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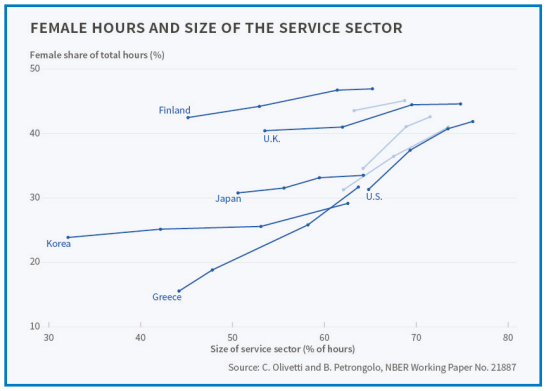

Program Report

Environmental and Energy Economics

Don Fullerton and Catherine Wolfram*

Researchers in the NBER's Environmental and Energy Economics (EEE) program have studied a wide range of issues, including both long-standing questions and emerging issues, in recent years. One particularly notable body of research has developed in response to the expanding discussion of the potential effects of climate change and of policy proposals designed to affect future greenhouse gas (GHG) emissions. Climate concerns have generated a host of new questions for study, and in light of the novelty as well as volume of the work that addresses them, the first five sections of this report describe this body of research. The last three sections touch on other important topics.

Consequences of Reducing GHG Emissions

Many EEE researchers focus on measuring the economic consequences of various types of emissions in order to inform the design of policies to affect those emissions. With regard to GHGs, the majority of papers have focused on the economic impacts of rising temperature. Early work measured the impact of temperature on the U.S. agriculture sector. While Olivier Deschênes and Michael Greenstone found minimal impacts of rising temperatures on agricultural outputs or profits,[1] Michael Roberts and Wolfram Schlenker found large negative effects.[2] This work sparked a debate, which has carried over to other economic outcomes, about the merits of using cross-sectional versus panel data to measure climate impacts,[3] and led to methodological contributions describing the merits of different weather datasets and climate forecasts.[4]

Researchers subsequently have analyzed the potential impact of ris-

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ing temperatures on international agriculture,[5] conflict,[6] mortality,[7] birth rates,[8] income,[9] test scores, and human capital formation.[10] Other work uses observations at a more macro level and examines the impact of temperature on output growth[11] and output per capita.[12]

An additional strand of research explores how people value temperature by examining their decisions on where to live and how much to pay for their homes. David Albouy, Walter Graf, Ryan Kellogg, and Hendrik Wolff use a hedonic model to estimate the amenity value of hot days across locations in the U.S.,[13] while Paramita Sinha and Maureen L. Cropper use a discrete choice approach and account for the disutility of moving.[14] Both papers find that people would pay to avoid the temperature patterns projected to come with climate change, although both also find considerable heterogeneity. H. Allen Klaiber, Joshua Abbott, and V. Kerry Smith suggest that local landscape choices can mitigate the urban heat island effect and thus partially offset the disutility from high temperatures.[15] Schlenker and coauthors Shuaizhang Feng and Michael Oppenheimer examine the link between migration, temperature, and agricultural productivity in the U.S. between 1970 and 2009.[16]

Policies that Affect GHG Emissions

In addition to analyzing the value of reducing GHG emissions, other research has analyzed policies to achieve those reductions. Such papers include general comparisons of policy types, as well as specific studies of the electricity sector, the transportation sector, and energy efficiency policies.

Recent work builds on a long-standing tradition of comparing command-and-control mandates, cap-and-trade permits, and pollution taxes to control emissions.[17] For example, although standard models suggest that market-based instruments are cost-minimizing, Lawrence Goulder, Marc Hafstead, and Roberton Williams III describe circumstances when standards might yield greater efficiency.[18]

Actual policy has mostly shied away from market-based instruments such as permits or taxes, which raise the cost of production, and instead favors energy efficiency standards, voluntary conservation,[19] and subsidies.[20] Some research has focused on R&D or technology policy,[21] and investigated new ways to combat climate change, such as work by Garth Heutel and coauthors, Juan Moreno-Cruz and Soheil Shayegh, and Moreno-Cruz and Katharine Ricke, on geoengineering.[22]

