Heading for the Hills?

Effects of Community Flood Management on Local Adaptation to Flood Risks

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Abstract

The Community Rating System (CRS) program was implemented by the U.S. Federal Emergency Management Agency (FEMA) in 1990 as an optional program to encourage communities to voluntarily engage in flood mitigation initiatives. This paper uses national census tract-level data from 1980 to 2010 to estimate whether CRS participation and flood risk affect a community's local patterns of population change. We employ an instrumental-variables strategy to address the potential endogeneity of CRS participation, based on community-scale demographic factors that predict when a tract's host community joins the CRS. The results find significant effects of the CRS program and flood risk on population change. Taken together, the findings point to greater propensity for community-scale flood management in areas with more newcomers and programs like CRS stabilizing population, though not especially in flood-prone areas. We observe the CRS neither displacing population toward lower-risk areas nor attracting more people to flood-prone areas.

1. Introduction

Flood disasters rate as the worst natural disasters in the world and in the United States in terms of damage (Kousky, Michel-Kerjan, and Raschky 2018). Climate change raises important questions about our ability to adapt, specifically to flood hazards (Kahn 2014, Sant'Anna 2018). Many of those adaptations to flooding will involve the interplay between collective/community management decisions and decentralized household and firm decisions. We are interested in how local flood management activities have influenced local population change in the United States. A core concern with flood management is whether it is mitigating or exacerbating population shifts toward flood-prone areas.

A growing literature in economics examines the intersection of flood risks and adaptation (recently, see Li and Landry 2018; Sant'Anna 2018). Whether better community flood management diverts development and population away from flood-prone areas can inform policymakers, local planners, and others with crucial answers about the indirect implications of adaptation efforts. Because better management may reduce the vulnerability of those areas and attract more in-migration and development, the net effect on local populations remains an empirical question. In a world where residents can "vote with their feet" and move from risks (Kahn 2009), the extent to which residents "head for the hills" in response to enhanced flood management remains a critical empirical question for adaptation to disaster risks. At least *a priori*, important ambiguity remains as to whether mitigation will attract or deter more migration and private investment in high-risk areas (e.g., Bagstad, Stapleton, and D'Agostino 2007; Boustan, Kahn, and Rhode 2012; Husby et al. 2014; Millock 2015).

Resolving this ambiguity is critical to understanding behavioral responses and how we view local flood management policies. Whether management policies are engaging in a positive feedback loop of public protection that encourages private investment or using incentives and mandates to boost resilience and redirect development away from risky areas (Cordes and Yezer 1998; Davlasherizde , Fisher-Vanden, and Klaiber 2017) remains an open empirical question.

Recent work has examined questions of how socioeconomic and natural conditions influence community flood risk management through a program such as the national Community Rating System (CRS) in the United States (Sadiq and Noonan 2015a; Li and Landry 2018). But relatively little research has examined the impacts of community flood mitigation efforts on key economic outcomes. Prior studies of CRS impacts have centered on property damage and insurance claims (e.g., Michel-Kerjan and Kousky 2010; Highfield and Brody 2017). Aside from rather immediate damages, the question of how community-scale flood management moderates population responses to flood risk remains unexplored. We focus on local flood management in the US to examine if and how a program like the CRS affects where migration and development occurs. This informs other discussions of the factors encouraging population growth in flood-prone areas (e.g., individuals struggling to understand flood risk, charity hazards) and factors discouraging such growth (e.g., a growing toolkit of regulations, effective mitigation strategies). The question of how population shifts in response to community flood management, across a large sample and several decades, can greatly inform our understanding of these countervailing forces.

The purpose of this paper is to identify the effects of local flood risk and participating in the CRS program on population change at a small geographic scale. We combine detailed flood risk data, CRS program participation data, and Census data at the tract level to form a panel from 1970-2010 in order to understand the patterns in population changes and turnover rates. We use tract-level fixed effects and an array of other socioeconomic controls to explain variation in tract-level population change, testing how a community's decision to participate in the CRS affects subsequent population growth. Because participation decisions are taken at the community (city or county) level, we exploit this feature of the CRS design to instrument for tract-level participation status by using community-scale predictors of CRS participation. The fine-resolution analysis leverages policy design features, where community flood management decisions are taken at city or county scales while risk and responses occur at much finer scales, to mitigate the endogeneity in local policy responses. We show the importance of correcting for the endogeneity of CRS participation, especially in the residential turnover model. As flood risks can vary widely within a community and CRS activities generally target certain areas, we also test for impact heterogeneity by tract-level flood risk and find significant results there. In our most unrestricted models, tract population growth declines after joining CRS while turnover rates fall in relatively low-risk tracts. Rather than the flood insurance discounts and improved flood management attracting newcomers to high-risk areas, overall long-term flood management efforts discourage population growth and stabilize populations, especially in low-risk areas.

The empirical analysis yields several innovations over existing research. First, the findings offer new empirical insight on the theoretically ambiguous effects of better floodplain management at the community scale on localized population change and migration. Second, using a very large (national) sample at a small geographic scale (tract) across a panel of several Census years extends the prior CRS research, which typically examines single states and often at the county level. Third, this approach also enables better controls for unobservables and policy endogeneity than in most prior research. A longer panel and tract-level fixed effects allow us to overcome limitations of past work, where unobserved amenities that correlate with flood risk may confound the results (Beltrán, Maddison, and Elliott 2018). It also enables us to exploit a design feature in the CRS, whereby program participation decisions are taken at the community (city or county) level but our unit of analysis is the much smaller Census tract. Overall, these results are broader, more robust to unobservables, and highlight a key outcome (population change) that has not received much attention in this context. This kind of research is critical as we try to better understand local and regional adaption to environmental risks and efforts to mitigate them.

The remainder of this analysis begins with a description of the prior literature and background on the policy context. The following section details the empirical approach, which describes the econometric model and the data used for estimation. The empirical results of the fixed-effect estimations follow, showing both the importance of addressing policy endogeneity and impact heterogeneity. Next, the discussion further contextualizes the results by linking them to previous results and discussing some policy implications. The conclusion revisits the central themes of mixed incentives, endogenous collective action, and adaptation to environmental risks in light of the findings.

2. Policy and Literature Review

FLOOD RISK AND ADAPTATION

The economic and policy aspects of flood risk in the U.S. have inspired a sizable literature that spans several important aspects. Perhaps first among them, insurance has received much more attention in the past decade (likely owing to a combination of high-profile disasters and better data availability). Kousky and Michel-Kerjan (2015) offer the first overview of the federal National Flood Insurance Program (NFIP) claims database, going beyond previous regional studies of demand (e.g., Landry and Jahan-Parvar 2011; Atreya, Ferreira, and Kriesel 2015) and those examining behavioral biases and risk information (e.g., Gallagher 2014; Kousky

2016), before drawing some general observations about flood insurance in the U.S. Three conclusions in particular bear on this analysis: (i) flood insurance claim rates are no greater inside flood zones than outside, (ii) claim rates are lower when community-based flood risk management activities occur, and (iii) more new construction in risky areas has occurred over time. This last observation raises questions about migration and self-protection, a topic addressed by Boustan, Kahn, and Rhode (2012) in their study of migration during the 1920s and 1930s. The observed tendency for young men to migrate toward flood risks, perhaps spurred on by public flood mitigation infrastructure projects, offers an early view of behavior patterns that may persist today. It also raises important questions about private investment and government protection (Kousky, Luttmer, and Zeckhauser 2006), including the Good Samaritan's Dilemma (Buchanan 1975), where incentives to overdevelop hazard-prone areas and positive feedback loops between private investment and public protection can exist (Cordes and Yezer 1998). Little wonder that Kahn (2005) finds that stronger institutions mitigate against disaster losses.

