domestic, Ag, Forest, and Biomass' data file. The original source of this data is Daigneault and Fawcett (2009). Again, taking the natural log of both sides of (A.34) provides an estimating equation in terms of abatement quantities and prices:

$$\ln A_k^H = \beta_0^H + \eta^H \ln P_k + \epsilon_k^H, \tag{A.36}$$

The resulting OLS regression again fits the data very well (adjusted $R^2 = 0.999$), with $\eta^H = 1.22$ and is statistically significant at the 1% level.

I calibrate the share parameters in (A.33) and (A.34), ζ^I and ζ^H, such that total offsets supplied as a share of total emissions reductions reflects the average share under the EPA's analysis for all years, with the breakdown between international and domestic offsets reflecting their average shares. To be precise, total emissions reductions of 1,132.6 Tg CO_2e are required in 2021 and the EPA's IGEM analysis predicts an allowance price of $P =$ \$0.01675 per Tg CO_2e in the same year. Thus I assume that $A = 654.6$ $(= 0.578 \times 1,132.6)$. Likewise $A^H = 236.7$ $(= 0.209 \times 1,132.6)$ and $A^I = 522.4$ $(= \frac{A - A^H}{0.8})$. Inverting (A.33) and

(A.34), I have:

$$\zeta^I = \frac{P}{(A^I)^{\eta^I}}, \tag{A.37}$$

and:

$$\zeta^H = \frac{P}{(A^H)^{\eta^H}}. \tag{A.38}$$

With offsets in the model, the last market clearing equation in (4.7) becomes instead: $\sum_{d=1}^{D} (\xi_d + N_d(r,P,\xi_d)) - A(P) = \bar{E}_0$. I note that offsets do not effect the private good production problem. Rather, offsets only impact the permit market. Since $\sum_{d=1}^{D} \xi_d = \bar{E}_0$, the implied market clearing for purchased permits is now: $\sum_{d=1}^{D} N_d(r,P,\xi_d) = A$ instead of $\sum_{d=1}^{D} N_d(r,P,\xi_d) = 0$. Thus net demand for purchased permits will reflect positive demand for offsets instead of zero.

When offsets are included in the model the private budget constraint is instead: $x_d = \pi_d + rK_d + P\theta_d A^H$, where θ_d is the share of domestic offsets supplied owned by the district.[45] Likewise, aggregate surplus as reported in (4.4) is instead: $U_d = u_d - \hat{\kappa}_d$, where $\hat{\kappa}_d = \kappa_d + \kappa^H$ and $\kappa^H = \theta_d \left(\frac{\eta^H}{1+\eta^H}\right)(\zeta^H)^{-\eta^H} P^{1+\eta^H}$. Intuitively, national aggregate surplus is simply the sum of the total value of the labor endowment ($\sum_{d=1}^{D} \pi_d$), producer surplus from supplying capital ($\sum_{d=1}^{D} (rK_d - \kappa_d)$), and producer surplus from supplying domestic offsets nationally ($\sum_{d=1}^{D} \left(PA^H - \kappa^H\right)$), less the sum of external damages from emissions ($e^0 \sum_{d=1}^{D} \phi_d$).

B Analytical Derivations

B.1 Centralized Policy

Consider a model consisting of one sector, e.g. $S = 1$. Assume that districts are identical in every way except with respect to their environmental preferences, that is restrict $\zeta = \zeta_d$, $\eta = \eta_d$, $\bar{L} = \bar{L}_d$, $\gamma = \gamma_d$, $\rho = \rho_d$, and $\omega = \omega_d$ for all districts $d = 1,...,D$. Assume that $\gamma \geq \left(\frac{1+\eta}{\eta}\right)$. Given $\omega = \omega_d$, it is also the case that $\alpha = \alpha_d$ for all $d = 1,...,D$. Further, suppose that $\rho = 1$, thus the private good is produced linearly as a function of y and γ and labor is effectively dropped from the model.

For simplicity also assume that ϕ_d is distributed uniformly on the interval $[\phi_L, \phi_H]$, where $\frac{\gamma}{D\alpha(1+\eta)} > \phi_H > \phi_L > 0$.[46] Let district subscripts be sorted such that $\phi_1 > ... > \phi_D$. Given this $\phi_1 = \phi_H$ is the greatest climate believer and $\phi_D = \phi_L$ is the greatest climate

[45] Note that $\sum_{d=1}^{D} x_d = PA^H + r\sum_{d=1}^{D} K_d + \sum_{d=1}^{D} \pi_d = PA^H + r\sum_{d=1}^{D} K_d + \sum_{d=1}^{D} f_d(y_d^*) - r\sum_{d=1}^{D} y_d^* - P\sum_{d=1}^{D} N^* = \sum_{d=1}^{D} f_d(y_d^*) - 0.8PA^I$, given $\sum_{d=1}^{D} y_d^* = \sum_{d=1}^{D} K_d$ and $\sum_{d=1}^{D} N^* = A$ by market clearing in capital and permit markets, respectively.

[46] The restriction that $\frac{\gamma}{D\alpha(1+\eta)} > \phi_H$ is for analytical tractability. This emerges from the requirement that the cap selected under indirect targeting, $\bar{E}_0^{IT}$, is greater than the cap that generates the greatest amount of

skeptic. All those districts in between will be believers if $\phi_d > 0$ or skeptics if $\phi_d \leq 0$. An important implication of this assumption is that: $U_1\left(\bar{E}_0\right) - U_1^{BAU} < \ldots < U_D\left(\bar{E}_0\right) - U_D^{BAU}$ for all $\bar{E}_0 \leq E_0^{BAU}$. Effectively, this means that the districts $d = 1, \ldots, D_M$ will be the cheapest to bring into any electoral coalition.

Note that these assumptions imply that $y = y_d$, $K = K_d$, $\pi = \pi_d = 0$, $\kappa = \kappa_d$ for all districts $d = 1, \ldots, D$. For simplicity, define the producer surplus from supplying capital as $W = rK - \kappa$. Given the other assumptions, it is the case that $y = K = \left(\frac{\bar{E}_0}{\alpha D}\right)$ (and so choosing y is equivalent to choosing $\bar{E}_0$), and thus $r(y) = \zeta y^{\frac{1}{\eta}}$, $P(y) = \frac{\gamma - \zeta y^{\frac{1}{\eta}}}{\alpha}$, $P(y)\bar{E}_0 = P(y)\alpha D y = \gamma D y - D\zeta y^{\left(\frac{1+\eta}{\eta}\right)}$, and $W(y) = \left(\frac{1}{1+\eta}\right)\zeta y^{\left(\frac{1+\eta}{\eta}\right)}$.

B.1.1 With Perfect Targeting

Define the electoral coalition that includes the legislator as the set $\mathbb{D}_p^* = \{(p,d) : d = 1, \ldots, p-1 \bigvee d = p+1, \ldots, D_M \text{ if } p \in [1, D_M - 1] \text{ or } d = 1, \ldots, D_M - 1 \text{ if } p \in [D_M, D]\}$. I note that this set includes all of the high ϕ type legislators as well as the proposer which can be anyone. So far I have asserted that the set $\mathbb{D}_p^*$ is the only viable electoral coalition. To understand why this is, suppose, for simplicity but without loss of generality, that $p \in [1, D_M - 1]$, and so the coalition consists of all legislators from $d = 1$ to $d = D_M$. Now consider an alternative coalition, $\mathbb{D}_p^{**}$, whereby the $d = D_M$ legislator is replaced with the $d = D$ legislator. This new legislator receives permits equal in value to: $P(y)\xi_D = \max\{0, W^{BAU} - \phi_D \alpha D y^{BAU} - W(y) + \phi_D \alpha D y\}$, whereas the previous legislator would have received $P(y)\xi_{D_M} = \max\{0, W^{BAU} - \phi_{D_M} \alpha D y^{BAU} - W(y) + \phi_{D_M} \alpha D y\}$. For simplicity, but again without loss of generality, suppose $\xi_D > 0$ and $\xi_{D_M} > 0$ that is the zero is not the solution to the maximand.