In the international context, a paper by Derek Kellenberg and Arik Levinson, and other papers by Martin Weitzman, have studied the formation of multinational environmental agreements,[23] and the problem posed by the possibility that a unilateral policy promulgated by one nation or coalition could provide an incentive to others to embrace policies that increase emissions.[24]

An emerging literature concerns adaptation policy to deal with prospective climate changes.[25] For example, analyses of adaptation in cities by Devin Bunten and Matthew Kahn, and by Kahn and Randall Walsh[26] complement work on emissions mitigation in cities.[27]

A substantial body of research has focused on the models that are used to analyze energy policy, considering for example the choices that have been made in the modeling of energy production[28] and the modeling of climate phenomena, uncertainty, and discounting.[29] Weitzman's seminal work on "fat tail" probability distributions for potential climate catastrophes has led to additional research on willingness to pay for current abatement.[30] For example, Robert Barro uses existing models of rare macro shocks and finds that optimal environmental investment can be a significant share of GDP.[31] But multiple types of potential catastrophes can affect the optimal response to any one such catastrophe.[32] An ongoing debate concerns the role of "integrated assessment models." Robert Pindyck shows that these models may not reveal much about optimal policy in response to the possibility of a catastrophic climate outcome.[33]

GHG Reductions in the Electricity Generating Sector

The burning of fossil fuels accounts for 75 percent of GHG emissions.[34] One-third of this total is from the electricity sector, one-fifth from the transportation sector, and the remainder from industry, including the production of fossil fuels.[35] Recent research has analyzed existing and proposed regulations on GHG emissions in each of these sectors.

The electricity sector has undergone several profound changes since the transformation brought on by regulatory restructuring in the late 1990s and early 2000s. These changes affect GHG emissions in the sector. Natural gas prices have fallen considerably, from a peak just above $14 per million Btu in 2005 to roughly $3 per million Btu in 2014. Natural gas and coal are the two primary fuel inputs to electricity generation, and as Christopher Knittel and coauthors Konstantinos Metaxoglou and Andre Trindade show, lower natural gas prices have displaced production from coal plants, particularly in regional markets that were not restructured.[36] Coal emits roughly twice the CO_2 per unit of energy as natural gas, so Joseph Cullen and Erin Mansur point out that falling natural gas prices provide insight on the impacts of a tax on CO_2.[37]

Solar photovoltaic prices also have fallen precipitously, leading to debates about the relative value of rooftop solar versus grid-scale solar installations. Severin Borenstein describes the private incentives to invest in rooftop solar in California, pointing out the significant implicit subsidies created by the tiered rate structure.[38] Finally, in some parts of the country, including California and New England, the electricity sector has been brought under cap-and-trade programs.[39]

Proposed regulations like the Clean Power Plan may bring further change to the sector. This plan allows states flexibility in complying with standards. Most notably, states can choose to comply with either a standard based on the total tonnage of their emissions or a standard based on the rate of emissions per kilowatt hour. James Bushnell, Stephen Holland, Jonathan Hughes, and Knittel use simulations to show that this flexibility could lead to inefficiencies, for example if some states choose rate-based standards while others choose mass-based.[40]

GHG Reductions in the Transportation Sector

U.S. federal gasoline taxes have remained at 18.4 cents per gallon since 1993 — falling significantly in real terms — and the average of state and local taxes adds 30.4 cents, for a total of 48.8 cents per gallon. Knittel uses historical polling data to show that consumers have preferred gasoline price controls, rationing, and vehicle efficiency standards to taxes.[41] He also finds that dirtier vehicles respond more to fuel prices, as seen in Figure 1 on the next page. This finding increases the second-best optimal fuel tax, but it is still far from a first-best tax on emissions.[42]

About the EEE Program

The NBER's research program in Environmental and Energy Economics (EEE) was launched in 2007. It brought together participants from an NBER working group on environmental economics, which included economists in trade, productivity, and public economics, and industrial organization economists with an interest in energy markets. While drawn from different backgrounds, the members of the EEE program recognize the key role of energy markets in affecting local pollution, greenhouse gas emissions, and other environmental concerns. Research in the EEE program draws on an amazingly interesting interplay of ideas from a number of other fields.

