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Food Manufacturers' Decision Making Under Varying State Regulation

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Abstract

States are increasingly regulating the production practices, ingredients, and labeling of food products sold within their borders. This patchwork approach to food policy is likely to have significant ramifications for the U.S. food sector and interstate agri-food trade. We develop a conceptual framework to assess how differences in states' regulations influence food manufacturers' costs and production decisions. Using the model, we examine differences in producer behavior across three policy examples, illustrating how firms respond to regulatory costs and highlighting the implications of interstate heterogeneity in food policy.

Keywords: state regulation, food policy, food manufacturing, federalism, interstate trade

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Introduction

Debate over the proper role of federal and state governments is as old as the nation. In the area of food policy, oversight was primarily entrusted to individual states until the early 1900s, when interstate commerce accelerated and food production issues moved to a national scale (Fortin, 2009). The federal government took charge over many aspects by establishing the regulatory system that exists today. Today, as the federal government plays a prominent role in regulating the agri-food sector through the work of federal agencies, including the Food and Drug Administration (FDA), the U.S. Department of Agriculture (USDA), and others, the role of states can become obscured. However, the principle of federalism—the rights and responsibilities of individual states to enact and enforce policy—ensures that state-level regulation remains a critical aspect of U.S. food policy (Foote, 1984). States' roles in regulating the food system occupies an increasingly prominent position in the U.S. regulatory environment (Sutton, 2024).[1] This patchwork approach to food policy has created a complex environment, requiring firms along the food supply chain to adapt to evolving and disparate regulations. Ultimately, these developments are likely to have significant ramifications for firms, consumers, and interstate trade in agri-food products.

A recent illustrative example can be found in California's Assembly Bill 418 (AB-418), passed in November 2023 and which by 2027 will ban the sale of food products that contain any of four additives identified by the law as harmful to human health. Specifically, the law bans the sale of products with brominated vegetable oil (BVO; an emulsifier used in soft drinks), potassium bromate (an improving agent for flour used to strengthen dough), propylparaben (a preservative), and Red Dye No. 3 (a coloring agent). Following the law's passage, lawmakers in several other states, including New York, Illinois, and Pennsylvania, followed suit in advancing similar regulations (Bottemiller Evich, 2024; Henderson, 2024). While the content of other states' proposed laws broadly aligns with California's, the new regulations reflect critical differences. For instance, Pennsylvania's proposed rules would ban an assortment of food coloring agents not targeted by other states' rules, and New York's proposal would outlaw several ingredients not covered by California's law. The proposed rules also reflect differences in which products would be exempt from the regulation, timelines for compliance, enforcement mechanisms, and penalties for noncompliance. At the time of the law's passage, the use of these additives remained mostly unrestricted at the national level and in many other states. Consequently, food manufacturers that use the soon-to-be-banned ingredients will need to respond to markedly different regulations across the states in which they sell their products.

Other instances abound of an individual state's regulation exerting significant influence on the food system. Prominent examples include Vermont's 2014 mandatory labeling law for genetically modified (GM) ingredients and California's 2018 law regulating animal welfare standards (Proposition 12). In both instances, food manufacturers who sold their products across multiple states or the entire country were obliged to react to a regulatory change in a single state. The passage of food laws at the state level has also become an increasingly politically charged issue,

[1] Likely to accelerate this patchwork approach to regulation is the U.S. Supreme Court decision in June 2024, which ended the so-called "Chevron Defense," thereby limiting the power of federal regulatory agencies.

as many laws are now seen as a precursor for the creation of national food regulations, driven by both increased salience and lobbying.

Following California's recent food additive law, for example, advocacy groups across the food system released statements either approving of or opposing the new law. The Environmental Working Group, a nonprofit advocacy group that focuses on policy issues affecting agriculture and the environment, noted that, "In the absence of federal action, states have stepped up to protect their consumers" (EWG, 2024). A representative from the National Confectioners Association (whose members are likely to be affected by the law) stated, "It's time for FDA Commissioner to wake up and get in the game. These activists are dismantling our national food safety system state by state in an emotionally driven campaign that lacks scientific backing" (Bottemiller Evich, 2024). Former FDA Deputy Commissioner Frank Yiannas opined that, while the law was well-intentioned, it set a "dangerous precedent" on how food safety standards are set (Yiannas, 2023). The FDA, for its part, reasserted its safety review process and then months later restricted the use of two of the additives restricted in the California law, first BVO in July 2024 and then Red Dye No. 3 in January 2025.

While these issues have grown in salience for both researchers and policy makers, remarkably little has yet been done to systematically assess the ways in which federalism in food policy shapes the decisions of firms in the food supply chain and to characterize the costs associated with this regulatory heterogeneity. The broader ramifications of this trend in policymaking for the U.S. food sector thus remain an open question.

To address this gap, in this paper we analyze food manufacturers' decision making under varying state regulations. To do this, we first provide an overview of the institutional background and survey of the existing literature on federalism in U.S. food policy. We next develop a conceptual framework that allows us to characterize the margins along which firms respond to differences in food policy across states. We then evaluate three policy examples—Vermont's GM labeling law, Illinois' sesame allergen labeling law, and California's food additive law—to illustrate the real-world responses of firms to heterogeneity in interstate regulation. Finally, we conclude by synthesizing the key takeaways of our analysis and offering policy recommendations toward maximizing the economic efficiency of the regulatory environment facing the U.S. food system. Taken together, the components of our analysis shed light on the increasingly important issue of federalism in U.S. food policy.

Institutional Context

Federalism in U.S. food policy is governed by a set of fundamental principles enshrined in the Constitution. The Constitution provides states with so-called "police power," allowing them to establish and enforce rules to protect the health and welfare of their people, an objective intrinsically related to food policy. Importantly, the Constitution also endows the federal government with two core powers that limit the scope of states' regulatory efforts: (i) the Supremacy Clause, which establishes that federal laws should take precedence over state laws when the two are in conflict, and (ii) the Commerce Clause, which assigns responsibility for the regulation of interstate commerce to the federal government. Today, with authority over many aspects of food regulation in the hands of the federal government, it is easy to lose sight of the fact that states can—and do—regulate the production and sale of food within their borders.

Courts have continued to uphold states' rights to regulate food produced or sold in their state, so long as such regulations are not inconsistent with federal law and do not unduly burden interstate commerce or discriminate against out-of-state producers (Foote, 1984; 1985; Fortin, 2009; McCabe, 2010). Fortin (2009) notes, "Accordingly, firms shipping into various states must be careful that they meet both federal and state requirements."

Literature Review

The literature evaluating the economic impacts of federalism's role in food policy remains nascent, and only a small number of existing studies directly analyze how firms respond to patchwork food regulation. An important example is work that investigates the case of California's 2010 law (AB-1437), requiring that all eggs sold in the state be produced using cage-free production methods by 2015. This research has documented that AB-1437 increased the price of eggs sold both within and outside of the state, the volume of California's imports of eggs from other states, and the proportion of cage-free production in the overall supply of eggs (Allender and Richards, 2010; Malone and Lusk, 2016; Carter, Schaefer, and Scheitrum, 2020; Oh and Vukina, 2021).

