Climate Migration, Liquidity Constraints, and Trapped Populations

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Abstract

Environmental shocks can increase the incentive to migrate but decrease the liquid assets needed to move, trapping some households in place. These opposing effects can mute migration responses, especially in rural economies where liquidity constraints are likely to bind. Yet separating them empirically is difficult because environmental shocks and income are jointly determined. We overcome this challenge using administrative migration data from rural Alaska, fine-scale information on heat shocks and land degradation, and the Permanent Fund Dividend, a universal annual cash transfer whose size varies independently of local environmental conditions. We find that land degradation increases rural-urban migration, while heat shocks decrease migration when the dividend is low but increase it when the dividend is high. Dividend payments offset 83% of the heat-induced decline in migration, relative to no payments. This effect is concentrated in low-wage communities and costly long-distance moves, consistent with a risk-based poverty trap.

Keywords: climate migration, liquidity constraints, trapped populations, labor mobility, adaptation, poverty traps, cash transfers, Permanent Fund Dividend

JEL Codes: Q54, O15, R23, J61, I38, Q56

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1. Introduction

Climate change is fundamentally altering global patterns of human settlement (Lustgarten, 2020; Carrington, 2025; Vince, 2025). Rising temperatures and environmental degradation have eroded both the productivity and amenity value of exposed regions, prompting some households to relocate (Liu, Shamdasani, and Taraz, 2023; Mueller, Gray, and Kosec, 2014; Bohra-Mishra, Oppenheimer, and Hsiang, 2014). Yet, migration responses to environmental change are highly heterogeneous: even in the most severely affected regions, many households remain, and the intensity of out-migration varies markedly across contexts (Azémar et al., 2026; Cattaneo and Peri, 2016). Why does environmental change induce some households to leave while others stay?

A leading explanation is that environmental change undermines not only the desire to stay but also the financial capacity to move, leaving some households unable to migrate despite a desire to do so. This "trapped populations" hypothesis posits that binding liquidity constraints, rather than preferences, can generate observed immobility under deteriorating conditions (Carling, 2002; Foresight, 2011; Black and Collyer, 2014). Consequently, low out-migration responses to climate shocks may reflect either a preference to stay or an inability to leave. This distinction carries important policy implications: a population that remains by choice may require no intervention, while a population that stays due to financial barriers may benefit from liquidity relief that enables migration-based adaptation.

In this paper, we ask: To what extent do liquidity constraints, rather than preferences, explain why some households stay in place while others migrate in response to environmental change? The main empirical challenge in answering this question is that the environmental shocks that prompt migration and the income shocks that enable it are rarely observed independently, making it difficult to distinguish between responses by those who want to remain in place and those who cannot leave because of liquidity constraints.

We address this challenge by leveraging a unique institutional setting in rural Alaska that decouples unearned income from local environmental shocks. As the fastest-warming U.S. state, Alaska is experiencing pervasive environmental degradation. This is particularly impactful to the state's rural communities, which are geographically isolated, credit-constrained, and highly reliant on natural resources for food security—characteristics often cited to motivate the trapped populations hypothesis. At the same time, Alaska administers the Permanent Fund Dividend (PFD), an annual and unconditional cash transfer. The PFD's universal design avoids the selection concerns associated with targeted transfers and is large enough to cover a meaningful share of migration costs. Importantly, the PFD's value is determined by lagged returns to a globally diversified wealth fund, rendering its variation plausibly exogenous to both potential migration decisions and community-level environmental shocks.

Within this setting, we develop a theoretical model based on a risk-based poverty trap framework (Barrett and Schofield, 2026). In our model, migration results from a dynamic program in which individuals jointly decide where to live and how much to consume. Environmental shocks affect non-consumptive utility, while both environmental and income shocks influence the accumulation of household assets. The model shows that environmental

shocks influence migration decisions through two distinct channels. First, a *disamenity* effect, whereby shocks degrade environmental quality, lowering amenity values and making migration more attractive. Second, an *income erosion* effect, whereby shocks reduce productivity and disposable income, depleting household assets and making migration less feasible. As a result, the overall migration response to environmental shocks is theoretically ambiguous, depending on which channel dominates. Our model demonstrates how we can use measures of environmental shocks and quality to empirically separate these two effects. We further show that unearned income shocks counteract the income-erosion effect, motivating several heterogeneity analyses to shed light on the trapped populations hypothesis.

To test our model's predictions, we use longitudinal administrative data that track migration flows between 321 Alaskan communities over 16 years. We combine these data with annual, community-level measures of wages, environmental shocks, and land degradation. We quantify environmental shocks using thawing degree days, capturing the accumulation of summer heat and its impact on the physical environment in rural Alaska. Environmental quality is measured using the U.S. Geological Survey's Climate Priming Index, which is used to predict land degradation events that are pervasive in rural Alaska (Spicer and Bolton, 2025). Our empirical strategy compares rural-to-urban migration responses to both environmental shocks and changes in environmental quality within the same community over time, leveraging variation in PFD payments to identify the moderating effect of unearned income. We use heterogeneity analyses, guided by our theoretical model, to assess whether the easing of liquidity constraints explains the observed pattern of migration responses.

Our results are consistent with environmental shocks influencing migration through two distinct, countervailing channels. First, summer heat accumulation reduces out-migration even when environmental degradation is held constant, consistent with an income-erosion effect. Supporting evidence suggests this stems from the negative impact of high summer temperatures on the marginal productivity of subsistence hunting. Notably, we find that the negative effect of heat accumulation on out-migration is partially offset by unearned income: while a one-standard-deviation increase in thawing degree days *decreases* the out-migration rate by roughly 4.7% at the lowest observed PFD payment, it *increases* the out-migration rate by 5.8% at the highest observed PFD payment. Second, warmer temperatures lead to greater land degradation, which in turn increases out-migration, consistent with a disamenity effect. We find no evidence that unearned income moderates this effect, providing further evidence that it operates primarily through changes in non-consumptive utility. Taken together, these findings indicate that the total effect of environmental shocks on migration may be obscured in observational data without independent variation in environmental shocks, quality, and income. Indeed, empirical specifications that do not model these underlying mechanisms produce misleading null effects.

Heterogeneity analyses support the interpretation that unearned income moderates migration primarily by easing liquidity constraints. Similar to Bazzi (2017), the moderating role of income is observed only in below-median wage communities—those most likely to face binding liquidity constraints. In line with Angelucci (2015), we find that this effect occurs only for higher-cost, longer-distance moves. We estimate that unearned income from the PFD enabled roughly 4,179 moves from rural Alaska to Anchorage, Alaska's largest urban

center, in response to above-average heat accumulation between 2000 and 2015, offsetting heat's negative effect on migration by 83% and accounting for 13% of all such moves in hotter-than-average years. Together, these results support the trapped populations hypothesis, indicate that unearned income enables environmentally driven migration in one of the world's most vulnerable regions, and highlight the critical role of financial constraints in shaping adaptation behavior.

Our findings speak to several strands of the literature on the drivers of climate migration. A large body of work examines migration with a sole focus on responses to environmental change, often finding responses to be highly heterogeneous and context-dependent (Dillon, Mueller, and Salau, 2011; Mueller, Gray, and Kosec, 2014; Bohra-Mishra, Oppenheimer, and Hsiang, 2014; Jessoe, Manning, and Taylor, 2018; Mueller, Gray, and Hopping, 2020; Beine and Parsons, 2015; VanCeylon and Melstrom, 2026; Blonz, Bowdle, and Weill, 2025; Baylis et al., 2025). Related literature emphasizes the disamenity effect of environmental shocks by using individuals' migration choices to estimate the non-market value of environmental quality, implicitly assuming that individuals can afford or finance the costs of migration (Maddison and Bigano, 2003; Bayer, Keohane, and Timmins, 2009; Rehdanz and Maddison, 2009; Albouy et al., 2016; Sinha, Caulkins, and Cropper, 2021). While this assumption may be reasonable in high-income contexts, it is less reasonable for resource-dependent regions, which are often geographically isolated, face incomplete credit markets, and are disproportionately exposed to uninsured environmental risk—precisely the conditions that give rise to risk-based poverty traps (Kraay and McKenzie, 2014; Jalan and Ravallion, 2002; Barrett and Schofield, 2026). Estimates of migration responses to environmental shocks for liquidity-constrained populations can thus conflate two opposing forces, the disamenity and income-erosion channels, potentially understating true migration responses and masking the presence of trapped populations who are most likely to benefit from targeted interventions.

Several studies have sought to address this limitation by comparing migration responses to environmental change in low- and high-income areas, often finding that environmental shocks reduce out-migration in low-income regions but increase it in high-income ones (Azémar et al., 2026; Cattaneo and Peri, 2016; Gröschl and Steinwachs, 2017; Nawrotzki and DeWaard, 2018). While these results are consistent with liquidity constraints in low-income areas, alternative explanations, such as unobserved factors correlated with both income and migration, may also explain this pattern. A separate literature shows that liquidity constraints substantially hinder both internal and international labor mobility (Gazeaud, Mvukiyehe, and Sterck, 2023; Tiwari and Winters, 2019; Angelucci, 2015; Bryan, Chowdhury, and Mobarak, 2014), often using environmental or weather shocks as proxies or instruments for income (Bazzi, 2017; Kleemans, 2015; Hirvonen, 2016). However, because these income shocks are themselves induced by environmental change, these studies cannot disentangle the overlapping channels central to the trapped populations hypothesis. An emerging literature uses independent variation in unearned income from cash transfer programs and randomized control trials (Chort and de la Rupelle, 2022; Mueller, Gray, and Handa, 2026; Mueller et al., 2020). Yet these transfers are often targeted aid programs, lack continuous variation in transfer size, and, like the studies above, do not observe environmental quality separately from the environmental shock itself. Thus, while these studies shed light on how income moderates migration responses to environmental change, they cannot distinguish be-

tween the disamenity and income-erosion channels—an important distinction for identifying how liquidity constraints shape environmentally-driven migration.

Our study addresses these limitations simultaneously by leveraging the PFD's unique combination of universal, unconditional, exogenous, and continuous temporal variation in unearned income. By observing both environmental shocks and the environmental quality that these shocks degrade, our research design separately identifies the disamenity and income-erosion effects of environmental change on migration. This distinction allows us to determine which types of migration are more likely to be suppressed by liquidity constraints, and to identify when cash transfers are most likely to facilitate adaptation behavior.

The paper proceeds as follows. Section 2 introduces the institutional background of the rural Alaskan economy and the Permanent Fund Dividend. Section 3 presents our theoretical framework. Section 4 summarizes our data and empirical approach. Section 5 discusses our results, and Section 6 concludes.

2. Institutional Background

2.1 Alaska's Rural Economy and Intra-State Migration

Alaska has a population of roughly 740,000 people, 290,000 of whom live in Anchorage, the state's largest city. The state's remaining residents live in small cities and villages, many of which are not connected to the road system and are accessible only by sea or air. Many Alaskans live below the poverty line (Huskey, Berman, and Hill, 2004), and the Federal Reserve has found that roughly 25 percent of the state's population lives in existing or potential "banking deserts"—Census tracts without physical bank branches. This is roughly three times higher than average (Flynn, 2025), a disparity partially due to the logistical challenges of Alaska's geography: building infrastructure requires transporting supplies by plane or barge, which can be prohibitively expensive (Mullen, 2026). These high transportation costs contribute to high costs of living in rural areas of the state, with a significant portion of household expenditures going to utilities, such as sewage and water.[1]

Rural-urban migration is the most common mobility pattern in Alaska (Howe, Huskey, and Berman, 2014), and roughly 11 percent of the state's rural population migrated to urban areas in each of the five-year periods between 1993 and 2013 (Howell, 2015). Anchorage and the nearby Matanuska-Susitna Borough routinely command the largest gross and net migration flows within the state, a pattern which has remained constant over the last thirty years (Williams, 2004; Howell, 2015; DLWD, 2024, Figure 1A). Intra-state migration has traditionally been motivated by economic opportunity, with individuals migrating to urban centers to take advantage of higher wages, educational opportunities, and a lower cost of living (Berman and Wang-Cendejas, 2024).[2]

[1] Saylor and Haley (2007) find that households in rural Alaska spend up to one third of their income on utilities. In a stark example of rural Alaskans' relative inability to borrow and smooth consumption, Johnson et al. (2024) show that following the arrival of the PFD, utility payments sharply increase and delinquency rates temporarily decrease.

[2] The rural-urban wage differential in Alaska is substantial. Using data from the Alaska Department of

While rural-urban migration within Alaska is common, it is still low relative to the observed wage differential (Howe and Huskey, 2022). The sizable costs of rural-urban migration may contribute to this pattern. Transportation from a rural village to Anchorage typically involves two flights: first to a medium-sized "hub" city, and then to Anchorage (Kurland, 2017). Individuals must also transport their possessions and purchase basic necessities at their destination. The unique cultural amenities of rural life also contribute to relatively low rural-urban migration (Marshall, 1993). Rural Alaskan communities are characterized by a mixed subsistence-cash economy in which the high cost of market goods, coupled with the cultural significance of hunting and fishing, results in a high proportion of nutritional needs being met through subsistence harvesting of fish and game (Green et al., 2021; Fall, 2016).[3] Past work has emphasized that the real income gains from subsistence harvesting may compensate individuals for lower wages and higher costs of living, potentially decreasing the utility of rural-urban migration (Berman, 2009; Howe and Huskey, 2022).

Rural Alaska's mixed subsistence–cash economy is a prototypical example of a household production framework (Berman, 2009; McNeeley and Shulski, 2011), analogous to subsistence agriculture in low- and middle-income economies (Blom, Ortiz-Bobea, and Hoddinott, 2022; Randell, Gray, and Shayo, 2022; Gray and Thiede, 2024; Stainier, Shah, and Barreca, 2026). However, this setting differs from the conventional agricultural household model (Singh, Squire, and Strauss, 1986; Taylor and Adelman, 2003) because individuals cannot legally sell their harvests. This restriction makes subsistence productivity especially important for nutrition and food security, given the high cost of store-bought food in rural Alaska.[4]

2.2 Environmental Change

Alaska is highly vulnerable to environmental change, having warmed 4.3° F since the 1970s, roughly twice the global average (NOAA, 2025). Eight of the state's hottest years on record have occurred since 2000, five of which are within our study period of 2000–2015 (Thoman and Walsh, 2019). These rapid temperature increases are jarring for residents of cold-adapted areas such as Alaska, which has the lowest rate of household air conditioner ownership in the United States at 7% (Davis, 2022). Accordingly, heat exposure in Alaska has been associated with increased cardiovascular illness and medical expenditures (Hahn, Kuiper, and Magzamen, 2023).

Increases in ambient air temperatures have directly affected subsistence harvesting and food security in rural Alaska by changing the movement and breeding patterns of land mammals commonly hunted by rural residents (Green et al., 2021; Davidson, 2020) and increasing the

Labor's ALARI dataset (described further in Section 4), we calculate that from 2000 to 2015, the average difference in median per-capita wage income between Anchorage and rural Alaskan communities was roughly $7,400 (2015 USD). By comparison, average median per-capita wage income in rural Alaskan communities during this timeframe was $12,500.

[3] In 2014, wild harvests in rural Alaska totaled 34.3 million pounds, or roughly 275 pounds per person (Fall and Kostick, 2018). Fall (2016) finds that wild harvests made up an average of 175% of recommended daily protein requirements and 25% of caloric requirements.

[4] In rural villages, transportation costs and high in-transit spoilage rates can push the cost of a comparable basket of groceries 80% higher than in Anchorage (Bennett, 2024; Segers and Wilder, 2025). For example, a $5 bag of rice in Anchorage can easily cost $15 in rural Alaska, and identical baskets of groceries can cost $75 in Anchorage and $134 in Unalakleet on the same day (Segers and Wilder, 2025).

effort required to harvest a fixed number of calories. Indeed, in years with substantial summer heat accumulation above 0°C, hunters experience reduced productivity (McNeeley and Shulski, 2011), often requiring increased effort to ensure communities' food security. Unseasonably hot temperatures also render hunting routes harder to traverse (Mason and Craver, 2023; Craver, 2001), requiring costly investments in new hunting equipment (McNeeley and Shulski, 2011; McNeeley, 2012). Thus, heat accumulation forces households to divert time and effort away from income-generating activities, eroding their liquid assets.[5]

Warmer temperatures also have consequences for rural infrastructure, as many communities are built on permafrost, ground which has historically stayed frozen year-round beneath the seasonally thawing active layer of soil (Obu et al., 2019; Creel et al., 2024). Roughly 190,000 individuals across 192 Alaskan communities live on permafrost (Ramage et al., 2021), and much of the state's rural infrastructure depends on its integrity (Melvin et al., 2017; Manos, Witharana, and Liljedahl, 2025). Rising temperatures contribute to rapid permafrost thaw across the state, causing land subsidence and infrastructure damage (Creel et al., 2024, Figure A2). On average, Alaskan communities experience an annual decline of 0.34 percentage points in the likelihood of overlaying permafrost and an annual increase in the thickness of the active layer of soil by roughly 0.02 meters, after controlling for community fixed effects (Table A.1).

The combined hazards of permafrost thaw, coastal erosion, and flooding are intrinsically linked, referred to as "usteq" or "surface caves in" by the State's Indigenous population. This rapid environmental change has eroded the foundations of homes and schools (Bean and Bethel, 2024; Schwing, 2023), damaged roads and airport runways important for transporting goods to rural areas (Verstraete and Zachwieja, 2025), and contaminated rivers (Moran, 2025).[6] Many individuals adapt in place to these changes, making piecemeal repairs to their homes or property (Witt, 2022). And although government agencies have repeatedly identified more than 150 communities as highly vulnerable to these compound environmental hazards (USACE, 2019), funding for adaptation projects is scarce, as most rural Alaskan communities do not have property values sufficient to justify the cost (George, 2024). In several cases, entire communities have relocated to avoid the consequences of environmental degradation, though this process is expensive and can take years to complete.

High exposure to environmental degradation thus impacts the cost of living and many of the unique cultural amenities of rural life, including subsistence harvesting (Berman, 2009; Howe and Huskey, 2022). While this could imply that individuals will begin to migrate to less vulnerable urban areas after a certain amount of degradation, survival-driven adaptation expenditures may erode the liquid assets needed to fund migration costs. Cash transfers, such as the Permanent Fund Dividend, may therefore ease binding liquidity constraints and enable out-migration (Bazzi, 2017).

[5]When interviewed about their decision-making process in the face of increasing summer heat, rural Alaskan hunters describe labor-leisure trade-offs consistent with those of a household production model (McNeeley and Shulski, 2011). The photographs in Figure A1 visually document the labor and capital investments involved in these household production processes.

[6]Figure A3 presents several photographic examples of how these processes, and the land degradation they cause, affect infrastructure in Alaskan communities.

2.3 The Alaska Permanent Fund Dividend

Established in 1976, the Alaska Permanent Fund is a wealth fund that conserves the state's resource revenues for future generations. The Fund currently totals $88.9 billion as of August 2026, and is well-diversified across regions and asset classes in the world market. Although state oil revenues originally capitalized the fund, they now account for only 1–2% of the fund's total value (Figure A4). Since the mid-1980s, reinvestment of the fund's earnings has been the primary driver of its growth (Watson, Guettabi, and Reimer, 2020). Accordingly, the fund's additions in a given year are not indicative of Alaska's economic performance.

In 1980, the State Legislature approved the Permanent Fund Dividend (PFD), an annual payment that distributes the Permanent Fund's earnings to all Alaskans who have resided in the state for at least one calendar year. The PFD filing period runs from January 1 to March 31st, and the dividend value is announced in September and paid in October. As part of the filing process, PFD recipients provide the State with their residential address, allowing the State to track migration flows between all Alaskan communities, no matter how small. Takeup of the PFD is high: on average, over 90% of the state's population received a dividend each year between 2000 and 2015.

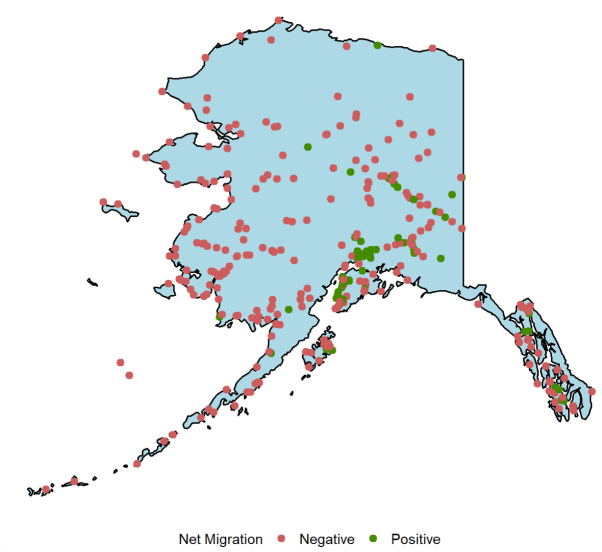
The PFD disbursement amount varies considerably over time and is based on the net income from the fund's investments, averaged over the previous five years. From 2000 to 2015, the real value of the PFD ranged from approximately $900 to $2800 (2015 USD; Figure 1d), creating temporal variation in unearned income that is large relative to the costs of rural-urban migration. For example, the average PFD payment during our study period was roughly $1,700 per person, or $6,800 for a household of four, which can cover a large share of a family's moving expenses from rural Alaska to Anchorage. These transfers represent a nontrivial share of household income: roughly 13% of per-capita wage income on average, with the dividend accounting for a much larger share of per-capita wages in rural communities (Figures 1b,c).

The PFD is unconditional and has no work requirements, avoiding the selective nature of other cash transfer programs, which are often only distributed to individuals below a certain income level (Angelucci, 2012, 2015). Because the PFD is predetermined and generated independently of local environmental conditions, it allows us to study how income causally moderates environmental migration.[7]

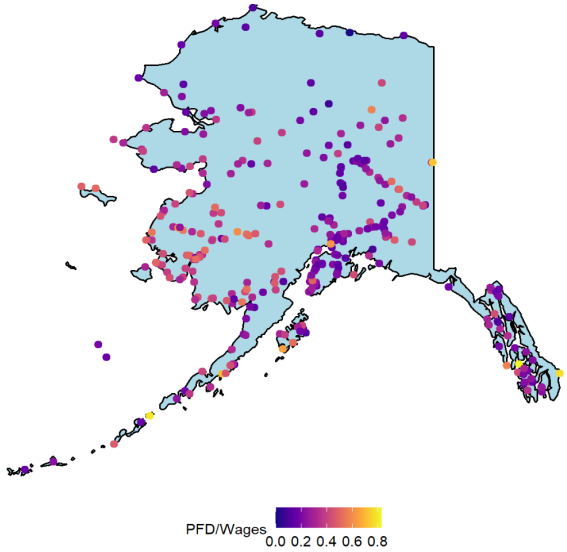
3. Theoretical Framework

To guide the empirical analysis, we develop a two-period model of migration that formalizes why environmental shocks have theoretically ambiguous effects on out-migration and how unearned income moderates this relationship. The model clarifies why reduced-form estimates linking environmental shocks to migration can appear small or null even when

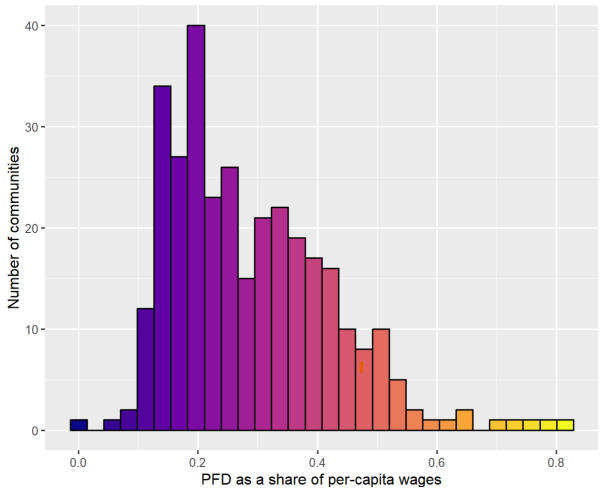
[7]Previous work has leveraged these desirable characteristics of the PFD to examine the effect of cash transfers on crime (Watson, Guettabi, and Reimer, 2020), labor market outcomes (Bibler, Guettabi, and Reimer, 2023; Jones and Marinescu, 2022; Feinberg and Kuehn, 2018), and fertility (Yonzan, Timilsina, and Kelly, 2024).



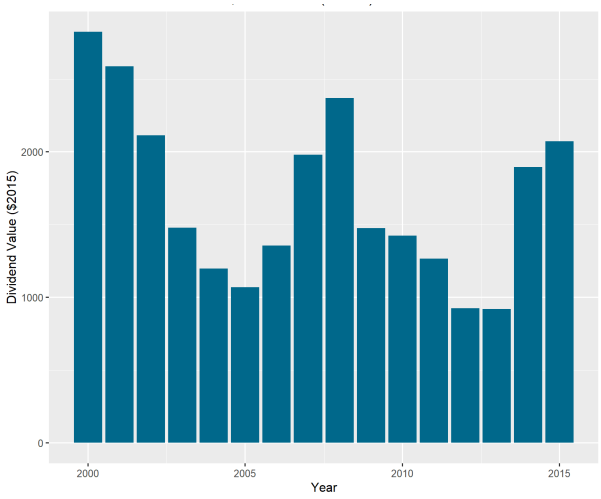
(a) Net migration by community



(b) PFD as a share of per-capita wages



(c) Distribution of PFD / wage ratio



(d) Real PFD disbursement, 2000–2015

Figure 1: Net migration and Permanent Fund Dividend payments in Alaska. (a) Positive (green) and negative (red) net migration between 2001 and 2015 using migration data from PFD applications. (b-c) The PFD payment in 2000 (measured in 2015 USD) as a fraction of per-capita annual wages. (d) PFD payments (2015 USD), 2000–2015.

environmental change meaningfully affects migration decisions, yielding the hypotheses we test in our empirical setting.

The model formalizes the trapped populations hypothesis, which bridges two economic concepts: poverty traps and adaptive migration. Poverty traps arise when individuals cannot accumulate the assets needed for welfare-improving investments. Rural-urban migration is one such investment, often motivated by spatial wage differentials (Bryan, Chowdhury, and Mobarak, 2014) or increased risk exposure and environmental degradation at the origin

(Black et al., 2011; Wang, 2025; Boustan, Kahn, and Rhode, 2012). Incomplete credit markets prevent individuals from borrowing to finance such investments, and low incomes limit savings-based accumulation (Carter and Barrett, 2006). In isolated rural areas, high transportation and migration costs compound these constraints, producing "geographic poverty traps" (Kraay and McKenzie, 2014). Because uninsured risk exposure and poverty are also highly correlated in resource-dependent areas, negative shocks can deplete liquid assets and make migration even less feasible, giving rise to risk-based poverty traps (Barrett and Schofield, 2026).

In our model, the poverty-trap mechanism operates through the resources needed to finance a move, while adaptive migration operates through the utility of leaving a degraded environment. We refer to these as the income erosion and disamenity effects, respectively. An *income erosion* effect occurs when shocks reduce income or raise the cost of meeting basic needs at the origin. We show that if households are liquidity constrained, the sign of this relationship is theoretically ambiguous because reductions in income affect migration along two distinct margins: they change the relative value of migrating for those who are able to afford it, and they erode the resources needed to afford migration. A *disamenity* effect arises when shocks degrade the non-consumptive value households derive from their environment, making adaptive migration more attractive without affecting the resources needed to finance it (Baylis et al., 2025; Maddison and Bigano, 2003; Rehdanz and Maddison, 2009; Bayer, Keohane, and Timmins, 2009; Albouy et al., 2016; Sinha, Caulkins, and Cropper, 2021). When this channel operates alone, the response to negative shocks is unambiguously positive. When both channels operate simultaneously, as they likely do in many real-world settings, a null or modest aggregate migration response can reflect two offsetting effects rather than the absence of a true relationship.

Rural Alaska is well suited to studying both channels. Its isolated, plausibly liquidity-constrained communities have a mixed subsistence-cash economy, low incomes, high costs of living, and heavy reliance on natural resources. Heat accumulation raises the effort needed to harvest a given number of calories from subsistence resources.[8] Households respond by substituting away from wage labor, increasing hunting effort, or buying costly store-bought food. In each case, they draw down liquid assets, which, absent borrowing against future wealth, reduces the feasibility of migration. Heat also drives permafrost thaw, coastal erosion, and land subsidence, which impose psychological costs and reduce quality of life but do not affect necessary biological inputs like the caloric constraint. The assets most exposed to these events, such as housing, are comparatively illiquid, so environmental degradation leaves liquid assets largely unaffected while raising the utility of adaptive migration.

3.1 Conceptual Model

To formalize these two channels, we model an individual's decision to migrate from a rural origin O to an urban destination D. Individuals choose consumption and migration subject to a liquidity constraint and face a temperature shock that affects both the local stock of environmental quality and, through its effect on subsistence productivity, disposable income.

[8] As shown in McNeeley and Shulski (2011) and Davidson (2020), this mechanism is likely most relevant for harvests of land mammals such as moose and caribou. In Section 5.4, we use the Alaska Department of Fish and Game's data on subsistence harvests to show suggestive evidence of this mechanism.

The model traces how environmental shocks shape migration decisions through income erosion and disamenity channels, and explores how unearned income differentially moderates each channel.

Individuals live for two periods, $t \in \{0, 1\}$, and begin at the rural origin O. At the start of $t = 0$ individuals receive unearned income Y_0 and observe temperature H_0. They then choose consumption C_0 and whether to migrate, $M \in \{0, 1\}$. Migration is costly and can be financed only with liquid resources. In $t = 1$, they earn income and consume at the urban destination D if they migrated and at the origin O otherwise. Because the return to moving accrues in the future, there is no migration in the terminal period.

We use the model to graphically depict the income erosion and disamenity effects of heat on migration, distinguishing between individuals who can afford to move and those who want to. We then illustrate how these effects are moderated by unearned income. Mathematical derivations and proofs can be found in Appendix B.

3.1.1 Setup

Resources and the liquidity constraint. An individual's resources that can be used for consumption and migration in period $t = 0$ are

$$R_0 = A_0 + I_0 = A_0 + \underbrace{Y_0 + I^O(H_0)}_{I_0}, \tag{1}$$

where A_0 is initial assets and I_0 is initial income, separated into unearned income, Y_0, and earned income at the origin, $I^O(H_0)$. Origin income is measured net of subsistence requirements and decreases with temperature, $I^O_H < 0$: hotter temperatures increase both the time and the cost of meeting subsistence needs, leaving less for discretionary consumption and for financing migration. Individuals are assumed to be liquidity constrained—i.e., borrowing against future income is not possible. An individual's budget constraint in period $t = 0$ is thus

$$C_0 + \delta M \leq R_0, \tag{2}$$

where δ denotes the fixed cost of migration. Migration therefore requires $R_0 \geq \delta$.

Unspent resources in period $t = 0$ are assumed to grow at an interest rate of r, so resources available for consumption in period $t = 1$ are

$$R_1 = \begin{cases} (1+r)(A_0 + I_0 - C_0) + Y_1 + I^O(H_1) & \text{if stays} \\ (1+r)(A_0 + I_0 - C_0 - \delta) + Y_1 + I^D & \text{if migrates,} \end{cases} \tag{3}$$

where I^D denotes income at the destination, which is assumed to be unaffected by conditions at the origin.

