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Effects of Environmental Regulation and Urban Encroachment on California's Dairy Structure

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Environmental regulatory compliance costs are often cited as a factor in dairy location decisions, but few studies estimate the impacts of regulation in this sector. This article uses California dairy regulations to examine the pollution haven hypothesis in agriculture. Dairy industry regulation has varied regionally within the state, with the more strictly regulated Southern California region losing production and the more environmentally lenient Central Valley gaining production. Results show that even after controlling for population density and property values, regulation had significant negative effects on dairying in Southern California.

Key words: dairy, differences-in-differences, environment, livestock, regulation

Introduction

The U.S. dairy industry has witnessed striking structural changes in the last several decades, coupled with increased geographic concentration and heightened scrutiny as a source of water and air pollution. Federal, state, and regional environmental regulations prompted by this scrutiny differ in stringency and application from region to region and may result in "pollution havens"–places where polluting industries locate to take advantage of relatively lenient environmental regulation. These havens have implications for regional economies, employment, and local tax revenues. Further, environmental regulations may have heterogeneous effects on differently-sized operations, impacting the industry's potential economies of scale. Despite these concerns, little research has econometrically estimated the effects of environmental regulation on location and structure in the dairy industry, and none have examined the effects of within-state heterogeneity in regulation.

California's dairy industry accounts for 20% of U.S. milk production (California Department of Food and Agriculture, 2007) and has generated significant environmental concerns. Studies have found dairies to be major contributors to ground and surface water pollution (California Regional Water Quality Control Board, Santa Ana Region, 1990). In response, California's regional water quality boards have adopted water quality regulations that differ between Southern California and the Central Valley, the state's two main dairy regions. Southern California's heavily populated Chino region adopted dairy water quality regulation in 1994 and increased stringency in 1999. In comparison, the Central Valley only adopted regulations on dairies that were more restrictive than state mandates in 2007 (California Regional Water Quality Control Board Central Valley Region, 2010). Concurrently, Southern California lost production, while the Central Valley gained, raising questions about the impact of regulation differences.

Omitted variable bias is a primary concern with regard to heterogeneous regulation effects on the location of economic activity. The presence of a polluting industry in a location with relatively lenient environmental regulation may be due to other factors such as less expensive labor or other

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inputs. In the case of California dairies, the primary potential covariate is urban development. Trade journals report that population growth and housing construction in Southern California encouraged local dairies to sell their property and relocate (Marsh, 2007; Molloy, 2004). By comparison, the Central Valley is less densely populated with lower property values and has experienced steady growth in dairy production. An important question is whether estimated effects of regulation are robust upon the consideration of property values.

I examine the effects of environmental regulation on the structure of the California dairy industry in terms of location and operation size by addressing three questions. First, what were the effects of regulation and urban encroachment on dairying in the Southern California? Second, did stricter regulations in Southern California encourage growth in the Central Valley? Third, did regulations have different impacts across differently-sized operations? To answer these questions, I use county-level annual data from 1980 to 2005 as well as supplemental Census of Agriculture data. I employ a differences-in-differences estimation coupled with controls for property values, population density, and building permits, as well as a number of other potential covariates influencing dairy location. Time- and county-level fixed effects along with data on areas outside of these two main dairying regions control for features that affect all regions within the state in specific years and control for features of counties that are static over time (such as county size, slope, and proximity to water bodies). The fixed effects alleviate many omitted variable concerns.

Results show that both environmental regulation and urban development played roles in the decline of dairy production in Southern California. While the two factors had nearly equal overall roles in reducing dairying in Southern California between 1994 and 1999, property values appear to have had a much larger overall effect than regulations after 1999. Early regulations in Southern California appear to have driven dairies not only from Southern California but from the state as a whole, while later regulations displaced approximately half of production lost by Southern California to the Central Valley. These effects are most significant among dairies with over 500 head, which may have had more difficulty meeting regulatory standards.

California Dairies and Pollution Problems

California's dairy sector has experienced marked growth over the past twenty-five years. Since 1993, the state has been the nation's top milk-producer. This growth has occurred concurrently with increased operation sizes. In 1982 the average number of head per farm with milk cows was 204; by 2007 this number was 850 (National Agricultural Statistics Service, various years).[1]

Dairies' primary pollution problem involves the manure production (Gollehon and Caswell, 2000). In California, most dairies use dry-lot technologies in which cows live in shaded paddocks with open-sided barns for feeding. Manure is scraped from these paddocks and then piled for later disposal or flushed into holding tanks or lagoons (Meyer, Garnett, and Guthrie, 1997). Manure is a source of nitrogen and phosphorus and can therefore be used as a crop fertilizer; however, larger dairies require more land for manure disposal. If manure is applied at rates above which soil and plants can absorb it, precipitation can wash excess nutrients into ground and surface waters.[2]

The effect of livestock production on water quality has been well-documented (for a review see Copeland and Zinn, 1998). The U.S. Environmental Protection Agency (2002) found that agriculture was the top polluter of rivers and streams and contributed to over 35% of impaired waters. Livestock production is estimated to account for a quarter of these impairments (U.S. General Accounting Office, 1995). Polluted run-off from livestock operations has also been linked to coastal water quality concerns. More specific to California, dairies have been blamed for polluting the Chino River Basin

[1] These averages are computed by dividing the state total number of milk cows by the state total number of farms with milk cows. They are not computed by finding the average sizes of farms with milk cows.

[2] Additionally, decomposing manure can emit gases, including hydrogen sulfide and ammonia, which can degrade air quality.

and compromising Orange County's drinking water (California Regional Water Quality Control Board, Santa Ana Region, 1990).

Effects of Environmental Regulation on Livestock Production Location

Livestock and crop production have historically occurred on the same farm and in the same region (Gardner, 2002). However, increasing specialization has led individual farms to focus on producing fewer commodities with the result that many livestock operations have no cropland. Between 2004 and 2006, 12% of dairy production, 19% of hog production, and 29% of broiler production occurred on farms with no cropland (MacDonald and McBride, 2009, table 6). Further, livestock production has grown in non-traditional areas where less crop production occurs (MacDonald and McBride, 2009). In particular, dairying has expanded in previously undesirable warmer, drier climates in the Southwestern United States (MacDonald and McBride, 2009). Irrigation technologies have allowed feed crops to be produced in such climates and provided new regions for the concentration of livestock production. Given fewer geographic constraints, regional variation in environmental manure management regulation plays a larger role in livestock production location decisions.

Much of the literature suggests that regulation plays an important role in dairy location. Pfost and Fulhage (2000, p. 1) note that "the first factor to consider in selecting a site for an animal feeding operation is state and local permitting requirements." A number of articles detail environmental regulation of dairies (Meyer, 2000, 2002, 2005; Meyer and Mullinax, 1999; Morse, 1996) and suggest that it may be pertinent to siting determinations (Abdalla and Lanyon, 1995; Clouser et al., 1994).

Other studies provide suggestive empirical evidence of regulation's role in livestock farm location. Stirm and St. Pierre (2003) conduct a national survey of dairy producers and find waste management regulations to be a primary factor in location decisions. Sneeringer and Hogle (2008) examine trends in the number of milk cows in areas of California with differing levels of regulatory stringency and find that areas with stronger regulation lost production while those with more lenient stipulations gained. However, Sneeringer and Hogle do not attempt to control for other factors that may be leading to changes in dairy location within the state, nor do they examine the direction of causation between regulation and dairy location.

Some econometric research controls for potential covariates or attempts to identify a causal relationship between regulation and the location of dairy production. (Isik, 2004) uses a spatial-econometric approach to estimate the correlation between regulation and dairy location and finds the stringency of state-level regulations to be negatively correlated with dairy production. However, Isik does not attempt to evaluate how a county's dairy production changes before and after regulation, making it difficult to ascertain a direction of causation. Herath, Weersink, and Carpentier (2005) address cross-sectional endogeneity problems by using state-level longitudinal data to examine the effects of regulation on different livestock sectors. The results show the dairy industry locating in states with relatively lenient environmental regulations. Further, they find no evidence that states adopt stronger regulations in response to local dairy industry growth. Research on the effects of regulation on the location of other types of livestock production also provide evidence of its pertinent role in location decisions (Roe, Irwin, and Sharp, 2002; Sneeringer, 2009).