Though most work in this area does not focus directly on food manufacturers' decision making, this literature finds evidence of differing responses of firms to changes in regulation. For example, Carter, Schaefer, and Scheitrum (2020) find that some egg producers began selling and some stopped selling to the California market following the law's enactment, with larger firms being more likely to exit and smaller firms being more likely to enter the state. Additionally, Allender and Richards (2010) note that some firms sold both cage-free and conventional egg products prior to the state law, and thus faced different constraints in complying with the law relative to firms that initially produced only one or the other variety. It is likely that the specific context of this case—the large size of California's market for eggs, consumer preferences surrounding the cage-free attribute, and the likelihood of federal involvement—was key in shaping firms' responses.

Most closely related to our analysis is the work of Caswell and Kleinschmit (1997), who developed a conceptual framework for assessing the costs and benefits associated with state food policy. They base their analysis on the specific case of a 1986 Massachusetts law establishing a maximum residue limit (MRL) for the plant growth regulator, Alar, used in the processing of apples. Critically, Massachusetts' rules for Alar were more conservative than federal limits established by the Environmental Protection Agency (EPA), thus binding the sale of apples in Massachusetts to a stricter standard than that maintained at the national level. Caswell and Kleinschmit delineate the different actions that a food manufacturer might pursue in response to the regulation. They specifically outline four possible responses: one in which the firm sells a single Alar-free product nationwide and three other strategies in which the firm produces two distinct products (an Alar-free version for Massachusetts and a conventional version for other states). The three cases captured by the two-product option differ based on the three potential pricing responses for Alar-free products faced by the firm: no price premium, partial price premium, and full price premium. In the conceptual analysis that we develop below, we extend Caswell and Kleinschmit's theoretical framework to a more general setting to analyze producers' responses to regulatory heterogeneity across different markets.[2]

The limited existing literature evaluating the impact of varying state food regulation has generally focused on laws that restrict the sale of food items produced using a particular agricultural practice. However, many recent state laws relate to the ingredients used in a food product or its packaging; in most of these cases, the prohibited ingredients remain largely unaffected by other states' regulations. These laws are likely to affect various decision makers (e.g., farmers versus food manufacturers versus retailers) in different ways and impose disparate costs on different actors in the supply chain. Food manufacturers often produce many products—each with many ingredients—and sell to distributors and retailers in most or all states. Research that estimates the costs of complying with federal bans or labeling of ingredients has found that these changes can impose a substantial cost on impacted firms (Muth et al., 2015a; Muth et al., 2015b), and results from focus groups with food manufacturers found that regulation was the concern most frequently raised by participants (Adelaja et al., 1997).

Finally, and despite our focus on the domestic policy setting, it is worth highlighting the analogous issue of regulatory heterogeneity in the international trade context. The fragmented approach to food policy as pursued by individual states offers close parallels with the application of non-tariff measures (NTMs), such as sanitary and phytosanitary standards and technical barriers to trade. In essence, many states' regulations toward the food system are themselves NTMs but in the setting of domestic trade. Considering the international policy context is thus informative about the likely effects of state-level regulations that impact interstate trade in agri-food products.

Though many NTMs are likely to be trade-inhibiting owing to both the costs that they impose on producers and exporters and their contributing to a more opaque trade policy environment (Fernandes, Ferro, and Wilson, 2019), the literature has nonetheless established that NTMs can yield either trade-reducing or trade-enhancing impacts (Santeramo and Lamonaca, 2019). While the explanation for the former relationship is intuitive, the origins of the latter could relate, for instance, to trade-expanding effects from bolstered consumer confidence due to more rigorous health and safety rules (Liu and Yue, 2012), decreased production and trade costs originating from

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[2] Several critical factors differentiate our modeling framework from that of Caswell and Kleinschmit (1997) (hereafter, C&K). First, our conceptual environment more strongly emphasizes firms' decisions along the extensive margin (i.e., decisions pertaining to which markets to serve and which versions of products to sell). By contrast, the primary focus of C&K is on the price responses faced by firms following regulatory changes (though C&K do consider the possibility of firms selling different versions of products in different markets). Second, our modeling approach analyzes changes in both fixed and variable costs arising from regulatory changes, another point that distinguishes our framework from that of C&K. Accounting for these two distinct types of costs has important implications for firm behavior relating to which markets to serve and the mode by which to serve them. Third, our conceptual framework considers consumer demand in a more flexible way than C&K. Whereas their analysis assumes that reformulated products (in their context, products adhering to stricter MRLs) are generally more preferred by consumers, we account for the possibility that new versions of products could either be more or less preferred by consumers to the original version, both of which outcomes have been observed in different real-world scenarios.

the harmonization of regulatory standards across markets (Ridley, Luckstead, and Devadoss, 2024), or reductions in information asymmetries (Xiong and Beghin, 2014).[3] Whatever effects the wide array of NTMs may have can vary widely across products, locales, and regulatory settings, which can make it difficult to draw systematic conclusions about how NTMs, and interjurisdictional heterogeneity in food policy more generally, ultimately affect producers, consumers, trade, and the welfare of market participants. Similar ambiguity in these effects is likely to characterize the impacts arising from the often-patchwork approach to U.S. interstate food policy.

Conceptual Framework

To formally characterize the economic factors that influence the reactions of food manufacturers to changes in state regulation, we develop a conceptual framework with which to analyze the various margins along which producers respond to differences in regulation in food manufacturing across states. By accounting for the various costs and benefits associated with different responses by firms to changes in regulation, this framework allows us to establish empirical predictions on firms' decision making that will inform our case study analysis detailed in the next section.

Consider a representative, profit-maximizing firm that, prior to any changes in regulation, sells product x in states A and B.[4] Production of x uses a specific ingredient that initially faces no restrictions on its use. We suppose that state A enacts a new regulation restricting the acceptable uses of the ingredient. In line with the real-world examples outlined above, such regulations might include a complete ban on the use of the ingredient, labeling requirements for products that contain the ingredient, or limits on the allowable levels of the ingredient contained in products. We focus on the case of a state-level ban on the ingredient's use, though our analysis also captures the key features of the other regulatory cases.

In response to the regulation, the firm can continue to produce the original formulation of x, which contains the banned ingredient and/or develop a reformulated version of the product, denoted as $\tilde{x}$, which contains a substitute ingredient not subject to the ban.[5] Consequently, the firm must choose which version of the product to sell (or not) in each state based on the relative profitability of different possible responses to the change in regulation.

Production takes place under a constant-returns-to-scale technology with variable and marginal costs that can differ between the two versions of the product (denoted as c_i for $i = x, \tilde{x}$). Depending on which version of the product the firm sells in a given market, the firm faces linear inverse demand $p_{i,j} = a_{i,j} - b_{i,j}q_{i,j}$, where $p_{i,j}$ is the price of product i in market j and $q_{i,j}$ is the

[3] Xiong and Beghin (2014) specifically analyze the effects of MRLs in internationally traded plant products. The consideration of MRLs in the context of international trade shares clear parallels with the domestic market impacts analyzed by Caswell and Kleinschmit (1997) in the case of Massachusetts' MRLs for Alar in apples.
[4] The logic of our analysis readily extends to cases of more than two states/markets.
[5] In the case of ingredient labeling requirements, $\tilde{x}$ can also be interpreted as the relabeled version of the product.

quantity purchased by consumers.[6,7] The parameters $a_{i,j}, b_{i,j} > 0$ reflect consumer preferences, with the demand shifter $a_{i,j}$ reflecting differences in consumer preferences for the two versions of the product across markets as well as differences in the sizes of the respective markets.

