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ABSTRACT

We study the resilience of payment systems to large disruptions in digital infrastructure caused by natural disasters and outages. While advanced economies have rapidly shifted toward electronic payments, these systems depend critically on electricity and information technology, raising concerns about their reliability during crises. We combine high-frequency county-level electricity outage data with detailed weather records, transaction-level expenditure data, household scanner data, and new representative surveys from the United States, Spain, and Sweden. Event-study evidence shows that natural disasters---especially hurricanes---generate persistent outages that sharply reduce expenditures. Natural disasters by themselves do not alter households' choice of payment method; instead, shifts toward cash arise through three channels: electronic payment methods become unavailable, households increase cash holdings for precautionary reasons, and cash is subsequently spent once available ("cash burn"). Consistent with these mechanisms, payment composition shifts markedly: spending rises before disasters due to stockpiling, largely financed with credit, while after disasters digital payments decline and cash usage rises, particularly in areas experiencing outages. Survey evidence confirms that nearly half of consumers are unable to use their preferred electronic payment during outages and that cash serves as a key fallback. Exploiting variation in cash holdings across households and locations, we find that greater access to cash increases the likelihood of completing transactions during outages and mitigates expenditure declines. Complementary survey evidence and the immediate response to our information treatment show that outages and official guidance increase desired cash holdings. Finally, we embed an RCT in the NielsenIQ panel: roughly half of panel households receive authoritative preparedness guidance, and we follow their realized purchases through the subsequent hurricane season. This design provides a clean framework for causal identification of whether greater cash preparedness smooths consumption during weather shocks. Together, the observational, survey, and experimental components of the paper show that cash plays a critical role in sustaining economic activity during payment-system disruptions and point to the value of offline-capable payment instruments, including CBDCs, in increasingly digital economies.

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1 Introduction

Extreme weather events can disrupt economic activity not only through physical damage, but also through the payment system itself. Modern retail payments depend on electricity, telecommunications, and data infrastructure. When these systems fail, cards, digital wallets, and peer-to-peer platforms can become difficult or impossible to use. This vulnerability is especially salient during disasters. After Hurricane Katrina, financial authorities warned consumers to prepare for a "cash only" environment because power and telecommunications failures were impairing electronic transactions (Federal Financial Institutions Examination Council, 2006). More recently, governments and central banks have emphasized the same concern in settings as diverse as Mexico, Sweden, and the Iberian Peninsula. These episodes highlight a simple but increasingly important question: how resilient are payment systems when digital infrastructure fails?

This paper studies the resilience of payment methods during outages and extreme weather events. We ask three related questions. First, how do natural disasters affect expenditures and payment composition? Second, through which mechanisms does cash mitigate the disruptions associated with outages? Third, what do these patterns imply for the design of resilient retail payment systems, including offline-capable central bank digital currencies? The answers matter for disaster preparedness, but they also matter for the broader debate over increasingly cash-light economies. A payment system that performs well in normal times may still be fragile in tail events.

To answer these questions, we combine several sources of variation and measurement that are rarely available in the same setting. We match county-day information on storm events from NOAA with high-frequency county-level electricity outages from EAGLE-ITM (Anderson et al., 2024). We then study spending and payment composition using four complementary sources: transaction-level convenience-store data from PDI Technologies; broad card-spending aggregates from MBHS3; debit-card data from challenger-bank accounts in Facteus; and household scanner data from the Nielsen Consumer Panel (HMS). Because administrative spending data do not typically observe cash balances, we also use the Survey and Diary of Consumer Payment Choice (DCPC) and a new cross-country survey effort designed from scratch for this project. We field nationally representative YouGov surveys covering 7,800 respondents in total: 6,000 in the United States, 1,000 in Spain, and 800 in Sweden. The survey instruments were built around a common core on cash holdings, disruption exposure, payment failures, cash as a fallback instrument, and intended changes in cash reserves, while also allowing country-specific modules tailored to local institutions and recent events. Finally, we embed a randomized field experiment inside the NielsenIQ panel. In May-June 2024, through a NielsenIQ omnibus fielded to panel households, we randomly assigned roughly half of the experimental sample to receive preparedness guidance from the U.S. Department of Homeland Security emphasizing the value of holding cash when disasters disrupt ATMs and card networks. Because these same households are observed in the purchase panel throughout calendar year 2024, we can compare treated and control

households within counties that later experience extreme weather. The timing is especially useful: treatment assignment occurred just before an above-normal Atlantic hurricane season that ultimately produced 18 named storms, 11 hurricanes, and 5 major hurricanes (National Hurricane Center, 2025). This design gives us a clean setting in which to study whether greater cash preparedness makes household consumption more resilient when outages occur.

Our analysis yields four main findings. First, hurricanes generate large and persistent outages. Outage intensity jumps sharply on impact and remains elevated for several days, while other weather events generate smaller but still visible disruptions.

Second, expenditures rise before hurricanes and fall sharply when the storm hits. The pre-event increase is consistent with stockpiling and is financed primarily through cards, especially credit cards. When the storm arrives, expenditures drop abruptly, reflecting both store closures and disruptions to electronic payments. Payment composition also shifts systematically around the event: the cash share of spending falls in anticipation of the storm, as households front-load purchases using cards, and then rises sharply after the event as digital methods become less reliable.

Third, the timing and composition of these responses point to two mechanisms: a precautionary motive and *cash burns*. Households increase cash holdings in anticipation of disaster risk, and they are more likely to use cash when they have it available. This distinction becomes particularly clear when we compare locations exposed to the same weather event but with different outage realizations. In places that experience the event without outages, the expenditure response mainly reflects the precautionary motive: households stockpile before the event, largely paying with cards, and there is little evidence of a sharp contemporaneous contraction in spending after the event. In the payment mix, however, these no-outage locations still display a post-event increase in the cash share, consistent with households drawing down previously accumulated cash balances once the risk materializes. By contrast, in locations that do experience outages, expenditures fall substantially on impact and spending shifts away from digital methods toward cash, consistent with electronic payments becoming temporarily unavailable. These patterns are in line with dynamic models of cash management and payment choice, in which households adjust both liquidity holdings and means of payment in response to the risk of disruption.

Fourth, cash availability matters for resilience. Using variation in the timing of household cash holdings over the month and predicted cash holdings projected from the DCPC into Nielsen HMS, we find that greater access to cash is associated with a stronger substitution toward cash during outages and a smaller decline in expenditures. In this sense, cash does not merely proxy for payment preferences; it provides a form of liquidity insurance that helps households smooth consumption when digital payment systems fail.

Finally, self-collected cross-country survey evidence shows that households with larger cash holdings are more likely to complete a purchase when digital payments fail, and that disruption experience raises the stated desire to hold more cash. The information-treatment evidence points in the same direction: official preparedness guidance increases desired cash

reserves. Beyond these findings, the paper introduces an embedded randomized control trial that links this treatment to the same households' realized purchases during the remainder of 2024. This design will allow us to compare treated and control households facing the same subsequent weather shocks and to isolate whether greater cash preparedness translates into smoother consumption.

The remainder of the paper proceeds as follows. Section 2 discusses the related literature. Section 3 describes the data and the measurement of cash holdings. Section 4 presents descriptive evidence from survey data on disasters, outages, and payment failures. Section 5 presents the event-study evidence. Section 7 studies how cash availability shapes resilience. Section 8 reports cross-country survey evidence from the United States, Spain, and Sweden, and Section 9 presents the information-treatment evidence and the randomized control trial design. Section 10 concludes.