The literature directly or indirectly points to the important role of home sales and migration in response to flood risks and events. Many researchers have investigated housing market responses to natural disasters (e.g., Bin and Polasky 2004; Hallstrom and Smith 2005; Smith et al. 2006). The results for flooding in particular reveal the influence of past flood experience (e.g., Atreya, Ferreira, and Kriesel 2013) and the type of housing stock, in particular those with jointly managed flood preparedness (Meldrum 2016). Beyond housing transactions, the accompanying property development and relocations manifest adaptation choices. Migration can smooth the shocks of environmental change, helping the victims of the change while also reducing windfall gains that might befall others (Portnykh 2014). Husby et al. (2014) show city-level populations endure slower growth following a major flood event in the Netherlands, followed by faster growth where local flood protection investments were subsequently made. Governments might engage in protective investments like improved flood management infrastructure and recovery programs, with different impacts (Davlasheridze, Fisher-Vanden, and Klaiber 2017), while households and firms might buy insurance or self-insure (e.g., migrate to less risky regions). Our analysis is especially interested in the interaction of these two forces on household location choices: local investments in improved public infrastructure and different flood risks (and insurance premiums) within the community.

THE COMMUNITY RATINGS SYSTEM

Recent empirical economics research on the NFIP covers topics such as drivers of flood insurance (Gallagher 2014; Atreya, Ferreira, and Michel-Kerjan 2015), insurance claims (Kousky and Michel-Kerjan 2015) and housing development (Dehring et al. 2014) under the program. Of particular interest here is the Community Rating System (CRS) program within the NFIP. The federal CRS program provides additional incentives to communities to voluntarily engage in flood mitigation initiatives. Recent counts indicate 1,466 communities (out of roughly 22,000) participate in the CRS, hosting over 69% of all flood insurance policies (Cunniff 2018). It has received considerable attention in the recent academic literature. Most of these studies focus on the determinants of community participation in the CRS (Landry and Li 2012; Sadiq and Noonan 2015a; Li and Landry 2018), adaptive capacity (Posey 2009), policy learning (Brody et al. 2009), the non-linear incentive structure of the CRS (Sadiq and Noonan 2015b), the effects of the CRS on flood insurance demand (Dixon et al. 2006; Zahran et al. 2009), and flood insurance claims (Michel-Kerjan and Kousky 2010; Frimpong and Petrolia 2016). Communities with greater flood risk are more likely to participate in the CRS, although participation rates also follow from the size of the community's government personnel (Sadiq and Noonan 2015a), flood experience and share of senior citizens (Landry and Li 2012), and population density (Brody et al. 2009). Yet this literature sheds little light on several key questions, such as within-city effects on migration and development patterns, cross-country migration effects at a national scale, and the interplay between local (and often overlapping) jurisdiction's policies. The evidence of the second-order effects of subsidizing flood insurance and communities' flood mitigation (through the NFIP and CRS) on migration and development patterns remains largely unstudied. One exception to this is Noonan and Sadiq (2018), who observe some significant effects of CRS participation on income inequality. Promoting flood-risk information, reducing flood risk, improving community flood resistance, and subsidizing flood-insurance premiums—all desired outcomes under CRS—should each affect the location and intensity of development and migration.

The NFIP was founded in 1968 to create flood protection programs throughout communities in the United States, lessen the impact of flooding on the built environment, and offer affordable insurance coverage to property owners. The CRS was implemented by FEMA in 1990 as an optional program to encourage communities – defined as towns, cities, or counties in this context – to exceed the expectations of the NFIP. The three objectives of the CRS program are to minimize flood damage, reinforce the insurance features of the NFIP, and to further awareness of flood insurance (King 2013). If communities participate in developing flood management activities that are in line with the three objectives, they are able to earn credit points and receive discounted flood insurance premiums that correspond to their total credit score (Kunreuther and Roth 1998). CRS status (and points) is attained by the community as a whole and does not vary within that participating city or county.

The CRS program places participating communities into one of ten classes based on its total credit points. Class 10 is the lowest tier with communities receiving no benefit because their corresponding score does not meet the minimum requirement while Class 1 is the highest tier and policyholders in communities in this class receive a 45% discount on flood insurance premiums if located in a special flood hazard area (SFHA) and a 10% discount if outside. Class 9 communities are the first to receive a discount, which starts at 5% inside the SFHA, and discounts in each Class after 9 increase in increments of 5% until the maximum 45% is reached.[1] An overwhelming majority of communities in the program are in the class range 10-7 (Zahran et al. 2010) and just a handful of the approximately 1,300 participating communities have earned a place in the top four tiers. Although most eligible US communities do not participate in the CRS, almost 70% of all flood insurance policies in NFIP are written in CRS communities (Federal Emergency Management Agency 2017).

Class attainment is based on points scored by communities. Communities receive points based on their ability to implement any of the 19 acceptable activities that further the CRS program's objectives and are a part of one of four categories: warning and response, public information, flood damage reduction, and mapping and regulations. The number of credit points awarded to communities varies by the mitigation activity in each category (Zahran et al. 2010). See Table 1 for a listing. Every 500 points earns a higher class ranking, with scores ranging from 0-500 for class 10 up to a 4,500 for class 1. Even though there is a rather comprehensive list of credited activities, the CRS allows communities to submit an alternative approach. Each of these submitted alternative proposals are reviewed on an individual case-by-case basis by an Insurance Services Office (ISO) specialist.

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[1] Properties in CRS-participating communities yet outside of SFHA are eligible for discounts of 5% (for classes 7-9) or 10% (classes 1-6) on insurance premiums.

Table 1: Credit Points Awarded for CRS Activities.

Activity	Maximum Possible Points	Percent of Communities Credited*
300 Public Information Activities		
310 Elevation Certificates	116	100%
320 Map Information Service	90	93
330 Outreach Projects	360	90
340 Hazard Disclosure	80	68
350 Flood Protection Information	125	92
360 Flood Protection Assistance	110	41
400 Mapping and Regulations		
410 Floodplain Mapping	802	50%
420 Open Space Preservation	2,020	68
430 Higher Regulatory Standards	2,042	98
440 Flood Data Maintenance	222	87
450 Stormwater Management	755	83
500 Flood Damage Reduction Activities		
510 Floodplain Mgmt. Planning	622	43%
520 Acquisition and Relocation	1,900	23
530 Flood Protection	1,600	11

540 Drainage System Maintenance	570	78
600 Warning and Response		
610 Flood Warning and Response	395	37%
620 Levees	235	0
630 Dams	160	0

*Includes communities credited partially. Source: FEMA (2013b).

To be eligible to participate in the program communities must comply with the rules and regulations of the NFIP for at least one year. Communities that apply to the CRS host their state's ISO specialist for a verification visit to evaluate the community's class by determining the qualifying flood protection activities.[2] The CRS requires every community to recertify each year to ensure that they maintain their flood protection activities. The recertification allows communities who have added creditable activities to receive a higher tier ranking. Conversely, communities that did not implement all of the promised activities may lose their ranking.

The CRS can be seen as addressing the collective-action problems associated with community-scale flood mitigation activities that a decentralized, market-based approach might face. Flood management infrastructure as a local amenity may be underprovided by markets (or local governments), and participating in the CRS offers a chance to remedy that. This can be especially important when the transaction costs involved in other institutional arrangements are too great. FEMA's "carrot" to encourage communities to overcome their collective action

[2] There is no charge to communities for participating. To begin the application process the community must submit a letter of interest to their state's ISO specialist and proof that their flood protection activities qualify for more than 500 points. The request is then sent to the Regional FEMA Office to evaluate the community's application based on their NFIP one-year minimum compliance and its additional actions taken to decrease the impact of flooding disasters. If the application is approved, the ISO specialist schedules its verification visit. After the evaluation the ISO specialist submits the report to FEMA to verify the ISO specialist's findings and notify the applicant community of its initial classification in the CRS tier system.

problems via the CRS – aside from its local amenity value itself – is the discounted insurance premiums for property owners. For federal flood insurance rates already thought to be underpriced, discounting rates further may exacerbate the NFIP's shortcomings. This is especially true for communities that would have undertaken mitigation efforts even without the CRS (Sadiq and Noonan 2015b).