Environmental Regulation of Dairies in California

California dairies are subject to a complex assortment of water quality legislation at the federal, state, and regional levels (Sneeringer and Hogle, 2008; Meyer, 2002, 2003, 2007a,b). More recently, air quality regulations have also become a concern. While federal and state regulations apply across the

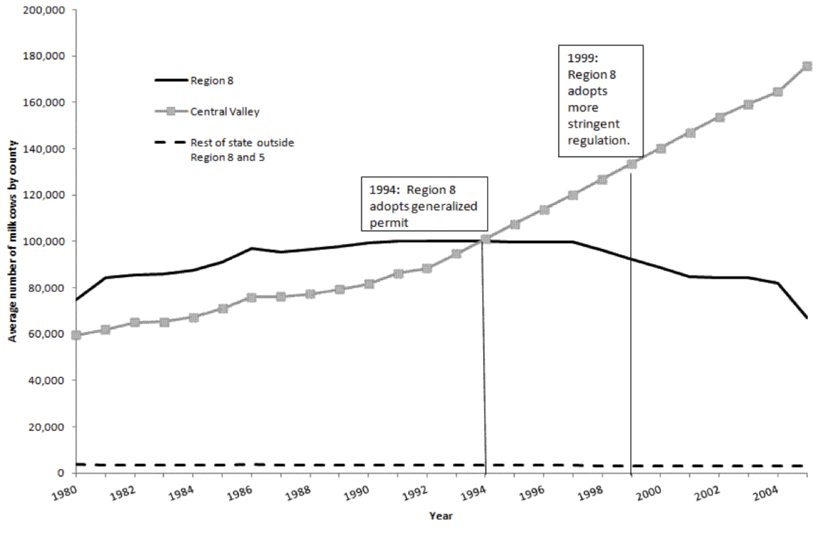

Figure 1. Number of Milk Cows by California Regions, 1980-2005

Notes: Averages for counties within each region shown.

state, California has also adopted regulatory schemes that enable different stringency levels within the state. California's 1970 Porter-Cologne Act divided the state into nine Regional Water Boards and enabled each to adopt regulations beyond the stringency of state-level rules. Separate governing bodies oversee the state's two main dairying regions; the Region 8 Water Board governs the Southern California Chino region while Region 5 covers the Central Valley.

In 1972, the Region 8 Water Board began issuing site-specific permits to dairies that required specific manure management practices. In 1994, Region 8 adopted a new permit requirement to reduce nutrient run-off stipulating maximum manure application rates for all dairies with more than 20 cows. For some operations, compliance required that additional land be accessed for manure disposal (California Regional Water Quality Control Board, Santa Ana Region, 1994). In response to 1998 EPA findings that dairies were a significant detriment to water quality in many Southern California waterways, Region 8 increased the stringency of their regulations in 1999 (California Regional Water Quality Control Board, Santa Ana Region, 1999).

In contrast, Region 5's Water Board did not impose any regulations beyond those stipulated by the state for several years after. In 2003, Region 5 began considering stronger regulations, which were eventually adopted in 2007 (California Regional Water Quality Control Board Central Valley Region, 2010). Dairies were required to implement these new regulations by 2011.

Dairying levels in Regions 8 and 5 appear to be correlated with Region 8's adoption of stricter regulations in 1994 and 1999. Figure 1 shows the average inventory of milk cows for the three counties in Region 8, the top eight dairy-producing counties in Region 5, and the forty-seven counties in the rest of the state. County milk cow inventories in Region 8 increase until the mid-1990s and then decline, suggesting a correlation between regulations and dairying. The Central Valley counties increase at a similar pace to Region 8 prior to the early 1990s,[3] after which they follow a steeper upward trend. This suggests that Southern California's regulations may have caused dairies to relocate to the Central Valley. Figure 1 provides some evidence of regulation effects

[3] Between 1980 and 1990, the Central Valley counties each added approximately 2,213 milk cows per year (on average) while the Region 8 counties each added 2,450.

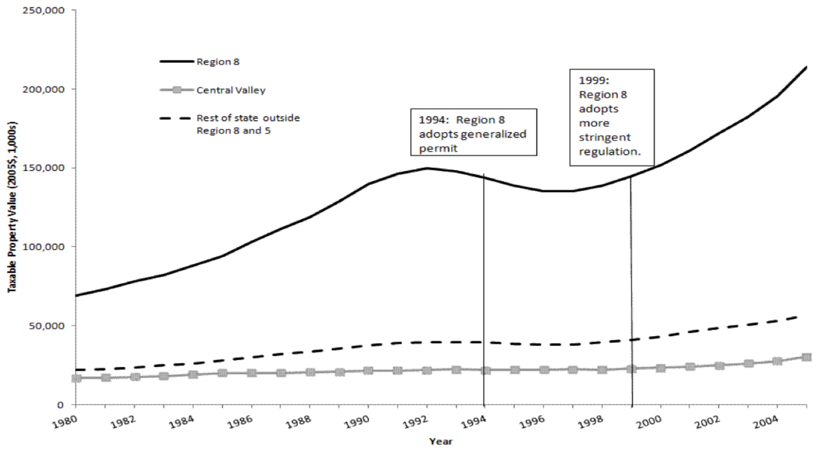

Figure 2. Property Values in California Regions, 1980-2005

Notes: Averages for counties within each region shown.

on dairy location within the state. However, it could also be that property values drove location changes. Figure 2 presents property values across each region. Region 8's higher property values dip in the 1990s; property values in the Central Valley and the rest of the state show little movement. Comparing figures 1 and 2, Region 8's property values and dairy presence do not appear strongly related; only after 1997 does dairy presence decline as property values increase, suggesting that property values alone did not drive dairying declines in Southern California and increases in the Central Valley.

Empirical Strategy

I employ a differences-in-differences (DD) model to compare changes in Region 8 counties before and after Region 8 regulation with changes in non-Region 8 counties over the same time period.[4] By comparing changes in regulated counties with those in unregulated ones,[5] factors that would have occurred in regulated counties even in the absence of regulation are netted out, even without adding to the model individual covariates for each of these conceivable factors. This lessens many concerns about omitted variable bias and allows for the estimation of changes attributable to regulation. The addition of county- and time-varying covariates further lessens concerns with omitted variable bias. A fundamental assumption underlying the DD model is that unregulated counties serve as a reasonable counterfactual to what would have happened in regulated counties in the absence of stricter regulations.[6]

[4] See Angrist and Pischke (2009) and Imbens and Wooldridge (2007) for overviews and examples of differences-in-differences analysis.

[5] For simplicity, I use "regulation" to refer to Region 8's regulation in 1994 and 1999. However, all counties in California were subject to state- and federal-level rules during this time period.

[6] In the language of treatments and controls, "counterfactual" refers to what would have happened to the treatment group in the absence of treatment. Because one only witnesses what happens to the treatment group when it is treated, the control group serves as the counterfactual to the treatment group. The "treatment effect" would be the outcome change in the regulated (treated) counties minus the outcome change in the unregulated (control, or counterfactual) counties. In this context, the Region 8 counties are "treated" by Region 8 regulation, while non-Region 8 counties are untreated by Region 8 regulation. Region 8 counties are the "treatment group," while non-Region 8 counties are the "control group," or counterfactual.

I make two modifications to the standard DD model.[7] First, since Region 8 adopted regulations in both 1994 and 1999, I examine two sets of regulations. Second, the standard DD model examines changes in outcome levels over time as a function of regulation over time. Instead, I examine changes in outcome trends over time as a function of regulation over time.

I use two sets of data with different time coverage in order to examine outcomes specific to each dataset. The exact model specification will differ slightly when applied to the two data sets. One dataset includes county-level annual data from 1980 to 2005. The second dataset includes county-level observations for every five years between 1982 and 2002. I specify the model as it is applied to the county-level annual data. The model specification for the five-year data is very similar.