Environmental stock. Let S_t denote the stock of environmental quality, representing land resources in our setting, which evolves according to

$$S_1 \;=\; S_0 - d(H_0), \qquad d_H > 0, \tag{4}$$

where the contemporaneous temperature shock degrades next period's environmental quality through permafrost thaw, erosion, and land subsidence. Since H_0 is observed by individuals prior to making migration and consumption decisions, S_1 is known and deterministic.[9]

Preferences. An individual's contemporaneous utility is

$$\begin{array}{ll} U(C_t) + h(S_t) & \text{at the origin} \\ U(C_t) & \text{at the destination,} \end{array} \tag{5}$$

with $U_C > 0$, $U_{CC} < 0$, and $h_S > 0$. For simplicity, we assume that individuals derive utility only from environmental quality at the origin and that this utility is additively separable from consumption-based utility. We also assume that consumption-based utility is the same at the origin and destination.[10]

3.1.2 The decision to migrate

The individual's problem can be expressed as a comparison of the relative value associated with staying and migrating:

$$\begin{aligned} \textbf{Stay:} \quad V^O(R_0, S_0, S_1) &= \max_{C_0 \in [0, R_0]} \Big\{ U(C_0) + h(S_0) + \theta\, \mathbb{E}\big[U\big(R_1\big) + h(S_1) \big] \Big\} \\ \textbf{Migrate:} \quad V^D(R_0, S_0) &= \max_{C_0 \in [0, R_0 - \delta]} \Big\{ U(C_0) + h(S_0) + \theta\, \mathbb{E}\big[U\big(R_1\big) \big] \Big\}, \end{aligned} \tag{6}$$

where expectations are taken over future temperature and unearned income shocks. Monetary resources and environmental quality evolve according to Eq. 3 and 4. The term $\theta \in [0, 1]$ denotes the discount factor. Since $t = 1$ is the terminal period, all available resources are consumed: $C_1 = R_1$. A migrant faces the same period-0 utility at the origin, but the feasible consumption set declines by δ. Migration, therefore, trades present resources at the origin for future consumption at the destination.

Define the propensity to migrate as:[11]

$$\Delta(R_0, S_1) = V^D(R_0, S_0) - V^O(R_0, S_0, S_1). \tag{7}$$

An individual migrates if they can afford it and the relative value of migrating is greater than the discounted cost of living away from home:

$$M = 1 \quad \Longleftrightarrow \quad \underbrace{R_0 \geq \delta}_{\textbf{feasible}} \quad \text{and} \quad \underbrace{\Delta(R_0, S_1) > 0}_{\textbf{desirable}}. \tag{8}$$

[9] We note that our model is a simplified representation of a community's stock of land resources. In reality, other environmental variables besides temperature (e.g., precipitation) influence the stock's evolution over time. We include such variables in our empirical approach.

[10] C_t can be thought of as discretionary consumption above a subsistence floor $\underline{c}$, so that $U(0)$ is finite—i.e., an individual who exhausts all liquid resources financing migration consumes at subsistence.

[11] Note that $\Delta(R_0, S_1)$ does not depend on S_0 given that utility from environmental quality is assumed to be additively separable from consumption-based utility at the origin, and is therefore differenced away when comparing migration to staying.

3.1.3 The effect of temperature and unearned income on migration.

For simplicity, consider a temperature shock equal to $dH = 1$. Heat influences the decision to migrate through two channels. First, heat depletes the next period's stock of environmental quality by d_H (Eq. 4). This *disamenity effect* reduces future non-consumptive utility at the origin by θh_S (Eq. 6), making migration more desirable. Second, heat depletes available resources by eroding disposable income by I_H^O (Eq. 1). This *income erosion effect* lowers the likelihood that migration is feasible and changes the desirability of migration for those who remain able to migrate by Δ_R.

We depict the migration decision for a single individual in Figure 2, distinguishing between cases where migration is a normal good ($\Delta_R > 0$) and where it is an inferior good ($\Delta_R < 0$). In general, $\Delta_R > 0$ or $\Delta_R < 0$, depending on whether an individual's optimal consumption is higher when they stay or when they migrate. For example, if a stayer's optimal consumption is greater than a migrant's, a marginal decline in disposable income hurts the migrant more, since their marginal utility is higher. Migration then behaves as a normal good: a decline in income makes migration less desirable. In Appendix B, we show that migration is a normal good for those individuals who are either (i) consumption-constrained by available resources or (ii) unconstrained but have migration costs that exceed the expected earnings premium from migrating. While we cannot distinguish whether migration is a normal or inferior good in our setting, we can still derive testable conditions that inform the trapped populations hypothesis, as we discuss below.

The effect of heat on migration is generally ambiguous. As drawn in Figure 2, an individual has enough resources to finance migration in the absence of a temperature shock, but they do not find it desirable (Point A). Heat's disamenity effect depletes environmental quality at the origin, thereby increasing the propensity to migrate, as depicted by the upward shift from $\Delta(R_0, S_1)$ (blue line) to $\Delta(R_0, S_1 - d_H)$ (red line) and the movement from Point A to Point B. In this case, an individual would choose to migrate in response to a heat shock, given their initial available resources. However, heat's income-erosion effect simultaneously depletes available resources, as shown by the movement from Point B to Point C, rendering migration infeasible. This specific case represents the trapped populations hypothesis: environmental change increases an individual's desire to migrate while simultaneously decreasing their capability to do so.

In general, an individual's overall migration response to heat depends on whether the income erosion effect or the disamenity effect dominates, which in turn depends on the level of unearned income the individual can use to finance migration. Unearned income counteracts the income-erosion effect by replacing resources lost from heat's negative effect on earned income. This is illustrated in Figure 2 by the movement from Point C to Point D. In this case, unearned income offsets the income erosion effect enough to make migration feasible.

3.1.4 Hypotheses

Figure 2 captures the migration decision for a single individual and how this changes in response to temperature and unearned income. Community-level aggregate migration rates will therefore depend on how individuals are distributed across the feasibility-desirability

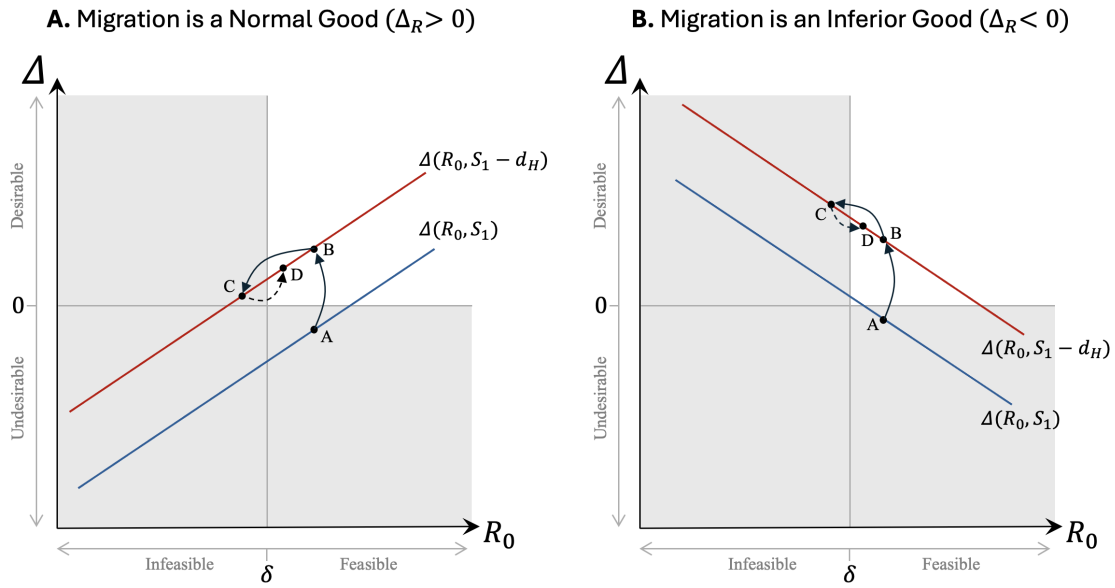


Figure 2: The effect of temperature and unearned income on migration. The x-axis represents the amount of initial available resources, R_0, that an individual has for consumption and migration decisions. The y-axis represents the value of migrating relative to staying (i.e., the propensity to migrate), Δ, which depends on an individual's resources, R_0, and the stock of environmental quality at the origin, S_1. Migration occurs only in the upper-right (white) quadrant, where it is both feasible and desirable. The blue line represents the propensity to migrate as a function of resources, R_0, for a given level of environmental quality, S_1, assuming that migration is a normal (Panel **A**) and inferior (Panel **B**) good. Point A represents an individual's initial resources and propensity to migrate. A temperature shock affects migration through two channels. First, heat degrades environmental quality, represented by the upward shift to the red line and the movement A $\rightarrow$ B. Second, heat erodes disposable income and the resources available for consumption and migration, represented by the movement B $\rightarrow$ C. Unearned income replaces resources lost from heat's negative effect on disposable income, represented by the movement C $\rightarrow$ D.

space. Here, we consider several different distributions to inform hypotheses regarding the income erosion and disamenity effects of heat on migration and how unearned income moderates these effects, summarized in Table 1.

Income erosion. Our first two hypotheses concern the income erosion effect. Holding the stock of environmental quality constant, temperature shocks erode the resources necessary for consumption and migration, changing the feasibility and desirability of migration in the absence of unearned income. Denote this effect as β_1. Increases in unearned income reverse this effect, changing the desirability of migration and enabling migration for marginally constrained individuals who desire it. Denote this effect as α_1.

Figures 3A and 3B depict three scenarios of how community-level out-migration rates may respond to income-erosion effects, depending on whether migration is a normal or inferior good. First, consider a population distribution concentrated in the grey region of the graph, far from the northeast quadrant. In this case, we would expect $\beta_1 = \alpha_1 = 0$: neither the decrease in resources caused by heat nor the corresponding increase in resources due to unearned income are sufficient to push individuals over the feasibility and desirability thresholds, leaving migration behavior unchanged for much of the population.

Second, consider a population concentrated in areas where migration is feasible, with individuals relatively indifferent between migrating and staying (orange region). In this region, changes in migration behavior are driven entirely by changes in the desirability of migration. If migration is a normal good, the reduction in resources caused by heat makes it less desirable, so migration declines. Unearned income reverses this effect, making migration desirable for individuals on the margin. In this case, $\beta_1 < 0$ and $\alpha_1 > 0$. Similar logic shows that the opposite is true if migration is an inferior good: $\beta_1 > 0$ and $\alpha_1 < 0$. Thus, while the direct effect of heat, β_1, and the moderating effect of unearned income, α_1, always have opposite signs, their individual signs depend entirely on whether migration is a normal or inferior good.

Finally, consider a population concentrated in areas where migration is desirable, but resources are nearly constraining (pink region). Heat-induced reductions in resources make migration less feasible, increasing the number of marginally constrained individuals just below δ who can no longer afford to move. Unearned income reverses this effect, making migration feasible for individuals on the margin. Thus, we would expect $\beta_1 < 0$ and $\alpha_1 > 0$, regardless of whether migration is a normal or inferior good. This region directly corresponds to the trapped populations hypothesis.

Disamenity. Our remaining two hypotheses concern the disamenity effect. Holding the heat-induced effect on income constant, heat reduces environmental quality, lowering the lifetime utility of staying at the origin and making migration more attractive. Denote this effect as β_2. Increases in unearned income then shift the resource distribution rightward from its initial position. Denote this effect as α_2.

Figures 3C and 3D depict three scenarios of how community-level out-migration rates may respond to disamenity effects, depending on whether migration is a normal or inferior good.

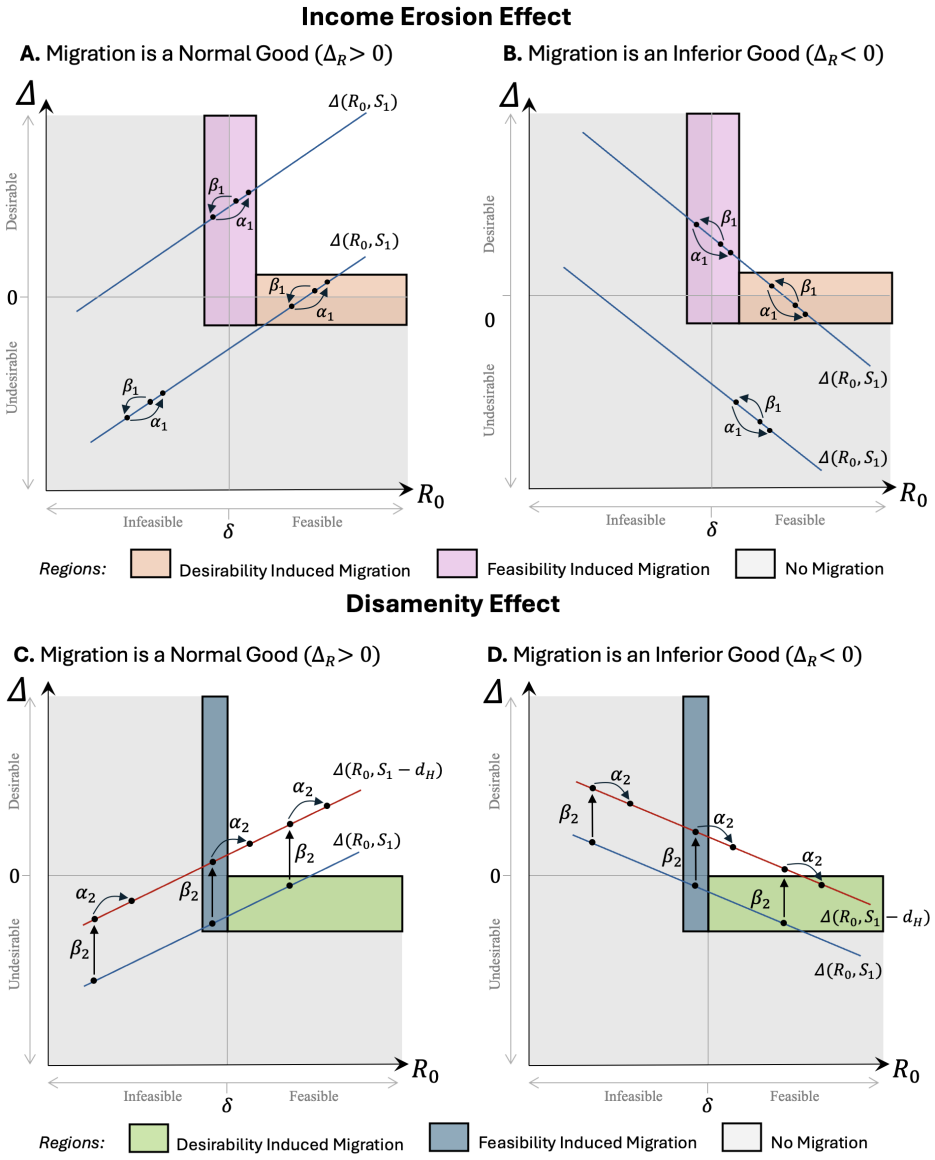


Figure 3: The income erosion and disamenity effects of heat on migration. Each panel illustrates three different examples of how heat influences the decision to migrate and how unearned income moderates this decision. The top row (Panels **A**–**B**) isolates the income erosion effect and the bottom row (Panels **C**–**D**) isolates the disamenity effect. The left panels (**A**, **C**) assume migration is a normal good ($\Delta_R > 0$) and the right panels (**B**, **D**) assume it is an inferior good ($\Delta_R < 0$). Shaded regions denote where different subpopulations are concentrated in (R_0, Δ) space. In the grey region, migration is unresponsive to both heat and unearned income ($\beta = \alpha = 0$). In the orange region (**A**–**B**) and the green region (**C**–**D**), migration is feasible, and the population responds only to migration's desirability. In the pink region (**A**–**B**) and blue region (**C**–**D**), the population sits near the feasibility threshold, and the response here reflects the trapped populations mechanism, in which resource constraints rather than preferences bind migration. Within each region, β_1 and β_2 denote the direct effect of heat (through income erosion and disamenity, respectively), and α_1 and α_2 denote the moderating effect of unearned income. In Panels **A**–**B**, the two parallel lines represent two illustrative subpopulations with different preferences and baseline resources. In Panels **C**–**D**, the blue line depicts $\Delta(R_0, S_1)$ prior to a disamenity shock and the red line depicts $\Delta(R_0, S_1 - d_H)$ after.

First, consider a population distribution concentrated in the grey region of the graph, far from the northeast quadrant of the feasibility-desirability space. Similar to the income erosion effect, we would expect $\beta_2 = \alpha_2 = 0$.

Second, consider a population distribution concentrated in areas where migration is feasible but initially undesirable (green region). The decline in environmental quality caused by heat raises the desirability of migration enough to increase observed migration. Thus, $\beta_2 > 0$, regardless of whether migration is a normal or inferior good. By contrast, the moderating effect of unearned income depends on whether migration is a normal or inferior good, and it behaves qualitatively similarly to how unearned income moderates heat's income erosion effect: $\alpha_2 > 0$ if migration is a normal good and $\alpha_2 < 0$ if migration is an inferior good.

Finally, consider a population distribution concentrated in the area where migration is desirable but only marginally infeasible (blue region). The disamenity effect increases the utility of migration, but without unearned income, individuals cannot afford to migrate. Thus, $\beta_2 = 0$. However, unearned income shifts the resource distribution rightward, pushing more individuals into the feasible area. Thus, in this case, we expect $\alpha_2 > 0$.

Summary. Table 1 summarizes the four main hypotheses produced by our conceptual model. Our main parameters of interest, β_1 and α_1, jointly test the trapped populations hypothesis. If migration is a normal good, $\beta_1 < 0$ and $\alpha_1 > 0$ is a necessary condition for trapped populations, but not sufficient, since desirability-driven migration produces the same pattern. If migration is an inferior good, $\beta_1 < 0$ and $\alpha_1 > 0$ is sufficient but not necessary: desirability-driven migration cannot generate this pattern alone, but it could still offset and mask trapped-population responses. Because of this possibility, we use heterogeneity analyses based on communities' proximity to the feasibility threshold δ: if estimates of $\beta_1 < 0$ and $\alpha_1 > 0$ are generated by the trapped-populations hypothesis, these effects should only occur near the feasibility threshold, regardless of whether migration is a normal or inferior good. The parameter α_2 offers additional information on which case applies: $\alpha_2 < 0$ is sufficient, but not necessary, for migration to be an inferior good. Finally, the disamenity effect operates exclusively through the desirability of migration: $\beta_2 > 0$ is unambiguous, unconditional on good type, and serves as a validation check on our strategy for separating the income erosion and disamenity effects.

		Normal		Inferior	
	Effect	**Feasibility**	**Desirability**	**Feasibility**	**Desirability**
β_1	Income Erosion (Direct)	≤ 0	≤ 0	≤ 0	≥ 0
α_1	Income Erosion (Moderator)	≥ 0	≥ 0	≥ 0	≤ 0
β_2	Disamenity (Direct)	0	≥ 0	0	≥ 0
α_2	Disamenity (Moderator)	≥ 0	≥ 0	≥ 0	≤ 0

Table 1: Main hypotheses.

Notes: This table provides the predicted sign of our main parameters of interest, differentiated by different population distributions in feasibility-desirability space and whether migration is a normal or inferior good. β_1, β_2 denote the direct effect of heat through the income-erosion and disamenity channels; α_1, α_2 denote the moderating effect of unearned income on each. *Feasibility* provides the predicted sign of the migration response for populations near the feasibility threshold δ (the trapped-populations region). *Desirability* provides the predicted sign when migration is already feasible, and the population responds solely to migration's desirability.

4. Empirical Approach

We test the main hypotheses of our conceptual model in Table 1 by taking advantage of temporal variation in heat shocks and changes in environmental quality within an Alaskan community, along with variation in unearned income payments from the State's Permanent Fund Dividend (PFD) program. We estimate the model parameters by assembling a longitudinal community-year dataset that measures rural-urban migration flows, heat accumulation, changes in environmental quality, and local economic conditions (summarized in Table 2). We use a flexible Poisson pseudo-maximum likelihood (PPML) approach that controls for unobserved time-invariant factors that vary across communities, time-varying factors that are common across communities, and differential out-migration responses to PFD payments across communities. Intuitively, our strategy compares rural-urban out-migration within the same Alaskan community under different heat-shock magnitudes and environmental-quality changes, allowing these comparisons to vary with the size of the PFD.

4.1 Data

4.1.1 Migration

We use a community-year panel of within-state migration flows between all 344 Alaskan communities between 2000 and 2015, maintained by the State of Alaska for the purpose of administering the PFD.[12] Migration flow m_{ijt} captures the number of migrants from origin i to destination j in year t, calculated by summing the total number of people who both a) submitted a PFD application in year t and denoted their permanent residence as community i, and b) submitted an application in year $t+1$ and denoted their permanent residence as community j. Because the PFD is universal and take-up is high, this data provides a near-comprehensive administrative record of within-state mobility.

[12]We obtained access to community-year migration flows through communication with the Alaska Department of Labor and Workforce Development (DLWD). Annual migration flows between Borough and Census Areas are publicly available online on the DLWD website.

The bilateral structure of migration flows allows us to disaggregate total outmigration by destination. Approximately 8% of each community migrates within Alaska annually, and most of these moves are either to Anchorage or to communities within the origin community's Borough and Census Area (BCA), the state's county equivalents (Table 2). Because migration to Anchorage makes up a disproportionate share of total out-migration relative to any other single municipality, we use out-migration from community i to Anchorage in year t to represent rural-to-urban migration and as the main dependent variable in our empirical specifications.[13] Notably, trends in out-migration rates to Anchorage align relatively closely with fluctuations in the PFD, but this pattern is less pronounced for within-BCA migration (Figure 4).

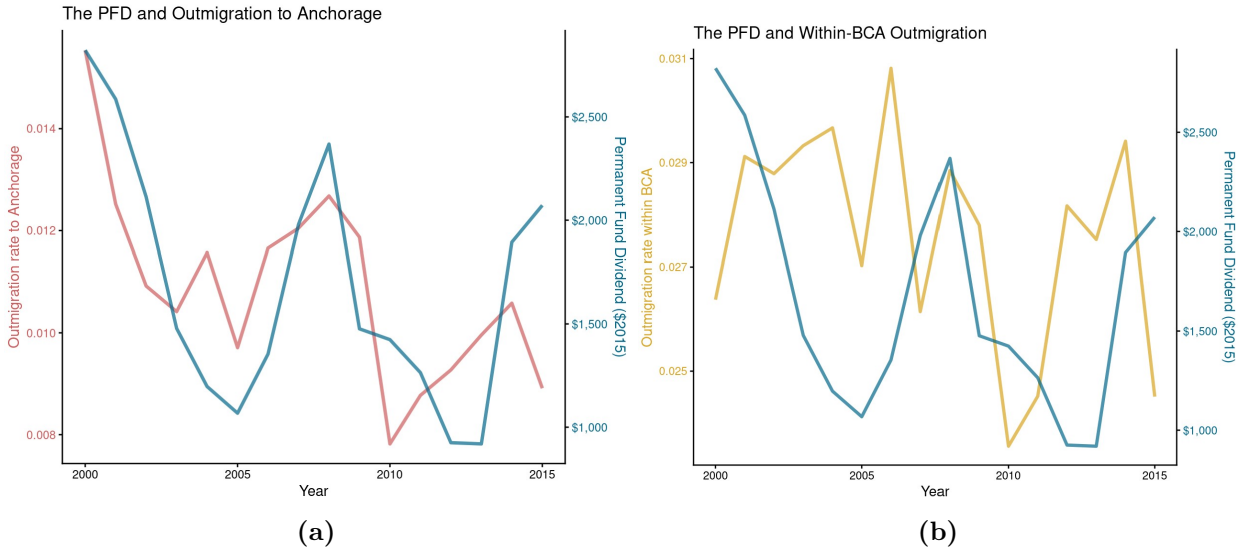


Figure 4: The PFD and rural out-migration rates. (a) Median out-migration rate to Anchorage from rural Alaska, and (b) median out-migration rate from rural Alaska to other communities within the same BCA. Out-migration is measured as the number of migrants divided by the origin community's population. Both panels compare the out-migration rate (y-axis, left) with the value of the PFD (y-axis, right), measured in 2015 USD.

4.1.2 Temperature

We use thawing degree days (TDD) as our measure of heat exposure, and as the empirical analog to our theoretical model's heat shock H_0. Let T_{igt} equal the average temperature in area i on day g in year t. Thawing degree days H_{it} measures total above-freezing heat accumulation within a year t in a given area i:

[13] We do not consider out-of-state migration. Alaska residency is a prerequisite for receiving the PFD. Therefore, individuals who move outside of the state do not apply for a PFD and therefore disappear from the PFD application database. Thus, our data are not representative of all rural-urban migration stemming from Alaska. However, they likely capture migration of lower-income populations, as moving outside the state has an additional cost: giving up the opportunity to receive the PFD.

Table 2: Estimation sample summary

Coverage						
Community-years	5,074					
Communities	321					
Years	16					
Years covered	2000–2015					
Variables						
	N	Mean	SD	Min	P50	Max
Out-migration rate, total (%)	5,074	8.57	7.09	0	7.14	100
Out-migration rate, Anchorage (%)	5,074	1.81	2.73	0	1.09	54.54
Out-migration rate, within-BCA (%)	5,074	3.81	4.69	0	2.77	80
Out-migrants, total	5,074	58.79	131.44	0	19.01	1218
Out-migrants, to Anchorage	5,074	12.57	28.19	0	3	229
Out-migrants, within-BCA	5,074	33.22	93.61	0	6	965
Population	5,074	842.33	1,742.27	1	248	17,097
Permanent Fund Dividend ($2015)	16	$1,683	$575	$919	$1,476	$2,823
Per-capita wages ($2015)	4,850	$12,470	$14,902	$297	$11,008	$905,275*
Employment Share < $5,000/yr	4,912	0.29	0.12	0	0.27	0.84
Employment Share < $10,000/yr	4,912	0.42	0.15	0	0.41	1
Thawing degree days (H_{it})	5,074	1,699.10	324**	231.9	1,736.6	2,699.8
Climate Priming Index (D_{it})	5,074	3.57	0.74**	1.24	3.51	5.61

Note: the descriptive statistics in this table describe our estimation sample of rural Alaskan communities, and therefore do not include the cities of Anchorage, Fairbanks, or Juneau.

*This large value is attributable to a single year in which the North Slope oil community of Prudhoe Bay/Deadhorse had 2 residents. The vast majority of community-years with available wage data (4761/4850 = 0.98) have per capita wages less than $30,000.

**After partialling out community and year fixed effects, the within-community standard deviations of H_{it} and D_{it} are 62 and 0.46, respectively. We standardize H_{it} and D_{it} by these values in our empirical analysis.

$$H_{it} = \sum_{g=1}^{365} \mathbf{1}[T_{igt} > 0°C] \times T_{igt}$$

TDD captures the above-freezing heat accumulation that leads to reductions in the marginal productivity of subsistence effort, motivating our model's income erosion effect. Further, heat accumulation is also a key predictor of physical environmental degradation in permafrost-rich areas (Spicer and Bolton, 2025; USACE, 2019), the channel through which our model's disamenity effect operates. We use data on thawing degree days at the 1km^2 × year resolution, obtained from the US Geological Survey's Climate Priming Index dataset (Spicer and Bolton, 2025), and average all TDD values within a 5km radius of each community's centroid in a given year.[14] Alaska communities experience roughly 1,700 thawing degree days per year (Table 2), with considerable spatial variation within a year (Figure 5a) and warming over time (Figure A5).

4.1.3 Environmental quality

We use the USGS Climate Priming Index to empirically proxy $d(H_t)$, which captures how heat alters environmental quality changes over time. The Climate Priming Index is used to predict thermokarst initiation—events caused by coastal erosion, subsidence, and permafrost thaw—based on six inputs: freezing degree days, thawing degree days, summer precipitation, winter precipitation, and early winter precipitation from the *previous year* $t-1$, and H_{it}, thawing degree days from the contemporaneous year t.[15] We denote the Climate Priming Index value for community i in year t as $D_{it} = d(H_{it}, \mathbf{W}_{it-1})$, where $\mathbf{W}$ denotes a vector of the five lagged inputs comprising the index.

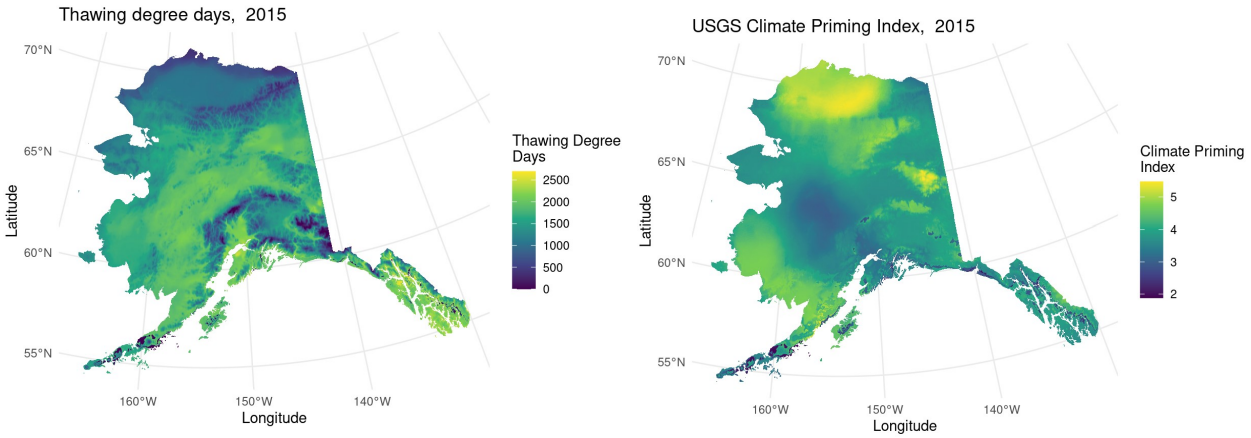
The Climate Priming Index has several properties which make it an ideal empirical proxy for $d = d(H_t)$. The lagged weather inputs $\mathbf{W}_{it-1}$ provide variation in D_{it} independent of variation in heat. This feature lets us separately identify migration responding to heat shocks from those responding to environmental degradation. The index also strongly predicts permafrost dynamics in areas with both continuous and discontinuous permafrost (Table A.3). Thus, the index provides an exogenous proxy for land degradation with extensive geographic coverage.

Like heat exposure, D_{it} has increased over time in rural Alaskan communities (Table A.2). The spatial distributions of H_{it} and D_{it} across Alaska demonstrate that high summer heat exposure often coincides with environmental degradation in some areas (like Western Alaska), but not others (Figure 5). This imperfect correlation, driven by the other atmospheric

[14] The TDD data was aggregated from downscaled monthly values of the CRU Time Series 4.0 climate dataset (Harris et al., 2020), which provides 1km^2 weather data interpolated from an extensive network of stations.

[15] Like thawing degree days, the underlying data for all weather inputs to the Climate Priming Index are sourced from the CRU Time Series 4.0 dataset (Harris et al., 2020). The Climate Priming Index identifies years in which measures of these inputs are extreme relative to their historical distributions (1901 to 2005). The index ranges from 0 to 6, with higher values indicating more extreme conditions (Spicer and Bolton, 2025).

drivers of environmental degradation, provides the variation required to separately identify the income erosion and disamenity effects of H_{it} on rural-urban migration.