The CRS program introduces several features into an already complex system. At its core, the CRS is a voluntary program where communities select from a menu of local regulations and information provision, intended to discourage exposure to flood risks while also making flood hazards less threatening. When a community joins the CRS, two main effects arise. First, there is a price shift as flood insurance premiums are discounted in floodplains, ostensibly reflecting the reduced flood risk that results from qualifying CRS activities. Second, CRS participation results in a bundle of CRS activities that alter local information, regulations, amenities, and more. Depending on which activities a community selects from the menu of CRS activities (see Table 1 for basics), there might be effects from enhanced flood risk information, better flood management plans, better public infrastructure to handle floods, and stricter regulations for developing in flood-prone areas. Highlighting flood risks might discourage settlement and development in certain areas, while better flood warnings might encourage even more floodplain development (by reducing flood uncertainty). Some activities may incur substantial costs borne by the community at large (e.g., plans, infrastructure), while other activities' costs tend to be borne by those in or owning flood-prone properties. Benefits (e.g., less vulnerability, reduced insurance premiums, better information) may concentrate in the risky areas, though some resiliency benefits extend to the larger community, especially when it is public property being protected from floods. And, for neighborhoods in low-risk areas of CRS communities (i.e., the majority of neighborhoods), participating in the CRS might bring minimal price and amenity or infrastructure effects while also entailing fiscal burdens for the community. Conversely, tightening floodplain development might bring more costs to some (e.g., pro-growth and pro-development) stakeholders, spare those on higher ground potential flood-disaster clean-up costs, and shift the public amenity bundle in a way that induces some Tiebout sorting.

These changes in information and incentives should have various effects on different economic outcomes. For instance, property values might increase because of the reduced flood risk and lower insurance premiums, possibly augmented by development restrictions and other supply-side regulations that compound the upward price pressure. In our context – population change – these activities have theoretically ambiguous implications. The premium reduction might induce some population turnover as incumbent residents capitalize on the reduced insurance 'penalty' and increased government commitment to protect from flood hazards. Population growth might accompany insurance discounts as disincentives to develop in flood-prone areas decline. Alternatively, changing regulations and better information may affect where population growth occurs. Better information about flood risks might deter development and migration into certain areas, although a 'market for lemons' approach might see better information as reducing uncertainty and promoting development, migration, and turnover. Investments in flood management may attract people to flood-prone areas while reducing the relative appeal of residing and developing in low-risk areas. Tighter regulations could generally reduce development and population (and perhaps turnover) especially in high-risk areas, although they might indirectly encourage development and population growth by making the environs safer for habitation more generally. Overall, the price effect is likely to have positive effects on turnover in flood-prone areas and no positive effect on population growth, and the regulatory and information effects have either countervailing or ambiguous effects. If we consider CRS programs as prioritizing long-term planning, greater up-front infrastructure costs, tighter regulations on housing and development, and greater hazard disclosure, then we might expect population growth to slow and the share of long-time residents to rise. Further, if tighter regulations target high-risk areas, then we might see populations grow even more slowly with relatively more turnover in those areas. The net result is theoretically ambiguous, thus motivating our empirical inquiry. The analysis below offers some initial evidence on the *net* impact of these regulatory and information programs under the CRS.

3. Empirical Approach

The primary goal of this paper is to examine the effects of the CRS program and flood risk on population change. Floods – including their damage, insurance policies, and management activities – are not typically confined to official (e.g., 100-year) flood plains. Thus, extra attention is paid to within-community effects of flood mitigation, where the analysis leverages the spatial mismatch between the participating jurisdiction (a city or county) and the extent of flood risks (typically only a small fraction of the jurisdiction). It also takes advantage of limited and discontinuous measures of flood risk (i.e., floodplain maps) relevant for the policies and richer characterizations of flood risk and recent flood experiences to identify effects of flood risk management and insurance subsidies separately from flood risk. Measuring behavioral responses along several dimensions paints a richer picture of the nature of adaption and how policies influence the responses. Population change and turnover (i.e., share of existing residents who lived the same house five years before) are among the most immediate indicators of local changes.

Using panel data for Census years (1980 – 2010) at the tract level, we estimate the drivers of local population change with two approaches. First, an OLS model with census tract-level fixed effects offers the most straightforward approach. This approach relies on the assumption that within-tract variation in a host communities' participation status in the CRS does not depend on tract-level population change. Noonan and Sadiq (2018) take this approach with their use of tract-level fixed effects. It controls for the local natural amenities that might jointly influence population change and CRS participation. Although possibly not an issue, as Dehring et al. (2014) argue for their study of NFIP participation, the potential for endogenous community flood mitigation activity remains a concern even with this approach. The second approach employs an instrumental-variables strategy to address the potential endogeneity of CRS participation, leveraging the difference in scale between the community-scale forces that drive demand for participation (motivated by Fan and Davlasheridze 2016) and local-scale predictors of local population change, to predict when a tract's host community joins the CRS. The tract fixed-effects models and the IV estimator provide robust results that control for a host of time-varying factors and local unobservables in identifying effects of flood management and availability of subsidized flood insurance, distinct from past flood events in the community, across different levels of flood risk within a community.

EMPIRICAL MODEL

As a starting point, we use the following basic empirical model to express the changes in population growth in a given tract,

$$Y_{\mathrm{it}} = \alpha_i + \delta_t + \beta_1 CRS_{it} + \beta_2 Risk_{it} + \mathbf{X}'_{\mathbf{it}}\phi + \varepsilon_{\mathrm{it}} \qquad (1)$$

where *i* indexes tracts and *t* indexes decennial censuses from 1980 to 2010. *Y* represents population change variables for tract *i* in year *t*. *CRS* is a dummy variable that equals to 1 if tract *i* participates in CRS during the census period. *Risk* measures a tract's flood risk. δ_t is year fixed effects, α_i is tract fixed effects to capture the effects of unobserved time-invariant local factors that affect local population change, such as geographic attributes, and ε_{it} is the idiosyncratic error that changes across time for each tract.[3] Adding tract fixed effects lets us obtain identification from within-group variation over time. *X* is a vector of time-varying control variables that are population change determinants.

If the flood-risk measure is time-invariant, we cannot identify β_2 after adding tract fixed effects. To address this issue, we have a modified equation:

$$Y_{\mathrm{it}} = \alpha_i + \delta_t + \beta_1 CRS_{it} + \beta_2 (CRS * Risk) + \mathbf{X}'_{\mathbf{it}}\phi + \varepsilon_{\mathrm{it}} \qquad (2)$$

We can estimate the coefficient of the interaction term since *CRS* varies across censuses. This flexible specification not only estimates an average effect of CRS participation on population growth in the community, but also allows for a heterogeneous effect based on local flood risk. Because the decision to participate in CRS or not is made at the community (i.e., county or city) level, it is expected that we will observe heterogeneous effects of CRS participation for tracts within the same community due to within-community tract-level flood risk heterogeneity. This heterogeneity is important to identify when treatment effects averaged across an entire community mask offsetting effects or fail to detect a few tracts' large impacts. Following Cameron and Miller (2015), we cluster the standard errors at the community level (city or county) throughout this paper to correct for heteroskedasticity and autocorrelation.[4]

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[3] We use tract fixed effects to control for any time-invariant unobservables. For example, natural amenities (like proximity to beach) are a possible confounding factor (Fan and Davlasheridze 2016) that may drive both CRS participation and population change decisions. Since natural amenities are generally time-invariant, this unobservable is soaked up by the fixed-effects model.

[4] Clustering standard errors at the tract level ignores the autocorrelation across tracts and thus may result in bias.