2 Related Literature

This paper contributes to the macro literature on payment choice, cash management, and the value of payment options. A central theme in that literature is that the attractiveness of a payment instrument depends on acceptance, convenience, and the cost of maintaining liquidity. Alvarez and Lippi (2009) study how financial innovation affects households' transactions demand for cash, and Alvarez and Lippi (2017) develop a dynamic cash-management model in which the current stock of cash governs the cash-credit margin at the point of sale. In related empirical work, Alvarez and Argente (2020b) and Alvarez and Argente (2020a) show that expanding the set of available payment instruments can have large usage and welfare effects, especially for users for whom cash relaxes access frictions. We add to this literature by showing that resilience to infrastructure failure is itself a first-order payment attribute. A payment method that is rarely used in normal times can become essential when electricity or communications networks fail.

This paper also contributes to the literature on digital payment adoption, network effects, and the design of public digital money. Alvarez, Argente, Lippi, Mendez-Chacon and Van Patten (2023a) show that the adoption of P2P digital payments exhibits strong strategic complementarities, so that scale and acceptance are central to the value of a payment technology. Kahn, Rivadeneyra and Wong (2020) analyze the circumstances under which a central bank may wish to issue e-money and emphasize the design trade-offs between public and private payment provision. Alvarez, Argente and Van Patten (2023b) study bitcoin as legal tender in El Salvador and show that formal legal-tender status and large subsidies are not enough to generate widespread transactional use when the instrument does not match users' underlying payment needs. Recent policy work by Faella and Zamora-Pérez (2025) makes a closely related point for physical currency, emphasizing that cash retains a distinct role during crises as a safe-haven asset and contingency payment instrument. Our evidence complements this work by highlighting a design margin that the adoption literature typi-

cally abstracts from: operational resilience. For CBDCs and other digital public money, the ability to function during outages is not just an engineering detail; it is part of what makes a payment instrument valuable.

This paper further contributes to the macro literature on rare disasters, climate risk, and adaptation. Barro (2006) and Barro and Ursua (2011) emphasize that tail events can have first-order macroeconomic consequences. In the climate-macro literature, Bansal, Kiku and Ochoa (2016) study how rising temperatures increase long-run growth risk, while Hong, Wang and Yang (2023) analyze adaptation and disaster-risk mitigation in an environment with climate-driven disaster arrivals. Bakkensen and Barrage (2018) connect cyclone exposure to persistent growth losses, bridging micro evidence on disasters with aggregate consequences. We contribute by identifying a concrete transmission channel through which extreme weather affects realized consumption in the short run: the retail payments system. That channel becomes more important as economies digitize and as extreme events become more frequent or severe. In that sense, the paper links the payments literature to the broader macro question of how economies should build resilience against tail risk.

This paper also contributes methodologically to the empirical study of payment resilience. Existing evidence on cash use during disruptions is largely observational, in part because household cash balances are difficult to measure and even harder to manipulate experimentally. A related strand uses high-frequency transaction data to measure economic resilience to disasters. Alfaro-Martínez et al. (2016) show that bank card payments and ATM withdrawals can be used to track recovery after Hurricane Odile in Mexico. In line with our findings, contemporary work by Gonzales, Ito and Reguant (2026) also shows that card payments drop during an outage in Chile. By embedding a randomized information treatment in a longitudinal purchase panel just before the 2024 hurricane season and then following the same households through realized weather shocks, the paper introduces a design that moves substantially closer to causal identification of the role of cash preparedness in smoothing consumption. In that sense, the paper complements the observational evidence in the payments and disaster literatures with a field design that isolates the preparedness margin directly.

3 Data and Measurement

Our empirical analysis combines several datasets that capture different aspects of geo-referenced extreme weather events, outages, and economic activity and means of payment over time and space. Crucial to the paper, we also describe how we measure cash holdings among households and how randomized preparedness information is embedded in a longitudinal household purchase panel. We also briefly describe our self-conducted surveys, for which we will provide more details in Section 8.

Storm events. We use NOAA Storm Events data to identify the timing, location, and type of extreme weather events at the county level (National Oceanic and Atmospheric

Administration, 2025). Hurricanes are our main focus because they are both severe and frequent enough to support high-frequency event studies. In supplementary work we also examine other events that generate outages, including tropical storms, storm surge and tide events, flash floods, and tornadoes.

County-level electricity outages. We use the EAGLE-ITM dataset from Oak Ridge National Laboratory, which provides 15-minute outage estimates from 2014 to 2024 with coverage of roughly 92 percent of U.S. electricity customers (Anderson et al., 2024). The data record the share of customers affected. Our preferred measure of disruption is *outage intensity during business hours*: the fraction of total population-business-hours in a county-day that is affected by outages.

PDI Technologies store data. The PDI panel contains SKU-level transactions for approximately 13,000 convenience stores in 2,572 counties from July 2019 through August 2024. Crucially, the data record the payment instrument used at the point of sale—cash, debit, credit, checks, and other categories—together with expenditures, the number of active stores, and the items sold. Convenience stores are especially informative in this context because they are heavily used for emergency purchases such as fuel, batteries, water, beverages, and basic supplies.

Card aggregates. We complement the store data with two broader sources. MBHS3 provides de-identified county-level credit and debit card expenditure aggregates from 2019 onward. Facteus provides challenger-bank debit card data from 2017 to 2020. These datasets are useful because they allow us to assess whether the patterns visible in convenience stores also appear in broader card-spending aggregates.

Household scanner data. We use the Nielsen Consumer Panel (HMS), which corresponds to NielsenIQ's longitudinal Homescan consumer panel, a persistent household panel designed to track purchase behavior over time (NielsenIQ, 2026). In our U.S. extract, the panel tracks the shopping behavior of roughly 60,000 households per year across nearly all U.S. states and approximately 2,700 counties. Beginning in 2013, the panel records the method of payment used for each transaction. This dataset is particularly valuable because it combines expenditures, demographics, and payment choice at the household level.

Randomized NielsenIQ intervention. A central design feature of the paper is that, in May-June 2024, we fielded a cash-preparedness module and randomized information treatment to roughly half of the NielsenIQ panel through an omnibus survey instrument. The message cited DHS guidance recommending that households keep cash on hand because ATMs and card systems may fail during disasters (Department of Homeland Security, 2024). Since these same households are then observed in the purchase panel through the rest of calendar year 2024, we can link randomized treatment assignment to realized household purchases around the weather events that occurred after treatment. The realized 2024 Atlantic hurricane season was above normal, with 18 named storms, 11 hurricanes, and 5 major hurricanes (National Hurricane Center, 2025), which gives the design a rich set of post-treatment shocks.

Representative surveys. We use the DCPC to observe household cash holdings directly,

and we complement it with a new cross-country survey effort designed from scratch for this project and fielded through YouGov. The surveys cover 6,000 respondents in the United States (August 14–27, 2025), 1,000 respondents in Spain (June 20–24, 2025), and 800 respondents in Sweden (June 20–26, 2025). In all three cases, respondents were matched to nationally representative sampling frames and weighted to population benchmarks. The scale of these samples is unusually large for detailed surveys on payment resilience. At the same time, the instruments were designed to be comparable across countries. Each survey measures a common core of outcomes: physical cash holdings, exposure to outages or payment disruptions, whether electronic payment methods failed, whether cash allowed the respondent to complete a transaction, and whether the respondent would increase cash reserves afterward. The U.S. survey adds modules on natural disasters, outage duration, cash withdrawals, and stockpiling before severe weather. The Spain survey focuses on blackout experience after the 2025 Iberian Peninsula outage. The Sweden survey asks about payment behavior during disruptions and about the official preparedness brochure *In Case of Crisis or War* (Swedish Civil Contingencies Agency, 2024).