(a) **(b)**

Figure 5: Heat and environmental degradation. Grid-cell level (a) thawing degree days and (b) Climate Priming Index, 2015

4.1.4 Economic and subsistence conditions

Our model illustrates that a community's migration response to heat shocks will depend on how its population is distributed in the feasibility-desirability space (Figure 3). To construct proxies of the distribution of liquid resources in a community, we use information from the DLWD's Alaska Local and Regional Information (ALARI) dataset, which includes annual earned income derived from linked unemployment insurance and PFD application data. We use two pieces of information: total per capita wages and employment shares within five discrete wage bins. During our study period, average per-capita wage income in Alaska was $12,000 (2015 USD; Table 2). Relative to this benchmark, the average PFD is sizable, accounting for 13 percent of per-capita wages. The share of employed individuals earning less than $5,000 in wages is often high, averaging 29%. The wage distribution is relatively uniform (Figure A6) and remains largely constant over time (Figure A7). We also use survey data on community subsistence harvests from the Alaska Department of Fish and Game to examine heat's effect on subsistence hunting productivity as a plausible mechanism for the income erosion effect.

4.1.5 Sample filtering

We make several restrictions to our sample. Given our focus on rural-urban migration, we remove Alaska's three largest cities: Anchorage, Fairbanks, and Juneau. We also remove island communities that are not included in the CRU TS 4.0 climate data, for which we are not able to calculate H_{it} and D_{it}. The temporal dimension of our panel extends from 2000 to 2015, the years in which the ALARI data, the DLWD migration flow data, and the climate data intersect. Our panel is unbalanced because several communities are missing

years in either the ALARI or DLWD migration datasets.[16] Our final panel consists of 321 communities over 16 years, for a total of 5,074 observations.

4.2 Timing

Our empirical approach uses idiosyncratic within-community shocks to identify their effects on out-migration, rather than relying on longer-horizon changes that may be correlated with other determinants of rural-urban migration (Azémar et al., 2026). This approach takes advantage of the within-year sequencing of the heat and income shocks we study (Figure 6). Out-migration is constructed using address data from the PFD application cycles occurring from January 1–March 31 in years t and $t+1$. Thawing degree days largely accumulate between May and September, directly between PFD application cycles (Figure A8). Additionally, the PFD amount is announced in mid-September and disbursed in October, directly after summer heat accumulation but prior to the next application cycle. Therefore, the dividend can plausibly serve as a liquidity relief mechanism for individuals who may desire to migrate but whose liquid assets were eroded by summer heat. Our migration data are thus well-suited to identify this effect, if it exists.

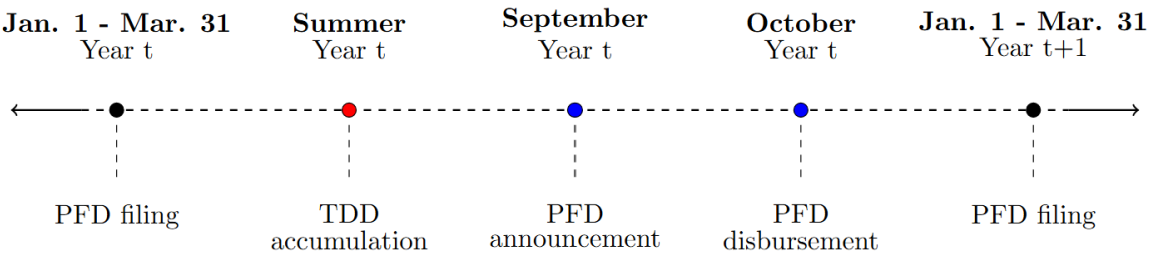


Figure 6: Timing. The temporal structure of within-year heat and income shocks.

4.3 Estimation

Our estimation strategy is directly informed by our conceptual framework, recognizing that the total effect of a heat shock, H, on a community's out-migration rate, M, can be expressed as the sum of the income-erosion and disamenity effects:

$$\frac{\mathrm{d}M}{\mathrm{d}H} = \underbrace{(\beta_1 + \alpha_1 Y)}_{\text{Income Erosion}} + \underbrace{(\beta_2 + \alpha_2 Y) d_H}_{\text{Disamenity}}, \tag{9}$$

where β_1, β_2, α_1, and α_2 denote the parameters from our conceptual model (Table 1), Y denotes unearned income shocks, and d_H denotes heat's first-order effect on changes in environmental quality over time.Equation 9 shows that the income erosion effect operates directly through H; in contrast, the disamenity effect operates indirectly through heat-induced degradation in environmental quality d_H. Isolating these effects therefore requires two estimating

[16] 294 communities have all 16 years, 18 have 15 years, 5 have 14 years, and 4 have less than 14 years.

equations: one which estimates how H affects D, and one which simultaneously estimates how H and D each individually affect out-migration:

$$D_{it} = \phi_i + \psi_t + d_H H_{it} + \mathbf{W}'_{it-1}\mathbf{\Theta} + \nu_{it} \tag{10}$$

$$m^A_{it} = \exp(\phi_i + \psi_t + \lambda_i Y_t + \beta_1 H_{it} + \beta_2 D_{it} + \alpha_1 H_{it} Y_t + \alpha_2 D_{it} Y_t + \tilde{\mathbf{W}}'_{it}\mathbf{\Upsilon} + \ln(P_{it})) + \epsilon_{it} \tag{11}$$

where m^A_{it} denotes out-migration counts, and ϕ_i and ψ_t are community and year fixed effects. We include lagged weather variables, $\mathbf{W}_{it-1}$, in Equation 10, consistent with the construction of the Climate Priming Index, D_{it}. Contemporaneous weather controls and their interactions with Y_t, denoted as $\tilde{\mathbf{W}}_{it}$, are included in Equation 11 to address their potential correlation with heat shocks and migration decisions (Auffhammer et al., 2013).[17]

Equation 10 linearly approximates the contemporaneous relationship between heat and environmental degradation. Although this relationship is largely mechanical, because thawing degree days is a component of the Climate Priming Index, an estimate of d_H shows how much environmental degradation is driven by contemporaneous heat and lets us scale heat's disamenity effect in Equation 9 by its relationship with environmental quality. We estimate Equation 10 using ordinary least squares.

Our main coefficients of interest are in Equation 11: β_1, β_2, α_1, and α_2. These coefficients are the empirical analogs of our theoretical parameters, allowing us to directly test the hypotheses in Table 1 and understand how liquidity constraints shape migration responses to environmental change. We estimate Equation 11 using Poisson pseudo-maximum likelihood (Santos Silva and Tenreyro, 2006) with a log-population offset $\ln(P_{it})$, allowing us to interpret the dependent variable as the out-migration rate and accommodating out-migration rates of zero, which are often observed in the data.[18]

Our approach modifies the traditional two-way fixed effects estimator by including community-specific slopes for the Permanent Fund Dividend, $\lambda_i Y_t$. These community-specific PFD slopes allow for differential out-migration responses to the PFD across communities and are necessary for unbiased estimation of the coefficients α_1 and α_2 in Equation 11. While the fixed effects ϕ_i and ψ_t remove *additive* time-invariant community-specific confounders and time-varying aggregate shocks, aiding the identification of β_1 and β_2, they do not purge *interactions* of time-invariant heterogeneity correlated with the error term. If one of the interacted variables is correlated with time-invariant unobservables that moderate the other interacted variable's effect on the outcome, the estimated coefficient on the interaction term will be biased (Balli and Sorensen, 2013; Giesselmann and Schmidt-Catran, 2022; Muris and Wacker, 2026).

[17] The contemporary weather controls include freezing degree days, winter precipitation, summer precipitation, and summer precipitation squared. As discussed in Feigenberg, Ost, and Qureshi (2025), failure to interact these controls with a moderator variable (Y_t here) can potentially result in model misspecification and biased estimates.

[18] Appendix C shows that our PPML specification estimates semi-elasticity versions of the theoretical parameters identified in Section 3, which represent level changes in the migration rate. Because these semi-elasticities are re-scaled versions of our theoretical parameters, qualitative tests of these parameters are equivalent to testing our hypotheses. For readability, we use the same notation for the empirical estimates and theoretical estimands.

This concern is plausible in our setting because income and uninsured environmental risk are often negatively correlated (Barrett and Schofield, 2026). For example, if communities with higher average heat accumulation are also lower-income on average, α_1 could erroneously capture how the marginal dollar of unearned income moderates the relationship between poverty and out-migration, rather than between heat and out-migration. Our specification addresses this potential bias by directly absorbing it in the community-specific PFD slopes $\lambda_i Y_t$, allowing α_1 and α_2 to be interpreted as the moderating effect of the marginal dollar of unearned income on the relationships between heat accumulation and out-migration and environmental degradation and out-migration.

4.4 Identification

Identification of β_1 and β_2 stems from within-community deviations in H_{it} and D_{it}. Additionally, their identification relies on the fact that the Climate Priming Index, D_{it}, is not determined solely by thawing degree days, H_{it}. Specifically, β_2 is identified by within-community variation in lagged index inputs, $\mathbf{W}_{it-1}$, that is strong enough to induce environmental degradation while holding contemporary heat accumulation constant. Similarly, β_1 is identified by within-community variation in contemporary heat, H_{it}, from years in which lagged index inputs were not strong enough to induce variation in D_{it}. Equation 11 uses these sources of variation to compare out-migration within the same community over time in response to different exposures to heat accumulation and environmental degradation. [19]

In addition to variation in H_{it} and D_{it}, identification of α_1 and α_2 relies on temporal variation in the Permanent Fund Dividend. Specifically, as we show in Appendix E, α_1 is identified by variation in $Y_t(H_{it} - \overline{H_i})$ after controlling for the community-specific PFD slopes $\lambda_i Y_t$. This variation is analogous to an exposure design in which idiosyncratic within-community variation in H_{it} determines community i's exposure to a universal shock of Y_t. PFD disbursements and H_{it} are generally uncorrelated (Figure 11), providing independent sources of variation for estimating α_1. We identify α_2 similarly by using variation in the interaction of Y_t and within-community shocks in D_{it}.

Causal interpretation of our estimates relies on two assumptions. First, within-community deviations in both H_{it} and D_{it} are uncorrelated with unobservable determinants of out-migration, net of time-varying common shocks. While this assumption is customary (Dell, Jones, and Olken, 2012), it would be violated if these deviations are spuriously correlated with migration due to common unobserved trends in both. Second, temporal variation in PFD disbursements is uncorrelated with unobserved year-specific shocks that moderate the relationship between heat and migration. The Permanent Fund is diversified across global financial markets, its additions come mainly from reinvestment, and its dividend is calculated using net income from the fund's investments, averaged over the previous five years $t-1$ to $t-5$. Thus, the performance of the fund is exogenously generated, decoupling PFD payments from contemporaneous economic conditions in Alaska. Nevertheless, our identifying assumption could still be violated if the PFD series is spuriously correlated with temporal confounders which moderate the heat-migration relationship. We conduct a series

[19] Because the lagged weather variables $\mathbf{W}_{it-1}$ are excluded from Equation 11, we assume they affect migration only through contemporary environmental degradation. We discuss this exclusion restriction further in Section 5.6 and present supporting evidence in Appendix G.

of robustness checks in Sections 5.5 and 5.6 to evaluate the validity of these assumptions.

4.5 Inference

Migration rates may be autocorrelated within communities, as social networks or remittances sent by past migrants make future migration more likely (Carrington, Detragiache, and Vishwanath, 1996; Munshi, 2003; Mckenzie and Rapoport, 2007). This could induce temporal dependence within the residuals of Equation 11. Additionally, several determinants of migration are spatially correlated, which could induce cross-sectional dependence in the residuals of our estimating equation. Because $H_{it}Y_t$ and $D_{it}Y_t$ are the product of spatially correlated weather conditions and a universal shock, they are also likely to be correlated across communities. If present, both patterns of spatial correlation (regressor and residual) would necessitate further clustering for robust inference.

We therefore estimate specifications that allow for both serial correlation and spatial correlation within radii of 25 to 500 km (Conley, 1999). Across all specifications, standard errors are smaller than those obtained from community clustering alone, and generally decline as the bandwidth increases.[20] Therefore, community clustering likely represents the more conservative choice, and we report community-clustered standard errors. Finally, the time-series structure of the PFD motivates a specific concern: common year shocks to the heat-migration relationship could induce cross-sectional dependence that is not accounted for by community or spatial clustering. We therefore conduct randomization inference, assigning 999 permutations of Y_t across years and re-estimating the model on each. This procedure tests the null hypothesis that the PFD does not moderate the heat-migration relationship without imposing assumptions about cross-sectional dependence in the data. Results remain statistically significant at conventional levels (Appendix F).

5. Results

Table 3 presents our estimation results, starting with several initial specifications in Columns (a-c) and ending with our main specification in Column (d). This sequential presentation demonstrates how the income erosion effect, the disamenity effect, and the moderating role of unearned income act together to obscure the mechanisms underlying migration responses to environmental change in aggregate relationships.[21] We first present our model parameter estimates, separating the total, income-erosion, and disamenity effects of heat on out-migration. We then present evidence on the mechanism underlying the income erosion effect, discuss the qualitative evidence supporting the trapped populations hypothesis, and conclude with several robustness checks.

[20] This is related to the phenomenon examined by Lehner (2026), who finds that allowing for arbitrary correlation outside of the true radius of spatial correlation can spuriously and incorrectly shrink standard errors. As shown in Appendix F and consistent with these findings, we are unable to detect spatial dependence in residuals even within very narrow distance bandwidths.

[21] Appendix D provides a detailed derivation of each estimated coefficient in Columns (a) through (c) as functions of our four theoretical parameters, which are then directly estimated in Column (d). This demonstrates how countervailing mechanisms push against each other to obscure the estimated effects of environmental change on migration in our initial specifications.

Table 3: The effect of thawing degree days, environmental degradation, and PFD payments on rural-urban out-migration

		(a)	(b)	(c)	(d)
Variable	**Estimand in (d)**	m_{it}^A	m_{it}^A	m_{it}^A	m_{it}^A
H_{it}	β_1	0.011	0.005	-0.052	-0.098**
		(0.011)	(0.011)	(0.038)	(0.039)
$H_{it} \times Y_t$	α_1			0.035*	0.055***
				(0.019)	(0.020)
D_{it}	β_2		0.024***		0.061**
			(0.007)		(0.028)
$D_{it} \times Y_t$	α_2				-0.016
					(0.015)
Observations		4,936	4,936	4,936	4,936
Weather Controls		Yes	Yes	Yes	Yes
Community-specific PFD slopes		Yes	Yes	Yes	Yes
Community FE		Yes	Yes	Yes	Yes
Year FE		Yes	Yes	Yes	Yes

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
H_{it} and D_{it} are measured in units of within-community standard deviations. Y_t is measured in \$1000 (2015 USD). Standard errors clustered by community.

Table 4: The effect of thawing degree days on environmental degradation

		(1)
Variable	**Estimand**	D_{it}
H_{it}	d_H	0.218***
		(0.013)
Observations		4,734
Lagged weather inputs		Yes
Community FE		Yes
Year FE		Yes

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
This table presents the estimation results for the parameter d_H in Equation 10. H_{it} and D_{it} are measured in units of within-community standard deviations. Standard errors clustered by community.

5.1 Bundled Specifications

Column (a) presents the estimated total effect of heat shocks, H_{it}, on the rural-urban out-migration rate. We find that a one-standard deviation increase in heat induces a 1.1-percent increase in the migration rate. However, we cannot reject the null hypothesis that this effect is equal to zero (p-value = 0.27). As Equation 9 shows, this estimate combines the income erosion and disamenity effects, which likely push migration in opposite directions. Thus, while this finding may correctly reflect the absence of a causal relationship between heat and migration, it could also reflect the theoretical ambiguity underlying an aggregate relationship that bundles countervailing mechanisms.[22] Moreover, both effects are averaged across the observed range of the PFD, obscuring any offsetting heat-driven migration responses to unearned income.

Column (b) unbundles the estimate in Column (a) by including D_{it} as a regressor. The resulting coefficient on H_{it} therefore represents the income erosion effect, and the coefficient on D_{it} represents the disamenity effect. Because this specification does not allow either relationship to be moderated by unearned income, both estimates average across the observed range of the PFD. The estimates in Column (b) indicate that the total effect of heat is composed of two parts. First, consistent with a disamenity effect, a one-standard-deviation increase in environmental degradation increases the rural-urban migration rate by 2.4 percent (p-value = 0.001). Table 4 confirms that heat shocks induce environmental degradation, equivalent to an elasticity of 0.771 (95% CI [0.683, 0.857]) evaluated at the means of both variables.[23] Together, these estimates imply that a one-standard-deviation increase in heat increases the rural-urban migration rate by 0.5 percent (95% CI [0.2, 0.8]), on average, through its indirect effect on environmental degradation. Second, a one-standard-deviation increase in heat directly increases the rural-urban out-migration rate by 0.5 percent (p-value = 0.57), but this effect is statistically indistinguishable from zero. While this may reflect the absence of an income erosion effect, it could also mask unearned income's offsetting effect on income erosion. Thus, this specification cannot inform whether liquidity constraints shape migration.

Column (c) presents an alternative specification that allows unearned income to moderate the total effect of H_{it} on migration by regressing out-migration on thawing degree days and its interaction with PFD disbursements. In this specification, a one-standard-deviation increase in heat reduces the out-migration rate by 5.1 percent (p-value = 0.16) in the absence of the PFD, but this effect is not statistically distinguishable from zero.[24] In contrast, the estimated coefficient on the interaction term indicates that the addition of $1,000 in unearned income increases the migration rate's response to heat by 3.5 percent (p-value = 0.08), illustrating that the muted effect of heat on migration in Columns (a) and (b) may be due to unearned income's offsetting effect on income erosion. However, like Column (b), this specification does not inform the trapped populations hypothesis: while the effect of heat is allowed to vary with unearned income, it bundles the income erosion and disamenity effects by omitting

[22] For instance, this would be consistent with the findings of Hamilton et al. (2016), who find no significant difference in out-migration from Alaskan communities more- and less-affected by environmental change.

[23] Because Equation 10 includes $\mathbf{W}_{it-1}$, the sample size decreases relative to Table 3.

[24] Note that we do not observe years in which the PFD is equal to zero. Thus, the estimate in Column (c) represents a linear extrapolation.

D_{it} as a regressor.

5.2 Main Specification

Column (d) presents the results of our main specification in Equation 11, which jointly estimates how income erosion and disamenity effects shape migration and allows unearned income to moderate both. This specification provides estimates of the four parameters comprising our main hypotheses, resolves the theoretical ambiguity in the previous specifications, and informs the role of liquidity constraints in shaping migration responses to heat shocks.

We find that the effect of heat on out-migration, holding environmental degradation D_{it} constant, β_1, is negative and statistically different from zero in the counterfactual absence of the PFD: a one-standard-deviation increase in thawing degree days decreases the out-migration rate by 9.3 percent (p-value = 0.011). This estimate is consistent with an income erosion effect in which heat renders migration infeasible for individuals with limited resources.

Our estimate of α_1, the moderating effect of unearned income on migration responses to heat, is positive and statistically different from zero: an additional \$1,000 in unearned income increases the migration response to heat by 5.7 percent (p-value = 0.007). Figure 7 shows that a one-standard-deviation increase in H_{it} reduces the rural-urban migration rate by roughly 4.7% at the lowest observed PFD (\$919), all else equal. The income erosion effect of heat is completely offset by unearned income from the PFD at approximately \$1,800, and by \$2,823, the largest value of the PFD, a one-standard-deviation increase in heat increases migration by roughly 5.8%.[25] Thus, unearned income offsets the initially negative income erosion effect of heat, consistent with the dividend making migration more feasible for individuals with limited resources.

Turning to the disamenity effect, we estimate β_2 to be positive and statistically different from zero: a one-standard-deviation increase in environmental degradation in the absence of the PFD, holding heat constant, increases the migration rate by 6.3% (p-value = 0.03). The point estimate of α_2 is negative but not statistically different from zero, consistent with D_{it} primarily increasing the utility of migration but minimally affecting its feasibility.

The estimates in Column (d) illustrate how countervailing mechanisms can obscure adaptive responses to environmental shocks in observational data. Specifically, using the decomposition of heat's total effect on migration in Equation 9, the total effect of heat on migration is composed of a -0.57% (95% CI [-2.68, 1.54]) income erosion effect and an offsetting 0.75% (95% CI [0.4, 1.11]) positive disamenity effect from a one-standard-deviation increase in heat, evaluated at the average dividend (\$1,683). These produce a total effect of 0.18% (95% CI [-1.93, 2.29]), statistically indistinguishable from zero.[26] Together, these two effects yield a

[25] The switch point at which the PFD completely offsets the income erosion effect, Y^*, is equal to $-\frac{\beta_1}{\alpha_1}$. We estimate that $Y^* = \$1,787$, with a 95% delta method confidence interval of $[\$1,415, \$2,159]$. Encouragingly, Y^* and its 95% confidence interval fall within the observed range of the PFD. Although our linear specification is somewhat restrictive in that it implies such a switch point exists, it imposes no assumptions on its magnitude. In Appendix I, we discuss the theoretical justification for possible nonlinearities in this effect, and provide suggestive empirical evidence to support this possibility.

[26] This estimate differs from the one in Column (a) of Table 3 because Equations 10 and 11 are estimated using different samples and control variables: Equation 10 excludes observations from the first year of the sample because it uses lagged weather controls, and does not control for contemporaneous weather

negative migration response to heat in the absence of the PFD, but a positive response when the PFD exceeds $1,647 (Figure 7). Thus, failing to account for heat's indirect effect on environmental degradation and income's moderating role in migration responses can obscure the relationship between climate shocks and adaptation behavior.

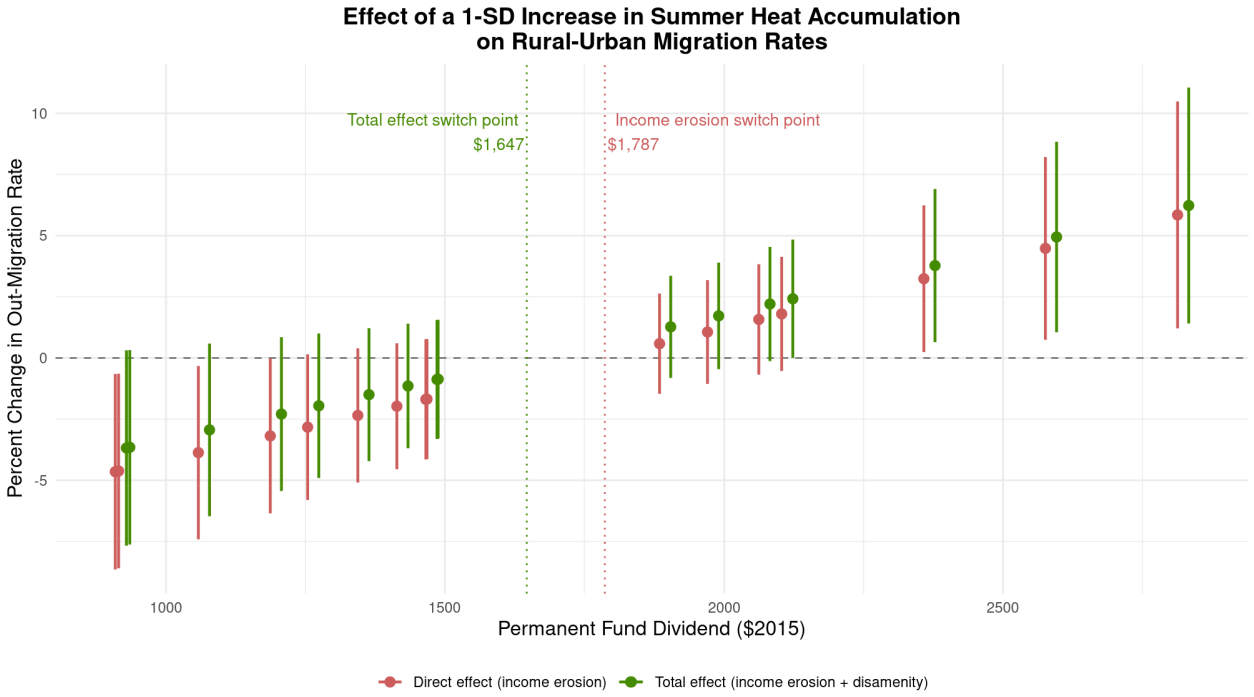


Figure 7: The PFD's moderating effect on the migration response to heat accumulation. This figure plots the effect of a one-standard-deviation increase in heat accumulation on rural-urban migration rates at observed PFD values for the total effect of heat (in green) and the income erosion effect alone (in red), as well as their switch points. These estimates represent heat's effect on aggregate community-level out-migration rates; therefore, the total effect also includes disamenity-driven moves by individuals with more liquid resources who are less likely to be constrained. These moves offset part of the income erosion effect in the aggregate, so the total effect of heat turns positive at a lower dividend ($1,647) than the income erosion effect alone ($1,787).

5.3 Heat-Driven Migration Facilitated by the Permanent Fund Dividend

To understand the meaningfulness of the PFD's contribution to facilitating heat-driven migration, we ask: how many individuals did the PFD enable to migrate in response to above-average summer heat accumulation? Let $\hat{m}^A_{it}(H, Y)$ denote the predicted number of migrants in community i and year t given summer heat accumulation of H and a PFD value of Y.

or community-specific PFD slopes $\lambda_i Y_t$, which are used in Equation 11. Moreover, we use Equation 9 to reconstruct the total effect of heat using the estimates in Column (d) and the sample average PFD. Because PPML weights observations by expected counts, the estimate in Column (a) is evaluated at a weighted average PFD level. If higher PFD values increase migration, then this count-weighted average PFD is likely larger than the simple average, which explains why the point estimate in Column (a) is larger in magnitude than the total effect we report here.

The counterfactual heat-driven migration enabled by the PFD is:

$$\mathbb{M}_{it} = \underbrace{[\hat{m}^A_{it}(H_{it}, Y_t) - \hat{m}^A_{it}(\bar{H}_i, Y_t)]}_{\text{Heat-driven migration with the PFD}} - \underbrace{[\hat{m}^A_{it}(H_{it}, 0) - \hat{m}^A_{it}(\bar{H}_i, 0)]}_{\text{Heat-driven migration without the PFD}}$$

We sum $\mathbb{M}_{it}$ over all community-years with positive heat shocks ($H_{it} - \bar{H}_i > 0$).[27] This restriction focuses on hotter-than-average years in which heat's income erosion effect reduces the feasibility of migration, and during which unearned income's role in reversing this effect is economically relevant.

We find that the PFD facilitated roughly 4,179 (95% CI [1,469, 6,891]) additional rural-urban moves in response to above-average heat accumulation between 2000-2015. Our estimates predict that above-average heat would have reduced migration to Anchorage by roughly 5,028 moves in the absence of the PFD, in comparison to only 848 moves with the observed PFD. Unearned income from the PFD therefore offsets roughly 83% of heat's negative effect on migration. This induced migration represents 13% of the total migration flows to Anchorage observed in these above-average-heat community-years (33,070 individuals total).

5.4 Evidence of the Income Erosion Effect

Our interpretation of β_1 as an income erosion effect rests on the claim that heat reduces the resources available for migration—for example, by increasing the cost of meeting subsistence needs. In principle, a negative β_1 could also reflect other mechanisms, such as warmer summers making it more pleasant to remain at the origin. To provide evidence for the income erosion mechanism, we examine how heat affects the productivity of subsistence hunting in rural Alaska.

We use the Alaska Department of Fish and Game's Community Subsistence Information System, which surveys a rotating subset of communities about their subsistence harvests. For each surveyed community-year, we observe per-capita pounds harvested and the shares of residents who attempted to harvest and who successfully harvested each resource. Following a Gordon-Schaefer production model (Gordon, 1954), we use the ratio of successful to attempted harvesters to measure the success rate of subsistence hunting effort. We focus on land mammals, such as moose and caribou, whose movements and breeding patterns are most directly disrupted by summer heat (McNeeley and Shulski, 2011; Davidson, 2020). We regress the harvesting success rate on H_{it}, D_{it}, community and year fixed effects, and the weather controls from our main specification. Because surveys are sparse, we use two estimation samples: all available survey years (1985 to 2015) and our study period (2000 to 2015). Additional details are provided in Appendix A.

We find that heat substantially reduces hunting success: in the 1985–2015 sample, a one-standard-deviation increase in thawing degree days reduces the success rate by roughly 8 percentage points, relative to a mean of 76 percent (Table 5). The estimate for 2000–2015 is nearly five times larger but less precise, reflecting the smaller sample. In contrast, we do not detect a statistically distinguishable effect of heat on per-capita land mammal harvests in either sample. Together, these results suggest that households maintain harvests in hot years

[27] See Appendix J for further details on how we use the results of our main specification to calculate $\mathbb{M}_{it}$.

despite lower productivity, requiring more hunting time, additional trips, or new equipment, and drawing down the time and resources available for other uses, including migration. Because we do not observe hunting effort or expenditures directly, we view this as suggestive evidence of an income erosion effect of heat.

Table 5: The effect of thawing degree days on land mammal subsistence harvests

	Success rate		Harvest (lbs per capita)	
	(1)	(2)	(3)	(4)
H_{it}	-0.078***	-0.389*	-15.9	36.0
	(0.024)	(0.199)	(13.3)	(49.2)
Outcome mean	0.76		83	
Timeframe	1985–2015	2000–2015	1985–2015	2000–2015
Observations	331	116	331	116
Communities	107	44	107	44
Weather controls	Yes	Yes	Yes	Yes
Community FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
H_{it} is measured in standard deviations. The success rate is the share of residents who successfully harvested land mammals divided by the share who attempted to. Standard errors clustered by community. See Appendix A for details.

5.5 The Trapped Populations Hypothesis

Estimates of our main specification indicate that unearned income offsets and, eventually, reverses the negative impact of heat shocks on migration. But this alone is not sufficient evidence of the trapped populations hypothesis. According to our conceptual model, $\beta_1 < 0$ and $\alpha_1 > 0$ is only a sufficient (but not necessary) condition if migration is an inferior good (see Table 1). Further, the model indicates that $\alpha_2 < 0$ is a sufficient (but not necessary) condition for migration to be classified as an inferior good. While we strongly reject the null hypothesis that $\beta_1 \geq 0$ or $\alpha_1 \leq 0$, we cannot reject the null hypothesis that $\alpha_2 \geq 0$, and thus cannot conclude that migration is an inferior good. Given this ambiguity, we further investigate the trapped populations hypothesis by conducting a series of heterogeneity analyses that do not depend on whether migration is a normal or inferior good.

The channel through which heat shocks and unearned income affect out-migration depends on the distribution of a community's population in feasibility-desirability space, as depicted in Figure 3. If the population is concentrated around the feasibility threshold, δ, our results likely reflect the feasibility-driven mechanism. Conversely, if the population is concentrated above the feasibility threshold, our results likely reflect the desirability-driven mechanism (see Figures A14 and A16).[28] Because the population of low-wage communities is more likely to be concentrated around the feasibility threshold, we split our sample into communities

[28] In similar fashion, Bazzi (2017) finds that positive income shocks induce migration from individuals in the lower half of the asset distribution but not the upper half, providing evidence of liquidity constraints.

above and below the sample average median per-capita wage,[29] and re-estimate our main specification on each.[30] Consistent with the trapped populations hypothesis, we find that our main results are primarily driven by communities in the lower half of the per-capita wage distribution: estimates of both α_1 and β_1 are considerably larger in absolute value for communities in the lower half of the wage distribution, while they are small and not statistically different from zero for communities in the upper half of the wage distribution (Table 6).[31]

Table 6: Heterogeneity, cross-community wage distribution

		Below Median Wage	**Above Median Wage**
Variable	**Estimand**	m_{it}^A	m_{it}^A
H_{it}	β_1	-0.402***	-0.028
		(0.089)	(0.042)
$H_{it} \times Y_t$	α_1	0.217***	0.017
		(0.049)	(0.022)
D_{it}	β_2	0.129**	0.061**
		(0.062)	(0.031)
$D_{it} \times Y_t$	α_2	-0.047	-0.017
		(0.031)	(0.017)
Observations		2,417	2,455
Weather Controls		Yes	Yes
Community-specific PFD slopes		Yes	Yes
Community FE		Yes	Yes
Year FE		Yes	Yes

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Standard errors clustered by community.