An alternative specification is to use CRS credit points earned rather than a CRS participation dummy to measure the effect of CRS program. The model is changed to:

$$Y_{\mathrm{it}} = \alpha_i + \delta_t + \beta_1 CRSPoints_{it} + \beta_2 (CRSPoints * Risk) + \mathbf{X}'_{\mathbf{it}}\phi + \varepsilon_{\mathrm{it}} \qquad (3)$$

CRSPoints is a continuous measure that equals to the total credit points earned through all 19 activities by tract *i* in year *t*. Higher points indicate greater flood mitigation efforts in the community.

DATA SOURCES AND DESCRIPTION

To estimate these models data are collected and merged from four different sources. (1) The Neighborhood Change Database (NCDB) from Geolytics, Inc. contains Census data at the tract level from 1970 to 2010, all normalized to 2010 tract boundaries to allow for constructing a geographically consistent panel. (2) Detailed CRS participation information from 2000 and 2010 includes data on the nature and intensity of local flood mitigation activities.[5] (3) The Spatial Hazard Events and Loss Database for the United States (SHELDUS) contains county-level information for natural hazards, including floods, hurricanes, and thunderstorms. (4) Flood risk data at high resolution (1 km grid cells) from the United States Department of Transportation (1996) provides a continuous measure of flood risk (on a 0-100 scale) using underlying topography and hydrography of an area and largely predates the CRS program. As described in Sadiq and Noonan (2015a), this raster data has several advantages in measuring flood risk: (i) it has a continuous quantitative scale for flood risk, (ii) it originates from calculations and data that largely predate communities joining the CRS program, (iii) it covers the whole contiguous 48

[5] This data set lists the total CRS points and class as well as the points awarded for each of the 18 creditable activities (excluding 370, Flood Insurance Promotion). For a program initiated in 1990, the first cohort of CRS communities began after the 1990 Census. Thus CRS participation is measured for 2000 and 2010 here.

states, and (iii) it offers a finer spatial resolution to better characterize the local distribution of flood risk, especially at scales much smaller than cities or counties.

a. VARIABLE DESCRIPTIONS

DEPENDENT VARIABLE

The dependent variables of interest are population change. We use two variables to measure such change: (1) *population growth rate* — decadal difference in population over the average of the previous and current census population, and (2) *percent of non-movers* — proportion of households in the same house 5 years ago.[6] All variables are measured for Census years 1980-2010.

INDEPENDENT VARIABLES

The key independent variables in this study are CRS participation and flood risk. Because communities as a whole are either participating or not participating in the CRS program, we first generate a dummy variable *CRS* that equals to 1 if the tract is in a community currently participating in the CRS, and 0 if not. We also generate a continuous variable *CRS Points* that equals to the total credit points earned through all 19 activities by tract *i*'s host community (if participating) in year *t*. With tract-level fixed effects included, the identification comes from tracts that joined the CRS through their communities' decision to join. With a retention rate of 99% (Michel-Kerjan, Atreya, and Czajkowski 2016) and strong year-to-year persistence in CRS participation (Li and Landry 2018), *CRS* essentially capture whether a tract's community joined the CRS between census years. As stated before, we use a variable from USDOT that measures

[6] A standard approach to define population growth rate is decadal difference over previous census population. We do not use this method because many tracts were coded as 0 in population in 1980, according to the NCDB from Geolytics. To avoid losing many observations, we use the midpoint formula for the average of previous and current census populations as the denominator.

the mean flood risk from 1km grid cells within a tract to measure flood risk, and name it *Flood Risk*. Its range is from 0 to 1, with 1 indicating the most risky tracts. This variable is time-invariant but varies across tracts. Following the specification in equation (2), we interact *Flood Risk* with *CRS* to indicate high-risk tracts in CRS participating communities.

CONTROL VARIABLES

To isolate the effect of CRS participation on the dependent variables, we control for a vector of socioeconomic characteristics at the tract level. *Poverty rate* is measured as the tract poverty rate. *Mean housing value* is measured as the mean housing value in the tract. We use logarithmic transformation to reduce skewness. *Population density* is measured as the total tract population divided by total land area. *County non-movers* is measured as the proportion of persons residing in the same tract five years ago. *Unemployment rate* is measured as the number of unemployed divided by total number in the labor force. *Renters* is measured as the share of total housing units that are rentals. *Vacant* is measured as the share of total housing units that are vacant. All these control variables are 10-year lagged, reflecting economic vitality of the previous decade and mitigating simultaneity concerns.

One important confounding variable in this setting is local property damage. Higher property damage due to flood hazard makes a community subsequently more likely to participate in CRS, and this attribute may also become a driver for relocation decisions. To address this issue, we generate a tract-level variable *property damage* that is measured as the total flood damage over the previous five years, per capita, weighted by a tract's share of county's area, population, and risk. We adjust it to 2013 dollars. This time-varying *property damage* variable complements the more localized, historic *Flood Risk* measure.

INSTRUMENTAL VARIABLES

We thus far use tract-level fixed-effects regressions to eliminate the effects of time-invariant omitted variables. We also add a vector of socioeconomic characteristics and local property damage to control for time-varying confounding variables. However, our results will be inconsistent if there still exists time-varying unobservables that drive both community-level CRS participation and tract-level population change. Of concern is the possibility that, conditional on these controls, some unexplained portion of a particular tract's growth (as a departure from its mean growth) also predicts its host city or county's decision to participate in the CRS. We cannot ignore this issue because previous literature has shown that CRS participation is generally endogenous to development patterns and likely to be correlated with flood risk, socioeconomic and local policy factors (Brody et al. 2009; Landry and Li 2012; Fan and Davlasheridze 2015; Sadiq and Noonan 2015a, 2015b). Even with the tract-level fixed effects, a community-wide shock that boosts its housing development, for instance, might also lead to the community joining the CRS. (We are less concerned about individual tracts possessing political power to drive community participation decisions based on their tract-specific shocks, given that individual tracts typically host a very small fraction of their community's population or area.)

To address this concern, we employ an instrumental variable (IV) approach. In our context, a valid instrumental variable should meet two qualifications: (i) it is correlated with CRS participation, and (ii) it is exogenous and not correlated with the tract-level error term ε in equations (2) and (3). We have a variety of possible IVs that meet the first qualification, but it is challenging to find a valid IV to meet the excludability assumption. Factors related to city- or county-scale flood management decisions may also drive local (tract-level) development and migration decisions. The identification strategy requires us to find factors that drive CRS adoption at the community (city or county) scale while sufficiently controlling for local (tract) scale drivers of population change so that the county-level shocks explain the community's decision to participate in the CRS but do not also explain local shocks.

To find an effective source of identifying variation, we select two county-level population shares as IVs: the first is the share of children (aged 18 less), and the second is the share of seniors (aged 65 plus). Previous studies have shown that children and senior populations are significant predictors of CRS participation (Sadiq and Noonan 2015a; Fan and Davlasheridze 2016). For example, the elderly are more sensitive to flood risk and value flood mitigation activities more than the young, so a community is more likely to participate in CRS in response to greater demand from a large elderly population. Similar reasoning would apply for children population shares. We use county rather than tract-level children and senior population shares because CRS participation decisions are made at the community (not tract) level. Similar to lagged socioeconomic variables, the two IVs are also lagged by one decade. To make the IVs more likely to satisfy the exclusion restriction assumption, we exclude individual tract's count of children and count of seniors when constructing the two county-level population shares.[7] This approach makes sure that the two IVs not only vary by census year, but also vary across tracts within a county. We believe these 10-year lagged population shares of children and seniors at the broader community level should not drive current tract-level changes in population growth and non-movers. Put another way, our basic identification strategy relies on exogenous variation in CRS demand drivers *at the community scale*, ten years prior, to instrument for whether a tract is in a participating community. The IVs prove to be significant predictors of subsequent CRS participation while not appearing to belong in the main equation explaining within-tract variation in population change. The main concern here would be that abnormal tract-level growth

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[7] For a given tract *i* in county *c*, the two IVs are the share of children (seniors) in all other tracts in the county *c* excluding the tract *i*. We thank an anonymous referee for suggesting this strategy.