Table 1: Overview of the cross-country survey effort

Country	Interviews	Field period	Country-specific emphasis	Common comparable modules
United States	6,000	Aug. 14–27, 2025	Natural disasters, outage duration, cash withdrawals, and stockpiling before severe weather	Cash holdings, disruption exposure, inability to use preferred electronic payments, cash as fallback, desired increase in cash reserves
Spain	1,000	Jun. 20–24, 2025	Blackout experience after the 2025 Iberian Peninsula outage	Cash holdings, blackout exposure, payment failures, cash as fallback, desired increase in cash reserves
Sweden	800	Jun. 20–26, 2025	Preparedness brochure and payment behavior during disruptions	Cash holdings, payment disruptions, cash as fallback, and intended changes in cash reserves and cash use

Notes: The surveys were designed from scratch for this project and fielded by YouGov. Respondents were matched to nationally representative sampling frames and weighted to population benchmarks. The instruments were built around a common core so that the central questions about cash holdings, payment failures, and preparedness are comparable across countries, while still allowing country-specific modules tailored to local institutions and recent events.

Table 1 summarizes the survey design. Two features are especially important for the paper. First, scale: the combined sample spans 7,800 respondents, which yields unusually precise descriptive evidence on rare but economically important events such as outages and

payment disruptions. Second, comparability: because the core questions are aligned across countries, we can use the surveys not only to document country-specific facts but also to compare the same mechanisms in very different payment environments.

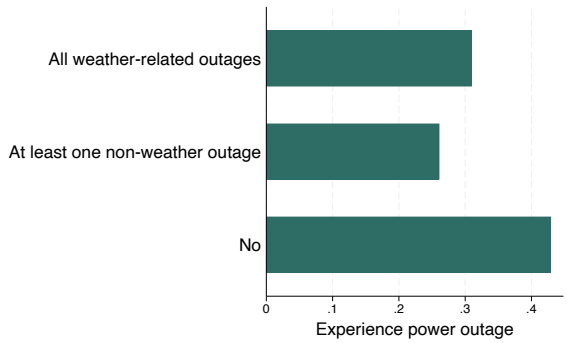
Measuring cash holdings Cash balances are central to the paper, but they are not directly observed in most administrative spending data. We therefore proceed in two steps. First, we use the DCPC to study the determinants of cash holdings at the household level. The DCPC records cash on hand, cash stored elsewhere, expenditures, payment shares, and demographics. Second, we use the estimated relationship between cash holdings and observables to impute predicted cash holdings in the Nielsen HMS. This procedure gives us a proxy for cross-sectional variation in liquidity that we can relate to spending and payment composition during disruptions. We also exploit an additional source of variation in cash availability: households report holding more cash in the first week of the month than later in the month. This pattern is visible both in survey responses and in the timing of store-level cash shares. The timing variation is useful because it provides a high-frequency shifter for local cash availability that is plausibly orthogonal to the exact timing of weather shocks. Finally, we explicitly measure cash holdings using our survey instruments and, in the U.S. NielsenIQ omnibus, randomize preparedness guidance that shifts desired cash reserves before subsequent weather shocks occur. This experimental first stage is important because it provides exogenous variation in cash preparedness that can later be linked to realized purchases.

4 Facts about Payments During Disruptions

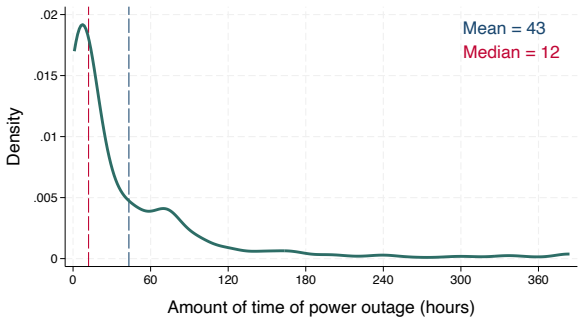
We begin with descriptive evidence from the U.S. survey. Figure 1 summarizes four basic facts. First, disasters and outages are common. In the U.S. survey, 45 percent of respondents report having experienced a natural disaster, and 81 percent of those episodes involved at least one outage. More broadly, 57 percent report having experienced a power outage, and a substantial fraction report outages lasting two days or more. These magnitudes are economically relevant. An outage that lasts several hours may be inconvenient; an outage that lasts days can materially impair the ability to purchase food, fuel, medicines, and other necessities.

Second, households adjust before disasters arrive. About 40 percent of respondents report withdrawing cash in advance of an extreme weather event. At the same time, many households stockpile purchases before the storm. Combined with the event-study evidence below, the survey suggests a natural pattern: households front-load expenditures using cards while preserving or accumulating cash for the period during which electronic methods may be impaired.

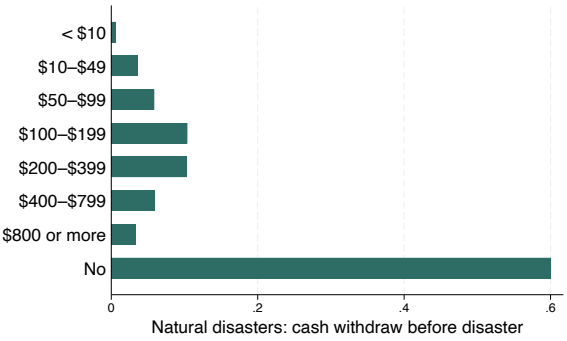
Third, payment failures during outages are common. Nearly half of respondents report being unable to use their preferred electronic payment method during an outage. Cash then



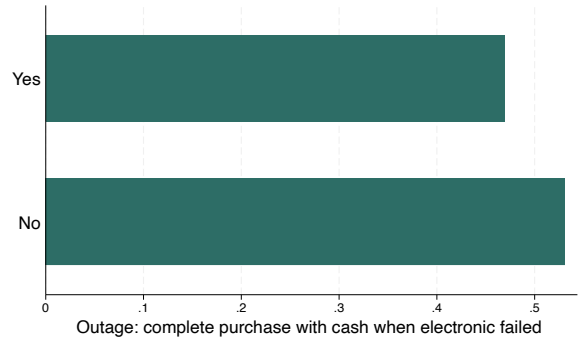
(a) Natural disasters and outages



(b) Outage duration



(c) Cash withdrawals before disasters



(d) Cash as fallback when digital payments fail

Figure 1: U.S. survey evidence on disasters, outages, and payment fallback

Notes: The figure reports descriptive evidence from the U.S. representative survey. Panel (a) shows that many natural disasters are associated with outages. Panel (b) shows that outages are often prolonged. Panel (c) reports precautionary cash withdrawals before severe weather events. Panel (d) shows the fraction of respondents who were able to complete a purchase with cash when digital payments failed.

becomes the main fallback instrument. Forty-seven percent report being able to complete a purchase with cash when electronic payments fail. These survey facts already point to the three mechanisms that organize the paper: outages make electronic methods unavailable; households respond by increasing or preserving cash holdings for precautionary reasons; and cash is then run down once the disruption occurs.

5 Event-Study Evidence

5.1 Empirical framework

Our baseline event-study specification is

$$Y_{it} = \alpha + \sum_{k=-\infty}^{\infty} \gamma_k \mathbb{1}\{K_{it} = k\} + \theta_i + \lambda_t + \epsilon_{it} \tag{1}$$

where Y_{it} denotes an outcome for county i on day t, θ_i are county fixed effects, λ_t are time fixed effects, and K_{it} measures event time relative to the hurricane. Depending on the dataset, outcomes include outage intensity, log expenditures, the number of active stores, expenditures per store, and expenditure shares by payment method. The unit of observation is a county-day, and standard errors are clustered at the county level.

For neighboring counties, we also estimate specifications that interact event time with whether the county experiences an outage. This allows us to distinguish the effect of exposure to the broader weather event from the effect of the payment-system disruption itself.