The trapped populations hypothesis also requires moving costs to be sufficiently large to constrain migration. Therefore, lower-cost migration is less likely to respond to heat shocks if liquidity constraints are the primary explanation of our results. Alaska's bilateral migration flow data allow us to test this prediction, comparing out-migration to Anchorage with lower-cost out-migration to communities within the same Borough/Census area (BCA) as the origin community. If liquidity constraints drive our initial estimates, we should expect a smaller migration response to heat shocks among local, within-BCA moves (see Figure A15).[32] Consistent with this prediction, β_1 and α_1 are small and statistically indistinguish-

[29] More specifically,

[30] Though wages and assets need not move together, several institutional features suggest this is likely in rural Alaska. Subsistence conditions and high costs of living likely render the marginal propensity to consume high, preventing substantial savings-based accumulation of assets for low-wage individuals. Further, individuals in rural Alaska are less likely to hold the illiquid assets that traditionally decouple wealth and income, such as real estate and retirement accounts (Kaplan, Violante, and Weidner, 2014).

[31] Consistent with D_{it} acting as a shifter of non-consumptive utility that does not affect the feasibility of migration, β_2 is positive and statistically different from zero in both halves of the wage distribution.

[32] Angelucci (2015) uses a similar logic to provide evidence of migration-suppressing liquidity constraints, showing that Progresa transfers in Mexico increased high-cost international migration, but minimally affected low-cost internal migration.

able from zero for within-BCA moves (Table 7).[33]

Taken together, these heterogeneity analyses demonstrate that the manner in which unearned income moderates out-migration responses to heat shocks is consistent with the trapped populations hypothesis. We note that the findings from these analyses should not be interpreted as causal, as comparing migration responses across high- versus low-wage communities and long- versus short-distance moves may conflate other, confounding differences. For example, despite higher migration costs, the utility of migrating to Anchorage may exceed that of within-BCA destinations because of larger wage differentials. Nevertheless, the heterogeneous patterns we identify align with the theoretical mechanisms of liquidity constraints, providing empirical support for this interpretation.

Table 7: Heterogeneity, Anchorage vs. within-BCA moves

		Destination: Anchorage	**Destination: Within-BCA**
Variable	**Estimand**	m_{it}^{A}	m_{it}^{ABCA}
H_{it}	β_1	-0.098**	-0.006
		(0.039)	(0.027)
$H_{it} \times Y_t$	α_1	0.055***	0.005
		(0.020)	(0.014)
D_{it}	β_2	0.061**	0.002
		(0.028)	(0.023)
$D_{it} \times Y_t$	α_2	-0.016	-0.005
		(0.015)	(0.014)
Observations		4,936	4,936
Weather Controls		Yes	Yes
Community-specific PFD slopes		Yes	Yes
Community FE		Yes	Yes
Year FE		Yes	Yes

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
Standard errors clustered by community.

5.6 Robustness

We conduct a variety of robustness checks to evaluate the sensitivity of our results to alternative specifications and sample restrictions. Below, we discuss a subset of these robustness checks, which are described in further detail in the paper's appendices.

To address concerns that our results are driven by differential trends in rural-urban migration rates and heat exposure, we re-estimate our main specification with the inclusion of community- and BCA-level linear time trends, as well as their interactions with Y_t. Our estimates remain robust to their inclusion. Although the magnitudes of β_1 and α_1 decline moderately with the inclusion of community-specific trends, they remain significant at conventional levels (Table A.4).[34] Similarly, expectations of future PFD values could threaten

[33] Interestingly, our estimate of β_2 for within-BCA out-migration is very small and statistically indistinguishable from zero. If origin-level changes in D_{it} are positively correlated among nearby communities, this finding is consistent with a gravity model of migration in which individuals compare the environmental quality differential between the origin and various destinations when making location decisions.

[34] Additionally, the "switch point" at which the PFD begins to increase heat-driven migration is stable in

identification of the income erosion channel. Because the PFD is correlated over time,[35] individuals may form expectations about the PFD in year $t+1$ based on its value in year t. In this case, the PFD could moderate migration responses to heat by changing individuals' total expected lifetime wealth, instead of through changes in liquid assets. To provide evidence against this competing mechanism, we estimate a version of our main specification in Table A.7 which replaces Y_t with Y_{t+1}, the PFD value in the next year. Consistent with the contemporary PFD explaining our main results, none of these estimates are statistically different from zero.

Another threat to identification arises from the aggregate economic stimulus induced by the distribution of the PFD. For instance, disproportionate increases in the demand for labor (and wages) in Anchorage from the PFD's distribution could increase the utility of rural-urban migration. We view this as unlikely given previous work showing that the labor-market effects of the PFD on employment are small and transitory (Bibler, Guettabi, and Reimer, 2023). Appendix H provides further empirical evidence that the labor-demand mechanism is unlikely to drive our estimates and shows that it is inconsistent with the observed results if migration is inferior.

Spurious correlation between the PFD and unobserved year-specific shocks could also invalidate our research design if these shocks moderate the relationship between heat and rural-urban migration. The most plausible temporal confounder is the price of oil, which affects both household budgets in rural Alaska and migration costs. The real price of Alaska North Slope crude oil is indeed moderately correlated with the size of PFD disbursements ($\rho = -0.45$). We therefore estimate alternative specifications that allow annual oil prices to moderate the effects of H_{it} and D_{it}. Our main coefficients of interest attenuate modestly but remain statistically different from zero (Table A.5). Further, these specifications show that oil prices have no discernible moderating effect on the heat-migration relationship.

To ensure that no single year's PFD value drives our results, we re-estimate our main specification 16 times, dropping each year in turn. All coefficients of interest are similar in sign and magnitude across these leave-one-out specifications, and although several are imprecisely estimated, the majority remain statistically significant at conventional levels (Figure A13). Point estimates fluctuate around those from our main specification and always remain within the initial estimates' 95% confidence intervals. Additionally, changes in migration rates may be sensitive to the behavior of relatively few individuals when populations are small. We re-estimate our baseline specification excluding communities with an average population below 50. Our results are robust to this sample restriction (Table A.6), confirming that our results are not driven by disproportionate swings in migration rates in very small communities.

We also conduct several tests of our assumption that the impact of lagged weather controls on contemporaneous migration operates only through contemporaneous environmental degradation. If this exclusion restriction were violated, our estimate of β_2 could reflect a separate channel from our hypothesized disamenity effect and would remove the independent variation required to simultaneously identify β_1 and β_2. Appendix G discusses possible

magnitude across both trend specifications.

[35] During our sample, the correlation between Y_t and Y_{t+1}, the next year's PFD, was roughly 0.7.

violations of this assumption and provides evidence of its validity.

6. Discussion and Conclusion

This paper tests the trapped populations hypothesis—the premise that environmental shocks can increase involuntary immobility by eroding the resources needed to finance migration. Testing this hypothesis is difficult because environmental shocks and income are highly correlated in rural, resource-dependent economies where liquidity constraints are most likely to bind. We address this challenge in rural Alaska, where the Permanent Fund Dividend provides universal, unconditional variation in unearned income that is generated independently of local environmental conditions. We find that summer heat accumulation reduces rural-urban out-migration when the PFD is low, and that this relationship reverses as unearned income rises: the PFD fully offsets heat's income erosion effect at roughly $1,800, near the average observed payment. Heat also increases out-migration by degrading environmental quality. Because these income erosion and disamenity effects push in opposite directions, an aggregate specification that bundles these effects masks the underlying mechanisms at work, yielding a misleading null effect.

Several patterns indicate that unearned income moderates the migration response to heat primarily by easing liquidity constraints. Consistent with prior evidence (Angelucci, 2015; Bazzi, 2017), the moderating effect of the PFD appears only for costly, long-distance moves to Anchorage and only in communities in the lower half of the wage distribution, where constraints are most likely to bind. In contrast, the disamenity effect is present in both halves of the wage distribution, and we find no evidence that unearned income moderates this effect. Together with our conceptual framework, these heterogeneity tests reveal why the income erosion and disamenity effects of heat offset each other within a given community: responses from higher-wealth individuals who can afford disamenity-driven moves largely mask the immobilizing effect of income erosion on lower-wealth individuals who cannot, consistent with a risk-based, geographic poverty trap (Barrett and Schofield, 2026; Kraay and McKenzie, 2014).

Our work focuses on how environmental shocks shape aggregate migration flows, which has several limitations. We do not observe individual characteristics before and after migration, preventing us from assessing migrants' selection on productivity (Grogger and Hanson, 2011) or understanding how migration alters the composition of the urban labor force. As emphasized by Cattaneo et al. (2019), these potential effects of "climate migrants" on labor dynamics remain an important area of future research. Additionally, because we do not observe wages pre- and post-migration, we cannot calculate the welfare gains enabled by the PFD's easing of liquidity constraints. Similarly, we cannot assess whether the liquidity relief provided by the PFD enables in-situ adaptation, in addition to facilitating migration. Complementarities between migration and adaptation in place remain a fruitful avenue for future research.

Despite these limitations, our findings have implications for climate adaptation policy. If migration is a margin of adaptation to environmental change but commands high fixed costs,

liquidity constraints can limit its effectiveness precisely where exposure is greatest.[36] Our within-community estimates complement cross-country evidence that environmental shocks suppress migration from low-income areas (Cattaneo and Peri, 2016; Azémar et al., 2026), and show that cash transfers can partially relieve this constraint. They also suggest where transfers are most likely to enable adaptive migration: where environmental shocks erode the resources needed to move, rather than where shocks primarily reduce the amenity value of staying for households that can already afford to leave. Settings in which livelihoods and nutrition depend directly on environmentally sensitive resources, common in rural areas of developing economies with incomplete credit markets, are the most likely candidates. In settings where the disamenity effect more plausibly operates in isolation, such as much of the continental United States (Baylis et al., 2025), location choices are more likely to reflect compensating trade-offs between environmental disamenities, wages, and housing costs (Wrenn, 2024).

Finally, our findings underscore the importance of understanding the mechanisms through which environmental change affects adaptation behavior, such as migration. Our results show that even causally identified relationships can be misleading if the mechanisms underlying those relationships are not carefully understood (Ferraro and Hanauer, 2014; Reimer and Haynie, 2018). If the same shock operates through countervailing mechanisms, even the most well-identified empirical designs can yield misleading results. In our context, an aggregate relationship that bundles these countervailing mechanisms obscures rich underlying dynamics. This mechanism is likely to generalize to other settings in which credit markets are incomplete, and could partially explain the low estimates of willingness to pay for environmental quality in low-income areas (Greenstone and Jack, 2015; Kremer et al., 2011). Ultimately, understanding why people move in response to environmental change, and what prevents them from doing so, is just as important as understanding if they move in the first place.

[36] This point echoes that of Astier (2026), who argues that the role of trade in mitigating the damages of climate change (Gouel and Laborde, 2021) may be overstated if climate change increases trade costs.

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A. Subsistence Effort and the Income Erosion Effect

This appendix uses the Alaska Department of Fish and Game's survey data on subsistence harvests to establish suggestive quantitative evidence of the income erosion mechanism, through which summer heat lowers productivity, increases the expenses necessary to harvest a given level of resources, and decreases the disposable income necessary to finance migration costs. Though the data is relatively sparse and may suffer from sample selection concerns, it is one of most granular data sources available on community-level subsistence harvesting behavior in isolated rural areas, where similar data is typically absent entirely.

To motivate our approach, let the pounds per capita of resource category s harvested in community i in year t, Y_{it}^s, be generated following a Gordon-Schaefer production function (Gordon, 1954), as follows:

$$Y_{it}^s = c_{it}^s(H_{it}) \times E_{it}^s \times X_{it}^s(H_{it}) \tag{12}$$

where $c_{it}^s(H_{it})$ is a catchability coefficient, E_{it}^s is the total amount of harvesting effort in hours, and $X_{it}^s(H_{it})$ is the stock of category s available to community i at time t.

The catchability coefficient $c_{it}^s(H_{it})$ characterizes the ease of harvesting a given level of biomass, and the marginal productivity of effort is increasing in $c_{it}^s(H_{it})$. The coefficient is a decreasing function of H_{it}, i.e. $c_H < 0$ (McNeeley and Shulski, 2011). This represents how in hot years, effort must increase to maintain the same level of harvest, all else equal. In the case of land mammals we assume that $X_H \leq 0$, representing how the breeding and migration patterns of caribou and moose are disrupted in hot years, lowering the stock available of a community (Davidson, 2020).

The Alaska Department of Fish and Game's Community Subsistence Information System (CSIS) publishes survey data on Y_{it}^s, for $s \in \{LandMammals, Fish, MarineMammals\}$ and a selection of community-years. For each community-year, the CSIS also records $\psi_{it}^s = h_{it}^s/P_{it}$, the percentage of the total population which harvested resource s in year t, and $\phi_{it}^s = \tau_{it}^s/P_{it}$, the percentage of the total population which *tried to* harvest resource s in year t. The ratio of these two forms an extensive-margin "success rate," which can be used to proxy the catchability coefficient:

$$c_{it}^s \approx \psi_{it}^s/\phi_{it}^s = h_{it}^s/\tau_{it}^s \tag{13}$$

Thus, we can observe or approximate both Y_{it}^s and c_{it}^s for a sample of community-years. Effort E_{it}^s and the resource stock X_{it}^s are unobservable. However, we can observe how both Y_{it}^s and c_{it}^s change with H_{it}, and use this to infer how community-level hunting effort adjusts in response to increases in heat.

If we assume that there is negligible substitution in harvesting across the types in s, then because a certain "target harvest" is needed to survive, total harvests Y_{it}^s may be largely invariant to changes in H_{it}. If $c_H < 0$ but $Y_H = 0$ for land mammals, as expected, then we

know that effort must have increased to keep harvests constant.[37] Because effort is costly, this establishes evidence of the "income erosion" channel.

We first characterize subsistence harvests in Alaska communities. To do so, we filter the CSIS data to community-year observations which had non-NA values for four "per-capita pounds harvested" variables, corresponding to the following resource categories:

$$s \in \{Land\ Mammals, Fish, Marine\ Mammals, All\ Resources\} \tag{14}$$

This results in an unbalanced panel of 225 communities across 45 years, with 465 total observations. Let T_i denote the number of time periods that community i is observed in the panel, and let Y_{it}^{All} denote the total per capita harvests of all resources in community i in time t. For harvest categories $s \in \{LandMammals, Fish, MarineMammals\}$, we calculate the community-level average fraction of per-capita harvests s as follows:

$$\overline{\sigma_i^s} = \frac{1}{T_i} \sum_t \frac{Y_{it}^s}{Y_{it}^{All}} \tag{15}$$

Figure 8 plots $\overline{\sigma_i^s}$ for $s \in \{LandMammals, Fish, MarineMammals\}$. The mean shares for each resource are represented by the dotted vertical lines. Fish make up just over half of communities' harvests on average, and land mammals make up roughly a quarter. There is a large mass of zero harvests for marine mammals, representing areas outside of the North Slope Borough where the harvest of marine mammals is less common. Because of this, we only focus on land mammals and fish going forward.

To directly analyze heat's effect on total harvests Y_{it}^s and catchability c_{it}^s, and thus indirectly analyze its effect on effort, we begin with land mammals. We first construct c_{it}^{LM} and filter the CSIS data to community-years from 1985 to 2015 which had data on both Y_{it}^{LM} and c_{it}^{LM}, resulting in 226 communities. Only 110 communities appear for multiple years, and this shrinks to 107 when we merge the CSIS data with H_{it}.

Figure 9 plots the distributions of Y_{it}^{LM} and c_{it}^{LM} across all community-years in the land mammal panel. Land mammal harvesters are successful on average $\overline{c^{LM}} = 76\%$ of the time. On average, communities harvest $\overline{Y^{LM}} = 83$ pounds per capita each year.

Table 8 shows the results of linear regressions of Y_{it}^{LM} and c_{it}^{LM} on thawing degree days H_{it}, community and year fixed effects, and all weather controls used in our main analysis, including D_{it}, the Climate Priming Index. We estimate these models for both 1985–2015 and 2000-2015, the timeframe of our main analysis. The panel is unbalanced because the ADF&G does not survey every community in every year, rendering total observations significantly smaller than $N \times T$. Standard errors are clustered by community.

A few conclusions emerge from these regressions. First, columns (1) and (2) show that H_{it} decreases catchability c_{it}^{LM} in both the 30- and 15-year samples. Using the result from

[37] Barring increases in the stock of s in response to H, which is the opposite direction of the expected effect.

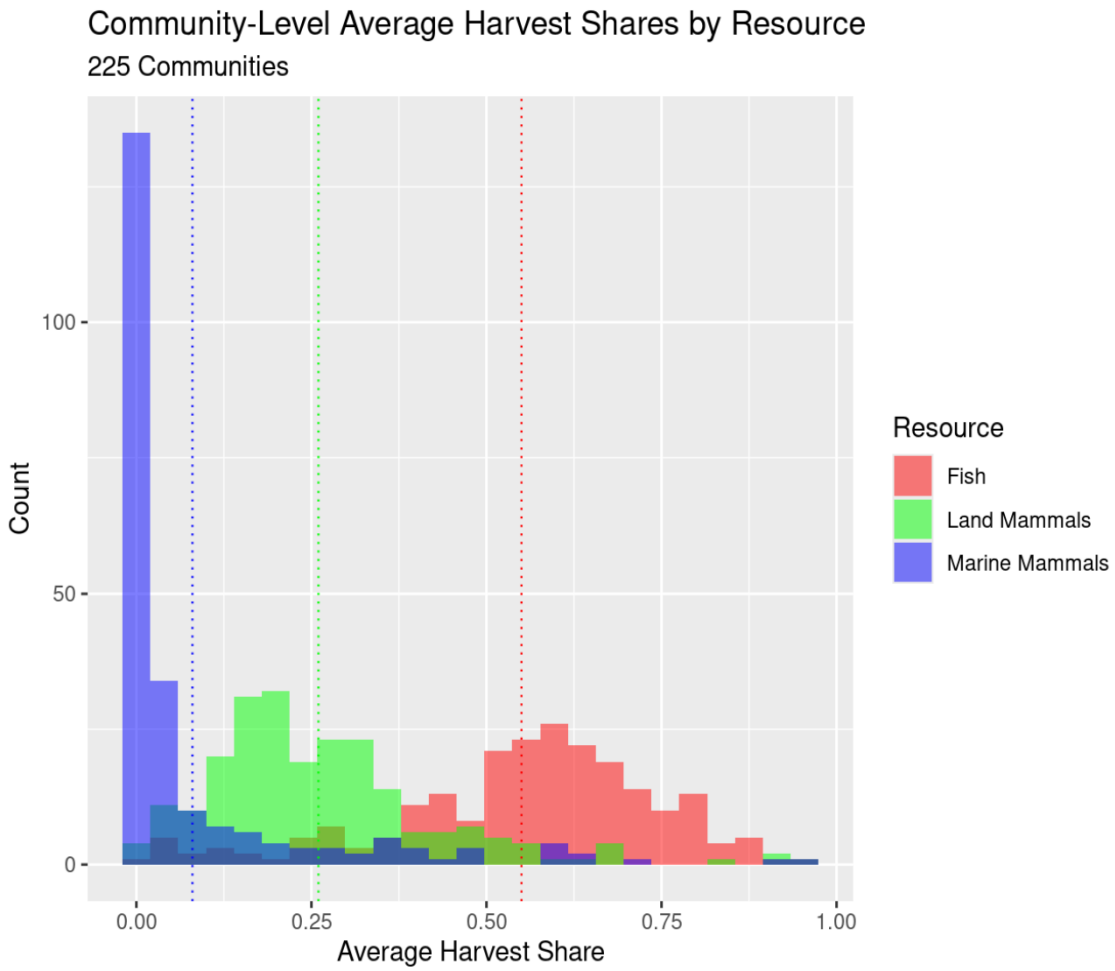


Figure 8: Resource shares

column (1), a standard deviation increase in H_{it} decreases c_{it}^{LM} by roughly 0.08, which is sizable compared to the average value of c_{it}^{LM}, 0.76. In the 2000–2015 sample, this effect is much larger, decreasing c_{it}^{LM} by roughly 0.389. However, as expected, this result is much less precisely estimated due to the smaller effective sample size. Additionally, Y_{it}^{LM} does not seem to be affected by heat accumulation in either sample. Thus, while total harvests remain constant in response to heat accumulation, this heat simultaneously decreases catchability. Effort likely increases to offset this loss in productivity, necessitating increases in input expenditures and lowering the hours available for wage labor.

For completeness, we then perform the same exercise with community-level fish harvests. We construct c_{it}^{F} and filter the CSIS data to community-years from 1985 to 2015 which have data on both Y_{it}^{F} and c_{it}^{F}, resulting in 237 communities. Only 110 communities appear for multiple years, and this shrinks to 106 when the CSIS data is merged with H_{it}.

Figure 10 plots the distributions of Y_{it}^{F} and c_{it}^{F} across all community-years in the fish panel. Subsistence fishers are successful on average $\overline{c^F} = 96\%$ of the time, and this is much less variable than the land mammal success rate. On average, communities also harvest more fish than land mammals, with $\overline{Y^F} = 179$ pounds per capita each year.

The results for fish are much less straightforward than those for land mammals, likely because our community-year measurements H_{it} are land-based and do not take into account the distance from each community to productive waters. Depending on the sample timeframe, heat accumulation can either positively or negatively affect fish catchability, and these effects are estimated with varying levels of precision. In contrast to the land mammal results, H_{it} also affects per-capita harvests Y_{it}^{F}. Importantly, these effects move in the same direction as the effect of H_{it} on c_{it}^{F}, likely indicating that effort does not substantially adjust in response to changes in catchability; there also may be corresponding changes in the fish stock that we don't observe.

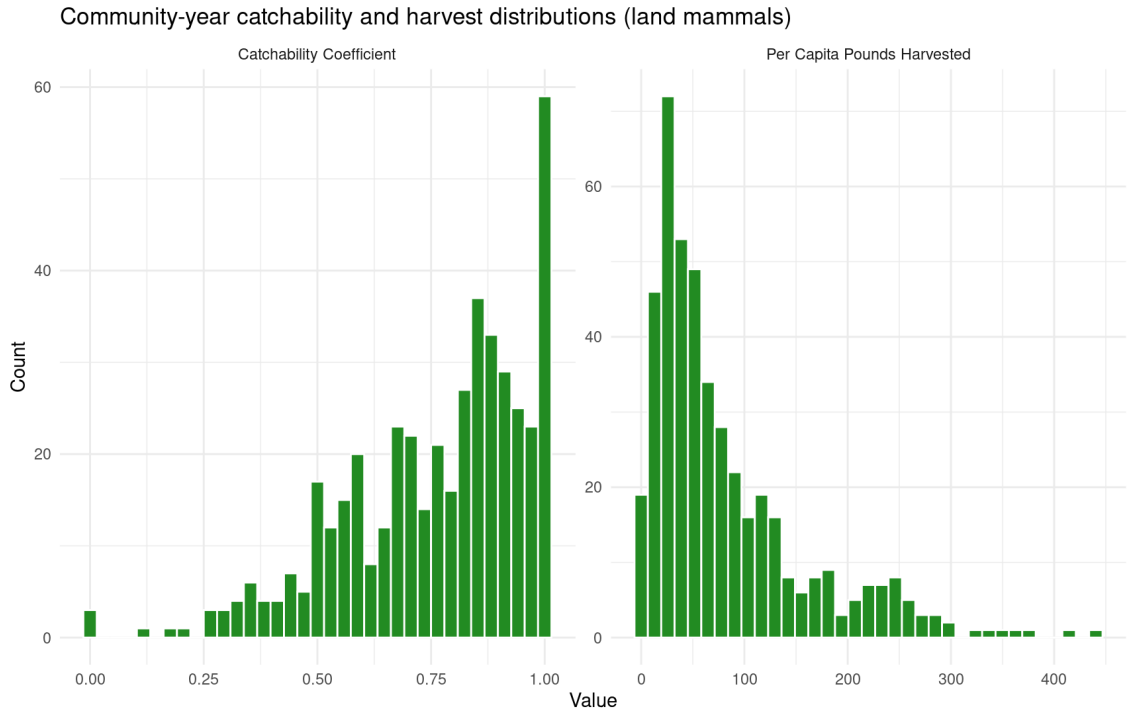


Figure 9: Land mammal distributions

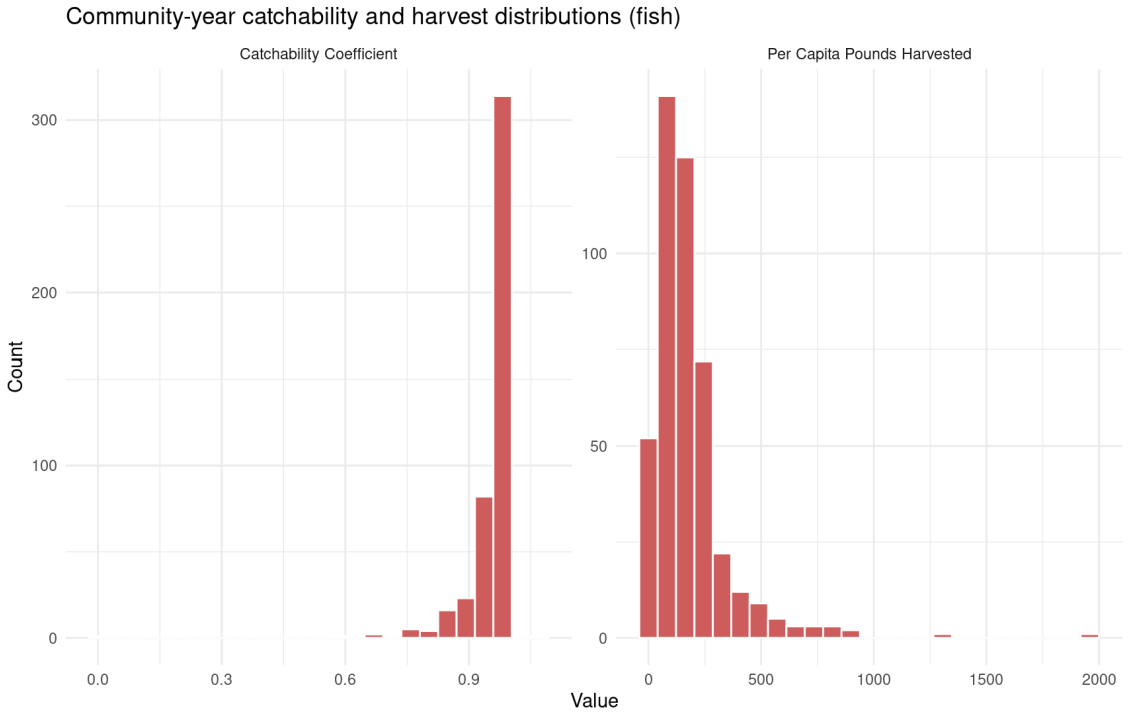


Figure 10: Fish distributions

Table 8: Results, Land Mammals

	(1)	(2)	(3)	(4)
Variable	c_{it}^{LM}	c_{it}^{LM}	Y_{it}^{LM}	Y_{it}^{LM}
H_{it}	-0.24e-03***	-0.12e-02*	-0.049	0.111
	(0.74e-04)	(0.613e-03)	(0.041)	(0.152)
Timeframe	1985–2015	2000–2015	1985–2015	2000–2015
Observations	331	116	331	116
Clusters (N)	107	44	107	44
Community FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Weather Controls	Yes	Yes	Yes	Yes

Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table 9: Results, Fish

	(1)	(2)	(3)	(4)
Variable	c_{it}^{F}	c_{it}^{F}	Y_{it}^{F}	Y_{it}^{F}
H_{it}	0.186e-04	-0.144e-03**	0.235**	-0.766**
	(0.49e-04)	(0.64e-04)	(0.112)	(0.299)
Timeframe	1985–2015	2000–2015	1985–2015	2000–2015
Observations	306	120	317	120
Clusters (N)	106	53	106	53
Community FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Weather Controls	Yes	Yes	Yes	Yes

Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

B. Comparative Statics: Migration Propensity

B.1 Optimal Consumption in Period $t = 1$

Since period 1 is terminal and $U_C > 0$, individuals will consume all of their remaining resources, regardless of location. Thus, $C_1^* = R_1$. Using Equation 3, consumption in period $t = 1$ can be expressed as

$$\begin{aligned} C_1^{O*}(C_0) &= (1+r)(R_0 - C_0) + I^O(H_1) + Y_1 \\ C_1^{D*}(C_0) &= (1+r)(R_0 - C_0 - \delta) + I^D + Y_1. \end{aligned} \tag{16}$$

B.2 Optimal Consumption in Period $t = 0$

Let C_0^{O*} and C_0^{D*} denote optimal consumption in period $t = 0$ if an individual stays or migrates, respectively.

Interior Solution. Using the value functions in Equation 6, we have the following first-order conditions if the solution is interior in both cases:

$$\begin{aligned} U_C(C_0^{O*}) &= \theta(1+r)\, E[U_C(C_1^{O*})] \\ U_C(C_0^{D*}) &= \theta(1+r)\, E[U_C(C_1^{D*})], \end{aligned} \tag{17}$$

where we use the fact that $\partial C_1^{O*}/\partial C_0 = \partial C_1^{D*}/\partial C_0 = -(1+r)$.

Corner Solution. If liquidity constraints bind consumption, then optimal consumption can be characterized as:

$$\begin{aligned} C_0^{O*} &= R_0 \quad \text{and} \quad C_1^{O*} = I^O(H_1) + Y_1 \\ C_0^{D*} &= R_0 - \delta \quad \text{and} \quad C_1^{D*} = I^D + Y_1 \end{aligned} \tag{18}$$

B.3 Comparative Static: $\partial\Delta/\partial R_0 = \Delta_R$

From Equation 7, $\Delta = V^D - V^O$ represents an individual's propensity to migrate, conditional on initial resources and the future stock of environmental quality at the origin. Provided C_0^{O*} and C_0^{D*} are interior, we can apply the envelope theorem to show that:

$$\frac{\partial V^O(R_0, S_1)}{\partial R_0} = \theta(1+r)\, E[U_C(C_1^{O*})] = U_C(C_0^{O*}) \tag{19}$$

$$\frac{\partial V^D(R_0, S_1)}{\partial R_0} = \theta(1+r)\, E[U_C(C_1^{D*})] = U_C(C_0^{D*}), \tag{20}$$

where the second equality imposes the first-order conditions in Equation 17.

Alternatively, if the budget constraint is binding for consumption in period $t = 0$, we have the following:

$$\frac{\partial V^O(R_0, S_1)}{\partial R_0} = U_C(R_0) \tag{21}$$

$$\frac{\partial V^D(R_0, S_1)}{\partial R_0} = U_C(R_0 - \delta), \tag{22}$$

since a marginal increase in resources increases consumption in period $t = 0$ only.