Federal policy requires car makers to meet a minimum Corporate Average Fuel Economy (CAFE). CAFE raises the average price of new cars sold, and Mark Jacobsen and Arthur van Benthem find that it delays the scrapping of older, fuel-inefficient cars, thus reducing expected fuel savings by 13 to 23 percent.[43] Koichiro Ito and James Sallee find that allowing larger vehicles to meet a weaker standard can have additional welfare costs.[44] CAFE standards that ignore differences in vehicle longevity obtain less than half the welfare gain of policies that account for it.[45]

Several studies suggest that environmental subsidies to the transport sector may have counterproductive effects. For example, biofuel subsidies shift agricultural activity with unexpected social costs;[46] fuel subsidies increase externalities from fuel use;[47] the "Cash for Clunkers" subsidy in the stimulus spending bill significantly reduced total spending on new vehicles for almost a year;[48] and subsidies to electric cars can reduce local emissions from gasoline, but reduce overall economic welfare in significant portions of the country by increasing emissions from electric power plants.[49]

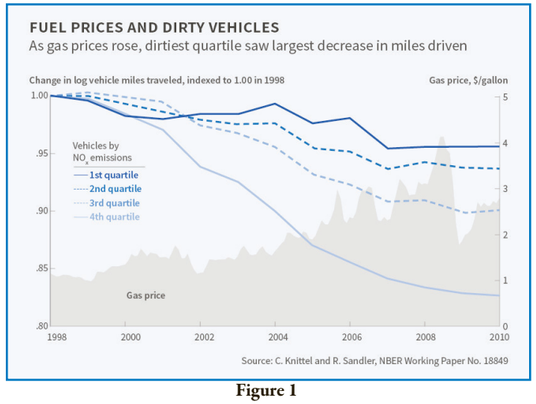

Figure 1

Energy Efficiency Policies

Detailed engineering projections, such as those summarized by the McKinsey GHG abatement cost curves, project positive net present value investments in energy efficiency based only on private returns.[50] Moreover, by reducing the energy necessary to achieve a given level of energy services, these investments promise to decrease GHG emissions in addition to other local pollutants. Yet a large and persistent difference remains between the levels of investment in energy efficiency that appear to be privately beneficial and the investments that private actors undertake. This disparity is known as the "energy efficiency gap." Several explanations have been offered for this gap, and research has touched on each of them.

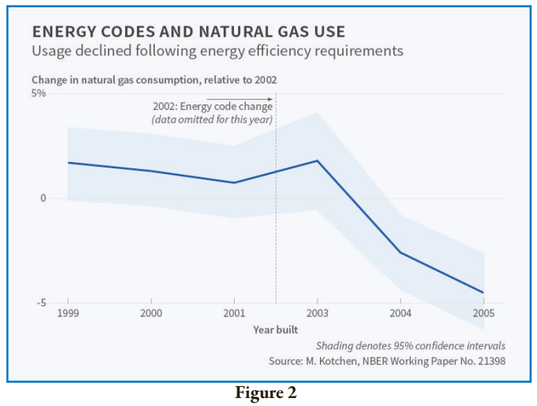

Figure 2

One explanation suggests that divergence of interests between landlords and tenants or workers and owners, information gaps, or credit constraints inhibit take-up of cost-effective, energy-efficient technologies. Several papers have explored how adding more information—for example, through sales agents at the point of purchase for water-heater consumers[51] or in-home displays[52]—can increase efficiency. Lucas Davis and Gilbert Metcalf;[53] and Richard Newell and Juha Siikamäki[54] all consider the role of appliance labels in providing useful information to consumers. Sallee suggests that consumers may be "rationally inattentive" to information about energy efficiency.[55] Newell and Siikamäki find considerable heterogeneity in households' discount rates, which are correlated with differences in credit scores.[56] They also find that individual time preferences play a role in willingness to adopt energy efficiency.

Codes and standards are often used to address the problem of market failures. Levinson questions whether California building codes have saved energy,[57] while Matthew Kotchen[58] finds that homes built just after Florida building codes became more stringent use less natural gas than homes built just before the change in code. [See Figure 2] Turning to appliances, Sébastien Houde and Joseph E. Aldy find that rebates for energy-efficient appliances have little additional impact on the energy efficiency of new appliance purchases in the face of state and federal standards.[59] Hunt Allcott and Dmitry Taubinsky consider whether minimum efficiency standards may be welfare enhancing in the presence of limited information or consumer inattention.[60]