(conditional on tract fixed effects and a host of tract-level demographic and control variables) is driven by past county-level demographics. The tract-level fixed effects combined with lagged IVs measured at a much larger scale help us satisfy the exclusion restrictions, although the scale mismatch does lead to some less-than-ideal statistical power for the IVs.[8] Diagnostic tests reported below allow investigation of these concerns.

To address the endogenous interaction terms in equation (2) and (3), we interact the two instrumental values with *Risk* to construct additional IVs for the endogenous interaction terms. The assumption here is that if the two instrumental variables are valid, then interaction terms between them and flood risk will also be appropriate instruments for the endogenous interaction terms. Concerns that the county-level IVs (including their interactions with flood risk) are closely related to the outcome variables of local (tract) growth remain mitigated by the use of tract fixed effects, different spatial scales, and many controls for local trends.

SUMMARY STATISTICS

Our final panel data include 73,056 tracts for the census years 1980, 1990, 2000 and 2010. Table 2 reports variable descriptions and their sources. Table 3 shows the descriptive statistics. For dependent variables, on average the tract-level population decreases by nearly 11%, and 58% of the households report living in the same house five years prior.[9] About 16% of tract-years participate in the CRS and the average mean risk is about 0.42 on a scale of 0-1.[10] The

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[8] A tract is only a very small portion of the whole county. On average, a county has 225 tracts, and typical CRS tracts contain only 0.1% of their participating community's population.

[9] In our dataset, the median population growth rate is 0.079. The right-skewed distribution follows from tracts with 0 population in the previous decade (i.e., population growth rate = 2.0).

[10] Because the CRS program was implemented in 1990, the values for CRS-related variables in Table 3 include census years 1980 and 1990 when CRS = 0 for all tracts. If we restrict our sample to 2000 and 2010 censuses, we find that about 33% of tracts are in communities that were participating in the CRS out of the 73,056 tracts.

average tract over the previous five years has experienced about $9,891 in weighted flood property damage, although the median value is $0.

Table 2: Variable Descriptions and Data Sources

Variable	Description	Data Source
Dependent Variables		
Population growth	Decadal difference in population over the average of the previous and current census population	US Census (Geolytics)
Non-movers	Proportion of households in the same house five years ago	US Census (Geolytics)
Independent Variables		
CRS (dummy)	Dummy variable indicating tract resides in a community participating in the CRS	FEMA (2013)
CRS Points	Totals CRS points for the participating community in which the tract resides	FEMA (2013)
Risk (0 to 1)	Flood hazard risk, mean flood risk for the tract based on 1km by 1km grid cells	US DOT (1996)
CRS × *Risk*	Interaction between CRS and flood risk	FEMA (2013)
Control Variables		

Property damage	Total flood damage over the previous five years, per capita, weighted by a tract's share of county's area, population, and risk, adjusted to 2013$	SHELDUS
Poverty rate	Tract poverty rate	US Census (Geolytics)
Mean housing value	Log of mean housing value in a tract	US Census (Geolytics)
Population density	Total tract population divided by total land area	US Census (Geolytics)
County non-movers	Proportion of persons residing in the same county five years ago	US Census (Geolytics)
Unemployment rate	Number of unemployed divided by total number in the labor force in a tract	US Census (Geolytics)
Renters	Share of total housing units that are renter occupied in a tract	US Census (Geolytics)
Vacant homes	Share of total housing units that are vacant in a tract	US Census (Geolytics)
Instrumental Variables		
Children population	Share of children population in a county	US Census (Geolytics)
Senior population	Share of senior population in a county	US Census (Geolytics)

Table 3: Descriptive Statistics

Variable	N	Mean	Std.Dev.	Min	Max
Dependent Variables					
Population growth rate	277,104	0.293	0.614	-2	2
Non-movers	291,451	0.575	0.233	0	1
Independent Variables					
CRS	292,138	0.163	0.370	0	1
CRS Points	291,373	2.266	5.800	0	47.02
Risk	292,086	0.422	0.274	0	0.99
CRS × Risk	292,086	0.064	0.182	0	0.99
Control Variables					
Poverty rate	291,336	0.124	0.116	0	1
Mean housing value (log)	201,725	10.982	1.047	-5.63	14.174
Population density	290,874	0.002	0.004	0	0.196
County non-movers	291,278	0.777	0.228	0	1
Unemployment rate	219,105	0.060	0.051	0	1
Renters	276,385	0.313	0.207	0	1
Vacant homes	276,385	0.092	0.091	0	1
Property damage (1,000 dollars)	292,138	9.891	375.604	0	116,538
Instrumental Variables					
Share of children (county-level)	277,596	0.256	0.034	0	0.474

Share of senior (county-level)	277,596	0.123	0.038	0.007	0.500

4. Results

OLS RESULTS

We begin by running a set of naïve regressions of equation (2), without using the instrumental variables. Table 4 reports the results of fixed-effects regressions for population growth and non-movers. The unit of observation is a tract for each census year. Columns 1 and 3 are baseline models that only control for CRS participation, flood risk, and tract- and year-fixed effects. Columns 2 and 4 add other control variables. Once the control variables are introduced, CRS participation and *CRS* interacted with *Risk* are individually insignificant predictors of population growth. But, as indicated in the bottom row of Table 4, the CRS variables are jointly significant factors. Overall, tract population growth declines after joining the CRS, and the decline is somewhat greater in high-risk tracts. Columns 3 and 4 show a significant and positive CRS effect: CRS participation increases the proportion of non-movers by 4 percentage points. The coefficient on the interaction term is negative and significant, indicating weaker CRS effects on the non-mover share in flood-prone tracts. For the effects of control variables, Column 2 shows several socioeconomic characteristics significantly associated with population growth. Many of the socioeconomic characteristics are also significantly correlated with non-movers, with most of them (population density, county-level non-movers, share of vacant housing) exhibiting the opposite sign as expected. Tracts with greater *property damage* then experience more population growth, but the non-mover share is unaffected by property damage.

IV RESULTS

Table 4 uses a fixed-effects approach to control for tract heterogeneity that may affect both CRS participation and local patterns of population change. To address the possibility of other time-varying omitted variables, we instrument for CRS participation using two instrumental variables: population shares of children and seniors for each county. As discussed before, the two instrumental variables are likely to be valid in that they are correlated with CRS participation but not with the error term. The assumption here is that the lagged, county-level children and senior population shares should not drive current changes of tract-level population growth and non-movers.

Table 4: OLS Regressions for Population Growth and Non-movers

VARIABLES	Population Growth		Non-movers	
	(1)	(2)	(3)	(4)
CRS	0.237***	-0.023	0.063***	0.041***
	(0.028)	(0.016)	(0.004)	(0.005)
	-			
CRS × Risk	0.103***	-0.023	-0.029***	-0.011*
	(0.033)	(0.021)	(0.005)	(0.006)
Poverty rate		0.160***		-0.007
		(0.042)		(0.012)
Mean housing value (log)		0.017**		0.001
		(0.008)		(0.003)
		-		
Population density		114.968***		29.117***
		(20.872)		(6.781)
County stayers		-0.210***		0.034***
		(0.027)		(0.009)
Unemployment rates		0.030		0.001
		(0.055)		(0.016)
Renters		-0.385***		-0.064***
		(0.031)		(0.009)

Vacant		0.849***		-0.298***
		(0.069)		(0.019)
Property damage		3.9×10^{-6}**		-4.3×10^{-7}
		(1.8×10^{-6})		(2.9×10^{-7})
Tract Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes
Number of tracts	72,868	72,248	72,863	72,243
Observations	275,934	200,575	275,828	200,478
Joint F-test for CRS Variables	36.61***	10.90***	182.77***	67.23***

Note: Standard errors are clustered at the community (i.e., all unique combinations of counties and places) level. Results are based on 1980, 1990, 2000 and 2010 censuses.