The difference in the value of permits received between the new and the replaced legislators is given by: $\varepsilon(y) = P(y)\xi_D - P(y)\xi_{D_M} = \alpha D\left(y^{BAU} - y\right)\left(\phi_{D_M} - \phi_D\right)$. Since $\phi_{D_M} > \phi_D$, by definition, and a binding cap will be such that $y \leq y^{BAU}$, then $\varepsilon(y) \geq 0$

permit revenue, $\bar{E}_0^{RM}$. This means that for any cap reduction below business as usual emissions, E_0^{CE}, i.e. $E^{CE} > \bar{E}_0^{IT} > \bar{E}_0^{RM}$ the imperfect cap selected for any proposer $p = 1, \ldots, D$ will generate a permit revenue pool that monotonically increases in magnitude as $\bar{E}_0^{IT} \to \bar{E}_0^{RM}$. Thus, for this portion of the parameter space greater emissions reductions correspond to a larger green cake (total value of permits), which is to say that emissions reductions complement the pool of green pork available for redistribution. The requirement that $\phi_L > 0$ means climate beliefs cannot be negative, and thus all possible proposers $p = 1, \ldots, D$ will choose an imperfect cap that results in emissions reductions. Were $\phi_L < 0$ then some proposers may seek to achieve an imperfect cap (a mandate) that is greater than emissions under no policy. In that case the cheapest districts to bring into an electoral coalition will be the $d = D_M + 1, \ldots, D$ group of skeptics, and given the previous assumption emissions increases are substitutes to the pool of green pork, e.g. as $\bar{E}_0^{IT} - E^{CE} \to \infty$ the green cake gets monotonically smaller. In the numerical model, while I permit $\phi_d < 0$, I impose the additional restriction that the climate policy must achieve emissions reductions, and so many of those same proposers would instead choose no policy.

for all possible caps implied by y. Now, note that the value of permits paid to the proposer equals $P(y)\left(\alpha D y - \sum_{d=1}^{D_M-1} \xi_d(y) - \xi_{D_M}(y)\right)$ under the original coalition $\mathbb{D}_p^*$ and $P(y)\left(\alpha D y - \sum_{d=1}^{D_M-1} \xi_d(y) - \xi_D(y)\right)$ under the new coalition $\mathbb{D}_p^{**}$. The difference between these two pay-outs for any cap implied by y is simply $-\varepsilon(y)$. Thus, the proposer would forfeit a pay-off equal to $-\varepsilon(y)$ in order to absorb legislator D in the coalition as opposed to legislator D_M. It follows that the proposer, in wishing to maximize their own utility, will never choose a coalition that includes D over D_M, except for the special case whereby $\xi_{D_M} = 0$ and $\xi_D = 0$ and a super-majoritarian (unanimous if in fact D) coalition will emerge.[47] By extension, if I replaced any members or subsets of members included in $\mathbb{D}_p^*$, with other legislators or groups of legislators along $d = D_M + 1, ..., D$, then the same conclusion must inevitably follow.

Consequently, choosing the cap that solves (4.9) is equivalent to finding the y that maximizes $U_p^D(y) = D_M W(y) + P(y)\alpha D y - \hat{\phi}_p \alpha D y - \sum_{d \neq p \in \mathbb{D}_p^*} U_d^{BAU}$, where $\hat{\phi}_p = \sum_{d \in \mathbb{D}_p^*} \phi_d$, and after substituting in the $\xi_d(y, U_d^{BAU})$ that solves $U_d(y, \xi_d) = U_d^{BAU}$ for all $d \neq p \in \mathbb{D}_p^*$.[48] This yields the cap under perfect targeting equal to: $\bar{E}_0^{DT} = \alpha D \zeta^{-\eta}\left[\left(\gamma - \alpha\hat{\phi}_p\right)\left(\frac{D\eta}{D(1+\eta) - D_M}\right)\right]^{\eta}$.

I note that I can define the aggregate surplus of those in the electoral coalition as $\sum_{d \in \mathbb{D}_p^*} U_d(y)$. Maximizing this object yields the same result as maximizing $U_p^{DT}(y)$ following(4.9), since $U_p^{DT}(y) = \sum_{d \in \mathbb{D}_p^*} U_d(y) - \sum_{d \neq p \in \mathbb{D}_p^*} U_d^{BAU}$, and $\sum_{d \neq p \in \mathbb{D}_p^*} U_d^{BAU}$ is exogenous. Consequently, the cap that maximizes $\sum_{d \in \mathbb{D}_p^*} U_d(y)$ is exactly equal to the cap under perfect targeting of $\bar{E}_0^{DT}$. This proves the first sentence in Proposition 1, although this only holds when the optimal coalition is a minimum-winning coalition consisting of $\mathbb{D}_p^*$ where $\xi_d > 0$ for all non-proposers in $\mathbb{D}_p^*$.[49]

Before I showed that of all possible minimum winning coalitions (coalitions that just achieve the vote threshold of D_M legislators) that $\mathbb{D}_p^*$ must be the only optimal solution. However, I did not show that a non-minimum winning coalition, i.e. a super-majoritarian or unanimous coalition is not feasible in this case. I note that in order for a non-minimum winning coalition (a coalition containing more than D_M legislators) to be sustained that

[47] Although I assumed that $\xi_D > 0$ and $\xi_{D_M} > 0$ to keep things simple, relaxing this assumption does not change this observation. To understand why note that if $\xi_D = 0$ then so too must ξ_{D_M}. That is, if the more skeptical legislator's vote can be secured without any pay-off, then so too must the believer's vote too, all else equal. If $\xi_{D_M} = 0$ when $\xi_D > 0$ then the same analysis clearly follows.

[48] To be precise, this is for the special case of $\mathbb{D}_p^*$ whereby $\xi_d(y) > 0$ for all non-proposing legislators in $\mathbb{D}_p^*$. Similar results can be shown when $\xi_d(y) = 0$ for some non-proposing legislators in the minimum winning coalition.

[49] If $\xi_d = 0$ for some, but not all non-proposing legislators in $\mathbb{D}_p^*$, then the proposer selects a cap that only reflects the preferences of those for whom $\xi_d > 0$. In that case, the perfect cap only maximizes the aggregate surplus of those legislators in $\mathbb{D}_p^*$ for whom $\xi_d > 0$, which is sufficient for this sentence to not be true in some cases.

$\xi_d = 0$ at least for all non-proposers in $\mathbb{D}_p^*$. Other legislators not included in $\mathbb{D}_p^*$ (i.e. for those $d \in [D_M + 1, D]$) would also need to have $\xi_d = 0$ in order to be included in a super-majoritarian or unanimous coalition. In fact, a super-majoritarian coalition implies that at least some non-proposing legislator would need $\xi_d > 0$ in order to secure their vote (but more than D_M need $\xi_d = 0$), whereas a unanimous coalition is sustained only if all non-proposing legislators require $\xi_d = 0$. Consequently, $\mathbb{D}_p^*$ is the only possible electoral coalition if and only if $\xi_d > 0$ for all legislators in $\mathbb{D}_p^*$ for any possible cap such that $\bar{E}_0^{DT} \leq E_0^{BAU}$. Given the way preferences are ordered and the symmetry assumptions then all legislators $d \in [D_M + 1, D]$ would also require positive permits in order to bring them into the coalition.