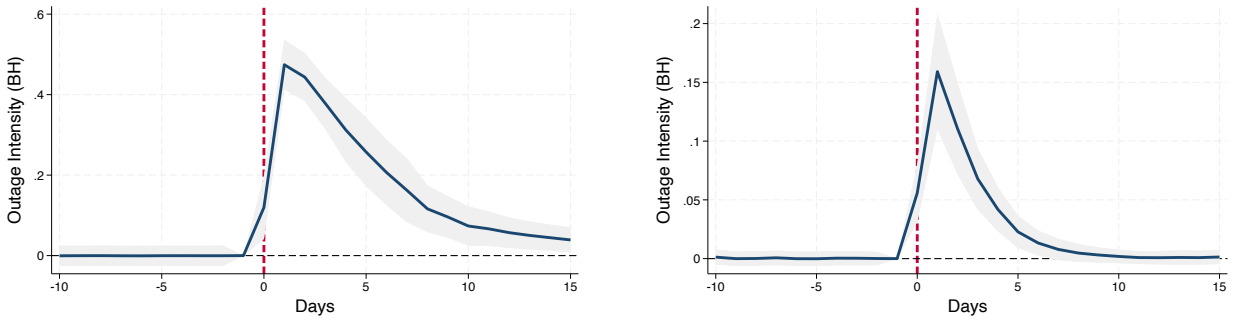
5.2 Outages after hurricanes

Figure 2 reports the evolution of outage intensity around hurricanes and, for comparison, tropical storms.

The response to hurricanes is large and persistent. Outage intensity jumps sharply on impact, peaks during the first few days after landfall, and remains elevated for more than a week. This persistence matters for spending: a short-lived outage may generate inconvenience, but an outage that lasts several days can materially constrain the ability of households and firms to transact. Other weather events also generate outages, but on a much smaller scale. In what follows we focus on hurricanes because they provide the clearest laboratory in which to study both the outage and the spending response.

5.3 Spending and payment composition at stores

We next turn to the PDI store panel. Figure 3 shows the path of total expenditures around hurricanes.



(a) Hurricanes (b) Tropical storms

Figure 2: Outage intensity around major weather events

Notes: Outage intensity is measured as the fraction of total population-business-hours affected by an outage. Hurricanes generate sharp and persistent disruptions. Tropical storms also increase outages, although the magnitude is smaller.

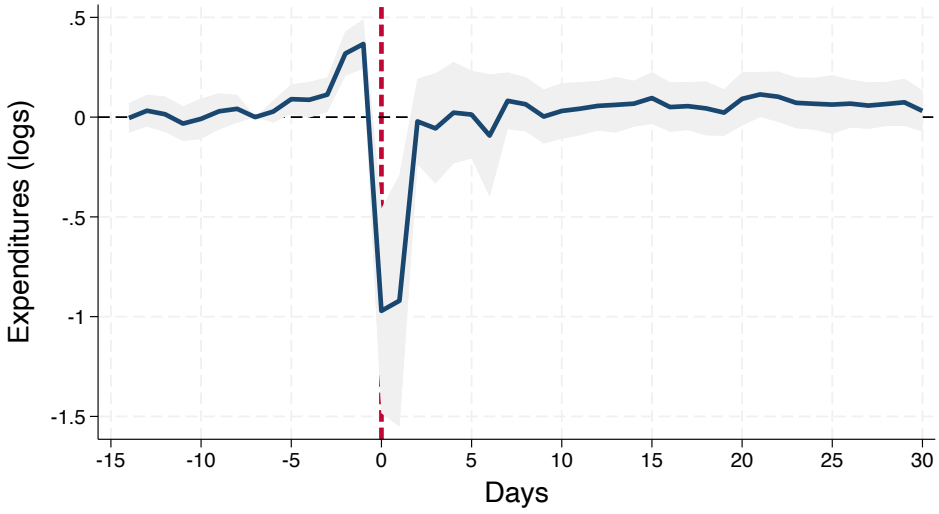
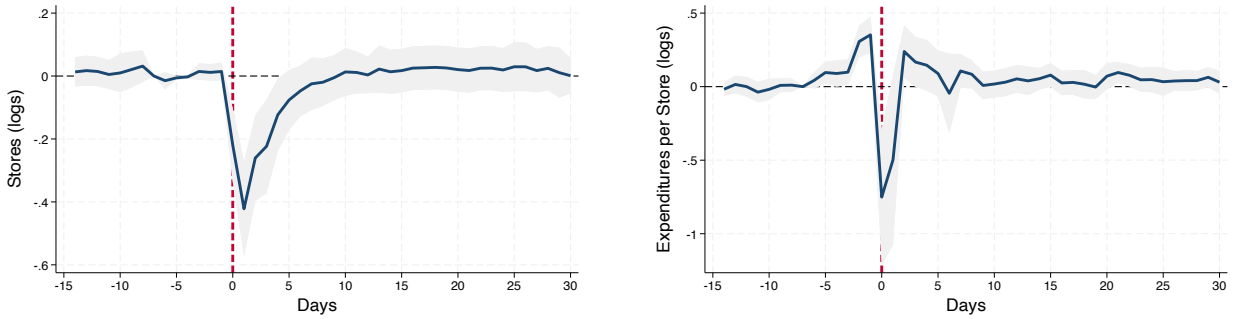


Figure 3: Expenditures at stores around hurricanes

Notes: The figure reports an event study of store-level expenditures around hurricanes. Expenditures rise before the storm, consistent with stockpiling, and fall sharply on impact.

The figure shows a pronounced intertemporal reallocation of expenditures. Spending rises before the hurricane and then drops sharply when the storm hits. The pre-event increase is consistent with households front-loading purchases in anticipation of the disruption. The post-event collapse is consistent with store closures, reduced local mobility, and the partial unavailability of electronic payments.

To understand the expenditure response more fully, Figure 4 decomposes total sales into the number of active stores and expenditures per store.



(a) Number of active stores

(b) Expenditures per store

Figure 4: Extensive and intensive margins of store-level spending

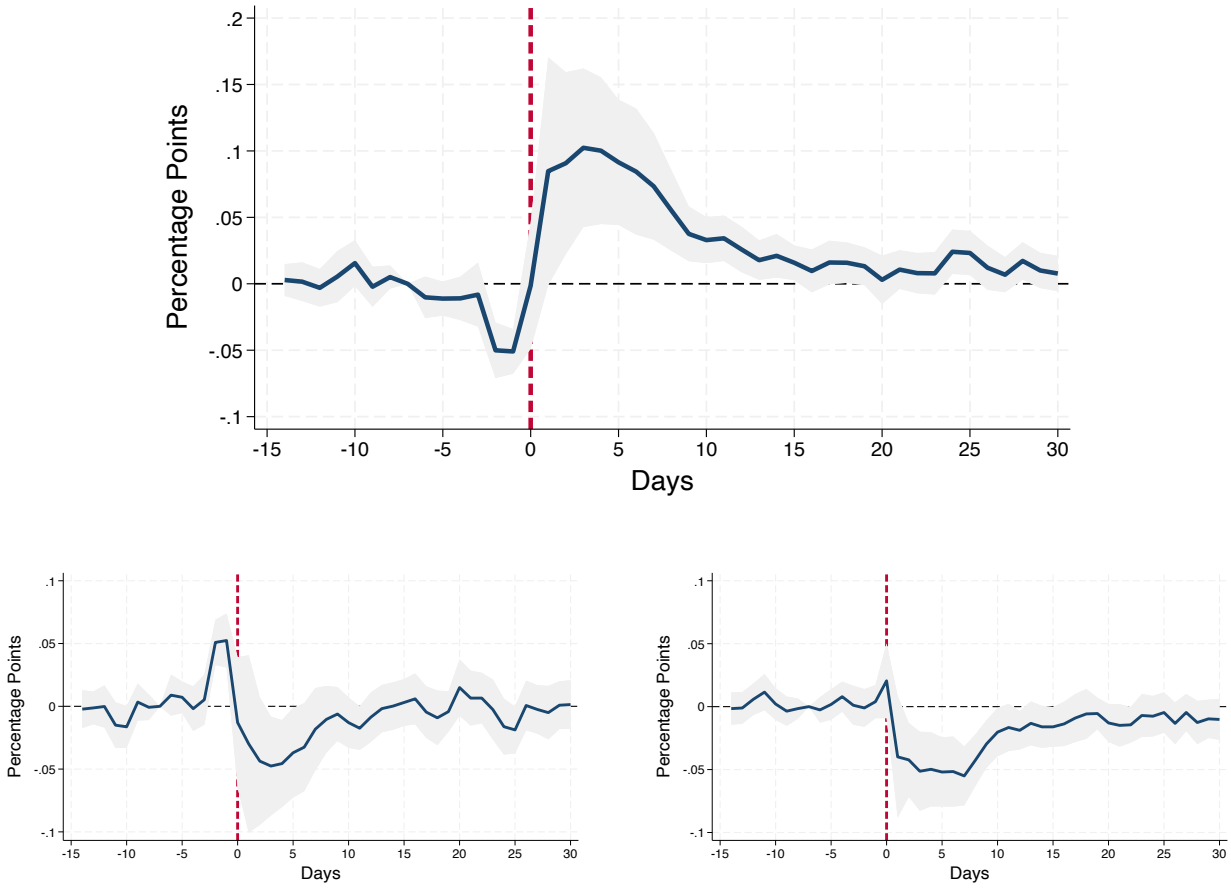
Notes: Hurricanes reduce both the extensive and intensive margins of spending. Some stores close, lowering the number of active stores, and expenditures per operating store also fall on impact.