The DD models control for long-term county-level trends in growth, factors affecting all dairies' growth in a particular year, and area- and time-varying potential covariates. The empirical model for the annual data is constructed by allowing c and t to index county and year, respectively, with R^1_{ct} and R^2_{ct} representing the two regulation variables such that:

(1) $$R^1_{ct} = \begin{cases} 1 & \text{if Region 8 = 1 and } t \geq 1994 \\ 0 & \text{otherwise} \end{cases}$$

and

(2) $$R^2_{ct} = \begin{cases} 1 & \text{if Region 8 = 1 and } t \geq 1999 \\ 0 & \text{otherwise} \end{cases}$$

I estimate the effects of regulation on two separate outcome variables, but the model is the same for each. Let D_{ct} represent the level of one of these dairy outcomes, which include the number of milk cows and milk cows per square county mile. To consider trends in the outcome variables rather than *levels*, the dependent variable will be $\Delta D_{ct} = D_{ct+1} - D_{ct}$.

Let $\boldsymbol{X}_{ct}$ refer to a matrix of county- and time-varying observable factors defined in time t that plausibly relate to both regulation and dairying growth. These variables include population density, land values, population growth, and labor market orientation toward agriculture. Let $\boldsymbol{County}_c$ and $\boldsymbol{Time}_t$ refer to vectors of indicator variables for each county and year, respectively. The model for the annual data is:

(3) $$\Delta D_{ct} = \alpha + \lambda^1 R^1_{ct} + \lambda^2 R^2_{ct} + \boldsymbol{X}'_{ct}\boldsymbol{\beta} + \boldsymbol{County}'_c\boldsymbol{\theta} + \boldsymbol{Time}'_t\boldsymbol{\gamma} + e_{ct}.$$

The estimated parameters on the regulation variables (λ^1 and λ^2) are the primary coefficients of interest; λ^1 is interpreted as the effect of Region 8's 1994 regulation on Region 8, netting out contemporaneous changes in unregulated areas as well as fixed characteristics of regulated counties.[8] The parameter estimate on the 1999 regulation (λ^2) represents the effect of the 1999 regulation.

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7 A standard DD model in this scenario might be the following: allow c and t to index county and year, respectively, and allow D_{ct} to represent the level of the dairy outcome in county c and time t. For this "standard" scenario, consider only one regulation that occurs in some counties but not others; let:

$$R_{ct} = \begin{cases} 1 & \textit{if County is in Regulated Region and Year is after Regulation} \\ 0 & \textit{Otherwise} \end{cases}$$

Let $\boldsymbol{County}_c$ and $\boldsymbol{Time}_t$ refer to vectors of indicator variables for each county and year, respectively. The "basic" DD model would be:

$D_{ct} = \alpha + \lambda \boldsymbol{R}_{ct} + \boldsymbol{County}'_c\boldsymbol{\theta} + \boldsymbol{Time}'_t\boldsymbol{\gamma} + e_{ct}$.

The coefficient of interest is λ. See Angrist and Pischke (2009) and Imbens and Wooldridge (2007) for further description of the DD model in a regression setting.

8 Note that the coefficients will capture the effects of regulation on the regulated counties, in relationship to changes in the unregulated counties over the same period. For example, if the regulated counties show an unconditional increase in growth after regulation but their growth is less than it would have been given pre-regulation trends and post-regulation growth differentials in unregulated counties, then the coefficient will be negative. Also note that each λ will reflect average post-regulation growth net of average pre-regulation growth, not just effects that may occur in year of regulation.

The model specification applied to the county-level data for every five years between 1982 and 2002 is slightly different from equation (3). To allow there to be more than one time period after regulation adoption, I only consider the first of the Region 8 regulations. The specification when applied to the five-year data is:

$$\Delta D_{ct} = \alpha + \lambda^1 R^1_{ct} + \boldsymbol{X}'_{ct}\boldsymbol{\beta} + \boldsymbol{County}'_c\boldsymbol{\theta} + \boldsymbol{Time}'_t\boldsymbol{\gamma} + e_{ct}. \tag{4}$$

Here, all variables have the same meaning as in equation (3), but t indexes years at five-year intervals (1982, 1987, 1992, 1997, and 2002). The outcome variables examined using this five-year data include the total number of dairy operations, the number of dairy operations with 500 or more head, the number of dairy operations with fewer than 500 head, the number of cows at operations with 500 or more head, and the number of cows at operations with fewer than 500 head.

The panel data introduces the possibility of county-level error terms correlated between time periods (Bertrand, Duflo, and Mullainathan, 2004). Positive serial correlation in the error terms will lead the standard errors of the coefficients to be underestimated. I therefore cluster standard errors at the county level to statistically correct for the likely similarity in individual counties' observations over time (see Angrist and Pischke, 2009, p. 315 for discussion).

The DD model provides more consistent estimates of the effects of regulation on outcomes than cross-sectional models by reducing two pertinent sources of potential bias in the coefficients of interest. First, the addition of the county and time fixed effects ($\boldsymbol{County}_c$ and $\boldsymbol{Time}_t$) lessens potential omitted variable bias. The county fixed effects control for time-invariant features associated with regulation and growth including total size of county, slope, elevation, historical setting, environmental features such as long-term average temperature and rainfall, and proximity to water. Importantly, county fixed effects also control for the long-term linear trend in growth when the dependent variable is measured in changes in levels. The time fixed effects control for factors experienced by all counties in an individual year, including market-wide changes and effects of state- and federal-level regulation which impact growth at all locations across the state.

In addition to reducing potential omitted variable bias, the model also plausibly reduces bias arising from feedback endogeneity. In a cross-sectional regression of an outcome on regulation status, the estimated coefficient may capture the effect of the regulation on the outcome, but may also represent the effect of the outcome on regulation adoption. The DD model lessens bias concerns by using a multi-period time frame. Further, the use of changes between times t and $t+1$ as an outcome variable helps limit potential endogeneity between production levels and regulation adoption.[9]

Testing for Feedback Endogeneity

Despite these steps to lessen feedback-related endogeneity, the estimates on regulation effects may be biased if dairy growth leads to regulation adoption. I therefore perform several specification and robustness checks to assess such endogeneity. Using the annual dataset, which contains more observations, I first perform regressions of regulation status in time $t+1$ on dairy growth between t and $t+1$ as well as the other explanatory variables in time t for each of the regulation variables:

$$R^1_{c,t+1} = \gamma_1 + \mu_1 \Delta D_{c,t} + \boldsymbol{X}'_{c,t}\boldsymbol{\theta}_1 + v_{c,t}, \tag{5}$$

[9] Another method of dealing with such feedback is the instrumental variable approach. To be valid, the instrument would need to strongly predict regulation but only affect growth via regulation. Variables that may predict regulation adoption–including population growth, population density, and land value–are also cited in the literature as directly affecting dairy location, thus these are not valid instruments. In their assessment of potential feedback effects of environmental stringency on livestock location of individual types, (Herath, Weersink, and Carpentier, 2005) use as instruments lagged growth rates in overall livestock inventory and livestock inventory density, total population, and median income. It is unclear why these variables would not directly affect location.

where $t+1=1994$, $t=1993$, $\Delta D_{ct}=D_{c,t=1994}-D_{c,t=1993}$, and

$$R^2_{c,t+1}=\gamma_2+\mu_2\Delta D_{c,t}+\boldsymbol{X}'_{c,t}\boldsymbol{\theta}_2+u_{c,t}, \tag{6}$$

where $t+1=1999$, $t=1998$, and $\Delta D_{ct}=D_{c,t=1999}-D_{c,t=1998}$. Statistical significance of the μ coefficients in equations (5) and (6) provides evidence that growth a year prior to regulation is correlated with regulation (and suggests feedback endogeneity).