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

Table 5 reports the IV results for equation (2). We have two endogenous variables: CRS participation and its interaction with flood risk. We use four county-level instrumental variables: share of children population and its interaction with flood risk, share of senior population and its interaction with flood risk. We expect the results from the IV model to diverge substantially from the OLS model when CRS participation is endogenous. Based on prior research (see, e.g., Li and Landry 2018), we expect dynamic populations might influence CRS participation decisions. If taste for regulation differs in high-growth areas, then OLS estimates may bias the true effect of joining the CRS on population change. High-growth areas with strong pro-development interests may be less supportive of floodplain management and regulation (a downward bias on β_1). Alternatively, more population and newcomers with different tastes for floodplain development and regulation may bias the OLS estimates in the other direction. With theoretically offsetting biases in the population growth model, it remains an empirical matter to identify any bias. In the non-mover model, however, the bias may be more straightforward to anticipate because population turnover per se might not imply a strong pro-development interest. It merely captures population turnover. If newcomers have stronger tastes for flood management, and if our instruments effectively purge the CRS variables of that unobserved taste, then a negative effect of joining the CRS on turnover would be understated in OLS. Instrumenting for CRS participation by using only variables that affect community-level participation decisions can mitigate this bias. The IV results in Table 5 indicate the diagnostic statistics for the instrumental variables in the various models and, in comparison to the OLS results (Table 4), demonstrate the correction.

We first focus on the diagnostic tests to check the necessity of the IV approach, as well as instrument strength and validity (excludability). The exogeneity tests strongly reject the null hypothesis that CRS participation is exogenous for non-movers, but it fails to reject for population growth in model (2). So the IV approach is warranted to address endogeneity of CRS participation for non-movers, but not for population growth. The F-tests for joint significance of the excluded instruments in the first-stage regressions all exceed the rule-of-thumb value of 10 and have p-values close to 0 for both *CRS* and *CRS*×*Risk* across all models, indicating that the IVs are relevant, even after controlling for tract fixed effects. More importantly, the Cragg-Donald F statistic from these models with multiple endogenous variables is 168.8. This value far exceeds the Stock and Yogo critical values for weak identification based either in terms of maximal relative bias or maximal size. (Both the Cragg-Donald statistic and the Stock and Yogo critical values rely on i.i.d. errors, which do not hold here.) The results indicate that the instruments are strongly correlated with CRS participation and thus weak instruments are unlikely in our model. Because this IV approach uses two overidentifying restrictions, we can test whether the IVs pass the exogeneity assumption. The instruments strongly pass the Hansen J-test for exogeneity with the p-values much greater than 0.05. The results support the null hypothesis that the instruments are valid and the excluded instruments are correctly excluded from the estimation equation. For population growth, the OLS model (2) in Table 4 remains preferred despite what appear to be strong and valid IVs, as the exogeneity test suggests that instrumenting yields little advantage and requires relying on inherently untestable IV assumptions. For non-movers, however, the IV model (4) in Table 5 is preferred.

Table 5: IV Fixed Effects Regressions

VARIABLES	Population Growth		Non-movers	
	(1)	(2)	(3)	(4)
CRS	-0.481***	-0.068	0.347***	0.318***
	(0.117)	(0.095)	(0.048)	(0.048)
CRS × Risk	0.517	-0.100	-0.383***	-0.387***
	(0.317)	(0.236)	(0.122)	(0.109)
Tract Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes

Number of tracts	72,393	71,331	72,368	71,307
Observations	203,034	199,414	202,905	199,298
Exogeneity test, p-value	0.000	0.264	0.000	0.000
F-statistic for CRS in the first stage	16.80(0.000)	16.45(0.000)	16.81(0.000)	16.47(0.000)
F-statistic for CRS×Risk in the first stage	16.40(0.000)	17.52(0.000)	16.40(0.000)	17.54(0.000)
Hansen J test of overidentification (p-value)	1.526(0.466)	0.649(0.723)	0.348(0.841)	4.417(0.110)
Joint F-test for CRS Variables	31.64***	5.76*	81.14***	59.14***

Note: The standard errors are clustered at the community (i.e., all unique combinations of counties and places) level. The results are based on 1980, 1990, 2000 and 2010 censuses. The instrumental variables for CRS are county-level, 10-year lagged shares of children and senior populations. Other control variables are as in Table 4 but are not reported to conserve space.
*** p<0.01, ** p<0.05, * p<0.1

Comparing the coefficients for CRS participation and flood risk between the IV and OLS estimations, we first recognize that the estimated effects are much larger in the IV regressions in which CRS participation is treated as endogenous. Ignoring endogeneity of CRS participation may underestimate CRS program and flood-risk effects. Column 4 shows that participating in CRS increases the proportion of non-movers on average. However, there is a significant difference between high-risk and low-risk tracts inside CRS communities. The expected increase in the share of the population that does not move fades as tract-level risk rises, to the point where joining the CRS predicts no appreciable change in *non-movers* for the riskiest tracts. In a sense, this means that tracts in communities joining the CRS tend to see sharp declines in the propensity of long-time residents to move or population reductions where primarily newcomers are those who exit, yet those effects do not hold for high-risk tracts.

Two conclusions are derived from this IV approach. First, although OLS and IV models yield qualitatively (but not quantitatively) similar estimates of the CRS and flood risk effects on local patterns of population change, the results suggest that endogeneity is a concern for the turnover model. The estimates in Column 4 of Table 5 indicate a downward bias of the *CRS* effect in OLS, a bias that is stronger in low-risk tracts. Therefore, failing to control for unobserved drivers of residents' relocation decisions, for both potential migrants and non-movers, would cause bias in the effects of CRS and flood risk. Tract shocks that also influence their host community's CRS participation decision substantively bias the estimated effects. If experiencing greater turnover leads communities to pursue joining the CRS, the OLS estimates of $CRS \times Risk$ could be biased downward in Table 4. And if that tendency is lessened in flood-prone areas, as perhaps newcomers to floodplains have weaker preferences for additional regulation or information, then the bias would be less as *Risk* increases. The IV estimates address this policy endogeneity and show markedly different results in the *non-mover* models. Second, the average effects of participating in the CRS belie how the effects vary with local flood risk. On average, tract populations grow slower and non-mover shares grow after their community joins the CRS. Yet flood-prone areas tend to experience even slower population growth and less increase in non-movers (even small decreases for the riskiest tracts). Newcomers disproportionately tend to relocate out of a tract once it joins the CRS, but more flood-prone tracts do not exhibit this tendency for newcomers.

Table 6 presents results analogous to Table 5, except the CRS dummy variable is replaced by the continuous CRS points measure. The main results continue to hold here, albeit with some differences. The diagnostic tests for the IV model tells a similar story. Of course the IVs retain their strength, and their Hansen's J tests fail to reject. *CRS Points* appears endogenous in the *non-movers* model, but not in model (2) for population growth. And, the signs of the CRS coefficients are the same as in Table 5. Perhaps the most notable difference is in the insignificance of the interaction term in model (4). In that model, a zero-risk tract joining the CRS at 1,000 points would expect a 14 percentage point increase in *non-movers*.