To show that $\xi_d > 0$ for all non-proposers in $\mathbb{D}_p^*$, note that: $P(y^{DT})\xi_d = \left(U_d^{BAU} + \alpha D\phi_d y^{DT} - W(y^{DT})\right)$. Since $P(y^{DT}) > 0$, then to show $\xi_d > 0$ is the same as showing that $\left(U_d^{BAU} + \alpha D\phi_d y^{DT} - W(y^{DT})\right) > 0$. Now $U_d^{BAU} = y^{BAU}\left(\frac{\gamma}{1+\eta} - \alpha D\phi_d\right)$, $\alpha D\phi_d y^{DT} - W(y^{DT}) = y^{DT}\left[\left(\frac{r^{DT}}{1+\eta}\right) - \alpha D\phi_d\right]$, where $r^{DT} = \zeta\left(y^{DT}\right)^{\left(\frac{1}{\eta}\right)}$. I note that $r^{BAU} = \gamma$ and, since $\bar{E}_0^{DT} \leq E_0^{BAU}$ (and thus $y^{DT} \leq y^{BAU}$), then $r^{DT} < \gamma$. Re-arranging terms of $\left(U_d^{BAU} + \alpha D\phi_d y^{DT} - W(y^{DT})\right) > 0$, I have: $\left[y^{BAU}\left(\frac{\gamma}{1+\eta}\right) - y^{DT}\left(\frac{r^{DT}}{1+\eta}\right)\right] + \alpha D\phi_d\left(y^{BAU} - y^{DT}\right) > 0$. Now the second term is positive given that $y^{DT} \leq y^{BAU}$, whereas the first term is positive because $y^{DT} \leq y^{BAU}$ and $r^{DT} < \gamma$. I note that I have shown this for any cap so long as $\bar{E}_0^{DT} \leq E_0^{BAU}$. This is the case here since all legislators are believers by construction, and since a cap larger than E_0^{BAU} can only be achieved through subsidization, that is $P < 0$. Consequently, the minimum winning coalition given by $\mathbb{D}_p^*$ is the only possible coalition.

To show the second sentence in Proposition 1, note that total national aggregate surplus is given by $\sum_{d=1}^{D} U_d(y)$. Maximizing this expression yields a cap that equals: $\bar{E}_0^{NAS} = \alpha D\zeta^{-\eta}\left(\gamma - \alpha\hat{\phi}\right)^{\eta}$, where $\hat{\phi} = \sum_{d=1}^{D}\phi_d$. The second sentence requires us to show that: $\bar{E}_0^{D} \leq \bar{E}_0^{NAS}$, or more simply that: $\left(\gamma - \alpha\hat{\phi}_p\right)\left(\frac{D\eta}{D(1+\eta) - D_M}\right) \leq \left(\gamma - \alpha\hat{\phi}\right)$. Cross-multiplying and re-arranging terms provides: $\gamma \geq \alpha\left[\left(\frac{D\eta - D_N}{D_N}\right)\hat{\phi} - \left(\frac{D\eta}{D_N}\right)\hat{\phi}_d\right]$. For sake of contradiction, suppose instead that $\alpha[\cdot] < \gamma$. Note my earlier requirement that $\frac{\gamma}{D\alpha(1+\eta)} > \phi_H$ and the fact that $\phi_H \geq \phi_d$ for all districts implies that: $\alpha\left[\left(\frac{D\eta - D_N}{D_N}\right)\hat{\phi} - \left(\frac{D\eta}{D_N}\right)\hat{\phi}_d\right] < \alpha\left[\left(\frac{D\eta - D_N}{D_N}\right)D\frac{\gamma}{D\alpha(1+\eta)} - \left(\frac{D\eta}{D_N}\right)D_M\frac{\gamma}{D\alpha(1+\eta)}\right]$, which simplifies down to: $\alpha\left[\left(\frac{D\eta - D_N}{D_N}\right)\hat{\phi} - \left(\frac{D\eta}{D_N}\right)\hat{\phi}_d\right] > \gamma$, which is a contradiction and so the cap that maximizes national aggregate surplus is less stringent then the cap from perfect targeting.

This makes intuitive sense as the cap that maximizes national aggregate surplus reflects an average of the preferences of all districts, whereas the cap from perfect targeting reflects the average of the preferences of all districts included in the coalition $\mathbb{D}_p^*$, which is comprised of districts that are on average greater climate believers than the national average. The first sentence of Proposition 2 follows from this result and Jensen's inequality.

B.1.2 With Imperfect Targeting

Without loss of generality, consider a proposer is selected such that $p \in [1, D_M - 1]$. The cap that solves (4.9) is equivalent, given my assumptions here, to the y that maximizes:

$$\begin{bmatrix} \max_y W(y) + \frac{1}{D}P(y)\alpha Dy - \phi_p \alpha Dy \\ \textit{subject to:} \\ W(y) + \frac{1}{D}P(y)\alpha Dy - \phi_{D_M}\alpha Dy \geq U_{D_M}^{BAU} \\ W(y) + \frac{1}{D}P(y)\alpha Dy - \phi_p \alpha Dy \geq U_p^{BAU} \end{bmatrix}, \tag{B.1}$$

where I note the first constraint in (B.1) binds the last voter joining the coalition which again consists of all legislators in the set $\mathbb{D}_p^*$. If the D_M voter is on board, then all of the other $d = 1, ..., D_M - 2$ voters in $\mathbb{D}_p^*$ must also be on board given my symmetry assumptions, the fact that permits are now symmetrically distributed, and the way the ϕ_d's are ordered. If instead the proposer is selected such that $p \in [D_M, D]$, then the first constraint in (B.1) is instead replaced by $W(y) + \frac{1}{D}P(y)\alpha Dy - \phi_{D_M - 1}\alpha Dy \geq U_{D_M - 1}^{BAU}$.

In either case, the solution to (B.1) consists of two candidates. The first candidate is the unconstrained solution to (B.1). In this case only the proposer's preferences matter in determining the cap and, as such, $\bar{E}_0^{ITU} = \alpha D \zeta^{-\eta}\left(\gamma - \alpha D \phi_p\right)^{\eta}$. This is a potential solution for $p \in [1, D]$ so long as the D_M legislator is on board, that is $U_{D_M}(\bar{E}_0^{ITU}) \geq U_{D_M}^{BAU}$. I note that when $p \in [D_M, D]$ that the D_M legislator must be on board since $U_{D_M}(\bar{E}_0^{ITU}) > U_{D_M}^{BAU}$. I note that $\bar{E}_0^{ITU}$ is a possible solution so long as the proposer's aggregate surplus constraint (the second constraint in (B.1)) is satisfied. I note that since $\gamma \geq \left(\frac{1+\eta}{\eta}\right)$ and my earlier assumption that $\phi_d \leq \frac{\gamma}{D\alpha(1+\eta)}$ for all $d = 1, ..., D$, it will be the case that $U_p^{ITU} \geq U_p^{BAU}$ for any unconstrained imperfect cap.[50]