As an additional check, I add lagged growth (between $t-1$ and t) as a regressor in equation (3):

$$\Delta D_{ct}=\alpha+\eta\Delta D_{ct-1}+\lambda^1R^1_{ct}+\lambda^2R^2_{ct}+\boldsymbol{X}'_{ct}\boldsymbol{\beta}+\boldsymbol{County}'_{ct}\boldsymbol{\beta}+\boldsymbol{Time}'_t\boldsymbol{\gamma}+e_{ct}. \tag{7}$$

This is akin to controlling for factors that may lead to both regulation adoption and to changes in growth (Wooldridge, 2002). If including ΔD_{ct-1} in equation (7) changes the λ coefficients on the regulation variables estimated in equation (3), then prior growth is correlated with regulation adoption and indicates the presence of feedback-related endogeneity. A minor complication of this procedure is that the fixed effects framework causes the regression error term to be correlated with this new regressor which makes D_{ct-1} endogenous (Angrist and Pischke, 2009). Therefore, I instrument for this lagged term with prior lagged growth (between $t-2$ and $t-1$) in equation (7).[10]

Validity of Counterfactual

The DD strategy relies on unregulated counties serving as a valid counterfactual to the Region 8 counties and capturing what would have happened in Region 8 in the absence of regulation.[11] If regulated and unregulated counties are similar in their pre-regulation observable characteristics, then their unobservable features are more plausibly controlled for by the model. Figures 1 and 2 suggest that the Central Valley and Region 8 both show high levels of dairy production prior to regulation (1980-1993) but differ strongly in property values. Examining the rest of the state suggests that no other region has both the high property values and milk cow densities of Region 8. Therefore, I explore two counterfactuals to establish a range of regulation effects.

I first examine the effects of regulation on Region 8 using the Central Valley as the counterfactual. Because these two regions are similar in terms of dairying growth and levels in the period before any Region 8 regulation, it is more likely that whatever variables are unobserved but related to dairy growth will be accounted by the DD methodology. However, Region 8 regulation may induce dairies to move from Region 8 to the Central Valley. Hence the Central Valley would, in fact, be affected by Region 8's regulations, albeit in a different manner than Region 8. If this is the case, the estimated effect of Region 8 regulation on Region 8 using the Central Valley counties as controls would capture emigration of production from Region 8 as well as immigration to the Central Valley. The estimated effects of regulation on Region 8 using the Central Valley as a control would therefore be over-stated.[12]

Assessing the potential overestimate garnered by movement to the Central Valley requires considering a second counterfactual. The use of counties in another state is problematic because trade journals suggest that some dairies moved from Southern California to other states. Thus, estimates using other states as the counterfactual would suffer the same problem as when using the

[10] The first stage of this instrumental variables approach is $\Delta D_{ct-1}=\alpha+\eta\Delta D_{ct-2}+e_{ct}$. See Angrist and Pischke (2009, p. 244-245) for discussion.

[11] Regulated and unregulated counties do not have to be precisely the same, as the DD strategy only uses variation from the means of the dependent and independent variables to estimate effects. Thus the unregulated counties may have a different average growth from the treatment counties.

[12] The "treatment" (regulation) affecting the "control" group (the unregulated counties) is a common concern in the literature using DD models (see Angrist and Pischke, 2009). For a mathematical representation of this concern, see Appendix B.

Central Valley. Additionally, another state's production may be influenced by a number of factors distinct from those facing California (including myriad state-specific regulations) which also makes these less-plausible counterfactuals. Counties in California outside of Region 8 and the Central Valley may serve as an alternative counterfactual in the sense that they are unlikely to receive any dairies because they may not have the infrastructure that encourages dairy production. While this lack of a dairy sector infrastructure makes these counties a more valid counterfactual for one reason, it also makes them a less appropriate counterfactual since they are conceivably not comparable to the Region 8 counties in this sense. I use these counties as a second counterfactual to provide another (and presumably lower) estimate of the effects of regulation on the regulated counties. Differences in the estimated effects of regulation using these two separate counterfactuals provides an estimate of how much of the regulation-induced decline in dairying in Region 8 relocated to the Central Valley. If the two estimates are the same, this suggests that dairy production exiting Region 8 did not enter the Central Valley.

Data and Variable Construction

Dairy production data come from two sources. County milk cow inventory data for each year between 1980 and 2005 are obtained from the National Agricultural Statistics Service (National Agricultural Statistics Service, various years). These annual data are limited in that they only provide the number of milk cows within a county, but not the number or size of farms. Thus, estimated effects using this measure will reflect growth and downsizing of individual farms (the intensive margin) as well as entry and exit (the extensive margin).

To examine effects on number and size of farms, I use county-level measures from the 1982, 1987, 1992, 1997, and 2002 Censuses of Agriculture (U.S. Department of Agriculture, 1982, 1987, 1992, 1997, 2002, 2007). To gain a balanced panel for all counties within the state, I impute suppressed values.[13] Region 8 covers portions of three counties: Orange, Riverside, and San Bernardino. For dairies in these three counties that are not in Region 8 (i.e., are not affected by the regulation), estimated effects of regulation will be biased toward zero. I characterize the Central Valley as the eight top-producing counties in this area: Tulare, Kern, Kings, Fresno, San Joaquin, Stanislaus, Madera, and Merced. These eight counties plus Riverside and San Bernardino account for over 99% all California milk cows in 2005.[14]

Property Values

Property value data are from the California Board of Equalization's annual reports for 1980-2005 and represent total county net property values as reported for taxation purposes (California Board of

[13] Imputation follows different routes for the two data sets. NASS reports county-level annual measures for 1980 to 1992 and 2001 to 2005 for most counties within the state. I add county-level data from the 1997 Census of Agriculture, and then create linear extrapolations between 1992 and 1997 and between 1997 and 2001 when possible. Counties without any observations for any year are coded all as zeros. Missing values are also coded as zeroes after inspection showed years prior to missing values with values under 50. Counties with censored data in the 1997 Census of Agriculture that also have blocked annual-level data are assigned values equal to the mean of the prior five years of available data. After performing these modifications, the sum of the county values differs on average 1.2% from the reported state totals for each year. Different methods of imputing data do not change results. Imputation for the Census of Agriculture data involves finding the difference between the reported state total with the sum of reported values, and then assigning an equal portion of the difference to each county with unreported data.

[14] The remaining forty-seven counties are Alameda, Alpine, Amador, Butte, Calaveras, Colusa, Contra Costa, Del Norte, El Dorado, Glenn, Humboldt, Imperial, Inyo, Lake, Lassen, Los Angeles, Marin, Mariposa, Mendocino, Modoc, Mono, Monterey, Napa, Nevada, Placer, Plumas, Sacramento, San Benito, San Diego, San Francisco, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Shasta, Sierra, Siskiyou, Solano, Sonoma, Sutter, Tehama, Trinity, Tuolumne, Ventura, Yolo, and Yuba.

Equalization, 1980-2005). In 1981 the ratio of the assessed value to the taxable value changed from 25% to 100%. In order to make the 1980 values comparable to later years, all values for 1980 are multiplied by four.

Other Time- and County-Varying Inputs and Local Economic Conditions

Other factors may influence the adoption of regulation and dairy production. I use two additional indicators of urban encroachment and population pressure as control variables. The first is county population density, which is measured as the number of people in a county divided its land area in square miles. Population data come from the U.S. Census Bureau (U.S. Bureau of the Census, Various Yearsc) and land area data come from the 2006 Area Resource File from the Health Resources and Services Administration (Health Resources and Services Administration, 2006). The effect of population density on dairy presence could be either positive or negative. Based on a desire to locate closer to end markets, dairy presence may be higher in areas with higher population density. On the other hand, dairies may desire to locate in areas with fewer people and, therefore, reduce urban-rural conflicts.

I use the number of new residential building permits as reported by the U.S. Census Bureau as a second measure of urban development (U.S. Bureau of the Census, Various Yearsa). Residential construction in California has followed a cyclical pattern since 1970, peaking in the mid-1980s, followed by a long trough stretching through the year 2000 (Myers and Park, 2002). Coupled with population growth, less residential property construction has the potential to drive up prices for existing homes and rentals, particularly in areas with higher population density. Hence, fewer building permits may be associated with higher land prices and fewer dairies, yielding a positive correlation between dairies and building permits. However, building permits may be an indication of more development and fewer dairies, leading to a negative correlation between dairy presence and building.

Dairies may be more likely to locate in areas with processing and testing facilities. Additionally, they may prefer to locate in areas where more people already work in agriculture. Therefore, I include the percentage of people employed in the county in agricultural support services. These data come from the County Business Patterns for individual years between 1980 and 2005 (U.S. Bureau of the Census, Various Yearsb).

Local economic conditions may play a part in the effect of urban encroachment and regulation on dairying. I include variables for the unemployment rate, the log of per capita income (in 2005$), and the average property tax rate. Unemployment rate data by county and year come from the Bureau of Labor Statistics (Bureau of Labor Statistics, Various Years), per capita income comes from the Bureau of Economic Analysis (U.S. Bureau of Economic Analysis, Various Years), and the tax rate comes from the annual reports of the California Board of Equalization (California Board of Equalization, 1980-2005).