Another explanation for the energy efficiency gap, which is not necessarily at odds with the foregoing explanations, is that behavioral biases prevent consumers from making privately optimal choices around energy efficiency. Allcott and Judd Kessler point out that policies that use behavioral approaches to influencing energy consumption may have unmeasured impacts on consumer welfare, and estimate that they are small and positive on average, with considerable heterogeneity in the context of energy-use social comparisons, a popular energy-efficiency nudge.[61]

Another possible explanation is that the supposed gap is overstated if the engineering calculations underlying potential savings from energy-efficiency measures are too high. Borenstein elaborates on the concept of "rebound," whereby consumers decide to consume more energy services after an energy-efficiency investment (for example, to keep their homes warmer in winter).[62] Rebound is often suggested as a possible explanation for discrepancies between engineering and actual estimates of savings. Meredith Fowlie, Greenstone, and Wolfram compare actual savings derived from a randomized encouragement design to before-the-fact engineering calculations and find that the engineering calculations overstated the potential savings by more than a factor of two.[63] They do not find significant evidence of rebound.

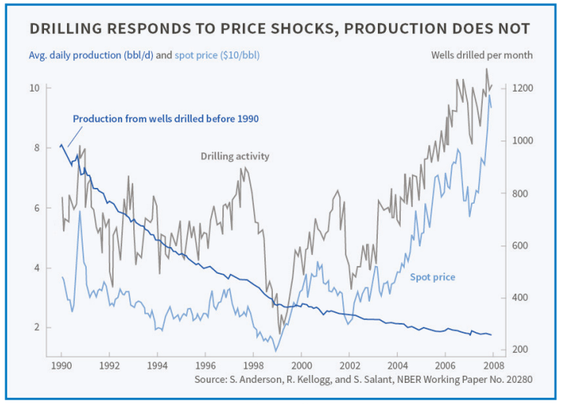

Figure 3

Oil and Gas Production

Many studies analyze the effects of prices and policies on energy production. James Hamilton explains how policy changes over the past decade affect world oil prices.[64] But how do oil prices affect production? In particular, how do they affect oil exploration, drilling, and pumping from existing wells? Soren T. Anderson, Kellogg, and Stephen W. Salant find that drilling activities respond strongly to prices, but pumping from existing wells in Texas does not.[65] [See Figure 3] Given that output from existing wells depends directly on reservoir pressure, which decays as oil is extracted, their analysis can help explain regional peaks of production and the way that observed patterns of price expectations follow demand shocks.

While technological innovation reduces cost and increases production of fossil fuels, Catherine Hausman and Kellogg note that the shale gas revolution also led to an increase in welfare for natural gas consumers and producers of $48 billion per year between 2007 and 2013.[66] Newell and Daniel Raimi find that it led to increased local government revenue, but also increased demand for local public services.[67] James Feyrer, Mansur, and Bruce Sacerdote find that horizontal drilling and hydrofracturing led to extra wages and royalties within producing counties and an overall increase of U.S. employment by 725,000 jobs.[68]

Crude oil prices have been volatile over the past decade, ranging from $40 per barrel in 2004 to $145 in July 2008, and then plummeting to about $30 by late 2008 before increasing to $110 in 2011 and falling again to less than $40 in parts of 2016. How much of this volatility is due to economic shocks, as opposed to speculation? Knittel and Pindyck conclude that speculators had little, if any, effect on prices and volatility.

Costs and Benefits of Abating Local Pollution

Most local pollutants are coproduced with greenhouse gases, so many of the policies to reduce GHGs also reduce local pollutants. A number of studies have measured the consequences of such reductions. For example, Jessica W. Reyes examines new outcomes in her study of the effects of lead exposure on antisocial and risky behavior.[69] Joshua Graff Zivin, Matthew Neidell and coauthors Tom Chang and Tal Gross, examine the impact of particulate matter on the productivity of manual laborers in a pear-packing plant.[70] [Figure 4] Evan Herrnstadt and Erich Muehlegger examine impacts on criminal activity,[71] while Michael Anderson and coauthors, Fangwen Lu, Yiran Zhang, Jun Yang, and Ping Qin examine impacts on self-reported happiness.[72] W. Reed Walker and coauthors Maya Rossin-Slater and Adam Isen examine impacts on labor force participation and earnings.[73]