We consider $\Delta_R = \partial\Delta(R_0, S_1)/\partial R_0$ for the four cases in Table 10.

	Stay Interior	**Stay Corner** ($C_0^{O*} = R_0$)
Migrate Interior	Case 1	Case 2
Migrate Corner ($C_0^{D*} = R_0 - \delta$)	Case 3	Case 4

Table 10: Four different cases considered for comparative statics according to budget constraints binding in the Stay and Migrate scenarios.

Case 1: Interior Solution. In this case, C_0^{O*} and C_0^{D*} are interior, which implies:

$$\begin{aligned}\Delta_R &= \theta(1+r)\,E[U_C(C_1^{D*})] - \theta(1+r)\,E[U_C(C_1^{O*})] \\ &= U_C(C_0^{D*}) - U_C(C_0^{O*}).\end{aligned} \tag{23}$$

That is, an individual is more likely to migrate if the marginal utility received from consuming at the destination is greater than that at the origin. Since $U(\cdot)$ is strictly concave in consumption, the sign of Δ_R is determined by the ranking of period-0 consumption:

$$\Delta_R > 0 \iff C_0^{O*} > C_0^{D*}. \tag{24}$$

The ranking of consumption in period $t = 0$ depends on the resources available for consumption in period $t = 1$: if resources are greater at the destination, individuals will have greater period-1 consumption, and in turn, greater period-0 consumption due to consumption smoothing. Whether period-1 resources at the destination exceed those at the origin depends on whether migration costs exceed the expected increase in earned income from migrating. That is:

$$\Delta_R > 0 \iff C_0^{O*} > C_0^{D*} \iff \delta(1+r) > I^D - E[I^O(H_1)]. \tag{25}$$

In other words, if migration costs exceed the expected increase in earned income from migrating, then an individual has fewer resources for consumption at the destination; thus, migration is a normal good: a marginal increase in period-0 resources makes migrating marginally more attractive. In contrast, if the expected increase in earned income from migrating exceeds migration costs, then an individual has more resources for consumption at the destination; thus, migration is an inferior good: a marginal increase in unearned income makes staying marginally more attractive.

Case 2: Budget constraint binds in the "stay" scenario only. In this case, if an individual stays at the origin, she would like to consume more than R_0, her total liquid assets, but cannot borrow against her future wealth. Therefore, she sets her origin consumption choice $C_0^{O*} = R_0$. In contrast, if an individual chooses to migrate, she consumes less than $R_0 - \delta$ so that C_0^{D*} is interior. This implies:

$$\begin{aligned}\Delta_R &= \theta(1+r)\,E[U_C(C_1^{D*})] - U_C(R_0) \\ &= U_C(C_0^{D*}) - U_C(R_0) \\ &> 0.\end{aligned} \tag{26}$$

In this case, a marginal increase in period-0 resources will increase the propensity to migrate. We know that consumption must be greater if an individual stays: $C_0^{O*} > C_0^{D*}$ since $C_0^{O*} = R_0$ and $C_0^{D*} < R_0 - \delta$. Thus, since $U_{CC} < 0$, a marginal increase in unearned income leads to a larger marginal increase in consumption-based utility for the migrating individual.

Case 3: Budget constraint binds in the "migrate" scenario only. In this case, if an individual migrates, she would like to consume more than $R_0 - \delta$, her total liquid assets after incurring the cost of financing migration, but she cannot borrow against her future wealth. Therefore, she sets her origin consumption choice $C_0^{D*} = R_0 - \delta$. In contrast, if an individual chooses to stay, she consumes less than R_0, so that C_0^{O*} is interior. This implies:

$$\begin{aligned} \Delta_R &= U_C(R_0 - \delta) - \theta(1+r)\, E[U_C(C_1^{O*})] \\ &= U_C(R_0 - \delta) - U_C(C_0^{O*}) \\ &>< 0. \end{aligned} \tag{27}$$

Since consumption-based utility is concave, the sign of Δ_R is determined by the ranking of consumption at $t = 0$ at the origin. Since $C_0^{O*} < R_0$ and $C_0^{D*} = R_0 - \delta$, consumption for the staying individual could be larger or smaller than the migrating individual, depending on their expected future income at the origin and how much of their current assets they decide to save. Thus, in this case, the effect of a marginal increase in period-0 resources on the propensity to migrate is ambiguous.

Case 4: Budget constraint binds in both "migrate" and "stay" scenarios. Finally, suppose that the budget constraint binds in *both* the "migrate" and "stay" scenarios. In this case, an increase in period-0 resources is fully decoupled from future consumption:

$$\Delta_R = U_C(R_0 - \delta) - U_C(R_0) > 0. \tag{28}$$

In this case, a marginal increase in period-0 resources will increase the propensity to migrate, as the marginal resource is more valuable at the lower level of consumption after incurring the migration cost, $C_0^{D*} = R_0 - \delta$.

C. Empirical Approximation

We now reproduce the total derivative of the community-year out-migration rate m_{it}^A with respect to H_{it}, which we denote $\mathbf{\Gamma_1}$:

$$\frac{\mathrm{d}m_{it}^A(H_{it})}{\mathrm{d}H_{it}} = \left(\frac{\partial m_{it}^A}{\partial H_{it}}\right) + \left(\frac{\partial m_{it}^A}{\partial D_{it}}\right)\frac{\partial D_{it}(H_{it}, \mathbf{W}_{it-1})}{\partial H_{it}} \tag{29}$$

$$= \left(\frac{\partial m_{it}^A}{\partial H_{it}}\bigg|_{Y=0} + \frac{\partial^2 M}{\partial Y_t \partial H_{it}} Y_t\right) + \left(\frac{\partial m_{it}^A}{\partial D_{it}}\bigg|_{Y=0} + \frac{\partial^2 M}{\partial Y_t \partial D_{it}} Y_t\right)\frac{\partial D_{it}(H_{it}, \mathbf{W}_{it-1})}{\partial H_{it}} \tag{30}$$

$$= (\beta_1 + \alpha_1 Y_t) + (\beta_2 + \alpha_2 Y_t) d_H \tag{31}$$

$$= \mathbf{\Gamma_1} \tag{32}$$

The total effect $\mathbf{\Gamma_1}$ is a (potentially nonlinear) function of the theoretical parameters graphically depicted in Section 3, and represents the sum of the income erosion and disamenity effects evaluated at the dividend level Y_t.

Taking the natural log of m_{it}^A and approximating this term with a first-order Taylor series expansion around the point $\mathcal{H}$ produces the following expression:

$$\ln m_{it}^A(H_{it}) \approx \ln M(\mathcal{H}) + \frac{M'(\mathcal{H})}{M(\mathcal{H})}(H_{it} - \mathcal{H}) \tag{33}$$

$$= \underbrace{\left(\ln M(\mathcal{H}) - \frac{\mathbf{\Gamma_1}}{M(\mathcal{H})}\mathcal{H}\right)}_{(a)} + \underbrace{\frac{\mathbf{\Gamma_1}}{M(\mathcal{H})}}_{=\gamma_1} H_{it} \tag{34}$$

Exponentiating and grouping term (a) into community- and time-specific unobservable factors, we can rewrite the out-migration rate as follows:

$$m_{it}^A \approx \exp(\phi_i + \psi_t + \gamma_1 H_{it}) \tag{35}$$

Finally, noting that $m_{it}^A = \frac{m_{it}^A}{P_{it}}$ (i.e., the out-migration rate equals total out-migrants over the initial population), and allowing the term ϵ_{it} to capture sampling variation in realized out-migration and any approximation error not absorbed by the fixed effects, we can write Equation 35 as follows:

$$m_{it}^A = \exp(\phi_i + \psi_t + \gamma_1 H_{it} + \ln(P_{it})) + \epsilon_{it} \tag{36}$$

This is a Poisson-pseudo maximum likelihood (PPML) estimating equation, with a log-population offset, and with $\gamma_1 = \frac{\mathbf{\Gamma_1}}{M(\mathcal{H})}$. Augmenting Equation 36 with the vector of weather controls $\mathbf{W}_{it}$ yields Equation 41 in Appendix D. We use PPML instead of a log-linear OLS model, as migration rates are often equal to zero and log-linear OLS cannot accommodate this data structure without ad-hoc transformations.

The coefficient γ_1 is a semi-elasticity of the migration rate with respect to heat, and because $M(\mathcal{H}) \geq 0$, γ_1 and $\mathbf{\Gamma_1}$ always share the same sign. The same logic applies to its sub-components (β_1, β_2, α_1, and α_2). Because our testable hypotheses about $\mathbf{\Gamma_1}$ and these sub-components are qualitative, testing their respective coefficients is equivalent to testing our theory's predictions. We therefore denote γ_1 in Equation 41 as $\mathbf{\Gamma}_1$ for ease of interpretation, and proceed with this convention throughout the paper.

D. "Bundled" Specifications

In this appendix, we present several candidate specifications to show what can be learned from empirically modeling the income erosion and disamenity channels, and how each is moderated by income. We then discuss why each of these specifications may obscure the theoretical model's underlying mechanisms in different ways, and how our main specification resolves these tensions. The initial specifications introduced here directly correspond to the estimates in the first three columns of Table 3 in the main text.

We first concentrate on the total effect of H_{it} on m^A_{it}, the out-migration rate from community i to Anchorage in time t. We denote this effect as $\mathbf{\Gamma_1}$, and write it as a function of the parameters derived in our conceptual model, as follows:

$$\frac{\mathrm{d}m^A_{it}}{\mathrm{d}H_{it}} = \left(\frac{\partial m^A_{it}}{\partial H_{it}}\right) + \left(\frac{\partial m^A_{it}}{\partial D_{it}}\right)\frac{\partial D_{it}(H_{it}, \mathbf{W}_{it-1})}{\partial H_{it}} \tag{37}$$

$$= \left(\left.\frac{\partial m^A_{it}}{\partial H_{it}}\right|_{Y=0} + \frac{\partial^2 M^A_{it}}{\partial Y_t \partial H_{it}} Y_t\right) + \left(\left.\frac{\partial m^A_{it}}{\partial D_{it}}\right|_{Y=0} + \frac{\partial^2 M^A_{it}}{\partial Y_t \partial D_{it}} Y_t\right)\frac{\partial D_{it}(H_{it}, \mathbf{W}_{it-1})}{\partial H_{it}} \tag{38}$$

$$= (\beta_1 + \alpha_1 Y_t) + (\beta_2 + \alpha_2 Y_t) d_H \tag{39}$$

$$= \mathbf{\Gamma_1} \tag{40}$$

$\mathbf{\Gamma_1}$ is the sum of our model's hypothesized income erosion and disamenity effects. To estimate this term, we use a two-way fixed effects specification as follows:

$$m^A_{it} = \exp(\phi_i + \psi_t + \mathbf{\Gamma_1} H_{it} + \mathbf{W}'_{it}\boldsymbol{\vartheta} + \ln(P_{it})) + \epsilon_{it} \tag{41}$$

where m^A_{it} is equal to the count of out-migrants from community i to Anchorage in time t, ϕ_i and ψ_t are community and year fixed effects, and $\mathbf{W}_{it}$ is a vector of contemporary community-year weather controls. We estimate Equation 41 via Poisson pseudo-maximum likelihood (Santos Silva and Tenreyro, 2006) with a log-population offset $\ln(P_{it})$.[38] This allows us to interpret the outcome variable as the community-year out-migration rate m^A_{it}, and accommodates out-migration rates of zero which are often observed in the data. $\mathbf{\Gamma_1}$ is identified using within-community variation in summer heat accumulation after netting out aggregate time-varying aggregate shocks. Thus, Equation 41 yields an unbiased estimate of the total effect of H_{it} on out-migration.

However, Equation 41 does not empirically model how the total effect of H_{it} is moderated by unearned income, and the resulting estimate of $\mathbf{\Gamma_1}$ is evaluated at a weighted average

[38] Appendix C shows that our PPML specifications estimate semi-elasticity versions of the theoretical parameters identified in Section 3, which represent level changes in the migration rate. Because these semi-elasticities are simply re-scaled versions of our theoretical parameters which take the same signs, testing these signs is equivalent to testing our hypotheses. For readability, we use the same notation for the empirical estimates and theoretical estimands.

of observed PFD values $\overline{Y}$. Therefore, while it has a causal interpretation, this total effect obscures our model's underlying mechanisms in two ways. First, the income erosion and disamenity effects likely push migration in opposite directions, and Equation 41 only captures the resulting net effect. Second, by averaging across the latent levels of unearned income which moderate these effects, the empirical model further obscures both.

Temporal variation in unearned income from the PFD offers a way to mitigate the former issue, and motivates an empirical specification in which the impact of H_{it} directly depends on Y_t. In general, such a specification takes the following form:

$$m_{it}^{A} = \exp(\phi_i + \psi_t + \lambda_i Y_t + \mathbf{\Gamma_2} H_{it} + \boldsymbol{\alpha} H_{it} Y_t + \tilde{\mathbf{W}}_{it}' \mathbf{\Xi} + \ln(P_{it})) + \epsilon_{it} \tag{42}$$

where $\mathbf{\Gamma_2} = (\beta_1 + \beta_2 d_H)$ and $\boldsymbol{\alpha} = (\alpha_1 + \alpha_2 d_H)$. $\mathbf{\Gamma_2}$ represents the bundled income erosion and disamenity effects evaluated when unearned income is zero, and $\boldsymbol{\alpha}$ represents how unearned income moderates this total effect. $\tilde{\mathbf{W}}_{it}$ represents the vector of weather controls $\mathbf{W}_{it}$ and their interactions with Y_t.

Our motivating theory predicts that if migration is a normal good, $\boldsymbol{\alpha} \geq 0$; if migration is inferior, however, this term's sign is ambiguous. On the other hand, $\mathbf{\Gamma_2}$ is ambiguous in all cases. When the income erosion effect operates through constraining migration's feasibility and the disamenity effect operates through increasing migration's desirability– the central tension of this paper– a specific pattern of ambiguity emerges. In this case our theoretical model predicts that $\beta_1 < 0$ and $\beta_2 d_H > 0$: when unearned income is zero, the income erosion and disamenity effects still push in opposite directions.[39]

Alternatively, we can use the Climate Priming Index $D_{it}(H_{it}, \mathbf{W}_{it-1})$ to separately estimate the income erosion and disamenity effects. The income erosion effect operates directly through H_{it}, while the disamenity effect operates indirectly through heat-induced degradation in environmental quality $D_{it}(H_{it}, \mathbf{W}_{it-1})$. Isolating these effects thus requires two related specifications: one which estimates how H_{it} changes $D_{it}(H_{it}, \mathbf{W}_{it-1})$, and one which estimates how H_{it} and D_{it} each individually affect out-migration. These specifications are presented below:

$$D_{it} = \phi_i + \psi_t + d_H H_{it} + \mathbf{W}_{it}' \mathbf{\Lambda} + \mathbf{W}_{it-1}' \mathbf{\Theta} + \nu_{it} \tag{43}$$

$$m_{it}^{A} = \exp(\phi_i + \psi_t + \mathbf{\Gamma_3} H_{it} + \mathbf{\Gamma_4} D_{it} + \tilde{\mathbf{W}}_{it}' \mathbf{\Phi} + \ln(P_{it})) + \epsilon_{it} \tag{44}$$

where $\mathbf{\Gamma_3} = (\beta_1 + \alpha_1 \overline{Y})$ and $\mathbf{\Gamma_4} = (\beta_2 + \alpha_2 \overline{Y})$. If our conceptual model accurately describes the data-generating process, $\mathbf{\Gamma_3}$ and $\mathbf{\Gamma_4}$ capture the income erosion and disamenity effects, averaged across the observed range of dividends. Equation 43's estimate of d_H linearly approximates $\frac{\partial D_{it}(H_{it}, \mathbf{W})}{\partial H_{it}}$, the indirect effect of heat on environmental quality.

Equation 44 yields causal estimates of $\mathbf{\Gamma_3} = (\beta_1 + \alpha_1 \overline{Y})$ and $\mathbf{\Gamma_4} = (\beta_2 + \alpha_2 \overline{Y})$, successfully separating the income erosion and disamenity effects. However, both estimates average across

[39] Figures A10 and A11 illustrate the coefficients of interest in Equations 41 and 42 in the feasibility-desirability space.

the observed range of dividends, reintroducing the issue which motivated Equation 42. $\mathbf{\Gamma}_3$ is ambiguous in all cases, and cannot separate the baseline income erosion effect (β_1) from how it is attenuated by increases in unearned income ($\alpha_1 \overline{Y}$). $\mathbf{\Gamma}_4$ is positive in most cases, but its sign is ambiguous if migration is an inferior good and the unearned income moderates the disamenity effect ($\beta_2 \geq 0$) by decreasing the desirability of migration ($\alpha_2 \overline{Y} \leq 0$).[40]

In summary, this sequence of specifications illustrates the challenge of isolating these competing mechanisms. Equation 41 shows that a regression of m_{it}^A on H_{it} collapses the income erosion effect, the disamenity effect, and how each is moderated by unearned income into a single parameter. A near-zero estimate could therefore imply the absence of an effect, or several opposing effects canceling each other out. Equation 42 isolates the role of unearned income on the total heat-migration relationship, but the income erosion and disamenity effects still work against one another. Symmetrically, Equation 44 isolates both of these effects but does not model how each is moderated by unearned income, which renders the direct effect of heat on migration ambiguous.

Our main specification combines the approaches of Equations 42 and 44, allowing the strengths of each to address the limitations of the other. In the main text, we jointly estimate the income erosion and disamenity effects, allowing both to be moderated by unearned income, using the following specifications:

$$D_{it} = \phi_i + \psi_t + d_H H_{it} + \mathbf{W}'_{it-1}\mathbf{\Theta} + \nu_{it} \tag{45}$$

$$m_{it}^A = \exp(\phi_i + \psi_t + \lambda_i Y_t + \beta_1 H_{it} + \beta_2 D_{it} + \alpha_1 H_{it} Y_t + \alpha_2 D_{it} Y_t + \tilde{\mathbf{W}}'_{it}\mathbf{\Upsilon} + \ln(P_{it})) + \epsilon_{it} \tag{46}$$

Table 11 estimates Equations 41, 44, 42, and 46. We note that community-specific PFD slopes $\lambda_i Y_t$ are necessary for the causal estimation of the interaction terms in Equations 42 and 46, but not necessary for estimating the level effects of H_{it} and D_{it} in Equations 41 and 44. Thus, our initial specifications in the first two columns do not include these terms. To ensure that our estimates are broadly comparable across these specifications, our main results in Table 3 re-estimates Columns (a) and (b) including the community-specific PFD slopes $\lambda_i Y_t$. Our qualitative findings in Table 11 are robust to this inclusion.

[40] Figure A12 in Appendix K illustrates the coefficients of interest in Equation 44 in the feasibility-desirability space.

Table 11: All empirical specifications

		(41)	(44)	(42)	(46)
Variable	**Estimand in (d)**	m_{it}^A	m_{it}^A	m_{it}^A	m_{it}^A
H_{it}	β_1	0.009	0.003	-0.052	-0.098**
		(0.009)	(0.009)	(0.038)	(0.039)
$H_{it} \times Y_t$	α_1			0.035*	0.055***
				(0.020)	(0.020)
D_{it}	β_2		0.025***		0.061**
			(0.007)		(0.028)
$D_{it} \times Y_t$	α_2				-0.016
					(0.015)
Observations		4,951	4,951	4,936	4,936
Weather Controls		Yes	Yes	Yes	Yes
Community-specific PFD slopes		No	No	Yes	Yes
Community FE		Yes	Yes	Yes	Yes
Year FE		Yes	Yes	Yes	Yes

H_{it} and D_{it} are measured in units of within-community standard deviations. Y_t is measured in \$1000 (2015 USD).
Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

E. Identifying Variation

Our coefficients of interest β_1 and β_2 are identified using idiosyncratic within-community deviations in H_{it} and D_{it}, net of aggregate time-varying shocks. α_1 and α_2 are identified using the interactions of these deviations and plausibly exogenous temporal variation in the Permanent Fund Dividend. Motivated by the decomposition derived by Giesselmann and Schmidt-Catran (2022), Equation 47 cross-sectionally de-means the interaction of Y_t and H_{it} to illustrate the latter type of variation:

$$H_{it}Y_t - \overline{H_{it}Y_t} = \underbrace{\overline{H}_i(Y_t - \overline{Y})}_{(a)} + \underbrace{Y_t(H_{it} - \overline{H_i})}_{(b)} - \underbrace{\sum_{t=1}^{T} \frac{(H_{it} - \overline{H}_i)(Y_t - \overline{Y})}{T}}_{(c)} \tag{47}$$

Term (a) is the interaction of community i's average heat level $\overline{H}_i$ and the time-demeaned PFD; as discussed previously, variation in this term is likely endogenous and is absorbed by our specification's community-specific PFD slopes $\lambda_i Y_t$. Term (b) is the interaction of the PFD value in year t with the within-community idiosyncratic heat deviation in community i in year t. After controlling for $\lambda_i Y_t$, variation in term (b) alone identifies α_1, and is analogous to the variation used an exposure design in which the exogenous, community-specific deviation $H_{it} - \overline{H_i}$ determines community i's exposure to the universal shock of Y_t.[41] α_2 is identified symmetrically, using both temporal variation in Y_t and idiosyncratic within-community shocks in D_{it}. Figure 11 graphs yearly PFD disbursement values Y_t, alongside the residual variation in H_{it} and D_{it} after partialling out community and year fixed effects. The PFD generally does not systematically move together with either series, and these independently-generated sources of variation allow us to estimate α_1 and α_2.

[41] Term (c) is a residual constant that ensures that the components sum exactly to the demeaned interaction, and contributes no independent identifying variation.



Figure 11: Identifying variation and PFD series. This figure graphs the residual variation in H_{it} and D_{it}, after partialling out community and year fixed effects (in blue) against the Permanent Fund Dividend (in red). All values are standardized into Z-scores for comparability.

F. Inference

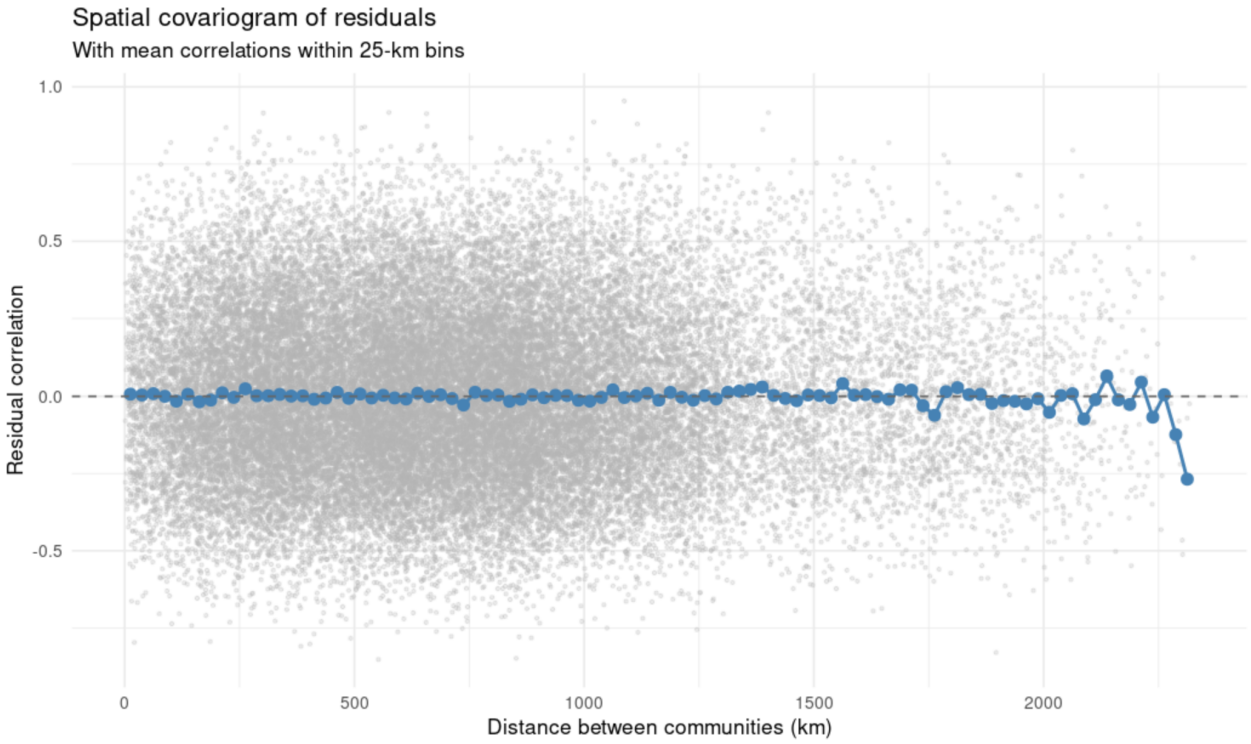


Figure 12: Empirical covariogram of regression errors shows no discernible spatial dependence

Table 12: Pesaran test fails to reject the null of no cross-sectional dependence in residuals

Test	Statistic (z)	p-value	Null hypothesis
Pesaran CD	-0.104	0.918	No cross-sectional dependence

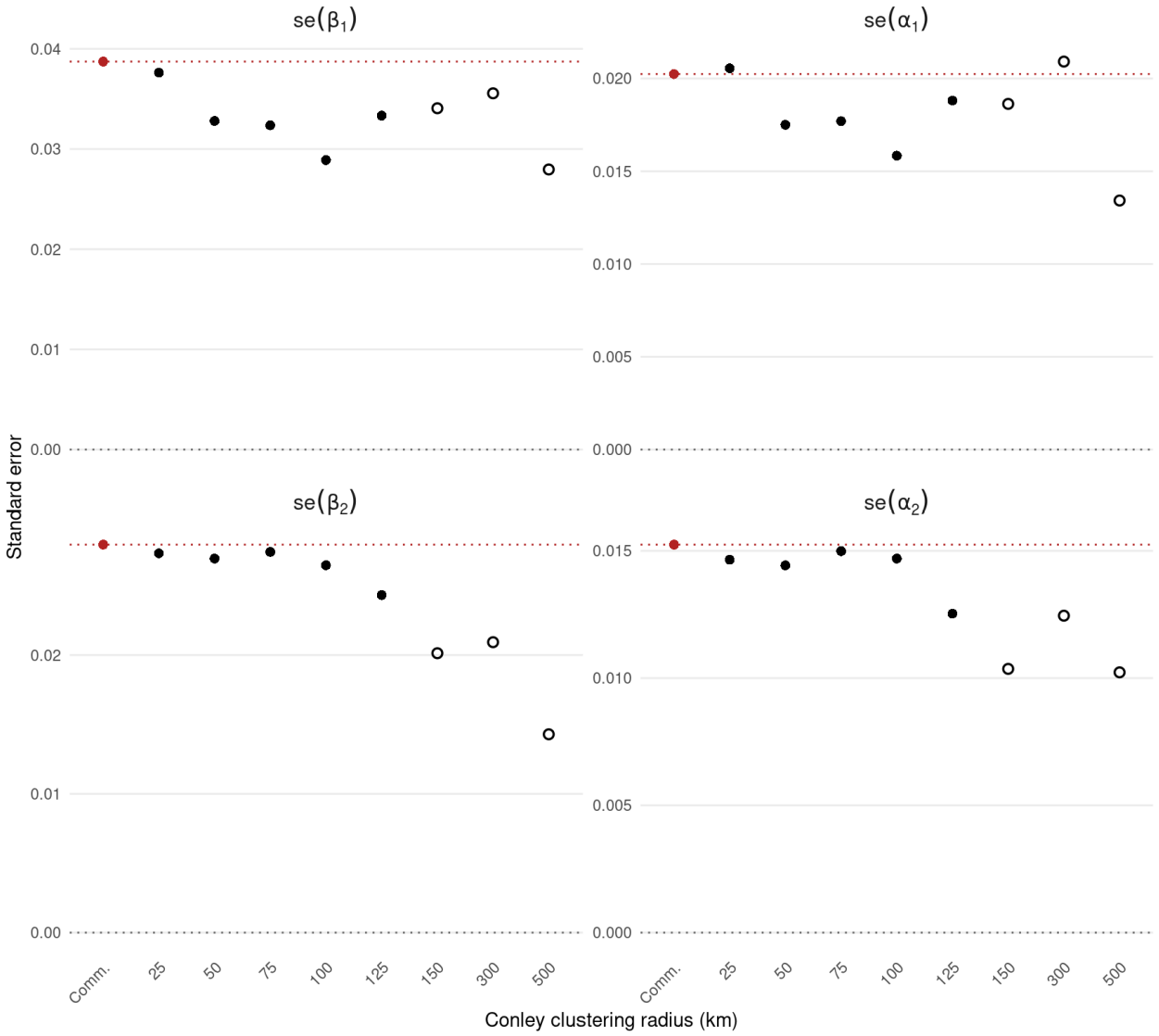


Figure 13: Standard errors at different clustering radii. This figure shows standard errors for our four estimated coefficients of interest from the main specification, and how these change when we allow for different patterns of residual correlation. The red points correspond to the reported standard errors in Column (d) of Table 3, which are clustered by community. The black points correspond to standard errors which allow both within-community error dependence and spatial dependence within a given radius (i.e., Conley (1999)). Beyond 125 km, the covariance matrix becomes numerically unstable; standard errors from these specifications are represented by hollow black points.