Both margins matter. Some stores close, lowering the extensive margin, and even among stores that remain open expenditures per store fall on impact. This decomposition helps reconcile the sharp aggregate decline in sales with the fact that surviving stores can later experience a rebound once the immediate disruption passes.

Figure 5 turns to payment composition.

The shift in payment composition is one of the central facts of the paper. The cash share of sales falls before the hurricane and then rises sharply for more than two weeks after the event. The mirror image appears for cards: both the credit share and the debit share decline after the event. The pre-event dynamics differ across card types. Credit rises more than debit before the storm, which is consistent with stockpiling financed through short-term borrowing rather than through cash drawdown.

These results are difficult to reconcile with a story in which natural disasters merely change *what* households buy. They are more naturally interpreted as changes in *how* households pay, driven by the temporary fragility of electronic methods. The event-time pattern matches the mechanism suggested by the survey data: stockpiling before the storm, impaired digital acceptance during the outage, and substitution toward cash once the disruption occurs.



(a) Credit share

(b) Debit share

Figure 5: Payment composition at stores around hurricanes

Notes: The upper panel reports the cash share of store sales. The lower panels report the credit and debit shares. The cash share falls before the storm and rises sharply after impact, while card shares fall after the hurricane. The pre-event dynamics are stronger for credit than for debit, consistent with stockpiling financed with credit.

5.4 Additional evidence from broader card data

The convenience-store results are corroborated by broader card-spending aggregates. In MBHS3, county-level card spending rises before hurricanes and falls sharply on impact. Facteus challenger-bank debit data show a similar decline in debit spending after the event. These datasets are useful precisely because they do not depend on one retail segment. The similarity of the event-time patterns suggests that the main spending response is not unique to convenience stores.

5.5 Outages versus disaster exposure

A natural concern is that hurricanes may change payment composition even absent outages, simply because they change the composition of purchases or local conditions. Neighboring-county comparisons help address this concern. In nearby counties that are exposed to the broader storm environment but do not experience outages, the dominant pattern is precautionary: expenditures rise somewhat before the storm, but the post-event decline is modest. By contrast, in nearby counties that do experience outages, expenditures fall much more sharply and substitution toward cash is substantially stronger. This comparison is important because it shows that natural disasters do not mechanically change the choice of payment instrument. The shift toward cash is concentrated where the digital infrastructure fails.

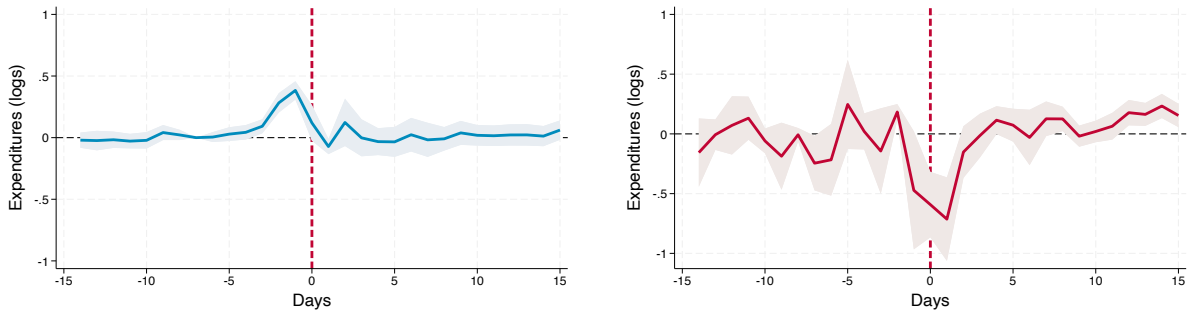
6 The Impact of Outages

To isolate the role of outages during natural disasters, we compare counties that experience an outage with counties that do not, restricting attention to counties neighboring those directly affected by a hurricane. This comparison is useful because counties that are directly hit by a natural disaster almost always experience an outage, so in those counties it is difficult to disentangle the effect of the disaster itself from the effect of the disruption to payment infrastructure. Neighboring counties provide cleaner variation. They are exposed to the same regional shock and the same rise in disaster risk, but some lose power while others do not. This allows us to separate the effect of the natural disaster from the effect of the outage.

We estimate the following event-study specification:

$$Y_{it} = \alpha + \sum_{k=-\infty}^{\infty} \gamma_k \mathbf{1}\{K_{it} = k\} + \beta \,\text{Outage}_{it} + \sum_{k=-\infty}^{\infty} \delta_k \mathbf{1}\{K_{it} = k\} \times \text{Outage}_{it} + \theta_i + \lambda_t + \varepsilon_{it}, \quad (2)$$

where Y_{it} is the outcome of interest in county i on day t, K_{it} denotes event time relative to the hurricane, Outage_{it} is an indicator for whether county i experiences an outage, θ_i are county fixed effects, and λ_t are time fixed effects. In this specification, the coefficients γ_k trace the dynamics for neighboring counties that do *not* experience an outage, while $\beta + \delta_k$ traces the dynamics for neighboring counties that *do* experience an outage.



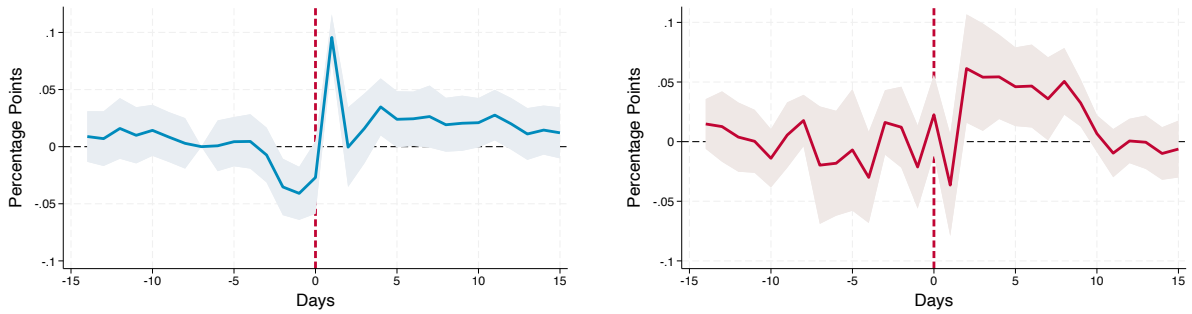
(a) No outage (b) Outage

Figure 6: Expenditures in neighboring counties, by outage status. Panel (a) plots the estimated event-study coefficients for neighboring counties that do not experience an outage, corresponding to γ_k in equation (2). Panel (b) plots the estimated response for neighboring counties that do experience an outage, corresponding to $\beta + \delta_k$. The vertical line denotes the day of the hurricane. Shaded areas represent 95 percent confidence intervals.