These relationships yield equilibrium pre-regulation profits (Π^0) for the firm equal to

$$\Pi^0 = \underbrace{(p_{x,A} - c_x)q_{x,A}}_{\pi_{x,A}} + \underbrace{(p_{x,B} - c_x)q_{x,B}}_{\pi_{x,B}}, \tag{1}$$

where $\pi_{x,A}$ and $\pi_{x,B}$ denote variable profits (i.e., producer surplus) received by the firm from selling product x in states A and B, respectively.[8] We assume that the firm can respond to the new regulation in one of four ways (see Figure 1):

> **Option 1 (reformulate and separate production):** Switch to producing the regulation-compliant product ($\tilde{x}$) for the regulating state (A) while maintaining separate production of the original (noncompliant) version of the product (x) for the non-regulating state (B). To reformulate production from x to $\tilde{x}$, the firm must incur a fixed cost (denoted f_R). Establishing separate production lines for the new (compliant) and old (noncompliant) versions of the product imposes an additional fixed cost on the firm (denoted f_S).[9,10]

[6] We assume that the markets of states A and B are sufficiently separated such that spatial arbitrage does not occur. Thus, the firm charges different prices in both markets. Additionally, and for tractability, we consider the firm's actions in terms of corner solutions (i.e., we assume that the firm only sells a single version of a product (x or $\tilde{x}$) in a given state's market). Based on our conversations with food industry representatives, such an assumption is consistent with the observed behavior of most food manufacturers.

[7] Our framework is intentionally agnostic on price effects and allows for impacts on prices to be flexibly realized through changes in firms' variable profits. There are two principal reasons for this. First, we do not impose explicit assumptions on market structure with which to solve for equilibrium prices. Because our objective is to analyze the behavior of firms in response to regulatory changes under a variety of settings, this decision is made to ensure the generality of the results. Second, our model does not take a definitive stand on how the various firm responses that we delineate affect either producers' variable costs or consumer demand. This is because, as evidence from the literature shows, different responses by firms to regulatory changes could either increase or decrease producers' variable costs and could likewise have either positive or negative impacts on consumer demand (see, e.g., Carter and Schaefer [2018] on impacts on input prices or Fan, Stevens, and Thomas [2022] on demand impacts, both relating to Vermont's GM labeling law). Because such impacts are ambiguous, we refrain from drawing any categorical conclusions about price effects.

[8] The Appendix provides the full description of the model's equilibrium.

[9] In reality, it is probable that the costs of product reformulation or separation are themselves a function of a firm's size. Though we treat these costs as independent of the firm's output levels ($q_{i,j}$), our framework nonetheless captures this aspect of real-world costs—larger firms would simply face a larger value of f_R or f_S.

[10] Previous literature has examined some of these costs, including the costs of both compliance and separation. Regarding compliance, the FDA has created a tool to estimate the cost of complying with national regulation via reformulation (Muth et al., 2015a) and relabeling (Muth et al., 2015b). We would expect the costs of complying with state-level regulation to be similar, with the caveat that states often require shorter timelines for compliance, which can substantially increase the associated costs. Similarly, maintaining separate versions of a product in both production and transportation can be expensive. For example, research has highlighted the high costs associated with segregation of GM and non-GM food products (Alston and Sumner, 2012; Lesser, 2014; Bovay and Alston, 2018).

Option 2 (reformulate for both markets): Switch to producing only the reformulated, regulation-compliant product for sale in both states. In this case, the only fixed cost incurred by the firm is the cost of reformulation (f_R).

Option 3 (exit the regulating market): Discontinue all sales of the product in the regulating state, while continuing to sell the original version of the product in the non-regulating state. The firm thus incurs no costs from reformulation, separation, or potential legal penalties, but foregoes all profits that would have been earned from sales in state A.

Option 4 (ignore the regulation): Sell the original, non-reformulated version of the product in both states at the risk of being subject to penalties and/or litigation due to noncompliance. In ignoring or imperfectly complying with the regulation and continuing to sell the original version of the product in state A, the firm runs the risk of incurring costly legal penalties (f_L) with probability θ. Penalties can range from fines to allowing for civil cases to be brought against offenders by either lawmakers or private citizens.