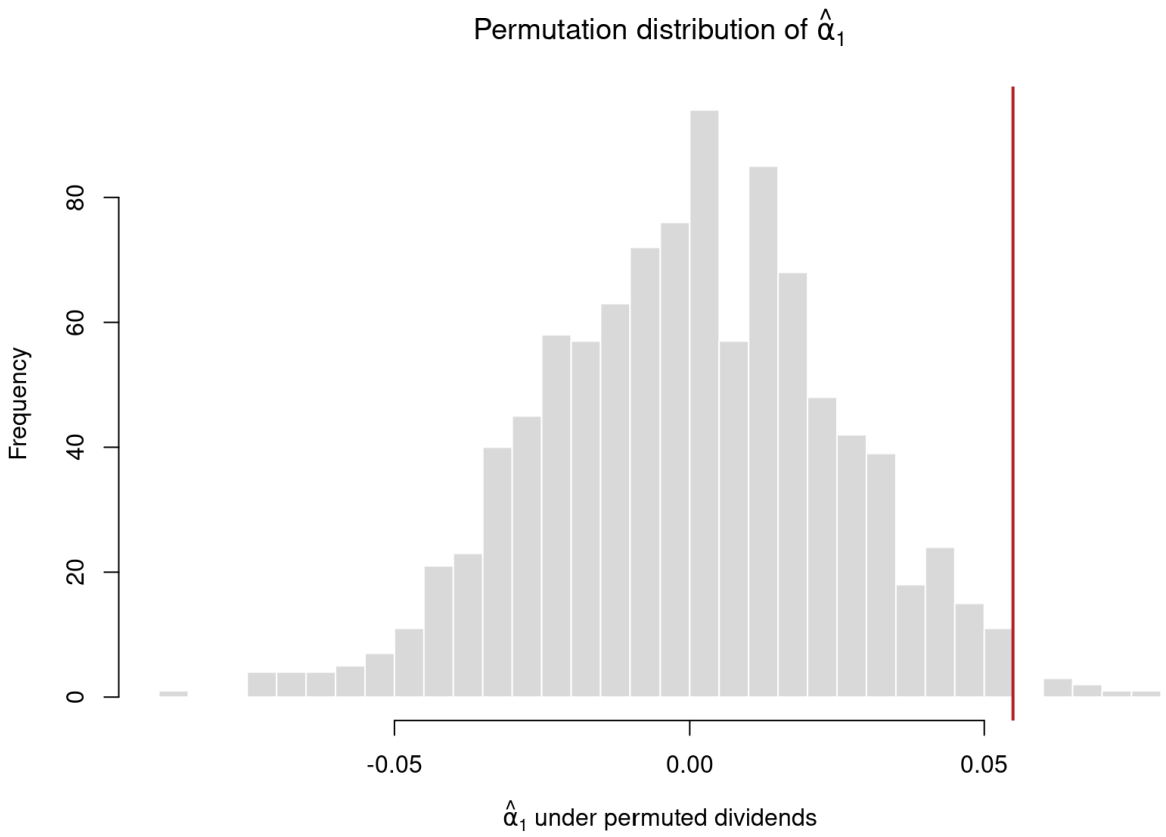


Figure 14: Permutation distribution of α_1 estimates. This figure shows the results of randomization inference for α_1, completed using the following procedure. We want to test the null hypothesis that the PFD value Y_t has no moderating influence on the relationship between heat and migration (i.e., $H_0 : \alpha_1 = 0$). Our estimate of $\hat{\alpha}_1 > 0$ in Table 3 is very precise, rejecting this null at the 1% significance level. However, this precision could be misleading, due to within-year correlation of our model's regressors (particularly $H_{it}Y_t$). Although we are unable to detect cross sectional dependence in the model's residuals, this within-year correlation of the regressors (due to the common Y_t value and likely spatial correlation of H_{it}) could still render our community-clustered standard errors too small even if residual dependence is too small to detect. One way to address this would be two-way clustering by community and year. However, with a 16 year panel, the resulting covariance estimates would be unreliable. Instead, we randomly re-assign the 16 annual PFD values across years without replacement, re-estimate Equation 11 on each permuted dataset replacing all occurrences of Y_t in the estimation equation with the permuted PFD value, and record $\hat{\alpha}_1$ from each re-estimation. Under the null, the PFD value should have no effect on the heat-induced migration response; if the null is true, our point estimate from Table 3 should be well within the empirical distribution of $\hat{\alpha}_1$ from these permutations. The figure shows a histogram of the estimates from 999 permutations, with the red line denoting the initial point estimate obtained using the true PFD sequence. 26 of the 999 permutation estimates were at least as large in absolute value as point estimate, resulting in a two-sided p-value of 0.027. On the other hand, 8 of the 999 permutation estimates were at least as large as our point estimate, resulting in a one sided p-value (for the null of $H_0 : \alpha_1 \leq 0$) of 0.009.

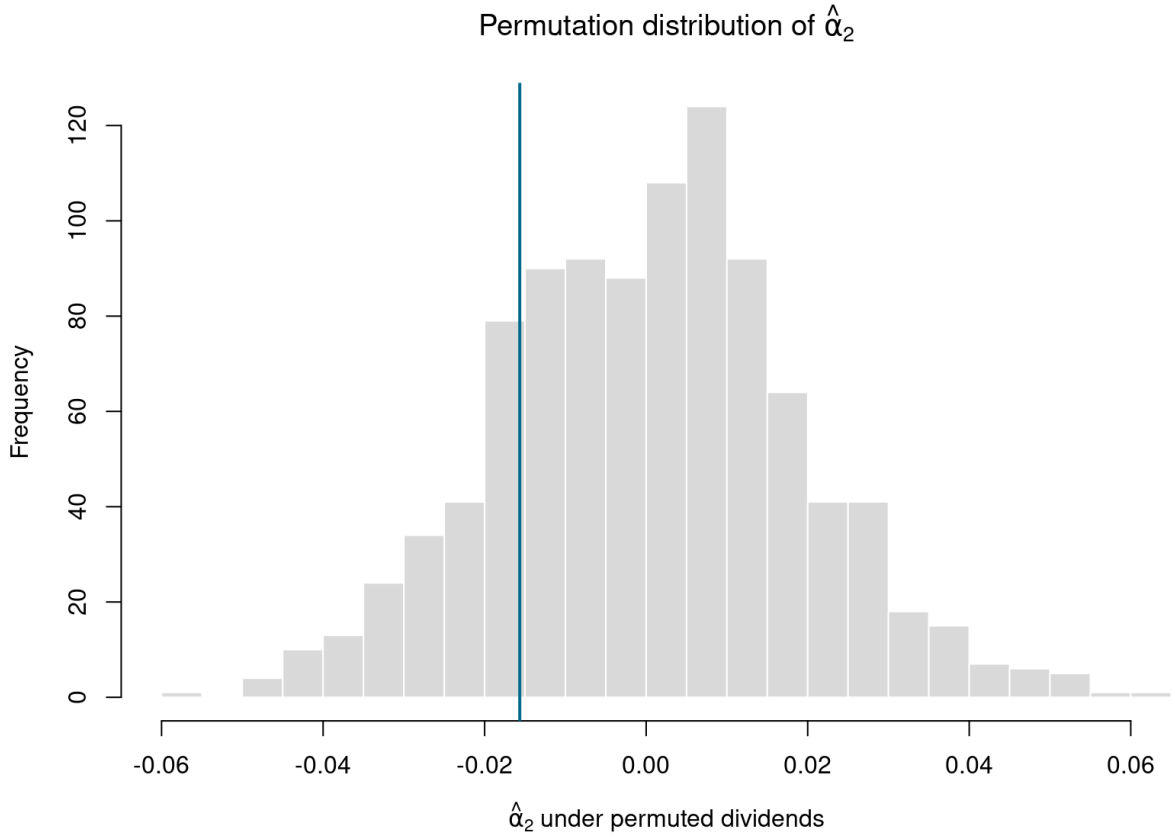


Figure 15: Permutation distribution of α_2 estimates. This figure shows the results of randomization inference for α_2, completed using the same procedure as described in Figure 14. The figure shows a histogram of the estimates from 999 permutations, with the blue line denoting the initial point estimate obtained using the true PFD sequence. 380 of the 999 permutation estimates were at least as large in absolute value as point estimate, resulting in a two-sided p-value (for the null of $H_0 : \alpha_2 = 0$) of 0.38. On the other hand, 192 of the 999 permutation estimates were at least as small as our point estimate, resulting in a one sided p-value (for the null of $H_0 : \alpha_2 \geq 0$) of 0.192.

G. Mediation and the Exclusion Restriction

As discussed in Section 4, D_{it} is a function of both H_{it} and $\mathbf{W}_{it-1}$, a vector of five lagged weather variables. The variation contributed by these variables means that D_{it} is not solely a deterministic function of H_{it}, and ensures that Equation 11 can simultaneously estimate β_1 and β_2. Taking the total derivative of $D_{it} = D_{it}(H_{it}, \mathbf{W}_{it-1})$ formally illustrates what drives the variation in environmental degradation:

$$dD_{it}(H_{it}, \mathbf{W}_{it-1}) = \frac{\partial D_{it}(H_{it}, \mathbf{W}_{it-1})}{\partial H_{it}} \times dH_{it} + (\nabla D_{\mathbf{W}})^{\top} d(\mathbf{W}_{it-1}) \tag{48}$$

The first term represents the isolated effect of heat accumulation H_{it} on D_{it}, and the second term represents the influence of the other five index components. β_2 is identified by within-community variation in $\mathbf{W}_{it-1}$, driven by years in which lagged weather was extreme enough to induce environmental degradation even in the absence of high contemporary heat accumulation. β_1 is identified using a symmetric logic—via idiosyncratic within-community variation in H_{it} during years when lagged weather was not extreme enough to induce environmental degradation.

Equation 11 excludes $\mathbf{W}_{it-1}$, under the assumption that these lagged variables only affect contemporary migration through their effect on D_{it}. If the assumption underlying this exclusion restriction does not hold, and the components of $\mathbf{W}_{it-1}$ affects migration through other channels, our estimates of β_2 and α_2 may be driven by these channels rather than the disamenity effect of contemporaneous environmental degradation. A natural threat to this restriction is lagged heat H_{it-1}. If heat's income erosion effect decreases the feasibility of otherwise desirable out-migration in year $t-1$, then migration may subsequently increase in year t purely due to this "pent-up" demand. This could, through the effect of H_{it-1} on D_{it}, generate a positive estimate of β_2 independent of our hypothesized disamenity effect. The other four components of $\mathbf{W}_{it-1}$ could similarly invalidate the exclusion restriction.

We formally evaluate this possibility by controlling for each element of $\mathbf{W}_{it-1}$ in successive versions of our main specification. Each of these specifications holds a separate lagged component of $\mathbf{W}_{it-1}$ constant, and therefore in each, β_2 is estimated using less identifying variation in D_{it} relative to our main specification. Note that we cannot control for all elements of $\mathbf{W}_{it-1}$ at once.[42] However, stable estimates of our parameters of interest and null estimates on each component of $\mathbf{W}_{it-1}$ would provide evidence in favor of the exclusion restriction.

For notational purposes, we now explicitly define the elements of $\mathbf{W}_{it-1}$:

$$\mathbf{W}_{it-1} = (H_{it-1}, F_{it-1}, Pr^{S}_{it-1}, Pr^{W}_{it-1}, Pr^{EW}_{it-1}) \tag{49}$$

where F is freezing degree days, Pr^S is summer precipitation, Pr^W is total winter precipitation, and Pr^{EW} is early winter precipitation. In Table 13, we estimate five versions of our

[42] This would absorb nearly all identifying variation in D_{it} by construction.

main specification, each of which controls for a different element of $\mathbf{W}_{it-1}$ and its interaction with Y_t. For comparison, the first column re-estimates the main specification dropping all observations from 2000, so that sample sizes are comparable across columns.

Across all columns, our main results are stable in sign, magnitude, and significance. None of the added controls are statistically different from zero. Additionally, the most immediately plausible violation of the exclusion restriction, "pent-up demand" for migration from the previous year's heat, predicts a positive coefficient on H_{it-1}; our estimate is *negative* and not statistically different from zero. Taken together, the estimates in this table provide evidence in favor of the exclusion restriction.

Table 13: Testing the exclusion restriction

Variable	m_{it}^A	m_{it}^A	m_{it}^A	m_{it}^A	m_{it}^A	m_{it}^A
H_{it}	-0.110**	-0.109**	-0.111**	-0.110**	-0.112***	-0.114**
	(0.044)	(0.043)	(0.045)	(0.043)	(0.043)	(0.045)
$H_{it} \times Y_t$	0.061***	0.061***	0.062***	0.060***	0.062***	0.063***
	(0.023)	(0.022)	(0.023)	(0.023)	(0.022)	(0.023)
D_{it}	0.078**	0.081**	0.079**	0.075**	0.078**	0.082**
	(0.035)	(0.034)	(0.033)	(0.036)	(0.039)	(0.040)
$D_{it} \times Y_t$	-0.028	-0.030	-0.029	-0.025	-0.027	-0.030
	(0.022)	(0.021)	(0.020)	(0.023)	(0.024)	(0.024)
H_{it-1}		-0.016				
		(0.040)				
$H_{it-1} \times Y_t$		0.010				
		(0.022)				
F_{it-1}			-0.021			
			(0.247)			
$F_{it-1} \times Y_t$			0.008			
			(0.128)			
Pr_{it-1}^S				0.009		
				(0.040)		
$Pr_{it-1}^S \times Y_t$				-0.008		
				(0.026)		
Pr_{it-1}^W					0.001	
					(0.026)	
$Pr_{it-1}^W \times Y_t$					-0.002	
					(0.014)	
Pr_{it-1}^{EW}						-0.017
						(0.068)
$Pr_{it-1}^{EW} \times Y_t$						0.007
						(0.043)
Observations	4,610	4,592	4,592	4,592	4,592	4,592
Weather Controls	Yes	Yes	Yes	Yes	Yes	Yes
Community-specific PFD slopes	Yes	Yes	Yes	Yes	Yes	Yes
Community FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

H_{it}, H_{it-1}, and D_{it} are measured in units of within-community standard deviations; other lagged inputs are in their original units. Y_t is measured in \$1000 (2015 USD).
Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

H. Induced Labor Demand Mechanism

A specific mechanism motivates our conceptual model's hypotheses of $\alpha_1 \geq 0$: increases in unearned income increase the feasibility of heat-driven rural-urban migration, which was initially infeasible due to binding liquidity constraints. Although there is substantial evidence that individuals in rural Alaska are liquidity-constrained, a specific alternative mechanism can generate an estimate of $\alpha_1 \geq 0$ in the absence of these constraints. This appendix discusses this mechanism and its plausibility.

Suppose that individuals are not liquidity-constrained, and can thus afford the fixed costs of migration by either drawing down their liquid assets or borrowing against their future wealth. Because the Permanent Fund Dividend is distributed to all Alaskans, it may increase the demand for goods and services. This in turn may increase the induced demand for labor in Anchorage, driving up urban wages I^D. This would increase the utility of rural-urban migration, potentially inducing labor reallocation from rural to urban Alaska. Although time fixed effects ψ_t absorb any universal rural-urban migration response to the PFD, and any remaining tendency for some communities to be more responsive to PFD-driven demand shocks than others is captured by the community-specific PFD slopes $\lambda_i Y_t$, this specific mechanism could nonetheless generate a positive causal estimate of α_1 in the absence of liquidity constraints.

We view this scenario as unlikely for several reasons. First, this competing mechanism requires that the wage increase induced by the labor demand response is concentrated disproportionately in Anchorage. It is not obvious that this would be the case; any PFD-induced increase in demand for goods and services would likely also increase labor demand in rural Alaska, with an ambiguous impact on wages (and the utility of rural-urban migration) depending on the baseline elasticities of labor supply in both areas.

Second, existing evidence suggests that the PFD's general equilibrium effects on labor demand are small in practice. Bibler, Guettabi, and Reimer (2023) find that increases in the PFD minimally affect employment in the seven months following the dividend: female employment shows no discernible response to a $1000 increase, and male employment increases by 1.7 percentage points. Though the latter finding is consistent with a PFD-induced increase in labor demand, this effect is small and is only statistically different from zero for two months after the dividend disbursement. It is highly unlikely that this increase in labor demand is large enough to induce any measurable increases in permanent rural-urban migration; it is even less likely that this hypothetical increase would be more concentrated in response to origin-level heat shocks, which would need to be true for this competing mechanism to generate estimates consistent with our hypothesized mechanism.

However, for completeness we graphically present the labor demand mechanism in feasibility-desirability space below, and discuss the hypotheses that it can generate. We show that if migration is an inferior good, our observed pattern of results cannot be generated by this mechanism. We then provide independent empirical evidence that even if migration is normal, these general equilibrium effects likely do not explain our results.

H.1 Conceptual model of the alternative mechanism

Suppose that individuals are not liquidity-constrained, and so migration is always feasible for those who desire it. Further, suppose that increases in the PFD increase induced demand for labor in Anchorage, leading to an increase in earned income via higher urban wages I_D. This then increases the utility of rural-urban migration by $\Delta_{I_D} > 0$.[43]

Figure 16 illustrates how the income erosion and disamenity effects influence migration in this scenario, and how unearned income moderates each. Migration is always feasible, and so the model's predictions exclusively operate through changing the its desirability.

Income erosion. We first concentrate on the income erosion effect, illustrated for the normal and inferior good cases in Panels A and B of Figure 16. In the absence of unearned income, the income erosion effect decreases individuals' liquid resources. If migration is a normal good, this decreases the utility of migration, generating an estimate of $\beta_1 \leq 0$. If migration is inferior, the utility of migration increases, generating an estimate of $\beta_1 \geq 0$. In both cases, unearned income non-negatively moderates this effect, generating estimates of $\alpha_1 \geq 0$ through two simultaneous desirability-driven effects. Increases in unearned income directly increase individuals' liquid resources in the origin, changing the utility of migration. General equilibrium effects of the PFD on earned income in the origin and destination then unambiguously increase the utility of migration, as reflected in the movement from the solid blue line to the dashed blue line. If this reflects the true data-generating process, estimates of α_1 from our main specification would jointly identify the sum of these two effects.

Disamenity. Panels C and D of Figure 16 illustrate the disamenity effect in the normal and inferior good cases. In the absence of unearned income, both cases predict $\beta_2 \geq 0$; as in our original conceptual model, an increase in heat degrades origin-level quality by d_H, and increases the utility of migration. This is captured by the movement from the blue line to the dashed red line. Increases in unearned income increase the utility of migration via the general equilibrium labor demand mechanism (the movement from the dashed red to the solid red line) and further change the utility of migration by increasing the potential migrant's liquid resources (the movement along the solid red line). In both the normal and inferior cases, the sum of these effects would generate empirical estimates of $\alpha_2 \geq 0$.

[43] If baseline labor supply in rural Alaska is perfectly inelastic, this mechanism would only increase wages in Anchorage. In reality, labor supply in rural Alaska is likely less elastic than in Anchorage, but still somewhat responsive to increases in wages. Thus, any general equilibrium increase in labor demand would disproportionately increase wages in Anchorage relative to the origin, potentially increasing the utility of migration. This situation yields the same qualitative predictions as our simplified version in which origin labor supply is perfectly inelastic, and so we use that version for ease of exposition.

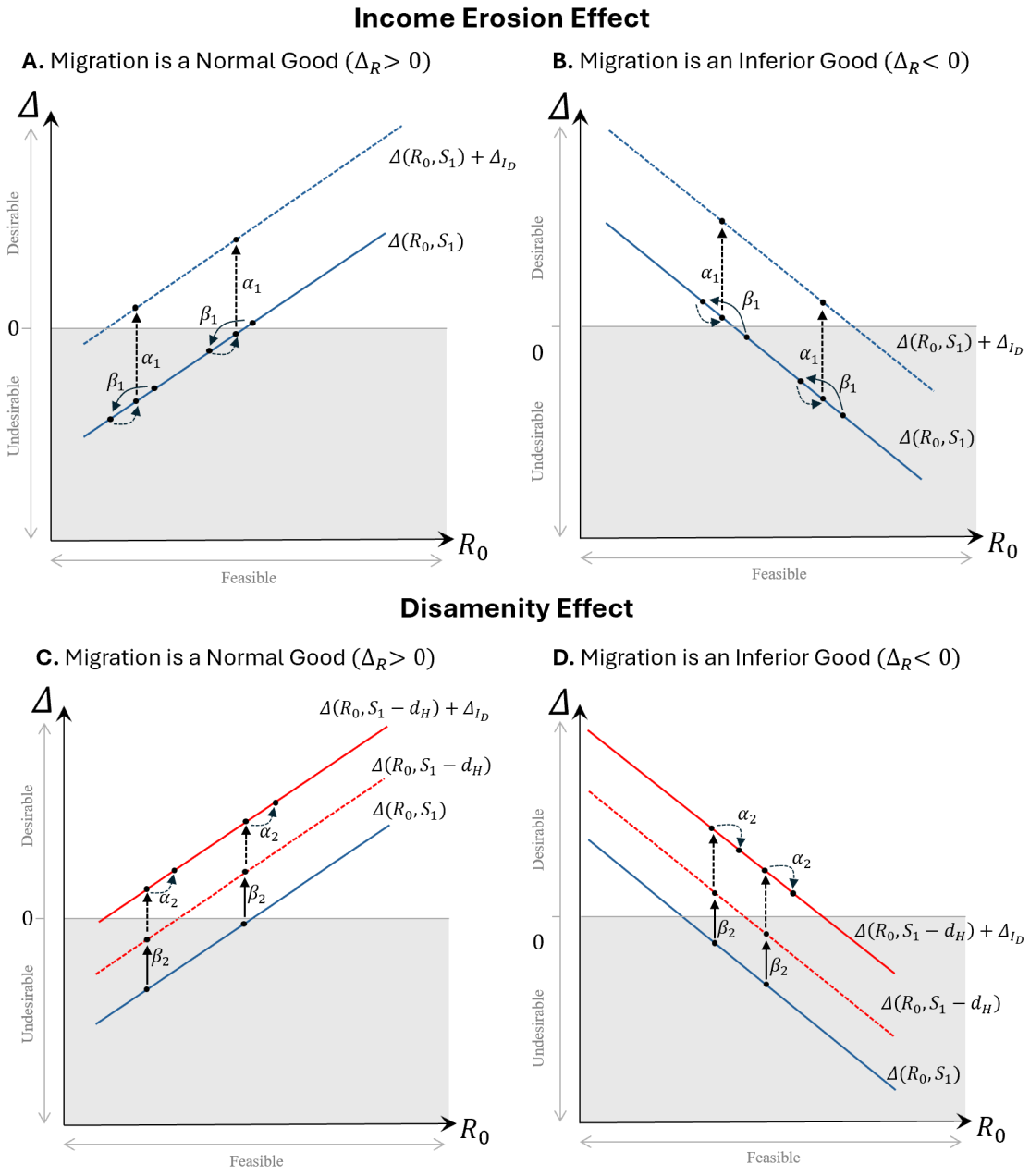


Figure 16: The income erosion and disamenity effects of heat on migration, under general equilibrium desirability effects and in the absence of liquidity constraints.

Summary. Table 14 summarizes the four main hypotheses produced by our alternative conceptual model. Note that if migration is an inferior good, the labor demand mechanism *cannot* generate our main specification's estimate of $\beta_1 \leq 0$. However, the observed pattern of results in Section 5 could be generated by the labor demand mechanism if migration is a normal good.

	Effect	Normal	Inferior
β_1	Income Erosion (Direct)	≤ 0	≥ 0
α_1	Income Erosion (Moderator)	≥ 0	≥ 0
β_2	Disamenity (Direct)	≥ 0	≥ 0
α_2	Disamenity (Moderator)	≥ 0	≥ 0

Table 14: Main hypotheses, labor demand mechanism.

Notes: This table provides the predicted sign of our main parameters in a conceptual model in which a) individuals are not liquidity constrained and migration is always feasible and b) there are substantial, positive general equilibrium effects of the PFD on labor demand in Anchorage, which increase the utility of rural-urban migration.

H.2 Empirical mechanism tests

As shown in Table 14, the labor demand mechanism could generate our observed pattern of results in the absence of liquidity constraints if migration is a normal good. We utilize two pieces of information to provide empirical evidence against this possibility. The first is the origin-Anchorage wage differential in time t, which we compute as follows using community-year median per-capita wages from the ALARI dataset, W_{it}:

$$\Delta_{it}^{w} = W_{At} - W_{it} \tag{50}$$

If increasing demand for labor disproportionately increases urban wages, this may in turn raise the utility of migration (Δ in our conceptual model). Δ_{it}^{w} serves as an approximation of this utility difference. If this relative increase is systematically larger in high-heat origin-years, this may explain our positive estimate of α_1. Controlling for Δ_{it}^{w} should render our estimate of α_1 null if it is solely explained by wage-induced changes in utility.

The second piece of information is the unemployment rate in Anchorage. As shown in Bibler, Guettabi, and Reimer (2023), there is a small statewide increase in male employment during the two months immediately following the dividend disbursement. If the labor demand mechanism explains our results, controlling for Anchorage-specific unemployment rates during this window should eliminate or substantially attenuate our results. Denote the Anchorage unemployment rate s months after the PFD disbursement in year t as $U_{s,At}$. We average the unemployment rate across the month of disbursement and the subsequent two months:

$$\overline{U}_{At} = \frac{1}{3}\sum_{s=0}^{2} U_{s,At} \tag{51}$$

We use Δ_{it}^{w} and $\overline{U}_{At}$ in several augmented versions of our main specification. Because α_1 is the main coefficient of interest which would be directly affected by this mechanism, we concentrate on it here.

Figure 17 plots a) our main specification's estimate of α_1 (in black), and estimates of α_1 from specifications which control for interactions of H_{it}, D_{it}, and the weather control vector $\mathbf{W}_{it}$ with b) Δ_{it}^{w} (in red) and c) $\overline{U}_{At}$ (in green). For both terms, we estimate specifications with and without confounder-specific community-specific PFD slopes (i.e., $\phi_i \Delta_{it}^{w}$ and $\phi_i \overline{U}_{At}$). All estimates are graphed with their 95% confidence intervals. If Anchorage-specific induced demand for labor were responsible for our results, we would expect the latter two estimates to be close to zero. However, they remain relatively stable compared to our main specification, and point estimates fluctuate around our main specification's estimate of α_1. All are statistically distinguishable from zero at at least the 5% significance level, and remain well within the 95% confidence interval of the main specification's estimate.

These results strengthen our conclusion, based on previous findings in the literature, that general equilibrium effects of the fluctuations in the PFD on the rural-urban wage differential are not substantial enough to generate our observed results. Together with Table 3's close mapping to our conceptual model and the affirmative results of Section 5.5's heterogeneity tests, we conclude that our results are consistent with the existence of trapped populations.

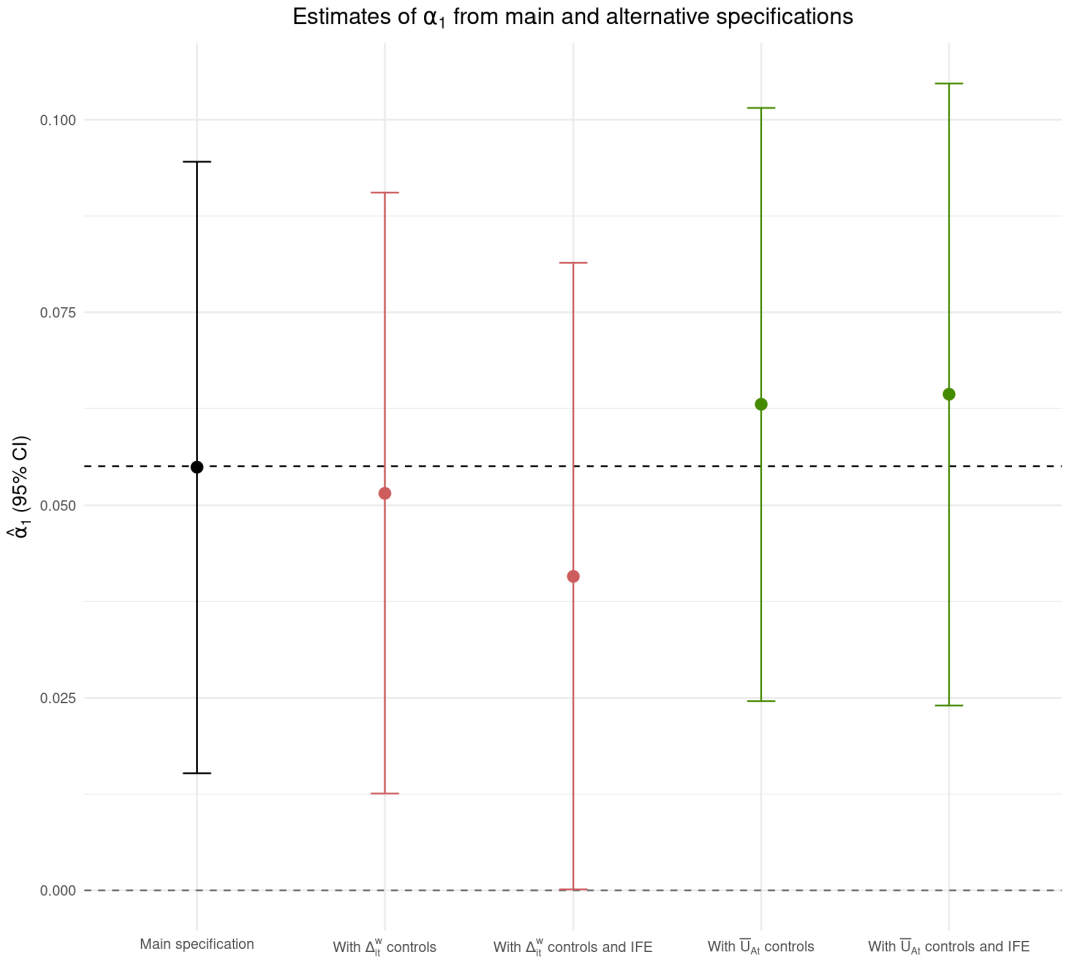


Figure 17: Evidence against the labor demand mechanism, from augmented specifications.

I. Main Results: Nonlinear Effects

While our main specification assumes that unearned income linearly moderates the relationship between H_{it} and m_{it}^A , this need not be true. Our conceptual model and heterogeneity tests show that a positive estimate of α_1 is consistent with a rightward shift in the resource distribution $f_{it}(R_0)$. This shift renders heat-driven migration feasible for the share of individuals with liquid resources directly below the fixed costs of migration, $f_{it}(\delta - \epsilon)$ for $\epsilon > 0$. As unearned income increases, $f_{it}(\delta - \epsilon)$ changes as well, altering the number of individuals induced to migrate. Thus, if the within-community resource distribution is not uniform near δ, the true impact of increases in income on heat-driven migration is likely to be nonlinear.

To illustrate these possibilities, suppose for simplicity that the resource distribution is single-peaked. Further, suppose an increase in H_{it} pushes the peak of the resource distribution far below δ in the absence of unearned income. This leaves δ in the low-density upper tail of the distribution. The marginal dollar of unearned income will likely have an increasing effect on the relationship between H_{it} and migration, as more and more individuals are pushed across the feasibility threshold. This would render $\frac{\partial M}{\partial H}$ convex in Y. Alternatively, if an increase in H_{it} pushes the peak of the resource distribution directly below δ, initial increases in unearned income push the densest segment of the population across the threshold. Subsequent increases would draw from the thinner lower tail of remaining constrained individuals, increasing migration at a decreasing rate. This would render $\frac{\partial M}{\partial H}$ concave in Y.[44] Alternatively, if migration is an inferior good, this concavity could appear as a result of the fact that at high levels of unearned income, migration has been facilitated for many previously-constrained individuals and thus the positive, feasibility-driven effect of Y on $\frac{\partial M}{\partial H}$ is attenuated downward by the negative, desirability-driven effect of Y on the same relationship.

To evaluate this empirically, we augment our main specification with a single-knot linear spline in Y_t. This allows the marginal dollar of unearned income to differentially affect the relationships between both H_{it} and D_{it} and migration above and below the knot value, which we refer to as $\tilde{Y}$. In separate specifications, we use two candidate knots: the median and mean PFD disbursements from 2000 to 2015. Denote $K_t = \max(Y_t - \tilde{Y}, 0)$. To allow unearned income to nonlinearly affect the relationship between environmental change and migration, we augment our main specification as follows:

$$\begin{aligned} m_{it}^A = \exp(&\phi_i + \psi_t + \lambda_i Y_t + \phi_i K_t + \\ &\beta_{\mathbf{1}} H_{it} + \alpha_1 H_{it} Y_t + \alpha_1^k H_{it} K_t + \\ &\beta_{\mathbf{2}} D_{it} + \alpha_2 D_{it} Y_t + \alpha_2^k D_{it} K_t + \\ &\tilde{\mathbf{W}}_{it}' \boldsymbol{\Upsilon} + \ln(P_{it})) + \epsilon_{it} \end{aligned} \tag{52}$$

Here, the vector $\tilde{\mathbf{W}}_{it}$ includes all weather controls used in our main specification, as well as their interactions with Y_t and K_t. Similar to the motivation for including $\lambda_i Y_t$ in our main

[44] We note that this example is stylized, and assumes that the distribution of the net migration utility Δ is uniform in the neighborhood of δ. This may not be true, providing further evidence that $\frac{\partial M}{\partial H}$ is likely to be highly nonlinear in Y. However, incorporating the utility distribution makes the relationship between the resource distribution's position and the convexity of $\frac{\partial M}{\partial H}$ ambiguous.

specification, we also include $\phi_i K_t$ in this estimating equation to ensure that all interaction terms have a causal interpretation. This specification is very demanding, and presents a bias-variance tradeoff: given that the model is estimated using roughly 4,900 observations, these additional parameters are likely to greatly reduce its precision.