Table 6: IV Fixed Effects Regressions

VARIABLES	Population Growth		Non-movers	
	(1)	(2)	(3)	(4)
CRS Points	-0.029***	-0.005	0.018***	0.014***
	(0.008)	(0.006)	(0.003)	(0.003)
CRS Points × Risk	0.039	-0.001	-0.018**	-0.011
	(0.024)	(0.017)	(0.009)	(0.008)
Tract Effects	Yes	Yes	Yes	Yes
Year Effects	Yes	Yes	Yes	Yes
Other Controls	No	Yes	No	Yes
Number of tracts	72,317	71,255	72,292	71,231
Observations	202,198	198,580	202,070	198,465

Exogeneity test, p-value	0.000	0.245	0.000	0.000
F-statistic for CRS in the first stage	15.73(0.000)	17.37(0.000)	15.75(0.000)	17.40(0.000)
F-statistic for CRS×Risk in the first stage	19.68(0.000)	20.03(0.000)	19.69(0.000)	20.08(0.000)
Hansen J test of overidentification (p-value)	2.261(0.323)	1.928(0.381)	0.257(0.880)	1.910(0.385)
Joint F-test for CRS Variables	32.07***	4.71*	99.80***	77.55***

Note: The standard errors are clustered at the community (i.e., all unique combinations of counties and places) level. The results are based on 1980, 1990, 2000 and 2010 censuses. The instrumental variables for CRS are county-level, 10-year lagged shares of children and senior populations. Other control variables are as in Table 4 but are not reported to conserve space. *CRS Points* is measured in 100s of points.

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

5. Discussion and Policy Implications

Our empirical results find significant effects of the CRS program and flood risk on population change. For the population growth model, CRS-participation is associated with declining population for low-risk tracts as well as high-risk tracts. This result indicates that participating communities slow down and even reduce population growth without much targeted impact on flood-prone areas. At least two explanations may account for this consequence. First, the CRS effect on population primarily comes through its role as a crude signal of a community's aggressiveness in growth and development. Its incentives to develop in flood-prone areas and its improved infrastructure and amenity levels are just insufficient to attract in-migration. Rather, the CRS informs residents of the community's flood hazards, especially in flood-prone areas, and this deters growth. Second, communities joining the CRS implement a bundle of regulation and infrastructure improvements that raise costs to residents and especially developers, throughout the community. Any additional incentives to develop in floodplains (e.g., discounted insurance, less uncertainty) are offset by additional costs and regulations in those areas. The combined effect of the two is strong enough to discourage new households from moving into (or staying in) the community. This voluntary flood management program where communities can go above-and-beyond the minimal NFIP requirements tends to stabilize populations and reduce population growth throughout the community. These communities' slower population growth and reduced turnover may cast CRS participants as pursuing sustainability and limited growth more than hazard reduction and disaster management.

How programs like the CRS influence population change in flood-prone areas can shape future total costs of flood events. Due to climate change, the likelihood and intensity of flooding and other extreme events have steadily increased over the past few decades in the United States (Melillo, Richmond, and Yohe 2014). Therefore, it is critical that flood management address the trend of larger population residing in risky areas – either by diverting populations to "higher ground" or by improving preparedness for and reducing damage effects of flood events. The results here do not lend much support to the idea that CRS activities are effectively targeting population change in flood-prone areas. In theory, drawing more households and businesses into high-risk areas is a possible unintended consequence of the CRS program, similar to what some prior studies (Burby 2001; Chakraborty et al. 2014) have shown for flood mitigation activities and flood subsidies. Based on the evidence here, at least CRS participation does not appear to be attracting people to high-risk tracts.

The policy implications stemming from this empirical study suggest that the CRS program should better target the application of some activities, such as preventative land use policies, zoning ordinances, building codes, to guide households and property owners to relocate homes and business away from flood-prone areas. In practice, the federal government could change the CRS incentive scheme to give more weight in assigning credits so that local governments have incentives to take the category of actions aimed at limiting future population growth and new building construction in known flood-prone areas. This recommendation is consistent with recent findings that the tiered, non-linear CRS incentive scheme yields counterproductive results, because local governments strategically placed emphasis on easier-to-achieve activities, such as public information, emergency services and warning systems, to achieve the discounted flood insurance premiums (Zahran et al. 2010; Sadiq and Noonan 2015b). More broadly, the evidence of weak connection between population declines and flood risk reinforces the call for more graduated risk-based premiums (Hudson et al. 2016). Discounted flood-insurance premiums in SFHAs in participating CRS communities may better approximate risk-based premiums than the conventional system, which has the potential to divert development away from risky areas, although the base (class 10) premiums may still not be optimal.

The results for *Non-movers*, an inverse measure of homeowner turnover, raise issues about sorting mechanisms. The proportion of existing households increases in low-risk tracts, but not in high-risk tracts, after a community participates in the CRS. This change may be partly driven by the population declines in model (2), as reducing the denominator of *non-movers* can account for the increase in share. This explanation requires a disproportionate exit rate for newcomers, perhaps due to newcomers being more mobile or having worse priors about community flood risks. It is possible that, relative to new migrants, existing residents have an enhanced awareness of local flood risk because of own experience and knowledge or the flood-risk information disclosure through the flood mitigation activities. This information asymmetry causes different decisions to be made by new migrants and existing residents. The disproportionate exit rate for newcomers does not hold in flood-prone areas, which is consistent with CRS activities being more appealing to newcomers selecting into floodplains or CRS activities pressuring long-time floodplain residents more. Some mitigation activities in high-risk areas, especially series 500 activities, require acquisition and relocation of existing buildings that forces existing households to move to other areas.

Perhaps the most important part of model (4) is that CRS participation appears to be endogenous with respect to non-movers (and not for population growth). This endogeneity results from the non-random nature of participation in the CRS, a crucial aspect of any voluntary program. The evidence here suggests that something related to population turnover, but not population growth, helps explain CRS participation. An explanation for why CRS is endogenous for one population change variable and not for the other places sorting and different resident interests at the fore. While population turnover involves new residents replacing old, population growth involves new residents as other growth interests (e.g., housing construction sector, local planners and policymakers). Put another way, population growth generally is governed by planning and growth controls while directly impacting new construction, property tax base, schools, etc. Population turnover, holding population fixed, lacks those implications. If newcomers tended to support more community flood management than long-time residents, CRS might be endogenous in the turnover model. It need not be endogenous in the growth model, however, because growth implies new housing as well as new people. The residential composition effect (i.e., more newcomers with taste for flood management) could be offset by the quantity effect (i.e., more residences may be associated with stronger support for pro-development policies). Thus, while newcomers might see their taste for flood management leading to endogeneity in the turnover model, similar endogeneity need not hold in the population growth model. The results here emphasize the importance of population turnover in supporting CRS activities, which can bias estimates of CRS program effects. In this case, more newcomers make joining CRS more likely, which in turn reduces subsequent turnover in the community. Flood-prone areas experience much less turnover reduction, largely due to this sorting mechanism where newcomers to flood-prone areas are not as eager to regulate floodplain development as their neighbors on higher ground.

Table 7 provides another way to summarize the results across the two population change variables. The table illustrates the marginal effects of participating in the CRS across different levels of flood risk (median and top and bottom decile) for both dependent variables. The marginal effects are calculated using coefficients from the OLS model (Table 4) and from the IV model (Table 5) based on equation (2). For comparison, Table 7 presents estimates of β_1 from an estimation of equation (1), where *CRS* is included with no interaction term. The (OLS) results show a negative effect of *CRS* on population growth, where growth rates fall by 3.2 percentage points on average after joining the CRS and high-risk tracts experience slightly greater declines. This decline in growth rates appears more substantial compared to the mean tract population growth rate from 2000 to 2010 of 10.0%. The IV estimation of the population growth model yields marginal effects roughly three times larger than OLS estimates, but the IV estimates lacks strong support from the diagnostics. For the population turnover model, where the IV results are preferred, non-mover rates increase after joining the CRS by 16.1 percentage points in tracts with median flood risk. Estimated marginal effects on the non-mover rate for low-risk tracts are much larger (30 percentage points) than high-risk tracts (essentially zero).