Figure 6 shows the results for expenditures. Panel (a) plots the response for neighboring counties that do not experience an outage. Expenditures rise before the hurricane, consistent with stockpiling, but there is little evidence of a large or persistent decline after the event. This is precisely what one would expect if the dominant force in those counties is precautionary behavior: households prepare for the storm, largely by purchasing in advance, but once the hurricane passes and electronic payments remain available, expenditures return close to baseline. Panel (b), by contrast, shows that counties experiencing an outage suffer a large contemporaneous decline in expenditures. Even though these counties are not directly hit, the disruption to payment infrastructure generates a sharp fall in spending. This pattern suggests that outages are an important part of the mechanism through which natural disasters affect consumption.

Figure 7 shows the same exercise for the cash share of spending. In counties without outages, the cash share declines before the event and rises after it. The pre-event decline is consistent with stockpiling financed through cards. The post-event increase, despite the absence of an outage, is consistent with precautionary cash accumulation followed by cash burns: households that had built cash buffers in anticipation of the storm subsequently spend those balances once the event arrives. In counties with outages, the rise in the cash share is also evident, but here the interpretation is different. In those counties, the shift toward cash reflects substitution away from digital payment methods when electronic payments become unavailable or less reliable.

Thus, when there is no outage, the evidence points mainly to a precautionary effect in expenditures and to precautionary cash accumulation followed by cash burns in payment composition. When there is an outage, expenditures fall sharply and spending shifts from digital payments toward cash. In that sense, the natural disaster by itself does not mechanically change the choice of means of payment. Rather, it is the outage that makes electronic



(a) No outage (b) Outage

Figure 7: Cash share in neighboring counties, by outage status. Panel (a) plots the estimated event-study coefficients for neighboring counties that do not experience an outage, corresponding to γ_k in equation (2). Panel (b) plots the estimated response for neighboring counties that do experience an outage, corresponding to $\beta + \delta_k$. The vertical line denotes the day of the hurricane. Shaded areas represent 95 percent confidence intervals.

payments temporarily difficult to use and turns cash into a particularly valuable fallback instrument. This behavior is in line with dynamic models of cash management and payment choice, in which households jointly choose cash balances and payment instruments in response to the risk that some payment technologies may become unavailable (Alvarez and Lippi, 2009, 2017).

7 Cash Holdings and Resilience

The preceding evidence shows that cash use rises when outages disrupt digital payments. A natural next question is whether access to cash helps households and local markets weather the storm.

We exploit two sources of variation in cash availability. The first is the timing of cash holdings over the month. Households report holding more cash in the first week of the month than later in the month, which provides a high-frequency shifter for cash availability. The second is imputed cash holdings in Nielsen HMS, obtained by projecting the DCPC relationship between cash balances and observables onto the Nielsen panel.

The evidence points in the same direction across these measures. When cash is more available, the cash share of spending rises more during outages and the decline in expenditures is smaller. Figure 8 illustrates one margin using the first-week shifter.

The first-week evidence is suggestive rather than decisive, because it is only one proxy for cash availability and may capture other within-month patterns. But it lines up closely with the cross-sectional evidence from imputed cash balances, and with the survey evidence showing that households with more cash are more likely to complete transactions when digital payments fail.

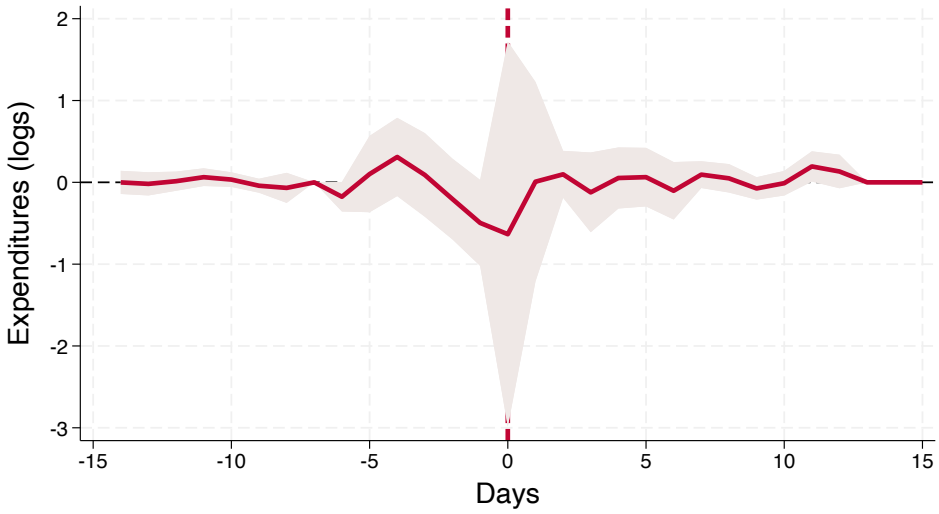


Figure 8: Expenditures around hurricanes when cash is more available

Notes: The figure reports the expenditure response around hurricanes in periods when local cash availability is higher, as proxied by the first week of the month. The decline in expenditures is attenuated relative to periods when cash availability is lower.

Table 2 summarizes the main regression evidence linking cash availability to substitution toward cash during severe weather events.

Taken together, the evidence suggests that cash holdings help sustain transactions during outages. We interpret this result carefully. Cash is not the only source of resilience, and our reduced-form estimates do not separately identify every channel through which it operates. But across timing variation, imputed balances, and direct survey responses, the same pattern emerges: when digital methods fail, access to cash mitigates the expenditure decline.

8 Survey Evidence from the United States, Spain, and Sweden

A distinctive empirical contribution of the paper is a new cross-country survey effort designed from scratch for this project. We field three nationally representative YouGov surveys covering 7,800 respondents in total: 6,000 in the United States, 1,000 in Spain, and 800 in Sweden. These are large samples for detailed surveys on payment behavior during outages, and they allow us to compare behavior across economies that differ sharply in baseline cash use and in the policy environment surrounding payment resilience.

Importantly, the instruments were built around a common core. Across countries, we measure cash holdings, exposure to outages or payment disruptions, whether respondents were unable to use their preferred payment method, whether cash allowed them to complete

Table 2: Cash availability and the cash share during severe weather events

	PDI stores		Nielsen HMS	
	(1)	(2)	(3)	(4)
Event$(t-1)$	0.009*	0.001	0.002	-0.195
	(0.005)	(0.005)	(0.011)	(0.126)
Outage(t)	0.013	0.006	-0.002	-0.267***
	(0.009)	(0.008)	(0.011)	(0.093)
Outage$(t)\times$Event$(t-1)$	0.126***	0.130***	0.107*	0.102*
	(0.047)	(0.047)	(0.061)	(0.058)
Outage$(t)\times$First week	0.031*			
	(0.018)			
Event$(t-1)\times$First week	0.047***			
	(0.018)			
Imputed cash holdings			0.027***	
			(0.003)	
Outage$(t)\times$Imputed cash holdings			0.058***	
			(0.020)	
Event$(t-1)\times$Imputed cash holdings			0.043	
			(0.027)	
Observations	3,849,639	3,849,639	3,527,204	2,931,085
R^2	0.096	0.096	0.123	0.126
Storm event FE	Y	Y	Y	Y
County FE	Y	Y	Y	Y
Time FE	Y	Y	Y	Y

Notes: The outcome is the cash share of expenditures. Columns (1) and (2) use store-level PDI data. Columns (3) and (4) use household-level Nielsen HMS data. The interaction terms show that substitution toward cash during outages is stronger when cash is more likely to be available.

a transaction when electronic methods failed, and whether they would increase cash reserves afterward. At the same time, the country modules reflect local institutions and recent events: the U.S. survey emphasizes natural disasters, outage duration, and preparedness behavior before storms; the Spain survey focuses on blackout experience; and the Sweden survey links payment resilience to the official preparedness brochure *In Case of Crisis or War*. This combination of scale and comparability allows us to study the same underlying mechanism in three very different payment environments.