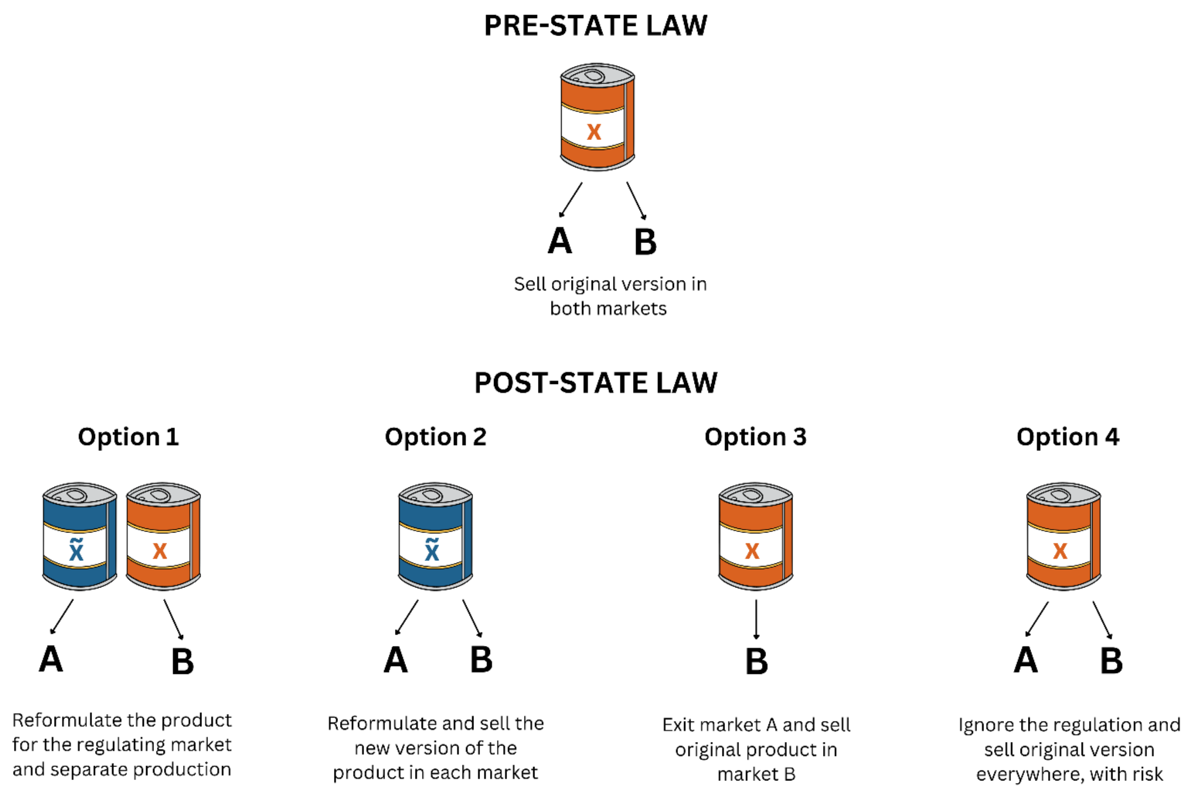

Figure 1. Possible Firm Responses to New Regulation in State *A*

On the demand side, the ultimate effect of reformulation depends on consumer preferences. If the reformulated product is preferred to the original product the effect is positive, if the reformulated product is less preferred it is negative, and if consumers are indifferent between them the effect is zero. Variable profits from selling the reformulated version of the product are thus denoted by $\pi_{\tilde{x},A}$

and $\pi_{\tilde{x},B}$ for states A and B, respectively, which are characterized by expressions analogous to their counterparts for $\pi_{x,A}$ and $\pi_{x,B}$ defined above. Based on this, we define $\Delta\pi_A = \pi_{\tilde{x},A} - \pi_{x,A}$ and $\Delta\pi_B = \pi_{\tilde{x},B} - \pi_{x,B}$ as the change in the firm's variable profits in states A and B, respectively, from selling the reformulated version of the product in the each market.

Following the implementation of state A's regulation, the firm's expected profits depend on which option the firm chooses in response. The profits earned by the firm in each case (with Π^k denoting profits under options $k = 1, \ldots, 4$) are given as follows:

Option 1 (reformulate and separate production)

$$\Pi^1 = \pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S \tag{2}$$

Option 2 (reformulate for both markets)

$$\Pi^2 = \pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R \tag{3}$$

Option 3 (exit the regulating market)

$$\Pi^3 = \pi_{x,B} \tag{4}$$

Option 4 (ignore the regulation)

$$\Pi^4 = \pi_{x,A} + \pi_{x,B} - \theta f_L \tag{5}$$

Based on these expressions, the firm's optimal response to the regulation can be analyzed in relation to the model's key elements, including differences in consumer tastes for the two versions of the product, the size of the costs of reformulating or separating production or legal penalties, changes in variable costs of production, and other factors. Below we summarize the key takeaways obtained from considering the firm's profit-maximizing decisions under the four options. Firms will optimally choose each option under the following conditions.[11]

Option 1:

$$\Pi^1 > \Pi^2 : -f_S > \Delta\pi_{x,B} \tag{6a}$$

$$\Pi^1 > \Pi^3 : \pi_{\tilde{x},A} - f_R - f_S > 0 \tag{6b}$$

$$\Pi^1 > \Pi^4 : \Delta\pi_A - f_R - f_S > -\theta f_L \tag{6c}$$

Equation (6a) describes that the firm will optimally reformulate the product for the regulating market and maintain separate production when the fixed cost of separation ($-f_S$) is less negative than the change in net profits from separating production and selling the original product in state B ($\Delta\pi_{x,B}$). If the firm's variable profits would decline due to selling the reformulated product in

[11] See the Appendix for the derivation of profits for each of the pairwise comparisons.

state B ($\Delta\pi_{x,B} < 0$), either because of decreased revenues, increased variable costs, or both, then the firm's expected loss in variable profits in state B would need to exceed the fixed cost of separation for this condition to hold. If the firm's variable profits strictly increase from selling the reformulated product in state B ($\Delta\pi_{x,B} > 0$), then this condition will never hold, and the firm would never optimally separate production. Intuitively, if separation costs are low, consumers strongly prefer the original version (revenues from selling version x are higher than from selling version $\tilde{x}$), and/or variable costs for the reformulated product are comparatively high ($c_{\tilde{x}}$ is higher than c_x), the firm will be more willing to bear the cost of reformulation and separation, all else equal. Equation (6b) indicates that the firm will optimally separate production over exiting the regulating market when the net total profits from selling the reformulated version of the product in state A ($\pi_{\tilde{x},A} - f_R - f_S$) are positive. Finally, equation (6c) describes that the firm will optimally separate production over flouting the regulation when the net change in total profits from reformulating for state A's market and selling the original version of the product in state B ($\Delta\pi_A - f_R - f_S$) outweigh the expected legal penalties from violations of the regulation ($-\theta f_L$). This will occur under the prospect of larger penalties (higher f_L) and/or more active enforcement (higher θ), both of which incentivize firms to more readily comply with the regulation.

Option 2:

$$\Pi^2 > \Pi^1 \colon \Delta\pi_{x,B} > -f_S \tag{7a}$$

$$\Pi^2 > \Pi^3 \colon \pi_{\tilde{x},A} + \Delta\pi_B - f_R > 0 \tag{7b}$$

$$\Pi^2 > \Pi^4 \colon \Delta\pi_A + \Delta\pi_B - f_R > -\theta f_L \tag{7c}$$

Equation (7a) reflects the inverse logic of equation (6a), in that firms will pursue Option 2 over Option 1 when the change in variable profits from selling the reformulated product in the non-regulating state is greater than the cost of separating production (i.e., $\Delta\pi_{x,B}$ is greater than $-f_S$). Equation (7b) depicts that the firm will optimally choose Option 2 over Option 3 when the variable profits earned in state A and the change in variable profits in state B minus the fixed cost of reformulation are positive; in essence, this condition describes that it will generally be more profitable to uniformly reformulate the product rather than exit the regulating market when the firm's profits in the regulating market are large ($\pi_{\tilde{x},A}$), the firm expects to earn higher variable profits or undergo only a small decrease in variable profits after reformulating for state B ($\Delta\pi_B$ is positive, or is negative and small), and/or if the costs of reformulation ($-f_R$) are small. Finally, equation (7c) shows that the firm will reformulate production for both markets when the changes in net profits across markets from selling the reformulated product outweigh the expected legal penalties from noncompliance (i.e., $\Delta\pi_A + \Delta\pi_B - f_R$ is greater than $-\theta f_L$). This occurs in instances where reformulation does not cause large negative changes in total variable profits (either through the revenue or variable cost components of $\Delta\pi_A$ and $\Delta\pi_B$), costs of reformulation are high, or the probability of regulatory enforcement and/or the size of legal penalties are small.

Option 3:

$$\Pi^3 > \Pi^1 \colon 0 > \pi_{\tilde{x},A} - f_R - f_S \tag{8a}$$

$$\Pi^3 > \Pi^2 \colon 0 > \pi_{\tilde{x},A} + \Delta\pi_B - f_R \tag{8b}$$

$$\Pi^3 > \Pi^4 \colon 0 > \pi_{x,A} - \theta f_L \tag{8c}$$

Equations (8a) and (8b) reflect the inverse of the cases captured by equations (6b) and (7b). Equation (8d) describes the conditions under which the firm would optimally exit the regulating market over not complying with the regulation: firms will pursue this option in instances where profits in the regulating state ($\pi_{\tilde{x},A}$) are small (i.e., when lost sales from exiting rather than reformulating would be small) relative to the cost of potential legal penalties from noncompliance with the regulation.