Table 15 presents the results of our main specification in Column (a), and results of Equation 52 in Columns (b) and (c). Column (b) uses the median PFD value as the knot $\tilde{Y}$, and Column (c) uses the mean PFD value. These estimates provide suggestive evidence of a nonlinear relationship between heat-induced migration and unearned income, which is linearly approximated by our main specification.

However, as expected, these specifications are very imprecisely estimated. We are unable to statistically distinguish many of our estimates in the spline specifications from zero. This also affects the point estimates of coefficents which were initially small in magnitude in our main specification. For example, the point estimates of β_2 are negative in Columns (b) and (c), but their 95% confidence intervals overlap substantially with the confidence interval of our initially positive estimate of β_2.

Finally, Figures 18 and 19 use these estimates to visually represent the impact of one standard deviation increase in H_{it}, evaluated at the observed values of the Permanent Fund Dividend. These estimates are presented with their 95% delta method confidence intervals. The red points in each figure correspond to their respective knots, the median and mean PFD values. These are the nonlinear versions of Figure 7 in the main text, and the point estimates offer suggestive evidence of a concave relationship between heat-driven migration ($\frac{\partial M}{\partial H}$) and unearned income ($Y$). However, due to these specifications' loss of precision relative to Column (a), the effect of unearned income on heat-driven migration is statistically distinguishable from zero only at the lowest PFD levels.

Table 15: Results, linear and spline specifications

		(a)	(b)	(c)
Variable	**Estimand**	m_{it}^A	m_{it}^A	m_{it}^A
H_{it}	β_1	-0.098**	-0.155*	-0.116
		(0.039)	(0.089)	(0.074)
$H_{it} \times Y_t$	α_1	0.055***	0.102	0.070
		(0.020)	(0.071)	(0.055)
$H_{it} \times K_t$	α_1^k		-0.072	-0.043
			(0.103)	(0.107)
D_{it}	β_2	0.061**	-0.047	-0.019
		(0.028)	(0.095)	(0.063)
$D_{it} \times Y_t$	α_2	-0.016	0.071	0.047
		(0.015)	(0.076)	(0.048)
$D_{it} \times K_t$	α_2^k		-0.115	-0.112
			(0.096)	(0.076)
Observations		4,936	4,936	4,936
Weather Controls		YES	YES	YES
Community-specific PFD slopes		YES	YES	YES
Community FE		YES	YES	YES
Year FE		YES	YES	YES

H_{it} and D_{it} are measured in units of within-community standard deviations. Y_t and K_t are measured in \$1000 (2015 USD).
Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

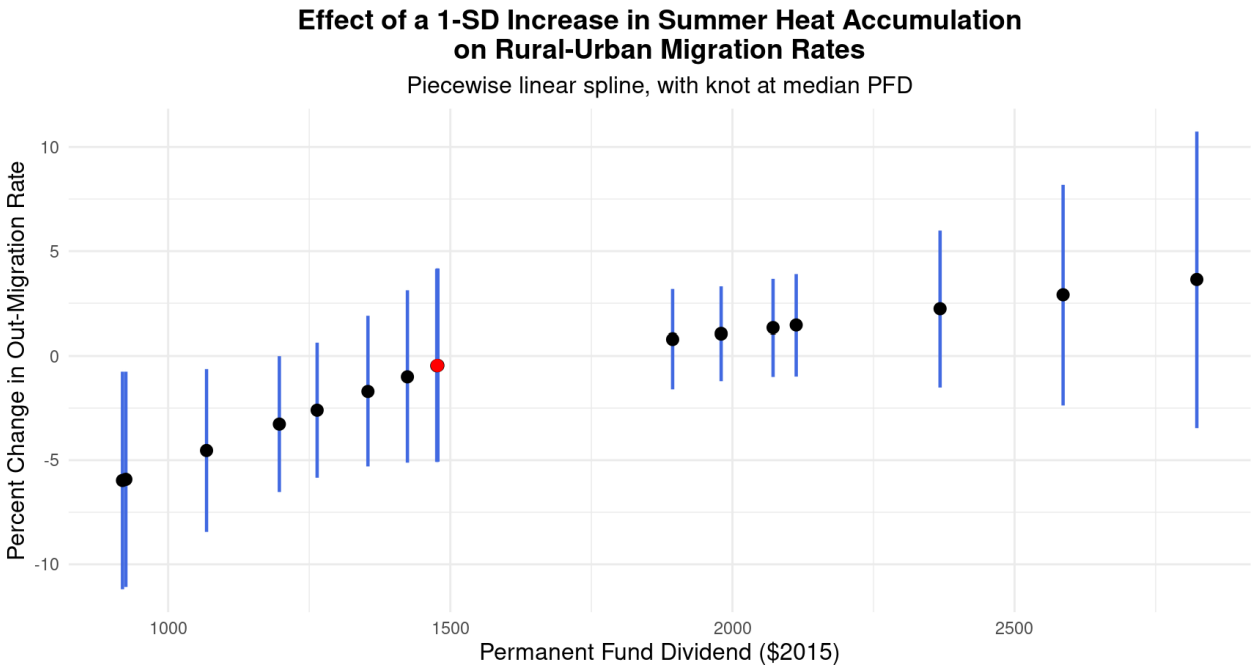


Figure 18: Effect of heat accumulation on migration at observed PFD values, knot at median

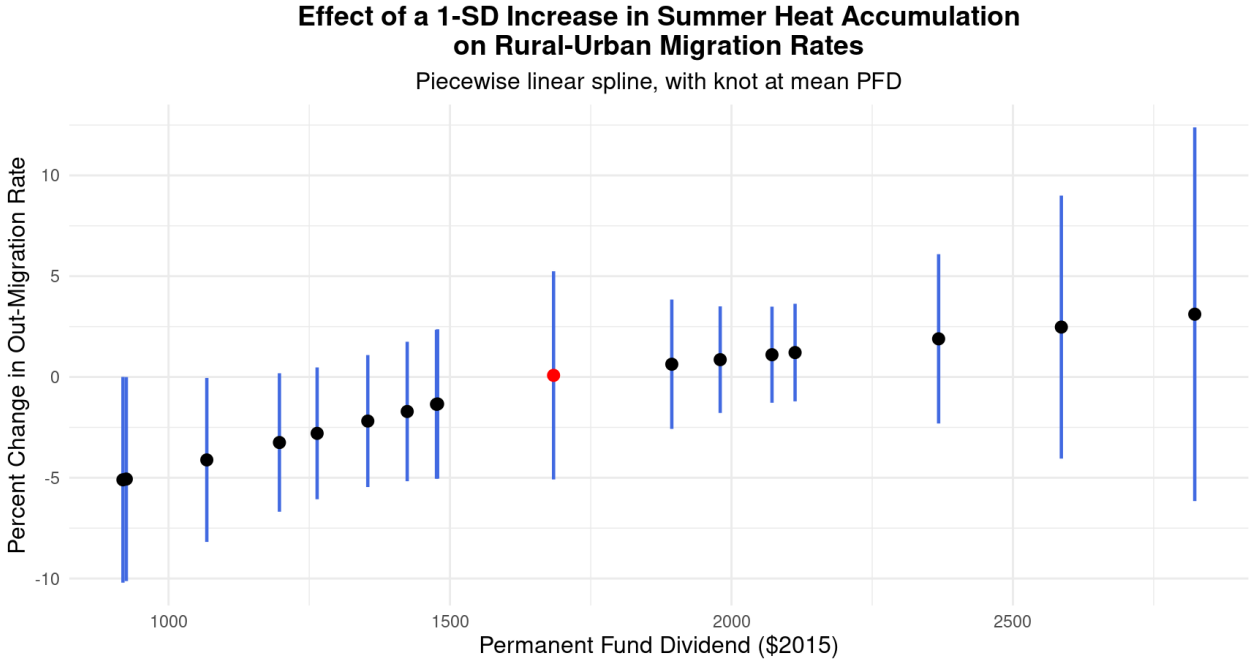


Figure 19: Effect of heat accumulation on migration at observed PFD values, knot at mean

J. Calculating Heat-Driven Migration Flows Enabled by the PFD

Let $\hat{m}_{it}^{A}(H, Y)$ denote the predicted number of migrants in community i and year t given summer heat accumulation of H and a PFD value of Y. We write this using the PPML structure of our empirical specification:

$$\hat{m}_{it}^{A}(H, Y) = \hat{m}_{it}^{AA,b} \exp[s(Y_t) \times \Delta H_{it}]$$

where $s(Y) = \beta_1 + \alpha_1 Y$ is the PFD's moderating effect on heat-driven migration, $\Delta H_{it} = H_{it} - \overline{H}_i$, and $m_{it}^{AA,b}$ is the predicted level of migration when $H_{it} = \overline{H}_i$. The counterfactual heat-driven migration facilitated by the PFD can be written in a difference-in-differences-style equation as follows:

$$\mathbb{M}_{it}^{A} = \underbrace{[\hat{m}_{it}^{A}(H_{it}, Y_t) - \hat{m}_{it}^{A}(\bar{H}_i, Y_t)]}_{\text{Heat-driven migration with the PFD}} - \underbrace{[\hat{m}_{it}^{A}(H_{it}, 0) - \hat{m}_{it}^{A}(\bar{H}_i, 0)]}_{\text{Heat-driven migration without the PFD}}$$

Conditional on predicted baseline out-migration, $\mathbb{M}_{it}$ does not depend on β_1, heat's direct effect on rural-urban migration, and only depends on α_1, how this response is moderated by unearned income. In constructing the counterfactual, we hold baseline migration fixed across the two dividend scenarios, and vary only the dividend's moderation of the heat response. As in our main specification, the dividend's level effect on migration is absorbed by year fixed effects and not separately identified. We calculate the total number of "heat-driven, PFD-facilitated" migrants using the following expression:

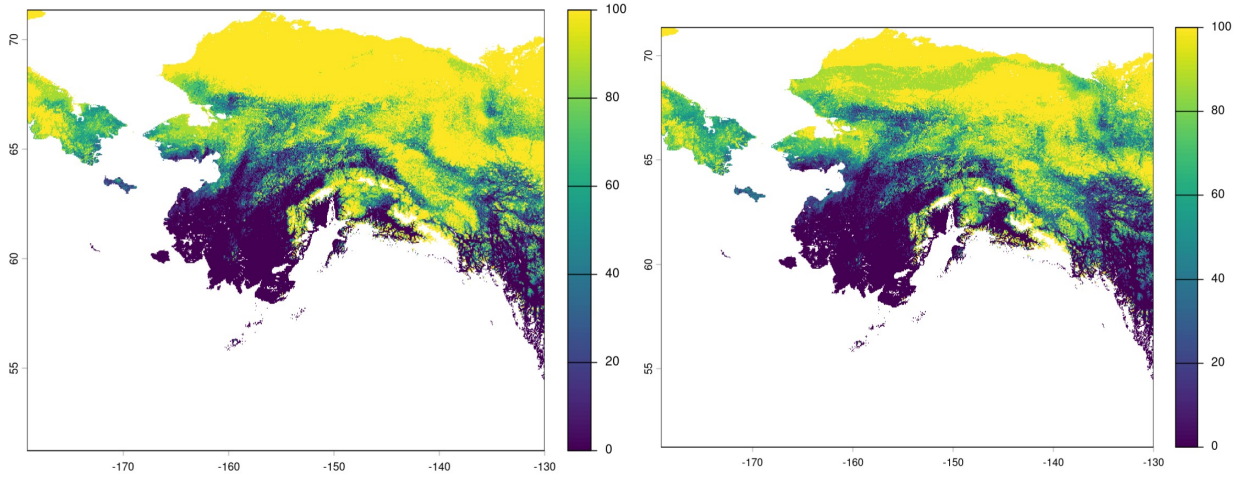
$$\begin{aligned}
\mathbb{M}_{it} &= [\hat{m}_{it}^{A}(H_{it}, Y_t) - \hat{m}_{it}^{A}(\bar{H}_i, Y_t)] - [\hat{m}_{it}^{A}(H_{it}, 0) - \hat{m}_{it}^{A}(\bar{H}_i, 0)] \\
&= \left[\hat{m}_{it}^{Ab} \exp[s(Y_t) \times \Delta H_{it}] - \hat{m}_{it}^{Ab} \exp[0]\right] - \left[\hat{m}_{it}^{Ab} \exp[s(0) \times \Delta H_{it}] - \hat{m}_{it}^{Ab} \exp[0]\right] \\
&= \hat{m}_{it}^{Ab} \exp[s(Y_t) \times \Delta H_{it}] - \hat{m}_{it}^{Ab} \exp[s(0) \times \Delta H_{it}] \\
&= \hat{m}_{it}^{Ab} \exp[s(Y_t) \times \Delta H_{it}] \left(1 - \frac{\hat{m}_{it}^{Ab} \exp[s(0) \times \Delta H_{it}]}{\hat{m}_{it}^{Ab} \exp[s(Y_t) \times \Delta H_{it}]}\right) \\
&= \hat{m}_{it}^{A}(H_{it}, Y_t) \left(1 - \exp[-\alpha_1 Y_t \times \Delta H_{it}]\right)
\end{aligned}$$

K. Supplementary Figures



(a) **(b)**

Figure A1: Alaskan subsistence harvesting. Panel (a) shows subsistence hunters cleaning moose after an early fall hunt. Panel (b) shows salmon drying before preparation.



(a) 1999 **(b)** 2015

Figure A2: Declines in permafrost. Grid-cell level permafrost extent, using data on the modeled probability of continuous permafrost from the European Space Agency's Climate Change Initiative (Obu et al., 2019) showing the decrease in permafrost extent from (a) 1999 to (b) 2015.



(a)



(b)



(c)



(d)

Figure A3: The impacts of land degradation in Alaska. In panel (a), a house outside of Fairbanks sinks into thawing permafrost. In panel (b), a bluff on the Itkillik River erodes into the water. In panel (c), a drainage culvert in Chevak splits in half due to a land subsidence event. In panel (d), a fire hydrant in Point Lay is uprooted by permafrost thaw.

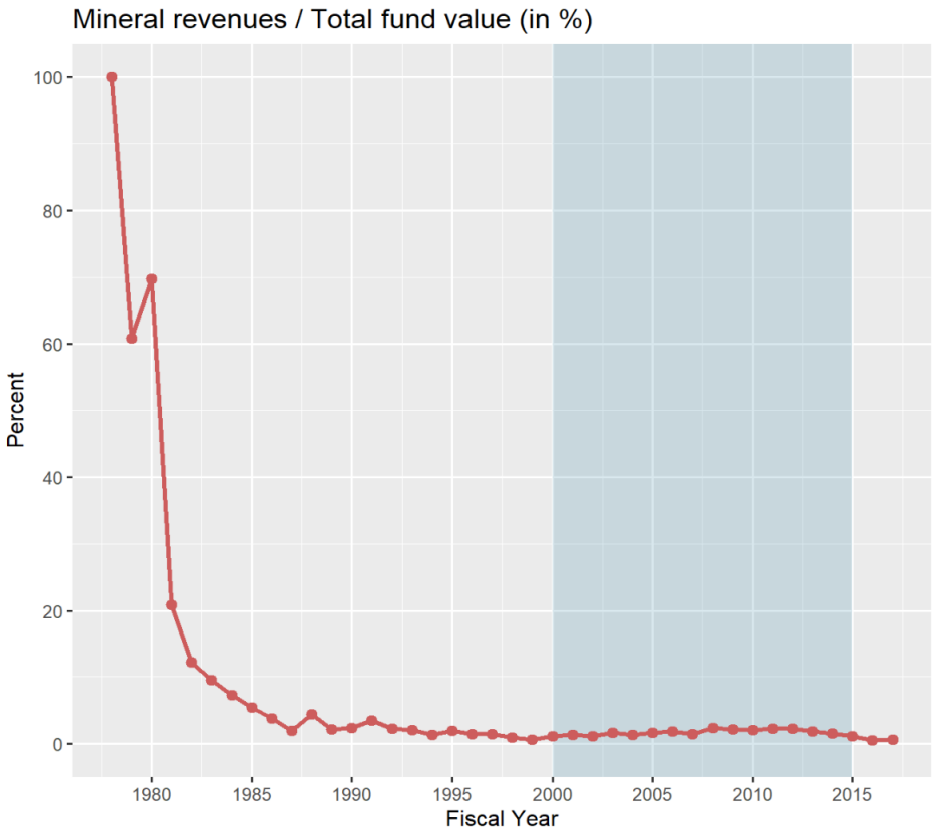


Figure A4: Mineral revenues and the Permanent Fund. Mineral revenues as a percentage of the Permanent Fund. Our study period of 2000–2015 is highlighted in blue. The Permanent Fund Dividend is determined by net income from the Permanent Fund's investments, averaged over the previous five years. During our study period, PFD disbursements varied considerably, but the fraction of the Fund capitalized by state mineral revenues remained roughly 1–2%. Annual changes in PFD disbursements from 2000 to 2015 are thus not driven by changes in Alaska's resource revenues. Figure reproduced from Kueng (2018).

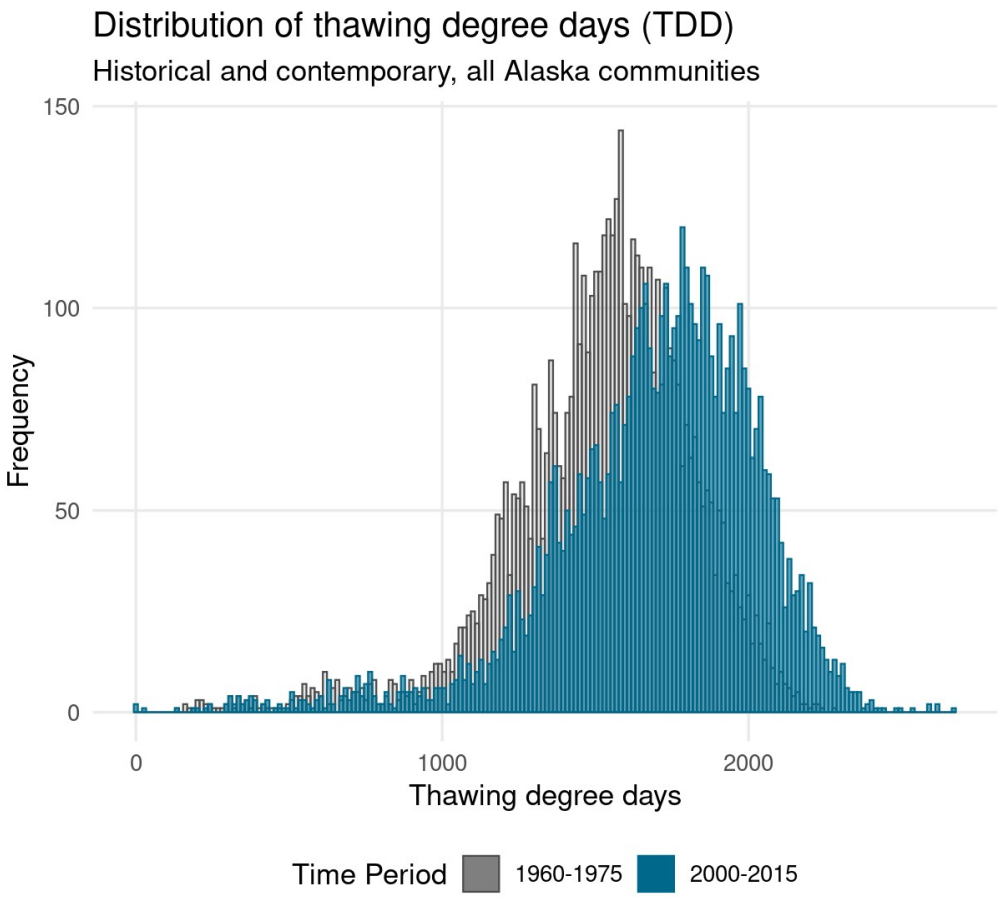


Figure A5: Thawing degree days, all Alaskan communities. The grey histogram plots the empirical distribution of thawing degree days for all Alaskan communities between 1960 and 1975. The blue histogram repeats this exercise, using our sample period of 2000–2015.



Figure A6: Wage distribution across communities, 2000

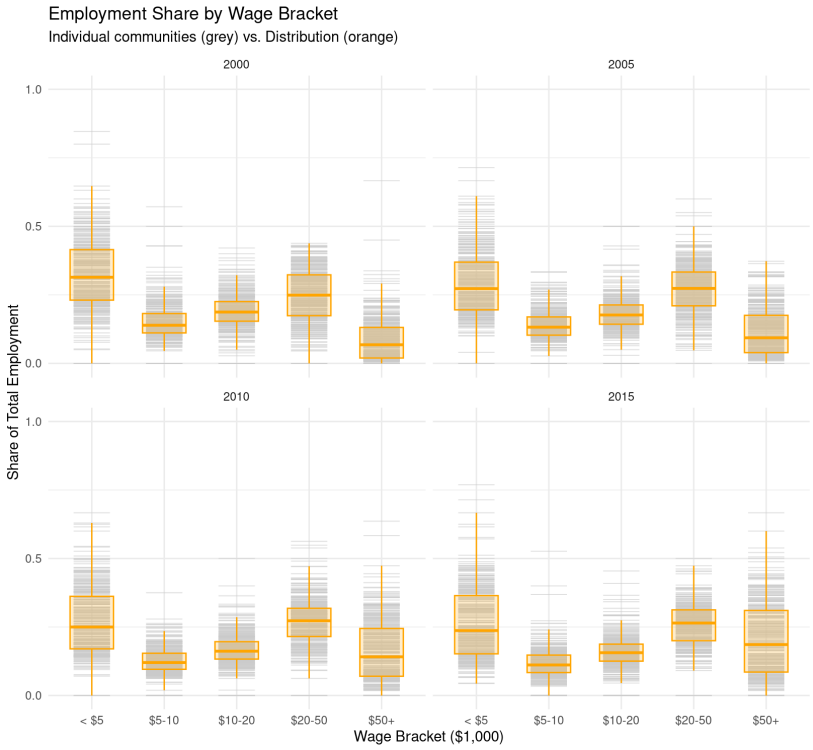


Figure A7: Wage distribution across communities, selected years

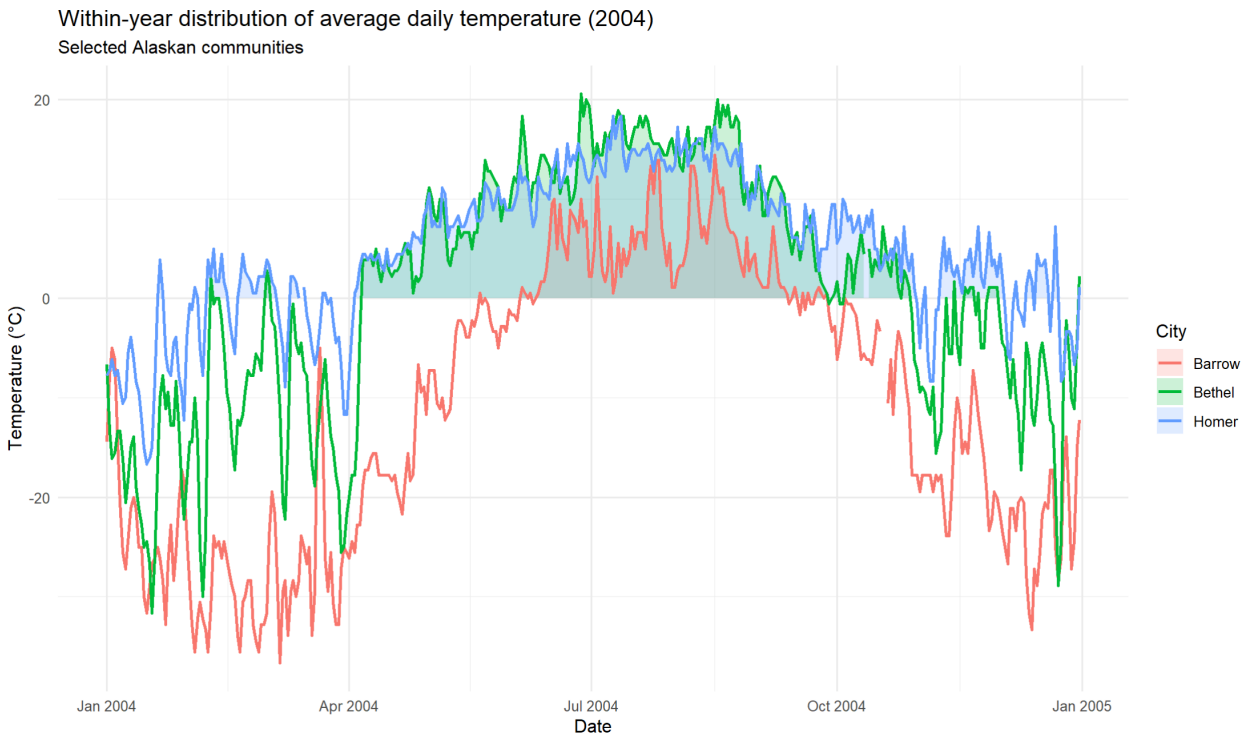


Figure A8: Within-year temperature distribution, selected Alaska communities. Accumulation of thawing degree days is represented by the shaded areas between $0°C$ and the relevant observations.

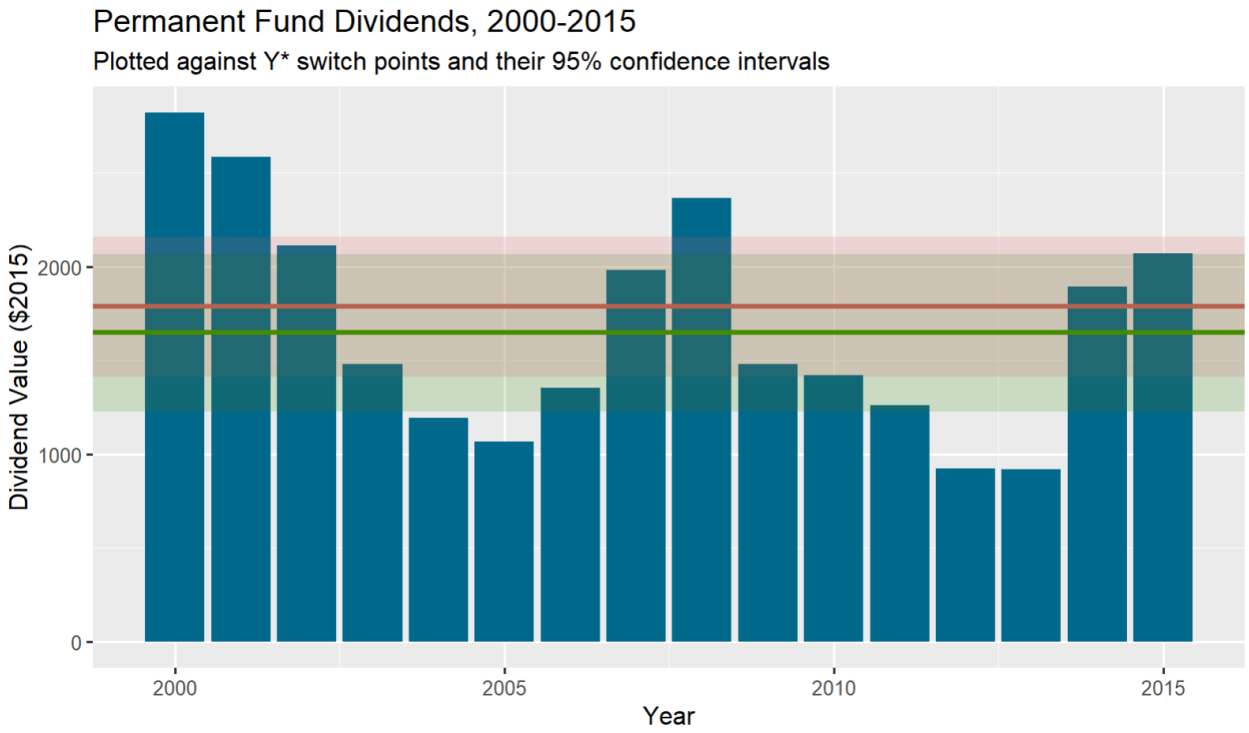


Figure A9: PFD "switch points" graphed against observed dividend values. The total effect's switch point, and its 95% confidence interval, are pictured in green. The income erosion effect's switch point, and its 95% confidence interval, are pictured in red.

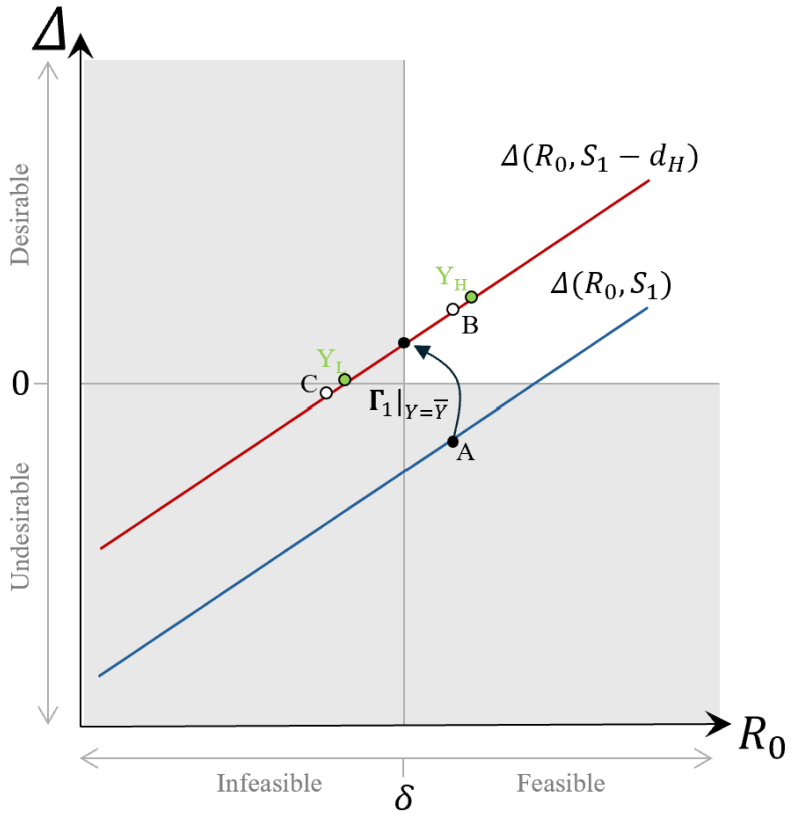


Figure A10: Individual-level representation of Equation 41. The disamenity effect increases the utility of migration, moving the individual from Point A to Point B. When unearned income is equal to zero, the income erosion effect decreases the utility and feasibility of migration, moving the individual to point C; the individual does not migrate. At the lowest level of unearned income, Y_L, the increase in liquid resources is still not sufficient to make migration feasible. At the highest level of unearned income, Y_H, the increase in liquid resources is large enough to completely counteract the income erosion effect, and the individual migrates. $\mathbf{\Gamma}_1$ is evaluated at a weighted average of PFD values $\overline{Y}$, represented by the arrow in the figure. In the aggregate case of community-level out-migration rates, this obscures the influence of both effects on out-migration. Note that although our conceptual model does not take a stand on whether migration is a normal or inferior good, it is depicted as normal in this figure for the sake of simplicity. A similar ambiguity in the sign of $\mathbf{\Gamma}_1$ arises when migration is inferior.