Table 7: Summary of Marginal Effects of Participating in CRS

Dependent variable	**Flood risk**	**OLS FE model**		**IV FE model**	
		CRS only	Equation 2	CRS only	Equation 2
Pop growth	Lower 10%		-0.024		-0.073
	Median	**-0.032**	-0.032	**-0.095**	-0.109
	Upper 10%		-0.042		-0.150
Non-movers	Lower 10%		**0.040**		**0.299**
	Median	**0.037**	**0.037**	**0.227**	**0.161**
	Upper 10%		**0.032**		**-0.0001**

Note: This table shows the marginal effect of participating in CRS by using the estimated coefficients and three flood risk points. The 10^{th}, 50^{th} and 90^{th} percentiles of flood risk distribution are 0.048, 0.405 and 0.822 respectively. The estimates in the columns of "Equation 2" are derived from the estimated coefficients (β_1 and β_2) in Columns 2 and 4 in Table 4 and Table 5. The estimates in the columns of "CRS only" are derived from the estimated coefficients on CRS dummy only, dropping the interaction term (*CRS*Risk*) in equation 2. Calculations using significant coefficients are shown in bold.

Recent CRS literature delves into the heterogeneous effects of different flood mitigation activity categories (Brody et al. 2009; Fan and Davlasheridze 2016; Davlasheridze, Fisher-Vanden, and Klaiber 2017). In the CRS program, flood management activities can be broadly defined as two approaches: information-based or regulation-based. The former focuses on disseminating information about flood hazard to local residents to help them understand flood hazards and thus make informed decisions, while the latter focuses on reinforcing concrete flood control regulations and plans. If the marginal effect of CRS participation on population growth and turnover also hinges on which of the two approaches is adopted (e.g., communities emphasizing information-based activities are more likely to attract new construction or new migrants relative to those communities emphasizing regulation-based activities conditional on the participation of CRS), then we expect to find different effects of the two approaches. To test this hypothesis, we expand equation (2) into a triple-interaction model by adding a new variable to indicate the strength of information-based activities in the community.[11] This model estimates a heterogeneous effect of CRS participation based on flood risk and the intensity of information-based activities. Although not shown in the table, our empirical results do not support the hypothesis of different effects between information-based and regulation-based activities. Perhaps FEMA's points system in its CRS menu is calibrated so as to equate the marginal effects of regulatory and informational activities. Or perhaps it is simply participating in the CRS, regardless of *how* (as the similarity of results between tables 5 and 6 might suggest), that matters. At least for these outcome measures of population change, more research is needed to be able to

[11] To measure strength of information-based activities, we define that the six activities from public information (300 level) are information-based, and the remaining twelve activities from other three categories (400, 500 and 600 levels) are regulation-based. We calculate the total credit points earned from information-based activities, and then divide it by the total credit points earned by a community in a given census year. A higher percentage means that the community relies more on information-based activities to carry out its floodplain management.

better illuminate exactly how it is that community-scale flood management efforts are affecting growth. The heterogeneity of policy effects identified here raise key questions about how different actors – the "Mr. Spocks" or "Homers" in Kahn's (2014) terms – respond to informational and regulatory treatments in making adaptions.

Our analysis relies on some key assumptions and focuses on only a few outcomes of flood management (rather than flood disasters themselves). While our tract-level fixed effects control for permanent natural amenity quality, which often correlates with flood risks, it leaves us unable to directly identify the effects of local flood risks on population change. Further, unobserved changes in a tract's amenities that correlate with its community's decision to join the CRS may bias our estimated effects. Lacking time-varying measures of flood risk at fine spatial resolution for such a large (national) sample constrains research in this area. Our use of historic flood risk measures, coupled with a time-varying flood event measure, imperfectly proxies for contemporaneous flood risk, especially if flood management activities have altered local flood risk. Thus, our historic flood risk measure cannot distinguish between flood risk itself and local improvements caused by CRS activities. The findings are also limited to the two key variables of population change: growth and turnover rates. Of course, other important outcomes (e.g., demolitions, vacancies, property values, flood damage) should be evaluated in future research. Further, the timing and duration of impacts of *CRS* and *CRS Points* merit additional study. Although Li and Landry (2018) recently show considerable year-to-year persistence in communities' CRS participation, our examining only decadal changes may overlook some temporary changes and does not identify the time lag in effects. Effects identified here are essentially averaged over the sample's varying entry dates in the CRS in their respective decade of joining (i.e., 1990s, 2000s).

6. Conclusion

The primary purpose of this paper is to offer insights about how local government flood mitigation activities, combined with the NFIP and flood insurance subsidies, influence the pattern of population change around floodplains. The changes in incentives from joining the CRS may not matter much to private entities, at least as compared to new information and regulations. More than just highlighting and quantifying the impacts of CRS, these results also point to ways to improve cities' adaptation to climate change. We see little impact of CRS incentives to move to floodplains to enjoy discounted insurance premiums or lower flood risks, which suggests that CRS is either not targeting its impacts or its incentives are simply too weak. Still, we do find evidence of sorting related to CRS, both in terms of turnover encouraging additional flood management efforts and in terms of CRS having weaker effects on turnover in areas near flood hazards. Household response to CRS activities does not appear to hinge on which activities occur, the underlying flood-risk, or possibly even the extent of those activities. This suggests that CRS programs operate at a more general level, as part of a platform of community-wide limited growth, or are simply not well designed to shift where population settles. This invites inquiries into possible CRS reforms to strengthen the incentives to reduce future flood damage.

Flood management and changing flood risks represent a regional amenity that likely drives migration and development. Yet evidence on the effects of flood management efforts on local population growth and housing development is scarce, especially across a study area as large as the U.S. over a few decades. The results here provide a richer description of how local patterns of population change, flood risk, and participation in a community-scale flood management program interrelate. Results indicate that there are fewer people in higher-risk tracts and less turnover in lower-risk tracts in CRS communities. While we often focus on how CRS participation affects residents or potential residents in flood-prone areas, we might overlook the impacts of CRS participation of other residents. Costly CRS activities may pose fiscal burdens that induce residents to relocate as well, especially if they concentrate benefits across town. Our results show reduced population growth on "high ground" in CRS communities as well. The results, especially those relying on the IV estimator, warrant some caution. They rely on some strong assumptions about exogeneity and instrument strength (which diagnostic tests reflect favorably on), measure population change in limited ways, and offer little insight into exactly *how* these communities are influencing outcomes. Nonetheless, these initial results offer some novel insights into the local growth patterns in high-risk areas of communities actively seeking to manage their flood risks in this program.

From a broader perspective, these results offer insights into a second theme of critical importance to better understanding how cities will adapt to climate change, alter their bundles of public goods offered, and compete for development, investment, and migration with other cities. The evidently endogenous participation in the CRS, even at the tract level, points to large roles for local demographics (and likely other factors) in explaining communities' willingness and capacity to participate in this voluntary federal program. The uneven distribution of the capacity for collective action raises questions about which cities – and which residents therein – will be best able to adapt to changing environments. Although joining the CRS can affect where subsequent population changes occur within the community with respect to local flood risks, prior population changes can also influence which communities join the CRS in the first instance. While the focus on flood management makes the research question more tractable, the issues and lessons generalize to other environmental risks associated with climate change.

Whether some groups are advantaged or disadvantaged in adapting to climate change, however, begs the question of whether the optimality of collective action is related to resident demographics and local capacity. Some communities may be investing too much or too little in flood management, and perhaps adopting misguided policies. Additional research is clearly needed to assess the net benefits of local collective action, such as community-scale flood management, because costly public investments and policies in this context may reflect an improved bundle of local amenities, subsidized floodplain development, and rent-seeking. The results here indicate that demographic pressures influence community-level actions, and those actions (and incentives, regulation, information, etc.) in turn affect population location choices. The mixed nature of the CRS incentives discourages newcomers in flood-prone areas and elsewhere in the communities, rather than encouraging them to "head for the hills." How communities respond to environmental risks through price and quality effects remains an important area of inquiry.

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