Option 4:

$$\Pi^4 > \Pi^1 \colon -\theta f_L > \Delta\pi_A - f_R - f_S \tag{9a}$$

$$\Pi^4 > \Pi^2 \colon -\theta f_L > \Delta\pi_A + \Delta\pi_B - f_R \tag{9b}$$

$$\Pi^4 > \Pi^3 \colon \pi_{x,A} - \theta f_L > 0 \tag{9c}$$

Because each of the comparisons portrayed in equations (9a) through (9c) were elaborated in the preceding equations, for brevity, we omit discussion of these relationships.

Before proceeding, it is important to underscore that our analysis considers a setting with only two states with only a single difference in regulation. In reality, regulatory differences are likely to create a significantly more complex policy environment than the one we consider, especially in instances where states pass similar (but not identical) laws. As the number of states with disparate regulatory environments increases, many of the costs in our framework (e.g., compliance, separation, lost sales in regulating states) would be likely to increase alongside.

Expected Firms' Decisions Under the State Regulations

Our analytical framework establishes a useful basis with which to examine current and proposed state food regulations, particularly when food manufacturers can make different decisions about how to comply. Below, we consider how food manufacturers responded to three prominent policy examples: (i) Vermont's GM labeling law, (ii) Illinois' sesame labeling law, and (iii) California's food additive law. We use the framework as a lens through which to describe the different margins along which recent state-level regulations impacted food manufacturers.

Policy 1: Vermont's GM Labeling Law

In 2014, Vermont passed a statewide mandatory GM labeling law, which went into effect in July 2016. To comply with the law, food manufacturers could respond to the labeling requirement either by reformulating (i.e., switching to the use of non-GM ingredients) or relabeling (i.e., adding labels indicating the presence of GM ingredients) their products. Research estimating the costs of compliance to federal regulation via relabeling or reformulating has found that, while reformulation is substantially more expensive than relabeling, both tend to be costly endeavors for firms (Muth et al., 2015a; Muth et al., 2015b). For example, reformulation of a low-complexity food (e.g., shelf-stable) is estimated to range from an average of about $50,000 for a minor nonfunctional ingredient to about $650,000 for substitution of a major ingredient (Muth et al., 2015a). However, costs vary across food products and firm types and increase when process time is short (Muth et al., 2015a). Following the enactment of the law, both responses were pursued by different firms; for example, Campbell's Soup Company chose to *relabel* their products to comply with the regulation, while General Mills *reformulated* Cheerios cereal to use non-GM ingredients (Strom, 2016). The regulation forced firms to weigh potential costs from compliance (relabeling or reformulation), separation of production, [12] the possibility of litigation/penalties from noncompliance, and the impacts on variable profits.

A few months prior to the deadline for compliance, many large food manufacturers including Mars, General Mills, and Campbell's announced plans to sell a single version of their products compliant with Vermont's regulations nationwide. NPR weighed in on the topic at the time with a telling headline describing "How Little Vermont Got Big Food Companies to Label GMOs" (Charles and Aubrey, 2016). Our framework can help us understand why many of the largest food firms chose to respond to the law with Option 2.

Beyond the costs of compliance discussed above, we can examine expected changes in variable profits in the regulating market ($\Delta\pi_A$ in the conceptual model). At the time of the decision, many food manufacturers were concerned about GM labels resulting in reductions in demand. The expected effect differed across products; for example, consumers of products marketed for children tended to express greater concerns towards GM ingredients. More recently, research has found that manufacturers' concerns were not unfounded: for example, Fan, Stevens, and Thomas (2022) find that demand decreased by about 5.9% on average for GM-labeled products in the state. For reformulated products, there arguably would have been little resulting change in demand, as the substitution from GM to non-GM ingredients typically does not meaningfully affect most important product characteristics (e.g., taste or appearance). However, the reformulation of products would have raised many producers' variable costs, as the cost of non-GM ingredients would have been higher. Prior work has also documented that the switch by food manufacturers from the use of GM beet sugar to non-GM cane sugar in response to Vermont's law led to an increase in the price of cane sugar (Carter and Schaefer, 2018).

[12] For processed products, separation costs include both separation during production (e.g., separate lines, cleaning) and, potentially, separation during distribution (e.g., separate trucks). The costs associated with separation during production are likely to be more costly and thus more central to firms' decisions.

Second, we can specifically consider the costs of separation (f_S). Maintaining separate products would have been quite costly. Costs would have been highest for firms that sold both a GM and non-GM version of their product, mostly due to the high costs of segregation, monitoring, and certification of non-GM ingredients (Alston and Sumner, 2012). To keep GM and non-GM versions of the product separate, firms would have to segregate GM and non-GM ingredients, separate or clean production lines, and maintain separation post-production during transportation and distribution. Firms choosing to operate separate product lines with and without a GM *label* (rather than GM and non-GM ingredients) would have avoided most of the costliest separation activities, including keeping ingredients and production lines separate. Indeed, at least one company (Schwan's) indicated at the time that they planned to relabel their products for the Vermont market only (D'Ambrosio, 2016). However, even the act of maintaining separation of a product with two different labels during transportation and distribution would still add significant costs. One news story following the law noted, "If you have to manage one product with two labels, that's incredibly complicated. … It's a logistics nightmare." (Spencer, 2016). At least one firm (Danon) attempted to avoid the post-production separation costs completely by asking Vermont grocery retailers to add GMO label stickers to their products upon arrival at stores; however, retailers were not supportive of the plan (D'Ambrosio, 2016).

Third, we can consider the expected costs of violations (θf_L). Vermont's law assigned liability for violations to food manufacturers, and penalties included \$1,000 daily fines per product found to be in violation. Both Vermont's attorney general and private citizens were granted the ability to bring civil action for violations, increasing the likelihood and costs of litigation. National attention arguably increased the likelihood of enforcement, and at the time, Vermont's government made clear that it would pursue "willful violators" (Rathke, 2016). Together, these factors signaled that ignoring the law would be costly.

Fourth, we can consider the costs of losing sales to the state (the foregone variable profits $\pi_{\tilde{x},A}$). Given Vermont's small size, in the short term it seems that the optimal decision of some food manufacturers was to simply avoid sales to the state. For example, the Coca-Cola Company indicated at the time that "some lower-volume brands and packages we offer within our broad portfolio could be temporarily unavailable in Vermont" (D'Ambrosio, 2016). However, and in the longer term, food manufacturers at the time seemed to understand and anticipate that similar laws were likely to soon be enacted in other (larger) states. Food manufacturers who chose to exit the Vermont market at the time seem to have done so with the understanding that ending sales in the state was a temporary decision.