Dairy production is affected by temperature and precipitation. Higher temperatures can lead to heat stress and less milk produced per cow (Stull et al., 2008). More precipitation can increase feed production and lessen costs of water used for evaporative cooling and irrigation. Further, climate can affect pollution problems associated with manure, and may therefore affect regulation adoption. I include variables for average annual temperature and total annual precipitation, constructed from the U.S. Historical Climate Network (Williams et al., 2007).

Feed purchases may influence dairy production as well as provide an indication of a farm's ability to abide by regulations. If a dairy has land on which to grow its own feed (and therefore purchase less feed) it may be more likely to have adequate amounts of cropland on which to dispose manure. Appropriately-applied manure may yield fewer pollution problems and lead to a lower likelihood of regulation adoption. In this sense, higher feed purchases may be negatively associated with regulation adoption. Additionally, higher feed purchases may be an indication of higher production costs and may therefore influence an operation's ability to grow or remain in business. Feed purchase data come from the U.S. Bureau of Economic Analysis (U.S. Bureau of Economic Analysis, Various Years).

Crops are necessary for dairies as a source of inputs as well as a potential place for manure disposal. I construct a measure of cropland by summing the harvested acres for wheat, oats, barley, corn for silage, and corn for grain.[15] These data come from the county-year data from NASS (National Agricultural Statistics Service, various years). For the Census of Agriculture regressions (using the five-year data), I use the total number of farm acres in a county (U.S. Department of Agriculture, 1982, 1987, 1992, 1997, 2002, 2007).

Although proximity to surface water is controlled for by county fixed effects and availability of rain water is captured in the precipitation variable, these two factors may not adequately control for water availability and cost in California. Omission of this factor from the regression analysis would bias results if water availability changed in Southern California in 1994 and/or 1999 but not in other areas of the state. The complexities of California's water rights system make it difficult to control for this aspect of water availability in a straightforward manner. However, calculations from Agricultural and Resource Management Survey data from 2000 and 2005 suggest that expenditures on water are on average less than 1% of dairy operating expenditures in these two years. Since water costs are likely only increasing due to increased demands from population and agriculture, these numbers are likely lower in earlier years (for which data are not available). It is therefore unlikely that water costs are driving location decisions within California.[16]

Summary Statistics

Table 1 presents summary statistics for three periods for Region 8, the heavy dairying counties in the Central Valley, and the rest of the state outside of Region 8 and the Central Valley. These periods are 1980 to 1993 (before regulation), 1994 to 1998 (after the first set of Region 8 regulations), and 1999 forward (after the second set of Region 8 regulations). Milk cow inventory and milk cows per square mile increased in Region 8 in the first period, after which their county-level annual changes were negative. Inventories in the Central Valley rose in each time period, but declined in counties outside of these two main dairy production areas.

Table 2 shows means for the potentially confounding variables in the time period before any regulation occurred. Examination of these observable variables in the pre-regulation period provides an indication of whether different areas are more or less likely to be similar in their unobservable characteristics.[17] Region 8 was more densely populated and generally wealthier than the rest of the state. Additionally, the region was warmer, had less precipitation, and less crop production. Comparisons of Region 8 to the Central Valley counties reveal why dairying in the Central Valley is attractive. Finally, table 3 provides means from the Census of Agriculture on the number of farms with milk cows and the number and inventories of farms with more or less than 500 head. In all regions, both the overall number of farms and the number of farms with less than 500 head declines. Region 8 experienced first an increase and then a decrease in its number of large farms, while the Central Valley steadily gained large farms.

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[15] While one would also like to include data on alfalfa production, data for this crop is not available on a county-year basis from NASS for California between 1980 and 2005.

[16] The Agricultural Resource Management Survey (ARMS) is conducted by the National Agricultural Statistics Service and covers a stratified sample of dairies within the United States. Weighting of these data enable statistics representative of the population. I use restricted-access data from the 2000 and 2005 Dairy Production Practices and Costs and Returns Report section of the ARMS. The ARMS includes two questions pertaining to water costs. These include one ascertaining irrigation-related water costs, and one ascertaining costs of other utilities including water used for purposes other than irrigation. Summing these two amounts and dividing by total operation expenditures yields a weighted average of 0.99% in both 2000 and 2005; note that this will be an over-estimate of water costs, as it includes expenditures on other utilities.

[17] Means for these variables in the other two time periods are shown in Appendix A table A1.

Table 1. Comparison of County Average Milk Production and Development in Regions of California, 1980-2005

Region	1980-1993	1994-1998	1999-2005
Region 8			
Milk cows	92,512	99,089	83,277
	(71,682)	(77,878)	(66,057)
Average change per year in milk cows	1,788	-1,540	-4,249
	(4,160)	(2,930)	(7,766)
Milk cows per square mile	7.9	8.5	7.1
	(6.1)	(6.6)	(5.4)
Average change per year in milk cows per square mile	0.17	-0.13	-0.41
	(0.38)	(0.19)	(0.70)
Property value ($1,000s, 2005$)	$109,357	$138,336	$174,424
	(65,556)	(64,820)	(89,144)
Central Valley (8 top dairying counties)			
Milk cows	74,996	113,855	153,422
	(46,041)	(75,383)	(105,596)
Average change per year in milk cows	2,961	6,485	7,061
	(4,153)	(5,848)	(7,534)
Milk cows per square mile	34.7	50.6	65.2
	(24.7)	(35.0)	(41.3)
Average change per year in milk cows per square mile	1.23	2.59	2.55
	(1.89)	(2.04)	(2.44)
Property value ($1,000s, 2005$)	$19,904	$22,145	$25,706
	(15,377)	(14,287)	(16,615)
Rest of state outside of Region 8 and Central Valley			
Milk cows	3,497	3,220	3,056
	(6,962)	(6,356)	(6,054)
Average change per year in milk cows	-35	-34	-11
	(532)	(285)	(297)
Milk cows per square mile	2.6	2.5	2.3
	(5.9)	(5.6)	(5.0)
Average change per year in milk cows per square mile	-0.01	-0.02	0.00
	(0.40)	(0.26)	(0.30)
Property value ($1,000s, 2005$)	$31,043	$38,654	$48,447
	(83,755)	(98,175)	(115,959)

Notes: Numbers in parentheses are standard deviations. The unit of observation is the county-year.

Results

I first examine the effects of Region 8 regulation using the Central Valley as a counterfactual and control for the effects of property values and other potential covariates. Table 4 shows the results of

Table 2. Comparison of Dairy Production Determinants in Different Regions of California, 1980-1993

County averages in years before regulation (1980-1993)	Region 8	Central Valley (Top 8 dairying counties)	Rest of State outside of Central Valley and Region 8
Local economic conditions			
Population density	1,013	118	584
	(1,320)	(92)	(2,231)
Number of building permits	14,385	2,495	2,456
	(8,145)	(1,835)	(6,598)
Property tax rate	1.12	1.06	1.07
	(0.05)	(0.03)	(0.05)
Per capita income (2005$)	$28,883	$22,902	$27,186
	($4,854)	($1,848)	($6,443)
Unemployment rate	6.5	12.2	9.4
	(2.2)	(2.3)	(4.3)
Climate characteristics			
Precipitation (inches)	9.5	13.5	25.9
	(6.0)	(6.4)	(16.2)
Temperature (F)	68.0	62.0	58.3
	(4.3)	(1.7)	(5.3)
Dairy input variables			
Total acres harvested, 3 crops	8,381	72,835	12,336
	(11,231)	(31,419)	(26,761)
Percentage of workforce employed in agricultural support	1.3%	2.0%	1.0%
	(0.7%)	(1.1%)	(1.3%)
Feed purchases (2005$)	$216,802	$203,029	$16,610
	($166,691)	($111,962)	($36,908)

Notes: Numbers in parentheses are standard deviations. Statistics for 1994-1998 and 1999-2005 are shown in Appendix A, table A.1.

regressing the change in milk cows in a county on regulation status; several models are used to test for robustness of coefficients of interest to alternative specifications. Models (i) and (ii) show that both the 1994 and 1998 Region 8 regulations had statistically significant negative relationships with the growth of production in Region 8. Model (iii) shows that property values exert a statistically significant and large negative impact on production. This suggests that increasing property values played a major role in encouraging dairies to leave Southern California. Model (iv) controls for both sets of regulations, property values, and fixed effects to show how the coefficients on the regulation variables change when property values and no other observable covariates are included. Model (v) includes all observable covariates and fixed effects. The 1994 regulation led to a 3,870 milk cow decrease per year and the 1999 regulation led to a further 5,555 milk cow decrease per year. A 1% increase in property values is associated with a 15,378 annual decrease.