The second candidate is the constrained solution, where $\bar{E}_0^{IUC}$ is the analytically intractable solution that solves: $U_{D_M}(\bar{E}_0^{ITC}) = U_{D_M}^{BAU}$. By the same intuition as before, it must be the case that this is only a candidate solution when $p \in [1, D_M]$, since $U_p(\bar{E}_0^{ITC}) < U_p^{BAU}$ when $p \in [D_M + 1, D]$ (that is, a skeptical proposer will have less utility under the constrained cap then under business as usual). I note that when $p \in [1, D_M]$, that $\bar{E}_0^{ITU} < \bar{E}_0^{ITC}$, since the greater believer p would select a more strict cap than that which just satisfied legislator D_M when not constrained. Thus, to prove the third result in Proposition 1, I simply need to show that $\bar{E}_0^{ITU} \geq \bar{E}_0^{DT}$. This is equivalent to showing

[50] Note that $U_p^{ITU} = \zeta^{-\eta}\left(\frac{1}{1+\eta}\right)\left(\gamma - \alpha D\phi_p\right)^{(1+\eta)}$, whereas $U_p^{BAU} = \gamma^{\eta}\zeta^{-\eta}\left(\frac{1}{1+\eta}\right)\left(\gamma - \alpha D \phi_p\right)$.

that $\left(\gamma - \alpha D \phi_p\right) \geq \left(\gamma - \alpha \hat{\phi}_p\right)\left(\frac{D\eta}{D(1+\eta)-D_M}\right)$. Cross-multiplication and re-arranging of terms yields: $D_N \gamma \geq \alpha D\left[(D\eta + D_N)\phi_p - \eta\hat{\phi}_p\right]$. For sake of contradiction, suppose the opposite inequality holds. Recall again the assumption that $\phi_d \leq \frac{\gamma}{D\alpha(1+\eta)}$ for all $d = 1, ..., D$. Given this the RHS of the previous expression implies that $\alpha D\left[(D\eta + D_N)\phi_p - \eta\hat{\phi}_p\right] < D_N \gamma$, which is a contradiction and so the cap selected by imperfect targeting is less stringent then the cap selected through perfect targeting.

Finally, the last line of Proposition 1 follows from the observation that the unconstrained imperfect cap may be larger (if $p \in [D_M + 1, D]$) or smaller (if $p \in [1, D_M - 1]$) than $\bar{E}_0^{NAS}$. The last line of Proposition 2 follows from this observation and Jensen's inequality.

C Numerical Algorithms

C.1 To Solve Business as Usual (Competitive) Equilibrium

The solution to the business as usual, or competitive equilibrium is simply the solution to the economic model in the absence of any climate policy:

1. Given the price of capital, r^i, compute the amount of capital demanded and supplied and the amount of capital demanded and construct the excess demand function, $\sum_{d=1}^{436}(K_d - y_d) = 0$.

The result is the solution, r^{BAU}, which can be fed through to provide the full output for this model, $\mathbf{X}^{BAU}\left(r^{BAU}\right)$.

C.2 To Solve Legislative Bargaining With Perfect Targeting

Given the cap $\bar{E}_0^i$, other exogenous parameters, and the output from the business as usual run (competitive equilibrium):

1. Given $\bar{E}_0^i$, solve for equilibrium prices that close the economic model $\left(r^i\left(\bar{E}_0^i\right), P^i\left(\bar{E}_0^i\right)\right)$ given (4.1.4).

2. Given $\left(r^i\left(\bar{E}_0^i\right), P^i\left(\bar{E}_0^i\right)\right)$, obtain the aggregate surplus for all legislators excluding the value of permits, $\hat{U}_d^{PT}\left(\bar{E}_0^i\right)$.

3. Given $\hat{U}_d^{PT}\left(\bar{E}_0^i\right)$, $P^i\left(\bar{E}_0^i\right)$, and U_d^{BAU}, compute the level of permits that would be needed to secure any legislator's votes, as $\hat{\xi}_d\left(\bar{E}_0^i\right) = \max\left\{0, \left(\frac{1}{P^i\left(\bar{E}_0^i\right)}\right)\left(U_d^{BAU} - \hat{U}_d^{PT}\left(\bar{E}_0^i\right)\right)\right\}$.

4. Drop the proposer, and sort the remaining $D-1$ vector $\hat{\boldsymbol{\xi}}\left(\bar{E}_0^i\right)$ from lowest to highest.

5. Locate the last zero element, z, of $\hat{\boldsymbol{\xi}}\left(\bar{E}_0^i\right)$. If $z \geq D_M$ then no permits are parsed out to non-proposers and all non-proposers up to and including z are yes voters who will vote for the policy. This allows for the possibility of super-majoritarian or unanimous coalitions, for example if $D > z > D_M$ or $z = D$, respectively. If $z < D_M$, then only a minimum winning coalition is possible, and the first D_M elements of $\hat{\boldsymbol{\xi}}\left(\bar{E}_0^i\right)$ are the positive pay-offs for non-proposers that are placed into $\boldsymbol{\xi}\left(\bar{E}_0^i\right)$, with all other non-proposer elements of $\boldsymbol{\xi}\left(\bar{E}_0^i\right)$ set equal to zero. The indices of those in the coalition are placed into the set $\mathbb{D}_p^i\left(\bar{E}_0^i\right)$.

6. Given $\bar{E}_0^i$ and $\boldsymbol{\xi}\left(\bar{E}_0^i\right)$, compute the residual permits going to the proposer as: $\xi_d\left(\bar{E}_0^i\right) = \bar{E}_0^i - \sum_{d\in\mathbb{D}_p^i\left(\bar{E}_0^i\right)} \xi_d\left(\bar{E}_0^i\right)$. This is then reincorporated into the full vector of permits $\boldsymbol{\xi}\left(\bar{E}_0^i\right)$.

7. Once $\boldsymbol{\xi}\left(\bar{E}_0^i\right)$ has been fully identified, I can evaluate the objective function (e.g. the proposer's aggregate surplus, $U_p^i\left(\bar{E}_0^i\right)$) and evaluate the proposer's aggregate surplus constraint, $U_p^i\left(\bar{E}_0^i\right) \geq U_p^{BAU}$.

The result is the solution, $\bar{E}_0^{PT}$, which can be fed through to provide the full output for this model, $\mathbf{X}^{PT}\left(\bar{E}_0^{PT}\right)$. Given the properties of the other functions of the model, this search is monotonic in $\bar{E}_0^i$, and thus this algorithm should converge quickly to a unique solution. This is a novel algorithm that exploits the logic of the legislative bargaining model to identify $\boldsymbol{\xi}\left(\bar{E}_0^i\right)$ rather than search for $\bar{E}_0^i$ and the entire vector of permits $\boldsymbol{\xi}$, simultaneously.

For a toy version of the model where $D = 10$, I have compared the results from this algorithm to a combinatorial bi-level program that explicitly solves the legislative bargaining model with direct targeting and that follows below. I show in Section C.5 using the model of Volden and Wiseman (2007, 2008), that specifying the legislative bargaining model as a nested optimization algorithm results in a solution that exactly replicates the corrected solution of Volden and Wiseman (2008). Although my model is different than Volden and Wiseman (2007, 2008) in that my economic equilibrium is endogenous, the same fundamental legislative bargaining structure applies here. Consequently, this algorithm can be used to solve other legislative bargaining models in which the optimal policy is conditional on the economic equilibrium.