While different firms engaged in different responses, the combination of factors elaborated above in conjunction with the results of our conceptual framework helps us understand that Option 1 was prohibitively costly due to high costs of separation (with the correspondingly large value of f_S causing Π^1 to be smaller, all else equal), and Option 4 would be undesirable for most manufacturers given the high likelihood of litigation and penalties (with the correspondingly large value of θf_L causing Π^4 to be smaller, all else equal). As Vermont is a small market, Option 3 would have been a reasonable choice for some firms, especially in the short term, as the opportunity cost of foregone sales ($\pi_{\tilde{x},A}$) would be smaller than the costs of compliance (f_R and

f_S) for many firms. For producers with strong sales in Vermont or who expected additional states to follow suit in establishing similar regulations, Option 2—selling a single version of their product compliant with Vermont's law nationwide—was a commonly observed response. A news story at the time called this choice "the reasonable thing to do" (Spencer, 2016).

Ultimately, following strong lobbying efforts by industry groups, the federal government intervened by creating a single, federal standard for GM labels in July 2016, which superseded Vermont's law. The USDA indicated that this was done to "avoid a patchwork of state labeling regulations that could be confusing for consumers and expensive for manufacturers" (Peikes, 2023).

Policy 2: Illinois' Sesame Allergen Labeling Law

In 2019, the state of Illinois enacted a law requiring specific allergen labeling for food products containing sesame. As with Vermont's GM labeling requirements, food manufacturers could comply with the new rules either by reformulating (i.e., removing sesame) or relabeling (i.e., adding labels indicating the presence or possible presence of sesame) their products.

First, we can explore the costs faced by producers in complying with the law. The costs of compliance (in particular, the cost of reformulation, f_R) would have been comparatively low as relabeling almost exclusively affected products' nutrition facts labels and reformulation was typically undertaken only for products containing small quantities of sesame (e.g., sesame seeds on top of a product) (Muth et al., 2015a; Muth et al., 2015b). Second, we can consider the changes to variable profits ($\Delta\pi_A$). On the consumer side, the effects from the addition of sesame allergen labels were conceivably muted, implying a zero or negligible change in firms' sales from complying with the regulation. For consumers without a sesame allergy, the label would have had little impact on demand. For consumers with an allergy (0.23% of the U.S. population; Gupta et al., 2018) the label could potentially have increased demand, though the aggregate impacts of such effects were conceivably minor. Similarly, there are likely to have been only limited effects on demand attributable to the reformulation of products except in instances where the removal of sesame substantially affected important characteristics of the product (e.g., taste). Third, as described above, the costs of separating products with different sets of ingredients or different labels (f_S) can be very costly. The costs required to produce and transport separate sesame and non-sesame versions of products would have thus imposed a significant burden on both manufacturers and distributors. Fourth, the expected costs of litigation and penalties (θf_L) were also low as the law did not set out any penalties for violations, nor did it explicitly outline any avenues for legal recourse in response to alleged violations. Reports from the time highlighted skepticism by food manufacturers toward the legal requirements to comply, saying, "the validity of the Illinois law is open to question" (van Laack, 2019).[13] Finally, removing products from sale in Illinois (foregoing $\pi_{\tilde{x},A}$) would also have been a costly response for producers given its status

[13] Importantly, the Illinois state law was passed in 2019. At that time there were no national requirements to label sesame as a major allergen. Sesame was added as a major allergen to federal regulation in 2021, and the law went into effect in 2023. Whereas the costs of violating Illinois' law seemed to be low, violating the federal requirements for allergen labeling would result in recalls, penalties, and litigation, which would be expected to be very costly.

as the sixth most populous state, and as with Vermont's GM labeling law, many stakeholders anticipated that the state-level law had the potential to bring on additional regulation across the United States. For example, a news report at the time noted that the Illinois law and manufacturers' responses to it "could easily turn the tide to ensure sesame is disclosed on most items consumers buy throughout the U.S." (Poinski, 2020).

The cost framework would suggest that as costs of separation strongly outweighed the costs of reformulation (f_S was large, causing Π^1 to be smaller, all else equal), most firms would not have been inclined to create distinct versions of their products (Option 1). Similarly, given Illinois' large market size, removing products from the state (Option 3) would have been an undesirable response for most producers (foregone profits $\pi_{\tilde{x},A}$ would be large, reducing the chance that Π^3 would be larger than profits under the other options). In contrast with Vermont's GM-labeling law, the potential costs of violating the state law were low given the limited mechanisms for enforcement and an unclear legal standing. Together, it seems plausible that the optimal response of most food manufacturers would have been to either create a single compliant version to be sold nationwide (Option 2) or sell a noncompliant version nationwide (Option 4).

As with Vermont's law, Illinois' state law helped spur the establishment of national regulation. In 2021, a federal standard for sesame allergen labeling was enacted (the Food Allergy Safety, Treatment, Education, and Research [FASTER] Act), and in 2023 the federal law took effect nationally, formally superseding Illinois' labeling requirements.

Policy 3: California's Food Additive Law

As described above, in 2023, California lawmakers passed bill AB-418, which by 2027 will ban the use of four food additives. In contrast with the two previous examples, the only way for producers to comply with the law is through reformulation, either by removing any of the banned ingredients from their products or substituting any banned ingredients with a legal alternative. Firms cannot comply by relabeling.

First, we can consider the cost of compliance (f_R). As reformulation is the only response by which to comply with the rule, the costs of compliance are more substantial: substituting even a minor ingredient in a product can cost manufacturers between tens of thousands to hundreds of thousands of dollars per product (Muth et al., 2015a). News at the time highlighted the issue, with one headline describing that "California's food additive ban will require the urgent reformulation of 12,000 products" (Hyslop, 2023).

Second, we can consider changes to producers' variable profits ($\Delta\pi_A$). Variable profits would be affected by the differences in input prices and any changes in consumer demand resulting from modifications to the products. For example, synthetic colors like Red Dye No. 3 are generally substantially cheaper than non-synthetic alternatives (FMI, 2024); consequently, reformulating products to remove Red Dye No. 3 would have increased input costs for most firms using it as an ingredient. On the demand side, the probable direction remains ambiguous and depends on product types. For example, consumer demand may *decrease* if the removal of one of the banned additives detracts from attributes such as visual appeal, mouthfeel, shelf life, or other prominent characteristics. However, some consumers also prefer to avoid food additives, a factor which creates the potential for giving rise to *increases* in demand. One news article reported on this issue saying, "Many companies over the years have sought to shed additives to appease consumers' desire for simpler ingredients. But U.S. shoppers have sometimes revolted when food makers switched to more natural, but less colorful and less tasty, alternatives" (Newman, 2024). Products that currently use the regulated food additives include baked goods, candies, frostings, cereals, flours, and beverages (e.g., sodas, juice, sports drinks).

Third, we can consider the cost of separation (f_S). Separation costs in this example were conceivably lower than in the previous two cases, as segregating ingredients would be less expensive, concerns over accidental commingling would be diminished, and recordkeeping requirements would be less onerous. Despite these effects, separation costs are likely to be relatively high, as discussed above, given that keeping two versions of the same product separate during production and distribution can be difficult. One news report weighed in on this issue, saying that creating versions for California and other states would be "complex" for food manufacturers (Hyslop, 2024).