We use these surveys in two ways. First, they let us compare economies with very different baseline reliance on cash. Second, they provide direct evidence on mechanisms that administrative data cannot recover, including the inability to use preferred electronic payment methods, the role of cash as a fallback instrument, and desired changes in household preparedness.

The three countries differ markedly in their baseline use of cash. In the United States, cash use is moderate: a nontrivial share of purchases is still made in cash, and many households report holding at least $100 in physical currency. In Spain, cash remains more widely used and many households continue to hold meaningful cash balances at home. Sweden lies at the opposite extreme. Cash use is low, but preparedness guidance has made resilience concerns unusually salient.

Despite these differences, one finding is strikingly stable across countries: households with larger cash holdings are more likely to complete a purchase when digital payments fail. Table 3 reports the corresponding estimates.

Table 3: Cash holdings and the ability to complete a purchase when digital payments fail

	United States Natural disaster + outage	Spain Blackout	Sweden Payment disruption
Log Cash Holdings	0.0362***	0.0456***	0.0496***
	(0.005)	(0.008)	(0.010)
Observations	3,461	1,000	745
R^2	0.054	0.051	0.121
Demographic controls	Y	Y	Y
Region fixed effects	Y	Y	Y

Notes: The dependent variable is an indicator for whether the respondent completed a purchase with cash when digital payments failed. Controls include age, gender, education, employment, marital status, income, and region. Across all three countries, larger cash holdings are associated with a greater probability of completing the transaction.

The magnitudes are economically meaningful. A 20 percent increase in cash holdings raises the probability of completing a cash purchase during a disruption by roughly 0.7 to 1 percentage point depending on the country. That is a modest effect at the individual level, but it compounds quickly when one remembers that outages often affect entire local markets.

The surveys also show that disruption experience changes desired cash reserves. House-

Table 4: Experiences during disruptions and planned increases in cash reserves

	United States		Spain		Sweden	
	Disaster + outage	Cash during outage	Blackout	Cash during blackout	Disruption	Cash during disruption
Disruption indicator	0.0685***		0.1123*		0.1341***	
	(0.015)		(0.058)		(0.025)	
Cash worked during disruption		0.1579***		0.1403**		0.0893
		(0.017)		(0.054)		(0.071)
Log Cash Holdings	-0.0045	-0.0113*	-0.0250*	-0.0315**	0.0445***	0.0444**
	(0.005)	(0.006)	(0.011)	(0.013)	(0.008)	(0.011)
Observations	6,000	3,461	1,000	1,000	745	745
R^2	0.041	0.085	0.067	0.081	0.110	0.095
Demographic controls	Y	Y	Y	Y	Y	Y
Region fixed effects	Y	Y	Y	Y	Y	Y

Notes: The dependent variable is an indicator for whether the household reports planning to increase cash reserves. Controls include age, gender, education, employment, marital status, income, and region. Experience with disruption, and especially successful use of cash during the disruption, is associated with a higher likelihood of planning to hold more cash.

holds that have lived through an outage, and especially households that were able to use cash successfully during that outage, are more likely to say that they plan to hold more cash in the future. Table 4 reports the estimates.

The cross-country evidence therefore points to a common mechanism. Cash holdings matter because they provide a fallback when digital methods fail. Disruption experience, in turn, changes households' beliefs about the value of holding cash. This mechanism appears in economies with very different starting points for cash use, suggesting that it is not unique to one institutional environment.

9 Experimental Evidence

9.1 Information Treatment

The observational evidence indicates that cash holdings matter for resilience. A natural next question is whether official guidance changes those holdings. To address that question, we fielded a randomized information treatment to approximately half of the NielsenIQ panel in May-June 2024. The treatment presented respondents with guidance from the U.S. Department of Homeland Security emphasizing that households should keep cash on hand for emergencies because ATMs and card networks may not work during severe weather events (Department of Homeland Security, 2024).

The treatment is informative for two reasons. First, it provides a direct test of whether information about payment-system fragility changes desired cash reserves. Second, because respondents are part of the Nielsen panel, the design opens the door to linking treatment assignment to realized expenditure behavior around subsequent natural disasters.

Figure 9 summarizes the immediate treatment response.

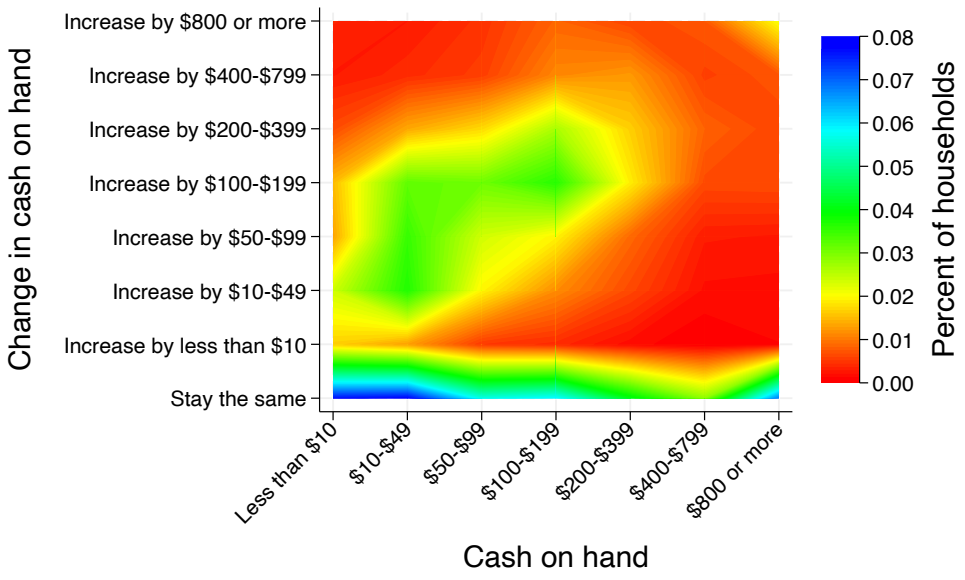


Figure 9: DHS information treatment and desired cash holdings

Notes: The horizontal axis reports the respondent's initial cash on hand. The vertical axis reports the self-reported change in desired cash holdings after receiving DHS preparedness guidance. Colors indicate the share of households in each transition cell.

Households with relatively low initial cash holdings are the most likely to report substantial intended increases after receiving the guidance. Many move from less than $50 in cash toward the $50–$199 range, and a meaningful fraction report even larger intended increases. The treatment therefore shifts desired reserves on both the extensive and intensive margins.

By itself, this evidence establishes that authoritative preparedness guidance changes desired cash balances. The broader value of the design, however, is that it allows us to follow these same households after treatment and to study whether the induced preparedness translates into smoother expenditure dynamics during subsequent weather shocks. That question is the focus of the randomized control trial described next.

9.2 Randomized Control Trial

The key experimental advantage of the paper is that treatment assignment can be linked to realized purchases. The same NielsenIQ households that were randomized in May-June 2024 are observed in the purchase panel for the remainder of calendar year 2024. We then merge those households to county-level weather and outage data and identify the extreme weather events that occurred after treatment. For each county that later experienced an event, we therefore observe both treated and untreated households facing the same local shock.