In the context of my model, for the bottom program I first solve, given a possible coalition, $\mathbb{D}_p^k$:

$$\begin{bmatrix} \max_{\bar{E}_0,\xi} U_p\left(\bar{E}_0,\boldsymbol{\xi}\right) \\ \textit{subject to:} \\ U_d\left(\bar{E}_0,\boldsymbol{\xi}\right) \geq U_d^{BAU}\ \forall\, d \in \mathbb{D}_p^k \\ U_p\left(\bar{E}_0,\boldsymbol{\xi}\right) \geq U_p^{BAU} \\ \sum_{d=1}^{D} \xi_d \leq \bar{E}_0 \end{bmatrix}. \tag{C.1}$$

Once the optimal policy for every possible coalition has been identified, $\bar{E}_0\left(\mathbb{D}_p^k\right), \boldsymbol{\xi}\left(\mathbb{D}_p^k\right)$, in the upper program the proposer selects the policy *and coalition* that maximizes their aggregate surplus:

$$\begin{bmatrix} \max_{\mathbb{D}_p^k \forall k} U_p\left(\bar{E}_0\left(\mathbb{D}_p^k\right),\boldsymbol{\xi}\left(\mathbb{D}_p^k\right)\right) \\ \textit{subject to:} \\ U_p\left(\bar{E}_0\left(\mathbb{D}_p^k\right),\boldsymbol{\xi}\left(\mathbb{D}_p^k\right)\right) \geq U_p^{BAU} \end{bmatrix}. \tag{C.2}$$

I note that solution to (C.2) given (C.1) is robustly identical to the one returned from my efficient algorithm detailed above.

Finally, I note that my efficient perfect targeting algorithm is similar to the algorithm used to solve the legislative bargaining model with an equal share rule, except that under an equal share rule, $\xi_d = \frac{1}{D}$ and the steps 2-6 are unnecessary.

C.3 To Solve Legislative Bargaining With Imperfect Targeting

Given the policy vector $\boldsymbol{\Omega}^i = \left(\bar{E}_0^i, \theta_{s=1}^i, \ldots, \theta_{s=13}^i\right)$,[51] other exogenous parameters, and the output from the business as usual run (competitive equilibrium):

1. Given $\bar{E}_0^i$ solve for equilibrium prices that close the economic model $\left(r^i\left(\boldsymbol{\Omega}^i\right), P^i\left(\boldsymbol{\Omega}^i\right)\right)$ given (4.1.4).

2. Given $\left(r^i\left(\boldsymbol{\Omega}^i\right), P^i\left(\boldsymbol{\Omega}^i\right), \theta_{s=1}^i, \ldots, \theta_{s=13}^i\right)$, compute the vector $\xi^i\left(\boldsymbol{\Omega}^i\right)$.

3. Given $\left(r^i\left(\boldsymbol{\Omega}^i\right), P^i\left(\boldsymbol{\Omega}^i\right), \bar{E}_0^i, \xi^i\left(\boldsymbol{\Omega}^i\right)\right)$ obtain the remaining economic output of the model, $\mathbf{X}^i\left(\boldsymbol{\Omega}^i\right)$.

4. Given $\mathbf{X}^i\left(\boldsymbol{\Omega}^i\right)$, compute the vote vector, $v_d^i\left(\boldsymbol{\Omega}^i\right) = 1$ if $U_d^i\left(\boldsymbol{\Omega}^i\right) \geq U_d^{BAU}$ and $v_d^i\left(\boldsymbol{\Omega}^i\right) = 0$ otherwise for all $d = 1, \ldots, 436$ needed to evaluate the vote constraint, e.g. $D_M - \sum_{d=1}^{D} v_d^i\left(\boldsymbol{\Omega}^i\right) \leq 0$.

[51] Here I have re-sorted the s index such that the other economic sector (originally $s = 7$) is now $s = 14$. Consequently, by assumption $\theta_{s=14}^i = 0$ and so can be dropped from the analysis.

5. Given $\mathbf{X}^i\left(\mathbf{\Omega}^i\right)$, evaluate the objective function (e.g. the proposer's aggregate surplus, $U_p^i\left(\mathbf{\Omega}^i\right)$) and evaluate the proposer's aggregate surplus constraint, $U_p^i\left(\mathbf{\Omega}^i\right) \geq U_p^{BAU}$.

6. Given $\left(\theta_{s=1}^i, ..., \theta_{s=13}^i\right)$, evaluate the theta constraint, e.g. $\sum_{s=1}^{13} \theta_s^i \leq 1$.

The result is the solution, $\mathbf{\Omega}^{IT}$, which can be fed through to provide the full output for this model, $\mathbf{X}^{IT}\left(\mathbf{\Omega}^{IT}\right)$. While the algorithm that solves the perfect targeting model is monotonic in its search arguments, this is not case here. To be precise the imperfect targeting algorithm is not well-behaved with respect to $\left(\bar{E}_0^i, \theta_{s=1}^i, ..., \theta_{s=13}^i\right)$. Thus the solution to this algorithm requires multiple random restarts. Since I invert the algorithm to calibrate the vector ϕ^{ACESA} given the observed ACESA policy and electoral coalition I am able to uniquely characterize the true optimum as that which returns the ACESA policy and electoral coalition as its prediction. The additional maximand term in (5.3) assures this by effectively making all other coalitions more expensive from the perspective of the proposer.

C.4 To Solve State Model

Given the vector of state caps $\bar{\mathbf{E}}^i$, other exogenous parameters, and the output from the business as usual run (competitive equilibrium):

1. Given $\bar{\mathbf{E}}^i$, identify the price of capital and the price of permits, $\left(r^i\left(\bar{\mathbf{E}}^i\right), P^i\left(\bar{\mathbf{E}}^i\right)\right)$, such that capital and permit markets close following (4.7).

2. Given $\left(r^i\left(\bar{\mathbf{E}}^i\right), P^i\left(\bar{\mathbf{E}}^i\right)\right)$, obtain the aggregate surplus vector observed for the current vector of state caps, $\mathbf{V}^i\left(\bar{\mathbf{E}}^i\right)$.

3. For every $k = 1, ..., D$, solve:

   (a) Given $\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D$, obtain $y_{d\neq k}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right) = \sum_{d\neq k=1}^D \frac{\bar{E}_d^i}{\alpha_d}$.

   (b) Given $y_{d\neq k}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$, search for the $\hat{r}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$ that solves for the conditional competitive equilibrium, e.g. that solves: $\sum_{d=1}^D K_d\left(\hat{r}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)\right) = y_{d\neq k}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right) + y_k^i\left(\hat{r}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)\right)$. Note that $y_k^i(\cdot)$ is simply the no policy solution to (4.7) given $\hat{r}^i(\cdot)$.

   (c) Given $\hat{r}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$, obtain the conditional competitive equilibrium emissions level for the kth state, $\hat{E}_k\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right) = \alpha_k y_k^i\left(\hat{r}^i\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)\right)$ as well as the conditional competitive equilibrium aggregate surplus for the kth state, $\hat{V}_k\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$.