Region 8's property values increased by less than 1% between 1994 and 1999, corresponding to a 15,378 head decrease. The coefficient on the 1994 regulation suggests that between 1994 and 1999 the first Region 8 regulation led to an overall decline of 19,350 head. Thus increasing property values and regulation between 1994 and 1999 played relatively equal roles in driving dairying from Region 8. From 1999 to 2005, Region 8 property values increased by 50%, which is correlated with

Table 3. County Averages of Farm Sizes in Different Regions of California, 1982-2002

Region	1982	1987	1992	1997	2002
Region 8					
Farms with milk cows	184	143	126	102	74
	(164)	(124)	(114)	(94)	(67)
Milk cows at farms with 500 or more head	64,747	81,584	94,680	95,600	80,032
	(62,603)	(73,459)	(88,421)	(89,307)	(76,565)
Farms with 500 or more head	73	81	86	78	55
	(69)	(73)	(80)	(75)	(53)
Milk cows at farms with under 500 head	20,334	11,242	8,235	4,250	2,619
	(20,694)	(12,048)	(8,422)	(3,910)	(2,624)
Farms with under 500 head	111	62	41	24	20
	(95)	(51)	(35)	(20)	(17)
Central Valley (8 top dairying counties)					
Farms with milk cows	240	212	205	186	182
	(137)	(132)	(129)	(116)	(110)
Milk cows at farms with 500 or more head	33,854	48,390	71,702	98,759	139,216
	(25,060)	(33,969)	(52,948)	(75,401)	(112,300)
Farms with 500 or more head	41	54	72	86	91
	(31)	(37)	(51)	(60)	(61)
Milk cows at farms with under 500 head	31,439	30,388	27,175	21,385	17,102
	(22,029)	(22,363)	(22,028)	(17,723)	(13,654)
Farms with under 500 head	199	158	133	100	91
	(123)	(111)	(98)	(74)	(63)
Rest of state outside of Region 8 and Central Valley					
Farms with milk cows	46	32	23	17	18
	(52)	(43)	(36)	(28)	(27)
Milk cows at farms with 500 or more head	878	853	958	1,194	1,642
	(1,566)	(1,593)	(1,653)	(2,504)	(3,261)
Farms with 500 or more head	1	1	1	2	2
	(2)	(2)	(2)	(4)	(4)
Milk cows at farms with under 500 head	2,710	2,586	2,036	1,674	1,377
	(5,531)	(5,518)	(4,963)	(4,016)	(3,256)
Farms with under 500 head	45	31	22	16	16
	(51)	(42)	(34)	(25)	(24)

Notes: Numbers in parentheses are standard deviations. Data from 1982, 1987, 1992, 1997, and 2002 Censuses of Agriculture.

a 768,900 head decrease in Region 8 relative to counterfactuals. The 1999 regulations (combined with the 1994 regulations) led to a 9,425 head decline per year, which for six years yields 56,660 head. Thus, the effect of property values versus the 1999 regulation overall was over thirteen times larger between 1999 and 2005.

Model (vi) shows changes caused by regulation in milk cows per square mile of the county; the earlier regulations apparently had a stronger effect on dairy density and are correlated with 1.13 fewer milk cows per square mile. The 1999 regulations do not have a statistically significant effect,

Table 4. Effects of Region 8 Regulation on County-Level Dairy Production

Independent Variables	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)
	Using the Central Valley as a counterfactual						Using the counties outside of the Central Valley as a counterfactual	
	Dependent Variable: Change in Number of Milk Cows					Dependent Variable: Change in Milk Cows Per Sq. Mile	Dependent Variable: Change in Number of Milk Cows	Dependent Variable: Change in Milk Cows Per Sq. Mile
1994 Region 8 Regulation	-8,644***	-6,852***		-5,353***	-3,870*	-1.13***	-3,846***	-0.33**
	(2,487)	(1,863)		(1,649)	(1,810)	(0.33)	(881.2)	(0.13)
1999 Region 8 Regulation		-3,285*		-2,610	-5,555***	-0.59	-2,483***	-0.22***
		(1,692)		(1,779)	(1,416)	(0.52)	(646.2)	(0.07)
ln(Property Value)			-16,630***	-11,154***	-15,378***	-2.19	-1,948**	-0.17
			(3,720)	(2,703)	(4,614)	(2.48)	(826.5)	(0.16)
Population density					12.83*	0.00	4.74***	0.00*
					(6.45)	(0.00)	(1.44)	(0.00)
Building permits					0.10	0.00	0.01	0.00
					(0.10)	(0.00)	(0.01)	(0.00)
ln(Per capita income)					1,169	-2.05	1,610	-0.13
					(14,440)	(4.36)	(1,121)	(0.52)
Local economy covariates included?[a]	No	No	No	No	Yes	Yes	Yes	Yes
Climate covariates included?[b]	No	No	No	No	Yes	Yes	Yes	Yes
Dairy input covariates included?[c]	No	No	No	No	Yes	Yes	Yes	Yes
County and year fixed effects included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.481	0.486	0.46	0.519	0.564	0.52	0.211	0.061
Observations	275	275	275	275	251	251	1,095	1,095

Notes: Numbers in parentheses are robust standard errors. Standard errors are clustered by county. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level. Results of 8 separate regressions shown.

[a] Local economy covariates refers to property tax rate and unemployment rate.

[b] Climate covariates refers to annual mean temperature and annual precipitation.

[c] Dairy input covariates refers to ln(feed purchases), percentage employed in agricultural support services, and total acres harvested.

Table 5. Effects of Region 8 Regulation on County-Level Dairy Size, Agricultural Census Data 1982-2002

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
	Dependent Variable: Change in ...					
Independent Variable	**Milk cows**	**Farms with milk cows**	**Milk cows at farms with 500 or more head**	**Farms with 500 or more head**	**Milk cows at farms with less than 500 head**	**Farms with less than 500 head**
Using the Central Valley as a counterfactual						
1994 Region 8 Regulation	-55,606***	-20.12	-56,557***	-35.28**	8,864	15.16
	(16,263)	(26.81)	(12,007)	(14.35)	(7,691)	(29.92)
Other covariates included?[a]	Yes	Yes	Yes	Yes	Yes	Yes
County and year fixed effects included?	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.590	0.447	0.704	0.559	0.061	0.625
Observations	36	36	36	36	34	36
Using counties outside the Central Valley as a counterfactual						
1994 Region 8 Regulation	-25,693**	-10.45	-28,398**	-23.87**	4,665*	13.43
	(11,195)	(8.454)	(12,972)	(11.23)	(2,498)	(13.86)
Other covariates included?[a]	Yes	Yes	Yes	Yes	Yes	Yes
County and year fixed effects included?	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-squared	0.326	0.501	0.473	0.440	0.564	0.530
Observations	184	184	184	184	169	184

Notes: Numbers in parentheses are robust standard errors. Standard errors are clustered by county. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level. Results of twelve separate regressions shown.
[a]Other covariates refer to population density, building permits, ln(property value), ln(per capita income), property tax rate, unemployment rate, mean temperature, precipitation, percentage of county employed in agricultural support services, ln(feed purchases), and total farm acres in the county.

nor do property values. With an average of 8.5 milk cows per square mile in Region 8 between 1994 and 1998 (table 1), a 1.13 head decline suggests a 13% per year decline.