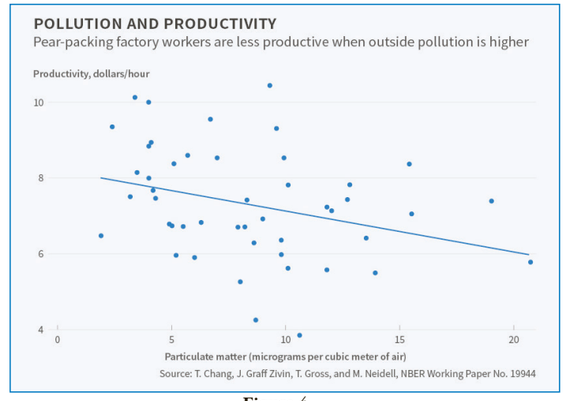

Figure 4

Research has also considered the impact of pollution exposure on fetal development. Graff Zivin and coauthors, Prashant Bharadwaj, Matthew Gibson, and Christopher A. Neilson examine fetal exposure to carbon monoxide on fourth-grade test scores.[74] Janet Currie, Graff Zivin, Jamie Mullins,

and Neidell review the literature on early-life exposure.[75] Several historians are accessing exciting new datasets to examine pollution impacts in early and mid-20th century America. For example, Karen Clay, and coauthors Joshua Lewis and Edson Severnini examine the impact of new coal-fired power plants on infant mortality between 1938 and 1962[76] and Alan Barreca, Clay, and Joel Tarr study the impacts of burning coal for residential heating between 1945 and 1960.[77]

Energy and the Environment in Developing Countries

Many of the topics we have raised thus far have unique manifestations in the developing world. Figure 5 shows that air pollution levels are much higher in developing countries.[78] Kahn and coauthors Siqi Zheng and Cong Sun show that avoidance behaviors—in particular purchases of masks and air filters—increase in developing countries during periods of high pollution, though primarily for the rich.[79]

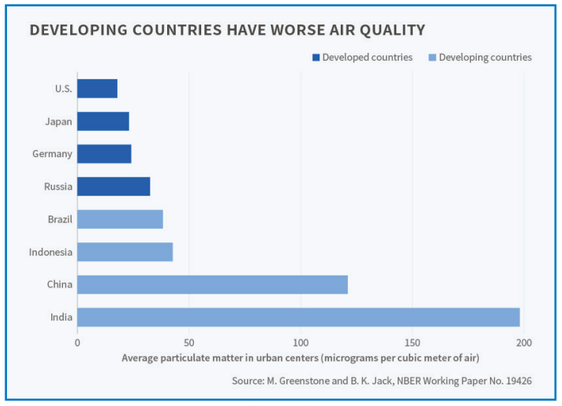

Figure 5

Weak institutions can impact the provision of both environmental and energy services. In a series of papers on Indian industrial plants, Esther Duflo, Greenstone, Rohini Pande, and Nicholas Ryan study the relationship between environmental regulators and third-party inspectors, highlighting the importance of conflicts of interest and regulatory discretion.[80] Ann Harrison and coauthors Benjamin Hyman, Leslie Martin, and Shanthi Nataraj find that higher coal prices constrained emissions more than command-and-control regulations in India.[81] Kahn and coauthors Pei Li and Daxuan Zhao demonstrate weaker enforcement of water pollution laws around political borders in China,[82] and Allcott, Allan Collard-Wexler, and Stephen O'Connell consider the impact of poor electricity reliability in India and find limited impact on short-run productivity.[83] Natasha Chichilnisky-Heal and Geoffrey Heal model the political influence of multinational corporations extracting rents from resource-rich countries.[84]

In the rapidly growing economies in the developing world, the energy infrastructure is just being built, and consumers are purchasing energy-using durables such as cars and refrigerators for the first time. Edward Miguel, Wolfram, and coauthors Kenneth Lee, Eric Brewer, Carson Christiano, Francis Meyo, Matthew Podolsky, and Javier Rosa document that many households that are not connected to the electricity grid in western Kenya are in fact quite close to existing grid infrastructure, and thus more accurately described as "under-grid" rather than "off-grid."[85] Randy Chugh and Cropper study the market for passenger vehicles in India, one of the world's fastest growing car markets, and examine consumer response to relative taxes on petrol versus diesel fuel, plus a diesel car tax.[86]