(d) If $V^i\left(\bar{\mathbf{E}}^i\right) \geq \hat{V}_k\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$, then:

i. Perturb $\bar{E}_k^i$ by a small increment, $\varepsilon > 0$, call this $\bar{E}_{k2}^i\left(\bar{E}_k^i\right) = (1+\varepsilon)\bar{E}_k^i$.

ii. Given $\bar{E}_{k2}^i\left(\bar{E}_k^i\right)$ and holding $\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D$ fixed, re-solve for the market prices $\left(r_2^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right), P_2^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)\right)$ that satisfy market clearing.

iii. Given $\left(r_2^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right), P_2^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)\right)$, compute the new aggregate surplus, $V_{k2}^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$.

iv. Given $V_k^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$ and $V_{k2}^i\left(\bar{E}_{k2}^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)$ characterize the kth equation in the system to set equal to zero as: $\frac{dV_k}{d\bar{E}_k} = \left(\frac{V_{k2}^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right) - V_k^i\left(\bar{E}_k^i, \left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right)}{\bar{E}_{k2}^i\left(\bar{E}_k^i\right) - \bar{E}_k^i}\right)$. Note that this is a numerical approximation of the first-order condition to the state's optimization problem given by (5.1), which is conditional on all other state policies $\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D$ and evaluated at $\bar{E}_k^i$. Because I only enter here if the above inequality is satisfied this is the non-binding solution to (5.1).

(e) Else, characterize the kth equation in the system to set equal to zero as: $\hat{E}_k\left(\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D\right) - \bar{E}_k^i$. That is to say, if a state policymaker does not wish to set a cap, then they will emit at the conditional competitive equilibrium which is also conditional on all other state policies $\left\{\bar{E}_d^i\right\}_{d\neq k=1}^D$. Thus, this is the binding solution to (5.1).

The solution that sets the resulting 50 by one system of equations equal to zero is, $\bar{\mathbf{E}}^{SP}$, which can be fed through to provide the full output for this model, $\mathbf{X}^{SP}\left(\bar{\mathbf{E}}^{SP}\right)$.

C.5 Equivalence of Solution Method with that of Volden and Wiseman 2007 and 2008

Recall the set-up from Volden and Wiseman (2007, 2008). Let there be n jurisdictions, infinite time periods with discounting between time periods at discount rate $\delta \in [0,1]$. There is a global public good y and as well as local public goods $x_k \forall k = 1, ..., n$. The central government plays a game of 'split the dollar' between the two classes of goods, e.g. the central government has a budget constraint given by: $y + \sum_{k=1}^n x_k = 1$.

For the simplest model of homogeneous jurisdictions, the preferences of each jurisdiction's legislator are given by: $U_k = \alpha x_k + y$. Note that α reflects the marginal rate of substitution between the local good x_k and the global good y.

C.5.1 Solution to the Basic Model with Homogeneous Jurisdictions

Let z denote the randomly selected proposer in a given period. Effectively there are three types of solutions that emerge: 1.) Collective, e.g. $y = 1$ and $x_k = 0 \forall k = 1, ..., n$ and whereby the vote is unanimous, 2.) Mixed, e.g. $x_z = \frac{n(1-\delta)}{n(1-\delta)+\delta\alpha} > 0$, $y = 1 - x_z = \frac{\delta\alpha}{n(1-\delta)+\delta\alpha} > 0$ and $x_{\neg z} = 0$ and whereby the vote is unanimous, and 3.) Particularistic, e.g. $y = 0$, $x_z = 1 - \left(\frac{\delta(n-1)}{2n}\right) > 0$ and $x_{\neg z} = \left(\frac{\delta}{n}\right) > 0$ for those in a minimum winning coalition and $x_{\neg z} = 0$ for those not in the MWC. Note that these three coalitions imply two cut-off's, $\alpha_{CM} = 1$ and $\alpha_{MP} = \frac{n+1}{2}$. The collective solution results for $\alpha \in (0, \alpha_{CM}]$, the mixed solution for $\alpha \in (\alpha_{CM}, \alpha_{MP}]$, and the particularistic solution for $\alpha \in (\alpha_{MP}, \infty)$.

C.5.2 Formulating the Problem as a Nested Optimization Problem

In this section I formulate the Volden and Wiseman (2007, 2008) problem for the case of homogeneous jurisdictions as a nested optimization problem implied by equations (**??**) and (**??**) in Section **??**. My objective is two-fold. First, I wish to show that if I set up the problem in this way, that I obtain the same solutions as those given in Volden and Wiseman (2007, 2008). Secondly, I wish to show that my algorithmic approach for identifying the vector of continuation utilities converges to the Volden and Wiseman (2007, 2008) solution as the number of iterations approaches infinity.

Before proceeding, define u_s^s as the utility received when s is selected as proposer, u_s^{in} as the utility received when s is not the proposer but is included within the coalition, and u_s^{out} as the utility received when s is not the proposer and outside the coalition. Given the assumption of homogeneity in this example, it will be the case that the proposer utility will be same for any legislator chosen as proposer, or $u^z = u_s^s = u_t^t \; \forall \; s \neq t = 1, ..., n$; the utility received by non-proposers in the electoral coalition will be the same, or $u^{in} = u_s^{in} = u_t^{in} \forall \; s \neq t = 1, ..., n$; and the utility received by those outside of the electoral coalition will be the same, or $u^{out} = u_s^{out} = u_t^{out} \forall s \neq t = 1, ..., n$. Likewise, the continuation utility for all legislators will be the same or $V = V_s = V_t \; \forall \; s \neq t = 1, ..., n$. Finally, I can also strip out the proposer index from my candidate coalitions, that is $\mathbb{J}_k = \mathbb{J}_k(s) = \mathbb{J}_k(t) \; \forall \; s \neq t = 1, ..., n$. Then the optimization problem is given by:

$$v_z(\mathbb{J}_k) = \begin{bmatrix} \max_{\{x_s\}_{s=1}^n, y} \alpha x_z + y \\ \textit{subject to:} \\ \alpha x_{in} + y \geq \delta V \; \forall s \in \mathbb{J}_k \\ y + \sum_{s=1}^n x_s = 1 \end{bmatrix}, \tag{C.3}$$

where I note that $V = \frac{1}{n}u^z + \frac{n-1}{2n}u^{in} + \frac{n-1}{2n}u^{out}$ in the case of a MWC, $\mathbb{J}_{MWC}$, and $V =$

$\frac{1}{n}u^z + \frac{n-1}{n}u^{in}$ in the case of a unanimous coalition, $\mathbb{J}_{Una}$. Given the earlier definitions, it is the case that $\alpha x_{in} + y = u^{in}$ in the constraints provided in (C.3). Likewise, $\alpha x_z + y = u^z$ in the objective function given in (C.3).

Likewise, (**??**) implies:

$$v_z = \left[\max_k \{v_z(\mathbb{J}_{Una}), v_z(\mathbb{J}_{Una})\}\right]. \tag{C.4}$$

Given, (C.4), it is the case that a unanimous coalition is preferred when $v_z(\mathbb{J}_{Una}) \geq v_z(\mathbb{J}_{Una})$, and a MWC is preferred when the reverse is true. I now proceed by solving (C.3) for the two coalition cases.