The timing of the intervention is central to the design. The treatment was fielded just before the main months of the 2024 Atlantic hurricane season. Realized hurricane activity

in 2024 was above normal: the season produced 18 named storms, 11 hurricanes, and 5 major hurricanes, all above 1991–2020 normals (National Hurricane Center, 2025). From the perspective of identification, this yields a rich set of post-treatment shocks across counties while leaving treatment assignment orthogonal to the subsequent realization of local weather events.

The randomized design lets us ask a sharper question than the observational analysis can answer: when two otherwise similar households in the same county experience the same extreme weather event, does the household that received the preparedness treatment display smoother consumption afterward? If the treatment increased cash holdings, and if those balances are useful when electronic payment methods are disrupted, then treated households should exhibit smaller post-event expenditure declines, a higher probability of completing purchases, and stronger resilience in categories that are particularly salient during disasters.

Our baseline specification will be a stacked household-level event study of the form

$$Y_{he\tau} = \alpha_h + \delta_{e\tau} + \sum_{k \neq -1} \beta_k \left(Treat_h \times \mathbb{1}\{\tau = k\} \right) + u_{he\tau}, \tag{3}$$

where $Y_{he\tau}$ is an outcome for household h in county-event episode e at event time τ, α_h are household fixed effects, $\delta_{e\tau}$ are event-by-event-time fixed effects, and $Treat_h$ indicates assignment to the DHS information treatment. The coefficients β_k trace the differential response of treated households relative to control households facing the same event. Depending on data availability, outcomes will include total scanner expenditures, the probability of making any purchase, category-level expenditures for emergency goods, and payment composition.

In the next version of the paper, we will report two sets of estimates from this design. First, reduced-form treatment effects that compare whether treated households experience smaller expenditure declines, a higher probability of making any purchase, or stronger spending in emergency-related categories after local disasters. Second, heterogeneity by realized outage exposure, baseline cash intensity, and event severity. These contrasts are economically informative because they map directly into the mechanism emphasized throughout the paper: if preparedness guidance raises cash holdings, and if cash is especially valuable when electronic payment methods are impaired, then the effect of treatment should be strongest precisely where outages are realized and among households for whom cash was initially scarcer.

The corresponding estimates are currently being finalized and are therefore not reported in this draft. We nevertheless describe the randomized control trial in some detail because it is a central contribution of the project. Relative to the observational evidence, the experimental design provides the cleanest route to causal identification of whether ex ante cash preparedness improves post-disaster household resilience. Once incorporated, the results from this exercise will allow us to move from documenting the resilience value of cash to identifying it directly.

10 Conclusion

This paper studies the resilience of payment methods during outages and extreme weather events. The central empirical fact is straightforward: when digital infrastructure fails, cash becomes a critical fallback instrument. Hurricanes generate large and persistent outages. Expenditures rise before the storm as households stockpile, largely using cards and especially credit, and then fall sharply afterward. At the same time, the cash share of spending rises. Neighboring-county comparisons indicate that this substitution is concentrated where outages occur, not merely where bad weather is observed.

Three mechanisms organize the evidence. First, outages make electronic payments unavailable. Second, households respond to disaster risk by preserving or increasing cash balances for precautionary reasons. Third, those balances are then run down once the disruption occurs. Survey evidence from the United States, Spain, and Sweden supports each part of this mechanism. Consumers frequently report that their preferred digital payment method was unavailable during an outage, and those with larger cash holdings are more likely to complete a purchase when that happens. Within the United States, areas and times with greater cash availability experience smaller expenditure declines and larger substitution toward cash. Experimental evidence further shows that official guidance increases desired cash holdings.

A final and distinctive component of the paper is the embedded randomized control trial. By randomizing preparedness information before the 2024 hurricane season and then following the same households through realized weather shocks, the design creates a clean test of whether ex ante cash preparedness causally smooths consumption when disruptions occur. The estimates from this component are currently being finalized, but the design already sharpens the paper's interpretation by showing exactly how the project moves beyond observational evidence and toward causal identification of the role of cash preparedness.

Our results have immediate policy implications. A move toward digital payments can improve convenience and efficiency, but it also increases reliance on a fragile infrastructure. Resilience therefore requires more than payment innovation; it requires fallback capacity. Cash remains one such fallback. So do payment instruments that can operate offline. For central banks and payment regulators, the implication is not that digitalization should stop, but that resilience should be built into its design; through cash distribution, acceptance rules in essential services, contingency planning, and offline-capable digital instruments, including CBDCs.

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Online Appendix for

On the Resilience of Payment Methods

April 14th, 2026

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Table of Contents

A Case study

The aggregate event studies average across many counties and events. Figure A.1 shows the same timing in a single store around a hurricane episode. Total sales spike before landfall, card sales collapse on impact, and cash sales rise sharply when the store reopens. The case study is not meant to identify a causal effect on its own. Rather, it provides a transparent illustration of the same timing that appears in the broader samples.

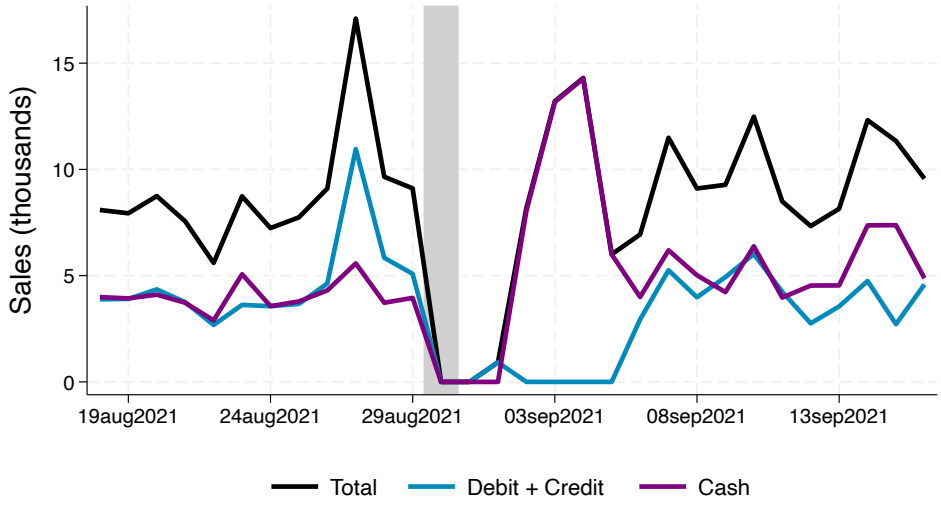

Figure A.1: Case study of one store around a hurricane

B Survey prompt used in the DHS information treatment

The NielsenIQ information treatment first asked respondents about their typical cash holdings and then presented DHS preparedness guidance. The wording was as follows:

> **Cash on hand question.** "Could you estimate the typical amount of physical cash your household might have on hand or at home on a given day (including cash for emergency purchases)?"
>
> Respondents then selected one of the following ranges: less than $10; $10–$49; $50–$99; $100–$199; $200–$399; $400–$799; or $800 or more.
>
> **Information treatment.** "In the following section, we will provide you with essential information on financial preparedness in anticipation of natural disasters. This guidance is based on recommendations from authoritative sources and

aims to ensure your safety and security during unpredictable events. Please read the following carefully.

During natural disasters, such as hurricanes, heavy storms, or floods, ATMs and credit card systems may be unavailable, making cash on hand particularly valuable. In fact, according to the U.S. Department of Homeland Security, it is important to have small bills on hand because ATMs and credit cards may not work during a disaster when you need to purchase necessary supplies, fuel, or food.

Considering this advice from the DHS regarding financial preparedness during natural disasters, would you consider increasing the typical amount of physical cash your household has on hand or at home (including cash for emergency purchases) in anticipation of such events?"