Researchers have also studied subsidies from the developed world, implemented in developing nations, for energy and environmental projects. B. Kelsey Jack, Paulina Oliva, and coauthors, Christopher Severen, Elizabeth Walker and Samuel Bell, examine how different forms of subsidies impact the efficacy of tree-planting programs,[87] while Kotchen and Neeraj Kumar Negi examine determinants of cofinancing for projects supported by the Global Environment Facility.[88]

Finally, gender dynamics among families may be more extreme than in many parts of the developed world, which Grant Miller and Ahmed Mushfiq Mobarak find partially explains low demand for improved cookstoves.[89]

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Research Summaries

How Economic Shocks Affect Spending

Matthew D. Shapiro

When faced with a common economic shock, such as a temporary drop in income, individuals may respond very differently: Some individuals will cut spending while others will draw on liquid assets or borrow.

My collaborators and I use administrative account data and surveys to analyze differences both in how individuals prepare for economic risks and in how they behave when confronted with shocks. This work helps quantify the economic impact of fiscal stimulus policies such as tax rebates and temporary tax cuts. It also provides insights into how households make choices about spending and saving in a world where income is quite variable.

Naturally Occurring Data and the Response of Spending to Income

Using a dataset that tracks daily banking and credit card transactions and balances for over one million individuals, Michael Gelman, Shachar Kariv, Dan Silverman, Steven Tadelis, and I produce estimates of spending behavior linked to individuals' liquidity.[1] These naturally-occurring account data create a comprehensive picture of spending, income, and liquidity with unprecedented precision, frequency, and timeliness, and provide a distinctive understanding of behavior.

The data shed new light on the well-established finding that individuals respond excessively to *predictable* changes in income. Such excess sensitivity is inconsistent with standard economic models that imply individuals should not let predictable movements in income affect their spending plans when income changes. That some households do spend from temporary and predictable increases in income implies that economic stimulus, for example from tax rebates, will noticeably increase aggregate demand. Hence, having credible estimates of spending from such income shocks is important for predicting the likely effects of countercyclical fiscal policy.

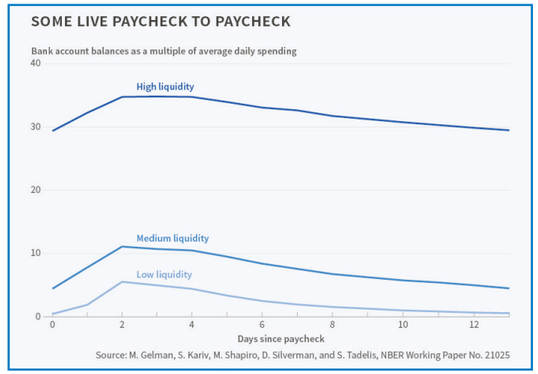

Figure 1

The naturally occurring account data allow a novel classification of spending. Recurring spending can be identified as payments, such as rent, mortgage payments, and utilities that occur at regular intervals and in regular amounts. Much of the measured excess sensitivity of spending to receipt of paycheck owes to the timing of recurring spending after paydays. This timing of payments after paycheck has been noticed in earlier research.[2] The finding that much spending after receipt of income is on recurring payments suggests that this behavior results from planned, prudent bill-paying behavior rather than necessarily excess sensitivity to having more cash on hand.

Still some excess sensitivity of spending to paycheck receipt remains that is largely explained by the differences in average liquidity across individuals. For those who typically hold low liquid assets, there is evidence of hand-to-mouth spending following the receipt of a paycheck.

A substantial fraction of individuals have very low liquidity. Figure 1 shows the ratio of bank account balances to average daily spending across the paycheck cycle. Liquidity is expressed as a ratio of checking and savings balances to average daily total spending, so the numbers in the figure can be interpreted as cash on hand relative to typical daily expenditure. The three lines are medians of this liquidity for households in the top, middle, and bottom thirds of the liquidity distribution. The top third of the liquidity distribution is well-positioned to handle an income shock. The median of this group could maintain more than a month of average spending with their checking and savings account balances, even in the days just before their paycheck arrives. The lower two-thirds of the liquidity distribution have a substantially smaller cushion. Over the entire pay cycle, the middle group has median liquid assets equal to 7.9 days of average spending. Liquidity drops to only five days of average spending in the days just before their paycheck arrives. The bottom