Fourth, we can consider the costs of halting sales of affected products to California (foregone profits $\pi_{\tilde{x},A}$). As California is the most populous state in the country, it would be exceedingly costly for most companies to stop sales to the state.

Finally, we can consider the costs of litigation and penalties (θf_L). The law establishes civil penalties of up to $5,000 for first violations and up to $10,000 for subsequent violations, and importantly, allows for a variety of enforcement actions to be taken by legal officials at both the state and local levels. In most cases, the costs to producers of flouting California's regulation would be too expensive to ignore.

Together, the costs associated with firms' potential responses to California's ingredient ban suggest that either ending sales in the state (Option 3) or selling noncompliant versions in California in violation of the regulation (Option 4) are unlikely to be systematically pursued as responses by impacted firms (Π^3 and Π^4) are smaller than profits under the other options due to the typically large magnitudes of f_S and θf_L. Consequently, it is probable that most food manufacturers will reformulate their products in response to the law, and either sell the modified products only in regulating states (Option 1) or in all states (Option 2). For food manufacturers finding that reformulation would have little effect on their profitability, the optimal reaction of firms would arguably be Option 2 in most instances. This would be the most desirable course of action for firms in cases for which reformulation has limited impact on consumers' demand and/or the substitute ingredient is similar in cost to the original. In contrast, for food manufacturers finding that reformulation would have a major impact on profit, pursuing Option 1 would arguably be the optimal decision for most firms.

In the meantime, and as producers weigh their responses to the impending legislation, food manufacturers and industry groups will likely continue to lobby and litigate, hoping for federal preemption and the establishment of nationwide standards that unify the various regulations applied by different states. In the months following the state regulation, the FDA has already followed suit in restricting first BVO and then Red Dye No. 3 at the national level.

Policy Comparisons

Table 1 summarizes the respective types of costs faced by food manufacturers and their expected magnitudes for each of the three policy examples. Together, the three cases show that food manufacturers weigh the respective costs and benefits under each course of action in choosing how to respond to new regulations. For example, Vermont's small size meant that Option 3—foregoing the relatively small volume of sales to Vermont's market to avoid a more costly systematic response—was potentially the most viable option for some firms following the state's GMO labeling requirements. In the case of Illinois' sesame labeling requirements, the law's limited scope for litigation and negligible potential for violators of the law to incur penalties meant Option 4 would present the most attractive option for some firms in this particular case. In the case of California's food additive ban, the potential for changes in product demand following reformulation to comply with California's law meant that Option 1 would reflect the most profitable choice for firms anticipating a large change in consumer demand from reformulating their products. It is thus important to highlight that, across different settings, firms could profitably pursue any of these options depending on the specific context. However, across the three widely differing policy cases, Option 2, under which manufacturers uniformly adapt their products to the new regulation nationwide, seems to have been a common response pursued by food manufacturers. One key implication of this is that, when faced with substantially different regulatory environments across states, many food manufacturers are likely to respond by conforming to the most restrictive set of state guidelines. A news report discussing the expected responses to the California additive law highlighted this issue, saying, firms' most straightforward course of action will be "to reformulate for the 'most strict' regulations" (Hyslop, 2024). This kind of systematic response from producers in reaction to an ever-evolving policy landscape is likely to have considerable ramifications for the U.S. food industry given the large costs that adjusting to these changes can entail.

While the domestic policy setting reflects fundamental differences with its counterpart(s) in the global arena, the U.S. interstate regulatory environment would arguably be well served in establishing firmer disciplines on such distortions. On the other hand, with regulatory ossification at the federal level, state-level regulation is likely to be an important and potentially powerful option for advocacy groups to effect changes in food policy.

Table 1. Summary of Affected Producer Margins in Case Studies

Cost Type	Case 1: Vermont GM Labeling	Case 2: Illinois Sesame Allergen Labeling	Case 3: California Food Additives
Compliance (reformulation or relabeling)	Can comply either by relabeling (low f_R) or reformulating (high f_R; \$50,000 for a minor non-functional ingredient to about \$650,000 for substitution of a major ingredient; Muth et al., 2015a).	Can comply either by relabeling (low f_R) or reformulating (high f_R).	Only able to comply with reformulation (high f_R).
Change in variable profits (change in demand or change in variable costs)	Relabeling – • Reduced demand ($\Delta q < 0$; demand decreased by about 5.9%; Fan et al., 2022). • Little/no change variable costs ($\Delta c \approx 0$). Reformulation – • Little/no change demand ($\Delta q \approx 0$). • Increased variable costs ($\Delta c > 0$).	Relabeling – • Little/no change demand ($\Delta q \approx 0$; only 0.23% of the U.S. population possesses a sesame allergy). • Little/no change variable costs ($\Delta c \approx 0$). Reformulation – • Little/no change demand ($\Delta q \approx 0$). • Little/no change in variable costs ($\Delta c \approx 0$).	Reformulation – Likely reduced demand ($\Delta q < 0$). Increased variable costs ($\Delta c > 0$).
Separation	Very high cost of separation during production and transportation (f_S). Cost would be higher under reformulation than relabeling.	Very high cost of separation during production and transport (f_S). Cost would be higher under reformulation than relabeling.	High cost of separation during production and transportation (f_S).
Sales to state	Vermont (2nd least populous state) represents a very small portion of demand, thus q is small. However, manufacturers anticipated that other larger states would likely follow suit with similar regulations.	Illinois (6th most populous state) represents a somewhat substantial portion of demand, thus q is medium.	California (most populous state) represents a very large portion of demand, thus q is large. Other states considering additive bans (e.g., New York, Illinois) are also large in size.
Litigation/ penalties	• Law includes penalties (\$1,000/day) and options for litigation ($f_L > 0$). • Positive probability of enforcement ($\theta > 0$).	• Law includes no penalties or options for litigation ($f_L \approx 0$). • Low probability of enforcement ($\theta \approx 0$).	• Law includes penalties (\$5,000/first violation and \$10,000 for subsequent violations) and substantial options for litigation ($f_L > 0$). • Positive probability of enforcement ($\theta > 0$).
Broader conclusions	High separation costs and high costs of potential legal penalties imply that Options 1 and 4 are prohibitively costly in most instances; Options 2 and 3 (uniform reformulation or market exit) present the most attractive options for most firms.	High separation costs and large size of Illinois' market imply that Options 1 and 3 are prohibitively costly in most instances; Options 2 and 4 (uniform reformulation or flouting the regulation) present the most attractive options for most firms.	Large size of California's market and high costs of potential legal penalties imply that Options 3 and 4 are prohibitively costly in most instances; high separation costs reduce the viability of Option 1. Option 2 arguably the most desirable option for most firms.