C.5.3 Solution for the Case of a MWC

Note that the inequality constraints in (C.3) are effectively, $u^{in} \geq \delta V$. It follows that I can net out u^{in} in V since it is determined as part of the solution to the proposer's problem. (While in the case of homogeneous jurisdictions I could simply directly substitute in *all* of the policies being considered into my equation for V, in the case of heterogeneous jurisdictions this is not possible for a large number of types and/or n. Since I net u^{in} out of V when I solve the heterogeneous model, I follow these same steps to demonstrate equivalence here.) For the case of a MWC, this is:

$$\begin{aligned}
&u^{in} \geq \delta V \Leftrightarrow \\
&u^{in} \geq \frac{\delta}{n}u^z + \frac{\delta(n-1)}{2n}u^{in} + \frac{\delta(n-1)}{2n}u^{out} \Leftrightarrow \\
&u^{in} \geq \left(\frac{2n\delta}{2n-\delta(n-1)}\right)\left[\left(\frac{1}{n}\right)u^z + \left(\frac{n-1}{2n}\right)u^{out}\right] \Leftrightarrow \\
&u^{in} \geq \hat{\delta}\hat{V},
\end{aligned} \tag{C.5}$$

where: $\hat{\delta} = \left(\frac{2n\delta}{2n-\delta(n-1)}\right)$ and $\hat{V} = \left[\left(\frac{1}{n}\right)u^z + \left(\frac{n-1}{2n}\right)u^{out}\right]$.

In the case of a MWC (C.3), given (C.5), implies:

$$v_z(\mathbb{J}_{MWC}) = \begin{bmatrix} \max_{x_z, x_{in}, y} \alpha x_z + y \\ \textit{subject to:} \\ \alpha x_z + y \geq \hat{\delta}\hat{V}\ (\mu_z) \\ \alpha x_{in} + y \geq \hat{\delta}\hat{V}\ (\mu_{in}) \text{ for } \frac{n-1}{2} \text{ legislators} \\ y + \left(\frac{n-1}{2}\right)x_{in} + x_z = 1\ (\lambda) \end{bmatrix}. \tag{C.6}$$

(C.6) yields the following first-order conditions:

$$\begin{aligned}
\frac{\partial L}{\partial x_z} &\equiv \alpha\left(1+\mu_z\right) \leq \lambda,\ \text{“=” if } x_z > 0, \\
\frac{\partial L}{\partial x_{in}} &\equiv \alpha\mu_{in} \leq \left(\frac{n-1}{2}\right)\lambda,\ \text{“=” if } x_{in} > 0, \\
\frac{\partial L}{\partial y} &\equiv 1+\mu_z+\mu_{in} \leq \lambda,\ \text{“=” if } y > 0, \\
\frac{\partial L}{\partial \mu_z} &\equiv \mu_z \geq 0;\ \mu_z\left(x_z+y-\hat{\delta}\hat{V}\right)=0;\ \alpha x_z+y \geq \hat{\delta}\hat{V}, \\
\frac{\partial L}{\partial \mu_{in}} &\equiv \mu_{in} \geq 0;\ \mu_{in}\left(x_{in}+y-\hat{\delta}\hat{V}\right)=0;\ \alpha x_{in}+y \geq \hat{\delta}\hat{V}.
\end{aligned} \tag{C.7}$$

(C.7) has eight possible solutions (1. $x_z > 0$, $x_{in} > 0$, $y > 0$; 2. $x_z > 0$, $x_{in} > 0$, $y = 0$; 3. $x_z > 0$, $x_{in} = 0$, $y > 0$; 4. $x_z > 0$, $x_{in} = 0$, $y = 0$; 5. $x_z = 0$, $x_{in} > 0$, $y > 0$; 6. $x_z = 0$, $x_{in} = 0$, $y > 0$; 7. $x_z = 0$, $x_{in} > 0$, $y = 0$; and 8. $x_z = 0$, $x_{in} = 0$, $y = 0$) of which only three do not yield a contradiction (2 or *Particularistic*. $x_z > 0$, $x_{in} > 0$, $y = 0$; 3 or *Mixed*. $x_z > 0$, $x_{in} = 0$, $y > 0$; and 6 or *Collective*. $x_z = 0$, $x_{in} = 0$, $y > 0$). Of these three the Mixed and Collective cases are not MWC, but instead unanimous and so are superseded by the solution that continues below.

The Particularistic solution to (C.7) is given by:

$$\begin{aligned}
x_z &= 1-\left(\frac{n-1}{2\alpha}\right)\hat{\delta}\hat{V} > 0, \\
x_{in} &= \left(\frac{1}{\alpha}\right)\hat{\delta}\hat{V} > 0, \text{ and} \\
y &= 0,
\end{aligned} \tag{C.8}$$

which holds for the case when $\alpha > \left(\frac{n+1}{2}\right)$, given the restrictions on the LaGrange multipliers given in (C.7).

Algorithmic Convergence to V&W Solution for the Particularistic Case

To continue with my solution, I need to recompute my calculation of $\hat{V}$ for each iteration t given the latest Particularistic solution. Given the current estimate of the continuation utility, $\hat{V}_t$, the new estimate of $\hat{V}$, $\hat{V}_{t+1}$, given that $\hat{V}_{t+1} = \left[\left(\frac{1}{n}\right)(\alpha x_z + y) + \left(\frac{n-1}{2n}\right)y\right]$ after substituting in my solution given in (C.8) (which is a function of $\hat{V}_t$) is given by:

$$\hat{V}_{t+1} = \left(\frac{\alpha}{n}\right) - \left(\frac{\delta(n-1)}{2n-\delta(n-1)}\right)\hat{V}_t. \tag{C.9}$$

Repeated substitution of (C.9) implies:

$$\hat{V}_t = \left(\frac{\alpha}{n}\right)\left[\sum_{s=0}^{t-1}\left(\frac{-\delta(n-1)}{2n-\delta(n-1)}\right)^s\right] + \left(\frac{-\delta(n-1)}{2n-\delta(n-1)}\right)^t \hat{V}_1. \tag{C.10}$$

Initializing my continuation utility to be $\hat{V}_1 = 0$, note that the limit as t approaches infinity is given by:

$$\hat{\hat{V}} = \lim_{t\to\infty} \hat{V}_t = \lim_{t\to\infty}\left(\frac{\alpha}{n}\right)\left[\sum_{s=0}^{t-1}\left(\frac{-\delta(n-1)}{2n-\delta(n-1)}\right)^s\right] = \left(\frac{\alpha}{n}\right)\left(\frac{2n-\delta(n-1)}{2n}\right). \tag{C.11}$$

Given (C.11), I substitute $\hat{\hat{V}}$ into (C.8), which is the final solution for the Particularistic case using my approach:

$$\begin{aligned} x_z &= 1 - \left(\frac{n-1}{2}\right)\left(\frac{\delta}{n}\right), \\ x_{in} &= \left(\frac{\delta}{n}\right), \text{ and} \\ y &= 0. \end{aligned} \tag{C.12}$$

It is clear that the solution from my approach for the Particularistic case is the same as that given in Volden and Wiseman (2007, 2008). It is also clear that the parameter restriction which characterizes this solution, $\alpha > \left(\frac{n+1}{2}\right) = \alpha_{MP}$, is the same as the corrected value reported in Volden and Wiseman (2008).

C.5.4 Solutions for the Case of a Unanimous Coalition

For the unanimous coalition case, netting out u^{in} in V implies:

$$\begin{aligned} u^{in} &\geq \delta V \Leftrightarrow \\ u^{in} &\geq \frac{\delta}{n}u^z + \frac{\delta(n-1)}{n}u^{in} \Leftrightarrow \\ u^{in} &\geq \frac{\delta}{(n-\delta(n-1))}u^z \Leftrightarrow \\ u^{in} &\geq \hat{\delta}\hat{V}, \end{aligned} \tag{C.13}$$

where: $\hat{\delta} = \frac{\delta}{(n-\delta(n-1))}$ and $\hat{V} = u^z$.