The effects of Region 8 regulations may be overestimated when using the Central Valley as the counterfactual if production moved from Region 8 to the Central Valley. To estimate the effect of Region 8 regulations, I use counties outside of Region 8 and the Central Valley as a counterfactual. Table 4 presents these results in the models (vii) and (viii) columns. The difference between the estimates using each of the counterfactuals provides an estimate of how much Region 8 regulations induced production growth in the Central Valley. The coefficients suggest that the 1994 Region 8 regulation led to a 3,846 head decline in milk cows per year and when compared to the prior estimate from model (v) suggest that a statistically insignificant number of cows per year moved from Southern California to the Central Valley after the 1994 regulation.[18] Clearly, these estimates suggest that dairies moving out of Region 8 due to the 1994 regulation generally did not move to the Central Valley. However, comparison of the estimates for the 1999 regulation suggests that production lost by Region 8 at this time moved to the Central Valley. Specifically, the difference

[18] To test the equality of the coefficients on R^1_{ct} across models (v) and (vii), I use seemingly unrelated regression methods. I fail to reject the hypothesis that λ^1 estimated from model (v) is equal to λ^1 estimated from model (vii).

between the two estimates suggests that of the 5,555 additional cows lost per year by Region 8, 3,072 (55%) were gained by the Central Valley.[19]

The effect of regulation on dairying densities suggests that lower densities in Region 8 were replaced by higher densities in the Central Valley. The 1994 regulations are correlated with a 0.33 per square mile decrease per year in milk cows in Region 8, but a 0.80 per square mile increase in the Central Valley. This suggests that larger operations entered the Central Valley upon leaving Region 8, a hypothesis supported by remarks in trade journals that dairies in Southern California could sell property and then afford to open much larger operations elsewhere.

Next, I examine whether Region 8 regulation had heterogeneous effects by size of dairy. The regressions on operation size (table 5) use Agricultural Census data that restrict the sample size. The top panel shows results using the Central Valley counties as the counterfactual, while the bottom shows results using the counties outside of the Central Valley as the comparison group. To have at least two periods after the first regulation, I only examine the 1994 Region 8 regulation.

The results for number of milk cows are similar in magnitude (over a five-year period) to those reported in table 4. While the number of milk cows changes, the effect of regulation on the number of diaries, while negative, is not significant. Results for dairies by size show significant effects only on dairies with more than 500 head. Specifically, Region 8 regulation is correlated with a decrease in both the number of large farms as well as the number of head at large farms, relative to Central Valley counties.

Comparisons of estimates in the panels of table 5 also reveal that Region 8 regulations affected growth in the Central Valley. As in table 4, the estimated coefficients on regulation are larger when comparing Region 8 to the Central Valley than when comparing Region 8 to the rest of the state. This suggests that Region 8 regulations encouraged growth in the Central Valley, specifically at operations with over 500 head.

Results of Tests for Feedback Endogeneity

Turning to the tests for the direction of causality described in equations (5) and (6), lagged growth is not statistically correlated with adoption of either of the regulations in the next period (results shown in table A2). Dairy growth in the year prior to regulation is not correlated with whether or not a county adopts regulation. Adding lagged dairy growth in the model (as in equation (7)) does not substantially change the coefficients estimated in model (v) (results shown in table A2). These results suggest that feedback-related endogeneity does not bias the results.

Discussion

Results show that regulation had significant negative impacts on dairy production in Region 8. The significance of the estimated effects of regulation is largely robust with respect to the addition of covariates, particularly property values. Disentangling the effects of property values and regulation is important in considering state policies. Understanding the extent of regulations' effect, separate from other factors, is important if states want to encourage certain types of production in one area versus another.

More stringent regulations in Southern California appear to have induced additional growth in the Central Valley beyond what was taking place independently. However, the loss in milk cows from Region 8 was not equaled by growth in the Central Valley, suggesting that regulation encouraged some production to move out of state. The total number of milk cows in the state of California

[19] A seemingly-unrelated-regressions test for the equality of the coefficients on R^2_{ct} across models (v) and (vii), rejects the hypothesis that λ^2 estimated from model (v) is equal to λ^2 estimated from model (vii).

increases monotonically and linearly between 1980 and 2005, suggesting that Region 8 regulation did not unconditionally lead to dairy declines in California as a whole.[20] The estimates suggest that of the Region 8 production lost after the 1994 regulation, only 0.6% was gained by the Central Valley. However, the 1999 regulations appeared to have moved production within the state, as nearly half was captured by the Central Valley.[21]

Residential property values played an important role in location of dairies in California. Their effects are most pronounced when comparing the two dairy producing regions of the state. The Central Valley's low property values and growing production contrasted with Southern California's extremely high property costs and declining dairy presence make property values appear to be a significant factor when choosing a location. In the 1994-1999 period, Region 8's property values increased by less than 1%, such that overall declines in dairy presence related to property values and the 1994 regulation were similar in magnitude. However, between 1999 and 2005, Southern California property values rose much faster (by nearly 50%), such that the effect of property values versus the 1999 regulation overall was over thirteen times larger.

Further results suggest that Region 8 regulation did not alter the number of operations in Region 8 but did alter the number of milk cows per square mile. This suggests that relative to the counterfactuals, larger operations may have been replaced by smaller ones in Region 8. Effects by size of operation show that the operations most affected by regulation were those with over 500 head. This result is somewhat surprising, given that the regulations did not differentially target larger versus medium-sized operations. However, the regulations did require manure application limits which may have affected larger operations more than smaller ones.

The DD methodology provides a better approach to identifying causation relative to cross-sectional or before-and-after designs if reasonable counterfactuals exist. To the extent that the two counterfactuals used here are valid, then regional regulation has led to a production decline in one area of the state, growth in another, and some exit to other states.

While differential regulatory stringency within the state appears to have affected farm location, the end result may not necessarily be unwanted. State law-makers may prefer to have most dairy production in the Central Valley, which may have more land available for manure disposal, soil with higher assimilative capacity, a population in greater need of economic opportunities, and fewer people to expose to possible pollution. However, regional law-makers may be concerned with loss of economic opportunity due to environmental regulations and may wish to understand the relative costs of compliance in order to craft legislation that does not lead to business loss. Farm-level analysis of environmental compliance costs in relation to overall operating costs would shed light on what level leads to firm relocation.

Differential regulations in California appear to have led to changes not only in dairy location but also in operation size and concentration. These findings are useful for evaluating state-level regulations aimed at equalizing pollution exposure across regions as well as economies of scale in the dairy industry. The results of this article also suggest that while environmental legislation may promote the existence of smaller operations in the regulated region, it may also encourage very large operations in less regulated areas.

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[20] See figure A1. Note that this interpretation does not address conditional effects, because I do not use a counterfactual for the entire state of California. I therefore cannot address whether growth in the state would have been even faster without the Region 8 regulations by using this model.

[21] These estimates are calculated by comparing the estimated effects using the two counterfactuals. For the 1994 regulations, Region 8 lost 3,846 milk cows per year relative to the rest of the state outside of the Central Valley, but 3,870 relative to the Central Valley. This suggests that 24 milk cows were moved to the Central Valley; this is 0.6% of the 3,846 lost by Region 8. Post-1999, the effect of the regulation is the sum of both regulatory effects. Relative to the Central Valley, Region 8 lost 9,425 cows per year; but relative to the rest of the state, it lost 6,329. The difference between these estimates (3,096) provides an estimate of the number of milk cows that moved to the Central Valley. This is 50% of the production lost to Region 8.

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Appendix A: Further Results

Table A1. Comparison of Dairy Production Determinants in Different Regions of California, 1994-2005

	1994-1998			1999-2005		
	Region 8	Central Valley (Top 8 dairying counties)	Rest of State outside of Central Valley and Region 8	Region 8	Central Valley (Top 8 dairying counties)	Rest of State outside of Central Valley and Region 8
Local economic conditions						
Population density	1,199	146	628	1,339	167	660
	(1,555)	(112)	(2,297)	(1,705)	(129)	(2,363)
Number of building permits	8,180	1,825	1,323	15,135	3,161	2,126
	(2,918)	(1,109)	(2,170)	(8,489)	(2,123)	(3,937)
Property tax rate	1.07	1.05	1.04	1.07	1.07	1.05
	(0.02)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)
Per capita income (2005$)	28,436	22,352	29,177	31,496	23,728	33,259
	(6,272)	(2,050)	(8,400)	(7,810)	(2,249)	(11,074)
Unemployment rate	6.68	14.18	9.32	5.10	10.22	6.80
	(2.23)	(1.64)	(4.55)	(1.00)	(1.73)	(2.73)
Climate characteristics						
Precipitation (inches)	11.0	16.5	31.0	6.7	12.0	25.0
	(7.9)	(6.3)	(17.4)	(3.9)	(3.9)	(12.7)
Temperature (F)	69.1	62.6	58.8	68.9	62.9	59.0
	(4.4)	(1.6)	(5.4)	(4.6)	(1.5)	(5.3)
Dairy input variables						
Total acres harvested, 3 crops	9,513	76,765	9,139	6,971	82,868	6,030
	(13,473)	(35,825)	(20,250)	(10,023)	(32,505)	(13,270)
% workforce employed in	1.1%	2.3%	1.0%	0.1%	1.3%	0.8%
agricultural support	(0.7%)	(2.6%)	(1.1%)	(0.1%)	(0.7%)	(1.1%)
Feed purchases (2005$)	167,925	223,081	9,467	167,629	232,693	9,381
	(124,430)	(120,781)	(18,072)	(124,142)	(128,191)	(18,101)

Notes: Numbers in parentheses are standard deviations.