Note: Authors' construction based on analysis of different components of firms' profits under the three regulatory cases

Future Research

When a new state regulation is passed, food manufacturers must make choices about how to react. Here, we focus on how the costs associated with a regulation determine food manufacturers' optimal production response. In reality, there are likely to be other critical factors and potential reactions that enter into food manufacturers' decision-making process. For example, the possibility of other states creating similar laws or the likelihood of a future federal mandate is likely to influence firms' decision making. Several producers weighed such considerations in the case of Vermont's GM labeling law, in that many food manufacturers correctly anticipated that federal standards would follow in the wake of Vermont's rules. Similarly, beyond making changes in their production and sales decisions, firms and industry groups can (and do) engage in lobbying for their preferred policy outcomes (as has been extensively analyzed in the international trade policy context; see, e.g., Grossman and Helpman, 1995). In our conceptual analysis we assume that the state policy is already in place, in which case lobbying efforts at the state level are conceivably of diminished relevance. However, firms may still engage in lobbying to seek a federal response or to dissuade lawmakers in other states from following suit. Additionally, firms' choices are also likely to vary in relation to producers' attributes, such as the firms' sizes or the types of products that they sell (e.g., branded versus private label products). Further research is needed to understand how food manufacturers' characteristics are related to their decision making under state regulation.

Conclusion

The U.S. regulatory landscape plays host to an increasingly patchwork system of state-level approaches to food policy. As more states pursue individualistic approaches to regulating the food system, food manufacturers must react to this heterogeneity by choosing among several costly responses in adhering (or not) to the new rules and regulations. And, while the recent regulations that we discuss have been implemented under the goal of safeguarding the well-being of consumers, the costs borne from adapting to these new policies—particularly when the specifics of the regulations frequently differ across states—implies that these policy actions do not deliver unmitigated benefits. Finally, though we focus on food manufacturers' decision making in our discussion and analysis, changes in state regulation can clearly have impacts on other stakeholders, most notably consumers.

In this paper we provide a comprehensive overview of this critical and timely issue facing the agri-food system. To help characterize the economic factors that influence firms' responses to changes in states' regulations, we develop a conceptual framework to formally characterize the various considerations weighed by firms in response to these changes, and then apply this framework to analyze three examples of states' food policies. Regardless of which responses individual producers pursue in response to changes in regulation, the increasingly heterogeneous U.S. food policy environment promises to have a sizeable impact on food manufacturers and other actors in the supply chain.

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Appendix

Additional Conceptual Model Details

Equilibrium prices and quantities prior to the regulation and the subsequent response of the firm are given respectively by

$$p_{x,j} = \frac{a_{x,j} + c_x}{2} \quad \text{and} \quad q_{x,j} = \frac{a_{x,j} - c_x}{2b_j} \quad \text{for} \quad j = A, B.$$

From the setup of the model, the firm's prospective profits following the implementation of state A's regulation are given as follows:

Option 1 *(reformulate and separate production)*

$\Pi^1 = \pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S$

Option 2 *(reformulate for both markets)*

$\Pi^2 = \pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R$

Option 3 *(exit the regulating market)*

$\Pi^3 = \pi_{x,B}$

Option 4 *(ignore the regulation)*

$\Pi^4 = \pi_{x,A} + \pi_{x,B} - \theta f_L$

The firm will optimally choose the option that maximizes its expected profits in response to the regulation. Define $\Delta\pi_A = \pi_{\tilde{x},A} - \pi_{x,A}$ and $\Delta\pi_B = \pi_{\tilde{x},B} - \pi_{x,B}$ as the differences in the firms' variable profits in states A and B, respectively, from selling the reformulated version of the product in the each market.

Firm optimally chooses Option 1 ($\Pi^1 > \Pi^2, \Pi^3, \Pi^4$)

- For $\Pi^1 > \Pi^2$,

$$\pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S > \pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R$$

$$\pi_{x,B} - f_S > \pi_{\tilde{x},B}$$

$$-f_S > \Delta\pi_{x,B}$$

- For $\Pi^1 > \Pi^3$,

$$\pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S > \pi_{x,B}$$

$$\pi_{\tilde{x},A} - f_R - f_S > 0$$

- For $\Pi^1 > \Pi^4$,

$$\pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S > \pi_{x,A} + \pi_{x,B} - \theta f_L$$

$$\pi_{\tilde{x},A} - f_R - f_S > \pi_{x,A} - \theta f_L$$

$$\Delta\pi_A - f_R - f_S > -\theta f_L$$

Firm optimally chooses Option 2 ($\Pi^2 > \Pi^1, \Pi^3, \Pi^4$)

- For $\Pi^2 > \Pi^1$,

$$\pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R > \pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S$$

$$\pi_{\tilde{x},B} > \pi_{x,B} - f_S$$

$$\pi_{\tilde{x},B} - \pi_{x,B} > -f_S$$

$$\Delta\pi_B > -f_S$$

- For $\Pi^2 > \Pi^3$,

$$\pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R > \pi_{x,B}$$

$$\pi_{\tilde{x},A} + \pi_{\tilde{x},B} - \pi_{x,B} - f_R > 0$$

$$\pi_{\tilde{x},A} + \Delta\pi_B - f_R > 0$$

- For $\Pi^2 > \Pi^4$,

$$\pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R > \pi_{x,A} + \pi_{x,B} - \theta f_L$$

$$\pi_{\tilde{x},A} - \pi_{x,A} + \pi_{\tilde{x},B} - \pi_{x,B} - f_R > -\theta f_L$$

$$\Delta\pi_A + \Delta\pi_B - f_R > -\theta f_L$$

***Firm optimally chooses Option 3* ($\mathbf{\Pi^3 > \Pi^1, \Pi^2, \Pi^4}$)**

- For $\Pi^3 > \Pi^1$,

$$\pi_{x,B} > \pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S$$

$$0 > \pi_{\tilde{x},A} - f_R - f_S$$

- For $\Pi^3 > \Pi^2$,

$$\pi_{x,B} > \pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R$$

$$0 > \pi_{\tilde{x},A} + \Delta\pi_B - f_R$$

- For $\Pi^3 > \Pi^4$,

$$\pi_{x,B} > \pi_{x,A} + \pi_{x,B} - \theta f_L$$

$$0 > \pi_{x,A} - \theta f_L$$

Firm optimally chooses Option 4 **($\mathbf{\Pi^4 > \Pi^1, \Pi^2, \Pi^3}$)**

- For $\Pi^4 > \Pi^1$,

$$\pi_{x,A} + \pi_{x,B} - \theta f_L > \pi_{\tilde{x},A} + \pi_{x,B} - f_R - f_S$$

$$\pi_{x,A} - \theta f_L > \pi_{\tilde{x},A} - f_R - f_S$$

$$-\theta f_L > \pi_{\tilde{x},A} - \pi_{x,A} - f_R - f_S$$

$$-\theta f_L > \Delta\pi_A - f_R - f_S$$

- For $\Pi^4 > \Pi^2$,

$$\pi_{x,A} + \pi_{x,B} - \theta f_L > \pi_{\tilde{x},A} + \pi_{\tilde{x},B} - f_R$$

$$-\theta f_L > \pi_{\tilde{x},A} - \pi_{x,A} + \pi_{\tilde{x},B} - \pi_{x,B} - f_R$$

$$-\theta f_L > \Delta\pi_A + \Delta\pi_B - f_R$$

- For $\Pi^4 > \Pi^3$,

$$\pi_{x,A} + \pi_{x,B} - \theta f_L > \pi_{x,B}$$

$$\pi_{x,A} - \theta f_L > 0$$