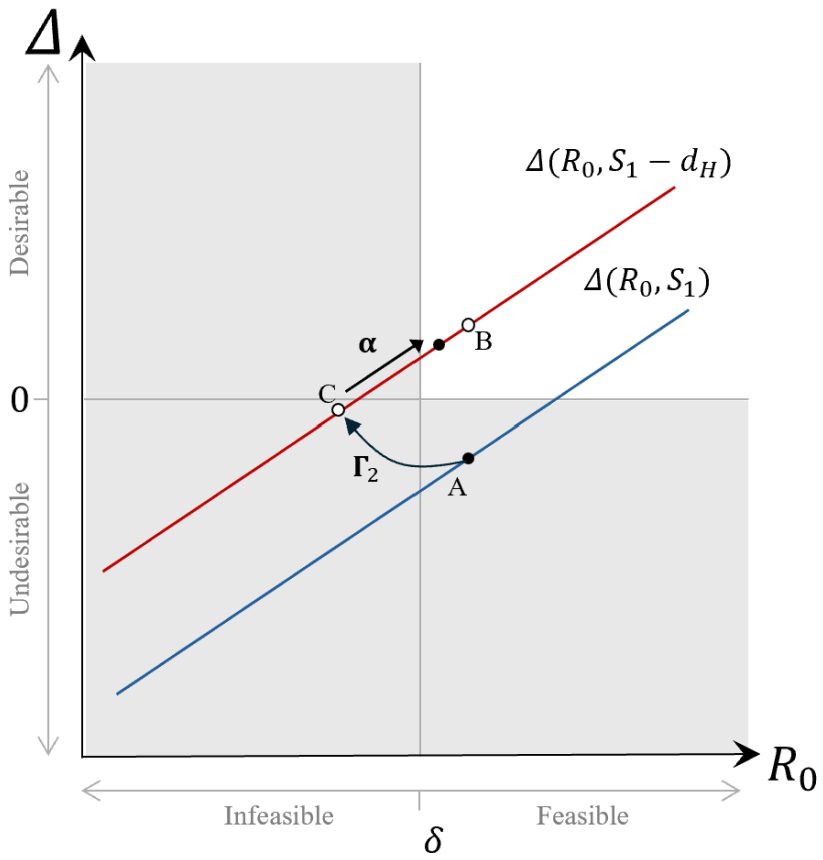


Figure A11: Individual-level representation of Equation 42. The disamenity effect increases the utility of migration, moving the individual from Point A to Point B. When unearned income is equal to zero, the income erosion effect decreases the utility and feasibility of migration, moving the individual to point C. $\boldsymbol{\Gamma}_2$ identifies the total movement from A to C, which is ambiguous in sign because of these countervailing effects. $\boldsymbol{\alpha}$ identifies how this baseline effect changes with increases in unearned income, which is unambiguously non-negative when migration is a normal good. Note that although our conceptual model does not take a stand on whether migration is a normal or inferior good, it is depicted as normal in this figure for the sake of simplicity. A similar ambiguity in the sign of $\boldsymbol{\Gamma}_2$ arises when migration is inferior, and the sign of $\boldsymbol{\alpha}$ is rendered ambiguous as well.

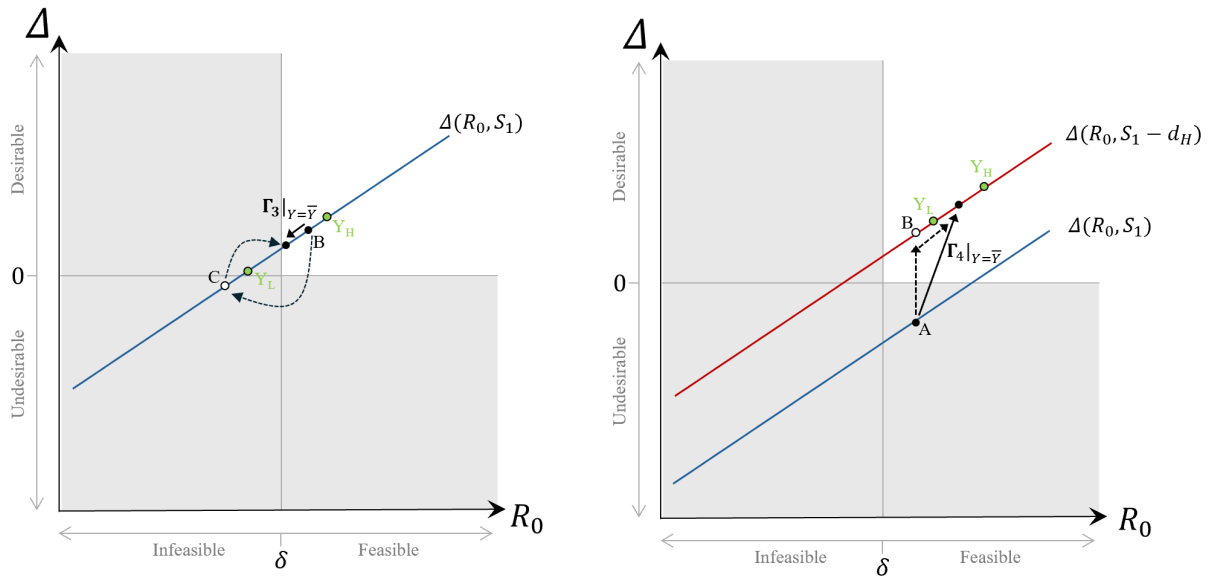


Figure A12: Individual-level representation of Equation 44. In the left panel, environmental degradation $D_{it}(H_{it}, \mathbf{W})$ is held constant. This identifies the income erosion effect, which decreases the utility and feasibility of migration, and the strength of this effect is moderated by increases in unearned income. $\mathbf{\Gamma}_3$ is evaluated at a weighted average of PFD values, $\overline{Y}$, represented by the arrow in the figure. In the aggregate case of community-level out-migration rates, this obscures the influence of the income erosion effect on out-migration. In the right panel, heat accumulation H_{it} is held constant. Decreases in environmental quality are induced by variation in $\mathbf{W}$. This identifies the disamenity effect, which increases the utility of migration. The strength of this effect is moderated by increases in unearned income. $\mathbf{\Gamma}_4$ is evaluated at a weighted average of PFD values $\overline{Y}$, represented by the arrow in the figure. In the aggregate case of community-level out-migration rates, this is unambiguously non-negative if migration is a normal good. Although our conceptual model does not take a stand on whether migration is a normal or inferior good, it is depicted as normal in this figure for the sake of simplicity. A similar ambiguity in the sign of $\mathbf{\Gamma}_3$ arises when migration is inferior, and the sign of $\mathbf{\Gamma}_4$ is rendered ambiguous as well.

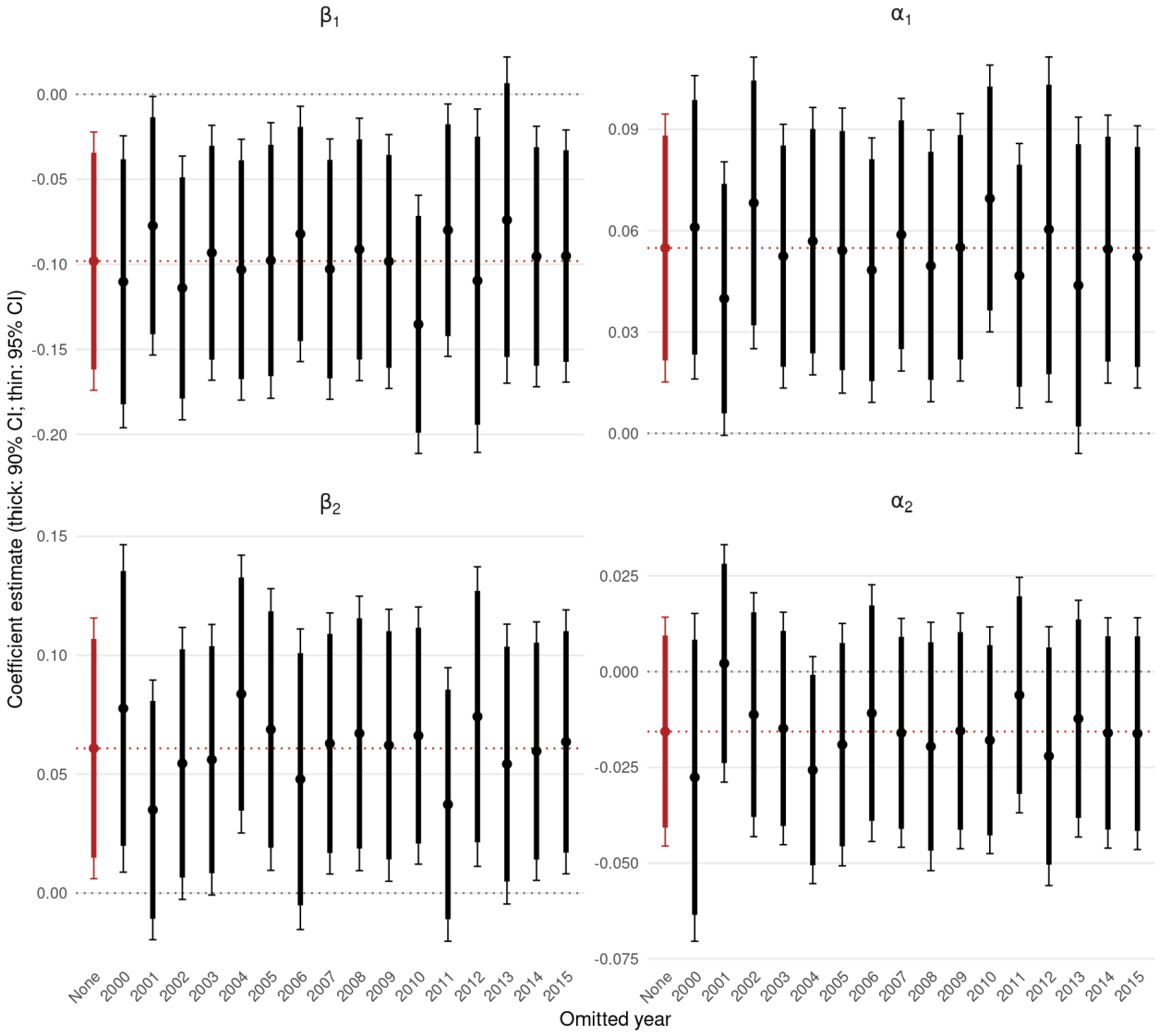


Figure A13: Leave-one-out estimates for each coefficient of interest. This figure shows estimates of the four main parameters of interest, across the paper's main specification (in red) and 16 specifications which successively drop individual years from the estimation sample (in black). All point estimates are pictured with their 95% and 90% confidence intervals.

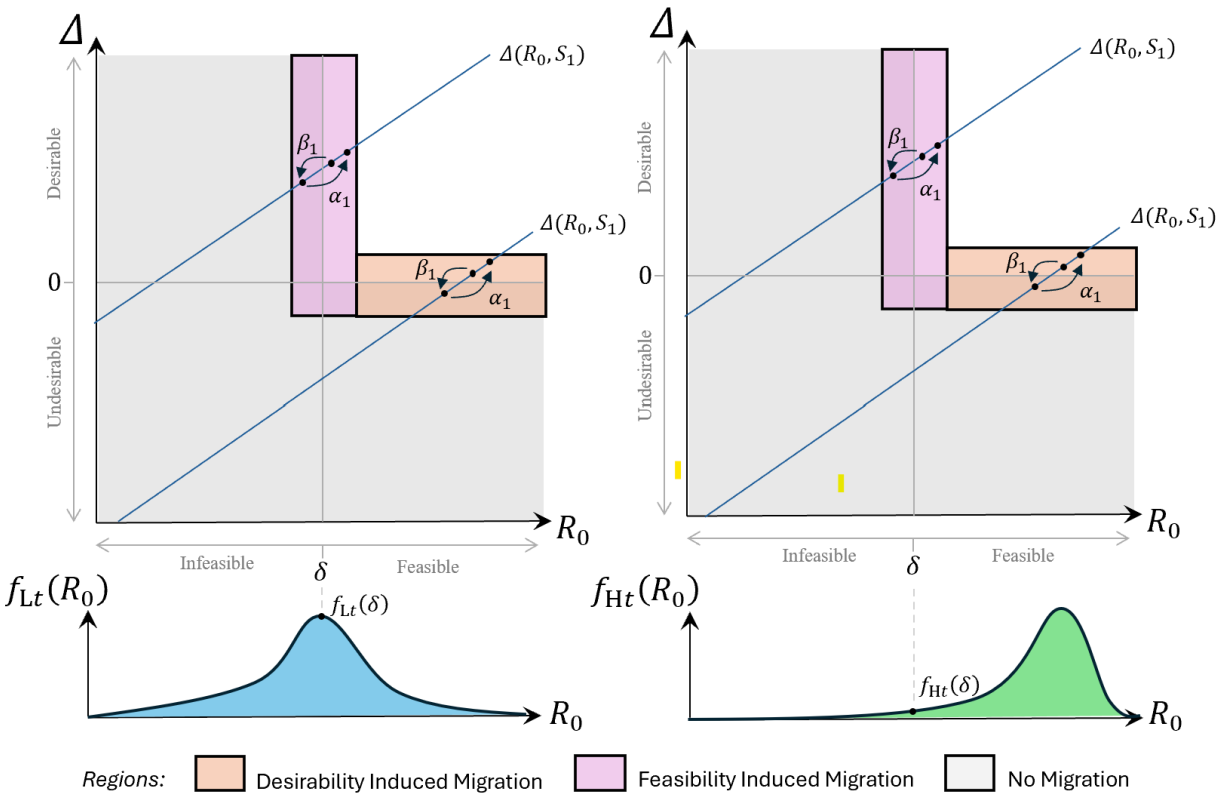


Figure A14: Heterogeneity test, low- vs. high-resource communities.

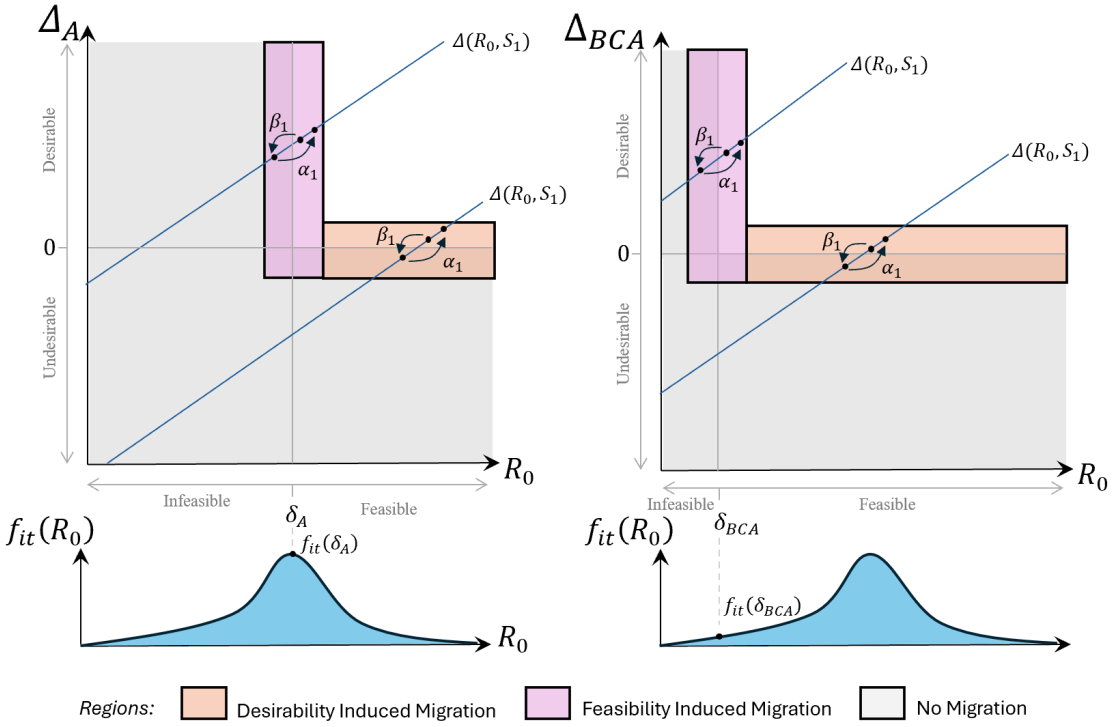


Figure A15: Heterogeneity test, Anchorage vs. within-BCA migration.

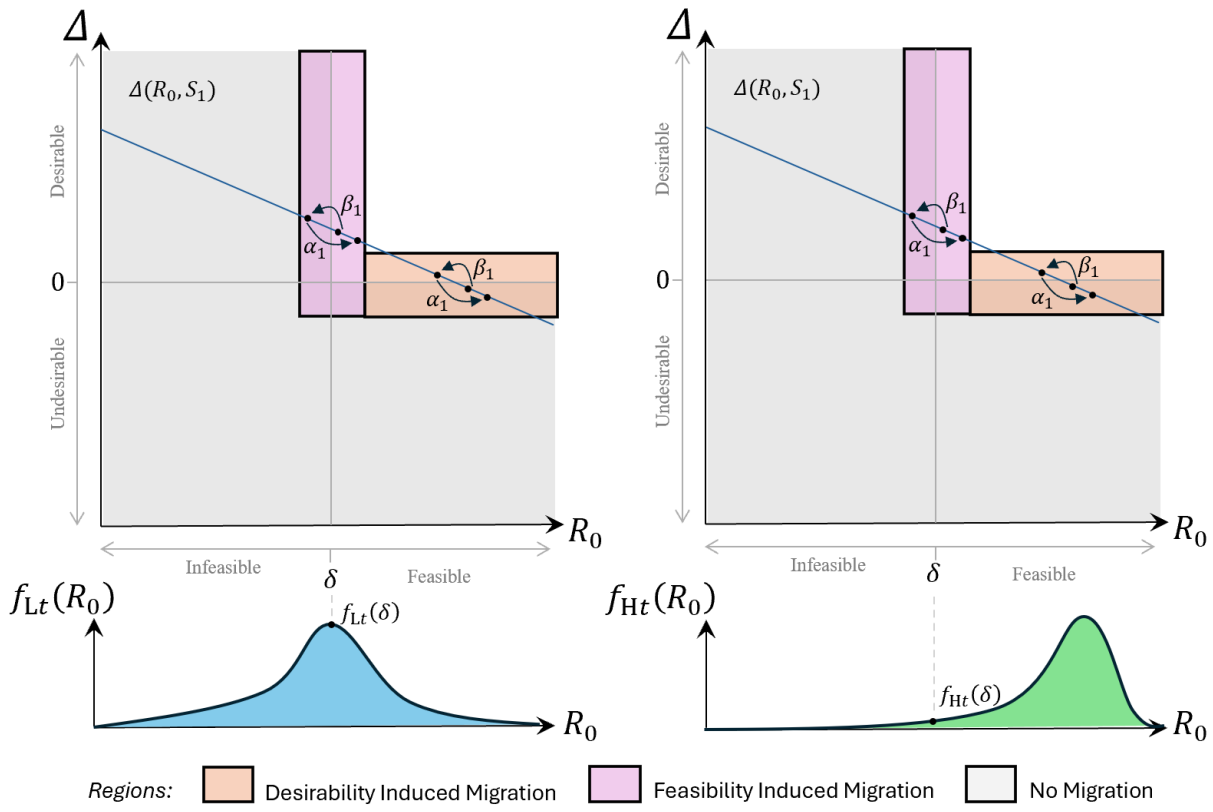


Figure A16: Wage-based heterogeneity test when migration is an inferior good. This figure recreates Figure A14 in the case when migration is inferior. In this case, estimates of $\beta_1 < 0$ and $\alpha_1 > 0$ are sufficient to show that "trapped populations" exist; desirability-driven migration cannot generate this pattern alone, and in fact predicts the opposite sign pattern ($\beta_1 > 0$ and $\alpha_1 < 0$). Thus, if the income erosion effect influences observed migration for a large share of the population simply by changing its desirability, we would expect to see $\beta_1 > 0$ and $\alpha_1 < 0$ in the subsample of high-wage communities where migration is feasible for a larger share of the population. Empirically, however, we are not able to reject that $\beta_1 = 0$ and $\alpha_1 = 0$ in this subsample. In summary, if migration is inferior then our results imply that trapped populations exist. In turn, our finding that $\beta_1 = 0$ and $\alpha_1 = 0$ for the subsample of high-wage communities suggests that feasibility is likely the only way in which the income erosion effect shapes observed migration responses to heat, and desirability-induced migration along this channel is negligible.

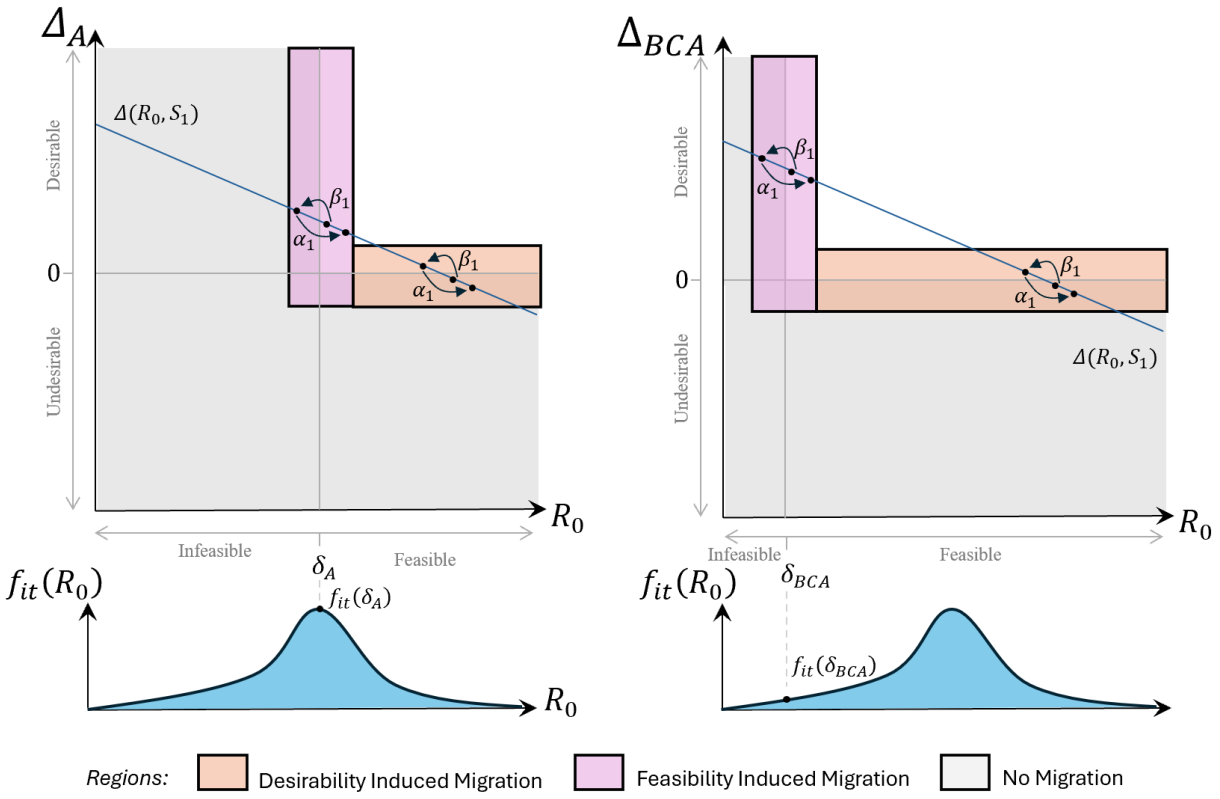


Figure A17: Destination-based heterogeneity test when migration is an inferior good. This figure recreates Figure A15 in the case when migration is inferior. In this case, estimates of $\beta_1 < 0$ and $\alpha_1 > 0$ are sufficient to show that "trapped populations" exist; desirability-driven migration cannot generate this pattern alone, and in fact predicts the opposite sign pattern ($\beta_1 > 0$ and $\alpha_1 < 0$). Thus, if the income erosion effect influences observed migration for a large share of the population simply by changing its desirability, we would expect to see $\beta_1 > 0$ and $\alpha_1 < 0$ for lower-cost, closer destinations which are feasible for a larger share of the population. However, we are not able to reject that $\beta_1 = 0$ and $\alpha_1 = 0$ for this group of moves. In summary, if migration is inferior then our results imply that trapped populations exist. In turn, our finding that $\beta_1 = 0$ and $\alpha_1 = 0$ for low-cost moves suggests that feasibility is likely the only way in which the income erosion effect shapes observed migration responses to heat, and desirability-induced migration along this channel is negligible.

L. Supplementary Tables

Table A.1: Permafrost indicators over time

	(1)	(2)
Variable	ALT_{it}	PE_{it}
t	0.018***	-0.336***
	(0.002)	(0.064)
Observations	2,040	3,672
Community FE	Yes	Yes

Standard errors clustered by community.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.
This table reports the estimation results of a community-level regression of (1) the active layer thickness of soil above permafrost, ALT_{it}, and (2) the annual probability of permafrost extent, $PE_{it} \in \{0, 100\}$, on community fixed effects and a time trend, t. ALT measures the depth (in meters) of the active layer of soil above the permafrost. A deeper ALT indicates permafrost loss. PE captures the extensive margin of permafrost thaw.

Table A.2: The Climate Priming Index over time

	(1)
Variable	D_{it}
t	0.032^{***}
	(0.002)
Observations	3,440
Community FE	Yes

Standard errors clustered by community.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. This table reports the estimation results of a community-level regression of the Climate Priming Index D_{it} on community fixed effects and a time trend, t. This regression thus estimates the average trend in environmental degradation within the same community.

Table A.3: The Climate Priming Index predicts permafrost dynamics

	(1)	(2)
Variable	ΔALT_{it}	ΔPE_{it}
D_{it}	0.107***	-0.777**
	(0.013)	(0.299)
Observations	1,904	2,752
Community FE	Yes	Yes
Year FE	Yes	Yes

Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.
This table reports the estimation results of community-level regressions of (1) the year-over-year change in active layer thickness ΔALT_{it}, and (2) the year-over-year change in probability of permafrost extent, ΔPE_{it}, on D_{it}. Like Table A.1, both variables are sourced from the European Space Agency's Climate Change Initiative (Obu et al., 2019). These regressions include community and year fixed effects, and thus estimate how the Climate Priming Index influences the year-over-year change in each permafrost indicator within the same community. We view these results as particularly reassuring, given that the Climate Priming Index and modeled permafrost data are sourced from independent institutions.

Table A.4: Alternative specifications

		(1)	(2)	(3)
Variable	**Estimand**	m_{it}^A	m_{it}^A	m_{it}^A
H_{it}	β_1	-0.098**	-0.080*	-0.098**
		(0.039)	(0.045)	(0.041)
$H_{it} \times Y_t$	α_1	0.055***	0.045**	0.053**
		(0.020)	(0.022)	(0.021)
D_{it}	β_2	0.061**	0.074**	0.077***
		(0.028)	(0.032)	(0.029)
$D_{it} \times Y_t$	α_2	-0.016	-0.025	-0.029*
		(0.015)	(0.019)	(0.017)
Observations		4,936	4,936	4,936
Weather Controls		Yes	Yes	Yes
Community-specific PFD slopes		Yes	Yes	Yes
Community FE		Yes	Yes	Yes
Year FE		Yes	Yes	Yes
Community linear trends		No	Yes	No
Community linear trends $\times Y_t$		No	Yes	No
BCA linear trends		No	No	Yes
BCA linear trends $\times Y_t$		No	No	Yes

H_{it} and D_{it} are measured in units of within-community standard deviations. Y_t is measured in \$1000 (2015 USD).
Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table A.5: Robustness to oil price moderation

Variable	(1)	(2)	(3)
H_{it}	-0.006	-0.005	-0.011
	(0.011)	(0.010)	(0.012)
$H_{it} \times Y_t$	0.055***		0.045*
	(0.020)		(0.024)
$H_{it} \times A_t$		-0.004	0.000
		(0.003)	(0.004)
D_{it}	0.035***	0.023***	0.032***
	(0.008)	(0.008)	(0.010)
$D_{it} \times Y_t$	-0.016		-0.010
	(0.015)		(0.018)
$D_{it} \times A_t$		0.004	0.003
		(0.003)	(0.005)
Observations	4,936	4,936	4,936
Weather Controls	Yes	Yes	Yes
Community-specific slopes (Y_t)	Yes	No	Yes
Community-specific slopes (A_t)	No	Yes	Yes
Community FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

H_{it} and D_{it} are measured in units of within-community standard deviations. Y_t is measured in \$1000 (2015 USD).

Standard errors clustered by community.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

This table presents results of several robustness checks designed to test whether our interaction coefficients are generated by the confounding factor of oil prices, which affect both household budgets (through fuel costs) and migration costs and are moderately negatively correlated with the PFD ($\rho = -0.45$). We estimate all specifications via PPML, using m_{it}^{AA} as the dependent variable. Unlike in the main text, we center Y_t in all specifications so that results can be compared across columns.

Column (1) reproduces our main specification from the text using the time-demeaned PFD, for comparison. Column (2) replaces Y_t in the specification with A_t, the time-demeaned real price of Alaska North Slope crude oil (\$2015 USD). The level effect of H_{it} is broadly similar across the two columns, and although the level effect of D_{it} attenuates, it remains highly significant. More importantly, neither interaction term is statistically different from zero. Thus, it is highly unlikely that confounding oil price fluctuations explain our main results. Finally, Column (3) augments Column (1) with all A_t controls from Column (2), including the community-specific PFD slopes $\phi_i A_t$. The results remain broadly similar to those in Column (1), although the precision with which α_1 is estimated decreases. This is to be expected; the mild correlation between A_t and Y_t means that the interaction terms in Column (3) are essentially "competing for variation."

Table A.6: Main results, excluding communities with < 50 residents on average

Variable	**Estimand**	m_{it}^A
H_{it}	β_1	-0.098**
		(0.039)
$H_{it} \times Y_t$	α_1	0.055***
		(0.020)
D_{it}	β_2	0.060**
		(0.028)
$D_{it} \times Y_t$	α_2	-0.015
		(0.015)
Observations		4,383
Weather Controls		Yes
Community-specific PFD slopes		Yes
Community FE		Yes
Year FE		Yes

H_{it} and D_{it} are measured in units of within-community standard deviations. Y_t is measured in \$1000 (2015 USD). Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Table A.7: Main results, using the PFD disbursement value in year $t+1$

Variable	**Estimand**	m_{it}^A
H_{it}	β_1	0.012
		(0.041)
$H_{it} \times Y_{t+1}$	α_1	-0.005
		(0.023)
D_{it}	β_2	0.018
		(0.033)
$D_{it} \times Y_{t+1}$	α_2	0.004
		(0.019)
Observations		4,631
Weather Controls		Yes
Community-specific PFD slopes		Yes
Community FE		Yes
Year FE		Yes

H_{it} and D_{it} are measured in units of within-community standard deviations. Y_{t+1} is measured in \$1000 (2015 USD). Standard errors clustered by community.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.