In the case of a unanimous coalition (C.3), given (C.13) implies:

$$v_z(\mathbb{J}_{Una}) = \begin{bmatrix} \max_{x_z, x_{in}, y} \alpha x_z + y \\ \textit{subject to:} \\ \alpha x_z + y \geq \hat{\delta}\hat{V}\ (\mu_z) \\ \alpha x_{in} + y \geq \hat{\delta}\hat{V}\ (\mu_{in}) \text{ for } n-1 \text{ legislators} \\ y + (n-1) x_{in} + x_z = 1\ (\lambda) \end{bmatrix}. \tag{C.14}$$

(C.14) yields the following first-order conditions:

$$\begin{aligned} \frac{\partial L}{\partial x_z} &\equiv \alpha(1+\mu_z) \leq \lambda, \text{ “=” if } x_z > 0, \\ \frac{\partial L}{\partial x_{in}} &\equiv \alpha \mu_{in} \leq (n-1)\lambda, \text{ “=” if } x_{in} > 0, \\ \frac{\partial L}{\partial y} &\equiv 1 + \mu_z + \mu_{in} \leq \lambda, \text{ “=” if } y > 0, \\ \frac{\partial L}{\partial \mu_z} &\equiv \mu_z \geq 0;\ \mu_z\left(x_z + y - \hat{\delta}\hat{V}\right) = 0;\ \alpha x_z + y \geq \hat{\delta}\hat{V}, \\ \frac{\partial L}{\partial \mu_{in}} &\equiv \mu_{in} \geq 0;\ \mu_{in}\left(x_{in} + y - \hat{\delta}\hat{V}\right) = 0;\ \alpha x_{in} + y \geq \hat{\delta}\hat{V}. \end{aligned} \tag{C.15}$$

(C.14) has eight possible solutions (1. $x_z > 0$, $x_{in} > 0$, $y > 0$; 2. $x_z > 0$, $x_{in} > 0$, $y = 0$; 3. $x_z > 0$, $x_{in} = 0$, $y > 0$; 4. $x_z > 0$, $x_{in} = 0$, $y = 0$; 5. $x_z = 0$, $x_{in} > 0$, $y > 0$; 6. $x_z = 0$, $x_{in} = 0$, $y > 0$; 7. $x_z = 0$, $x_{in} > 0$, $y = 0$; and 8. $x_z = 0$, $x_{in} = 0$, $y = 0$) of which only two do not yield a contradiction (3 or *Mixed*. $x_z > 0$, $x_{in} = 0$, $y > 0$; and 6 or *Collective*. $x_z = 0$, $x_{in} = 0$, $y > 0$).

The Mixed solution to (C.15) is given by:

$$\begin{aligned} x_z &= 1 - \hat{\delta}\hat{V} > 0, \\ x_{in} &= 0, \text{ and} \\ y &= \hat{\delta}\hat{V} > 0, \end{aligned} \tag{C.16}$$

which holds for the case when $\left(\frac{n+1}{2}\right) \geq \alpha > 1$, given the restrictions on the LaGrange multipliers given in (C.15).

The Collective solution to (C.15) is given by:

$$\begin{aligned} x_z &= 0, \\ x_{in} &= 0, \text{ and} \\ y &= 1, \end{aligned} \tag{C.17}$$

which holds for the case when $\alpha \leq 1$, given the restrictions on the LaGrange multipliers given in (C.15). Since (C.17) is not a function of $\hat{V}$, it will be the case that the algorithm terminates on the first iteration when $\alpha \leq 1$.

Algorithmic Convergence to V&W Solution for the Mixed Case

However, the Mixed solution is a function of $\hat{V}$. As before, to complete my solution, I need to recompute my calculation of $\hat{V}$ for each iteration t given the latest Mixed solution. Given the current estimate of the continuation utility, $\hat{V}_t$, the new estimate of $\hat{V}$, $\hat{V}_{t+1}$, given that $\hat{V}_{t+1} = (\alpha x_z + y)$ after substituting in my solution given in (C.8) (which is a function of $\hat{V}_t$) is given by:

$$\hat{V}_{t+1} = \alpha + (1-\alpha)\frac{\delta}{(n-\delta(n-1))}\hat{V}_t. \tag{C.18}$$

Repeated substitution of (C.18) implies:

$$\hat{V}_t = \alpha\left[\sum_{s=0}^{t-1}\left(\frac{\delta(1-\alpha)}{n-\delta(n-1)}\right)^s\right] + \left(\frac{\delta(1-\alpha)}{n-\delta(n-1)}\right)^t \hat{V}_1. \tag{C.19}$$

Initializing my continuation utility to be $\hat{V}_1 = 0$, note that the limit as t approaches infinity is given by:

$$\hat{\hat{V}} = \lim_{t\to\infty}\hat{V}_t = \lim_{t\to\infty}\alpha\left[\sum_{s=0}^{t-1}\left(\frac{\delta(1-\alpha)}{n-\delta(n-1)}\right)^s\right] = \alpha\left(\frac{n-\delta(n-1)}{n(1-\delta)+\alpha\delta}\right). \tag{C.20}$$

Given (C.20), I substitute $\hat{\hat{V}}$ into (C.16), which is the final solution for the Mixed case using my approach:

$$\begin{aligned} x_z &= \left(\frac{n(1-\delta)}{n(1-\delta)+\alpha\delta}\right), \\ x_{in} &= 0, \text{ and} \\ y &= \left(\frac{\alpha\delta}{n(1-\delta)+\alpha\delta}\right). \end{aligned} \tag{C.21}$$

It is clear that the solution from my approach for the Mixed case is the same as that given in Volden and Wiseman (2007, 2008). It is also clear that the parameter restriction which characterizes this solution, $\alpha \in (1, \left(\frac{n+1}{2}\right)]$, is the same reported in Volden and Wiseman (2007, 2008).

D Figures and Tables

Table 12: Emissions Intensity By Sector

Emissions Intensity (kg CO_2e per $ value of capital)	0.73
Electricity	13.72
Natural Gas	20.4
Heating Oil)	9.922
Petroleum Refineries	20.03
Automobiles	0.00
Trade Vulnerable Industries	1.36

Notes: Mean reported for congressional districts with standard deviation in parentheses.

Table 13: Share of Offsets to Total Emissions Reductions Under ACESA

	Average Annual	Totals: 2012-2050	Share of Total Reductions	Share of Total Offsets	Share of Net Domestic Offsets
Emissions Reductions (Tg CO_2e)	2,917.14	113,768.41	100.0%		
From Industry Abatement	1,231.82	48,040.96	42.2%		
From Offsets and Other Abatement	1,685.32	65,727.45	57.8%	100.0%	
International Offsets	1,075.51	41,944.94	36.9%	63.8%	
Net Domestic Offsets	609.81	23,782.47	20.9%	36.2%	100.0%
Domestic Offsets	318.85	12,435.32	10.9%	18.9%	52.3%
CCS	209.95	8,188.09	7.2%	12.5%	34.4%
Domestic Capped Bio-Electric	44.94	1,752.66	1.5%	2.7%	7.4%
Domestic Capped Non-CO_2e Abatement	36.06	1,406.40	1.2%	2.1%	5.9%

Table 14: Share of Regional Delegation Voting "aye" on Waxman-Markey

Region	Number of Yes Votes	Total Number of Reps	% of Yes Votes by Region
Northeast	74	92	80.43%
West	56	97	57.73%
Midwest	43	92	46.74%
South	31	99	31.31%
Plains	15	55	27.27%

Notes: Regions here are defined according to the ADAGE model documentation.