Table A2. Cross-Sectional Regressions of Regulation Adoption in Time t on Dairy Growth between $t-1$ and t

	Dependent variable: Regulation in time t	
	(i)	(ii)
	Regulation in 1994	Regulation in 1999
Change in milk cows (100,000s) between t-1 and t	0.000328	-0.00545
	(0.000309)	(0.00949)
Local economy covariates included? [a]	Yes	Yes
Climate covariates included? [b]	Yes	Yes
Dairy input covariates included? [c]	Yes	Yes

Notes: Sample includes all counties in the state.
[a]Local economy covariates refers to levels of the following variables in time t-1: ln(property value), population density, building permits, ln(per capita income), property tax rate and unemployment rate.
[b]Climate covariates refers to levels of the following variables in time t-1: annual mean temperature and annual precipitation.
[c]Dairy input covariates refers to levels of the following variables in time t-1: ln(feed purchases), percentage employed in agricultural support services and total acres harvested.

Table A3. Effects of Region 8 Regulation on County-Level Dairy Production

	Change in number of milk cows between times t and $t+1$			
	(i)	(ii)	(iii)	(iv)
	Central Valley as counterfactual		Counties outside of Central Valley as counterfactual	
	Main Specification	With instrumented lagged dependent variable	Main Specification	With instrumented lagged dependent variable
1994 Region 8 Regulation	-3,870*	-3,518***	-3,846***	-2,822***
	(1,810)	(1,353)	(881.2)	(506.9)
1999 Region 8 Regulation	-5,555***	-4,406***	-2,483***	-2,250***
	(1,416)	(1,122)	(646.2)	(560.5)
Instrumented lag change included?	No	Yes	No	Yes
Local economy covariates included?[a]	Yes	Yes	Yes	Yes
Climate covariates included?[b]	Yes	Yes	Yes	Yes
Dairy input covariates included?[c]	Yes	Yes	Yes	Yes
County and year fixed effects included?	Yes	Yes	Yes	Yes

Notes: Numbers in parentheses are robust standard errors. Single, double, and triple asterisks (*, **, ***) represent significance at the 10%, 5%, and 1% level.
[a]Local economy covariates refers to property tax rate and unemployment rate.
[b]Climate covariates refers to annual mean temperature and annual precipitation.
[c]Dairy input covariates refers to ln(feed purchases), percentage employed in agricultural support services and total acres harvested.

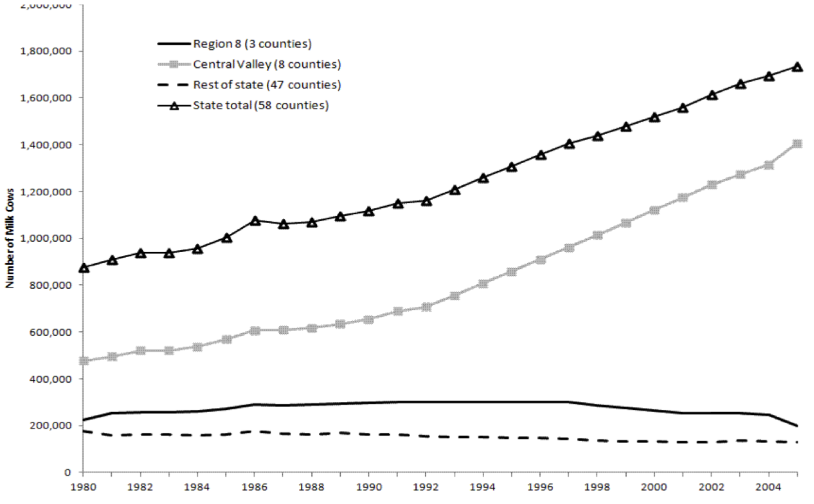

Figure A1. Total Number of Milk Cows in California, State Total and by Region, 1980-2005

Appendix B: Mathematic Representation of Comparison of Results using Two Counterfactuals

To understand the extra information obtained by comparing Region 8's outcomes to those in either the Central Valley or the rest of the state (outside of Region 8 and the Central Valley), consider the following. Let the average growth (ΔD) in Region 8 ("treatment" counties, denoted T) prior to a specific regulation be $\overline{\Delta D^{T,Pre}}$ and let the average growth in these same counties after regulation be $\overline{\Delta D^{T,Post}}$. The difference between these two values is:

(A.B1) $$\delta Y^T = \overline{\Delta D^{T,Post}} - \overline{\Delta D^{T,Pre}}.$$

Likewise, let δY^C refer to the change between post-regulation and pre-regulation in the outcome variable for the "control" (C) counties:

(A.B2) $$\delta Y^C = \overline{\Delta D^{C,Post}} - \overline{\Delta D^{C,Pre}}$$

The differences-in-differences estimator λ is therefore:

(A.B3) $$\lambda = \delta Y^T - \delta Y^C.$$

If the control counties are unaffected by the treatment, then δY^C will remove any secular effects occurring for all counties in the pre- to post-regulation time period and λ will provide an estimate of the effect of the treatment on the treated counties.

Now suppose that there are two potential sets of control counties, $C1$ and $C2$, and suppose that $C1$ are in fact affected by the treatment (i.e., the control group is the Central Valley, and Region 8 regulation drives dairies from Region 8 to the Central Valley). In this situation, the difference between the pre- versus post-treatment outcomes in the C1 control counties can be divided into two portions: the part representing the change attributable to the treatment (δY_a^{C1}) and the part that would have occurred regardless of the treatment (δY_b^{C1}) that happens to all counties in the state in the time period:

(A.B4) $$\delta Y^{C1} = \delta Y_a^{C1} + \delta Y_b^{C1}.$$

Comparing the treatment counties with the $C1$ counties, the differences-in-differences estimator will capture two treatment effects:

(A.B5) $$\lambda^{C1} = \delta Y^T - \delta Y_a^{C1} - \delta Y_b^{C1}.$$

The “true” effect of the treatment on the treated counties is $\delta Y^T - \delta Y_b^{C1}$. Not accounting for δY_b^{C1} will yield a biased estimate of the effect of the treatment on the treated counties.

Now consider the second control group ($C2$) which does not experience treatment effects. Thus:

$$\delta Y^{C2} = \delta Y_b^{C2}. \quad \text{(A.B6)}$$

The differences-in-differences estimator comparing the treatment counties with this control group will be:

$$\lambda^{C2} = \delta Y^T - \delta Y_b^{C2}. \quad \text{(A.B7)}$$

Because δY_b^{C2} is the change that occurs for all counties in the time period, regardless of regulation, $\delta Y_b^{C1} = \delta Y_b^{C2}$. The difference between the two differences-in-differences estimates will yield the treatment effect on the $C1$ control counties:

$$\lambda^{C2} - \lambda^{C1} = \delta Y_a^{C1}. \quad \text{(A.B8)}$$

If dairies leave Region 8 due to heightened regulation ($\lambda^{C2} < 0$) but move to the Central Valley, then $\lambda^{C2} > \lambda^{C1}$, and the difference between them will provide an estimate of how many exiting Region 8 dairies move to the Central Valley (δY_a^{C1}), controlling for the changes that would have occurred regardless of any within-state heterogeneity of regulation.