One Size Doesn't Fit All: Heterogeneous Depositor Compensation During Periods of Uncertainty*

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Abstract

We develop a new approach to identify different categories of depositors during periods of uncertainty and quantify their compensation to remain in the bank. We isolate withdrawals due to liquidity needs, deterioration of fundamentals, and expectation about withdrawal behavior of other depositors. We exploit variation in the cost of withdrawal induced by the maturity expiration of time deposits around unexpected uncertainty events and high-frequency microdata from a large Greek bank. Deposit withdrawals quadrupled in response to a policy uncertainty shock that doubled the short-run credit default swap (CDS) price of Greek sovereign bonds. About two-thirds of this increase is driven by direct exposure to deteriorating fundamentals, and the remainder due to strategic complementarities. We find that depositors need to be offered annualized returns exceeding 50% to remain in the bank during episodes of high uncertainty. Our findings provide new insights into the design of interventions that prevent runs by targeting depositors with the largest propensity to withdraw.

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I Introduction

The global financial crisis of 2007–2008 saw runs on several prominent banks and financial intermediaries. It reopened fundamental old debates on the rationale of a banking system with run-prone deposits (e.g., Diamond and Dybvig 1983, Goldstein and Pauzner 2005), as well as on policies that provide stability in the wake of uncertainty (e.g., Drechsler, Savov, and Schnabl 2018, Egan, Hortaçsu, and Matvos 2017).[1] At the heart of such debate is the notion that coordination failures among depositors can lead to self-fulfilling panic runs that threaten the financial institution's stability and generate enormous social costs, especially during periods of heightened uncertainty. Policymakers worldwide have therefore devoted considerable resources to intervention programs that aim to prevent panic among investors. An optimal design of such policies—whether these are guarantee programs, haircuts, or higher compensation to depositors to "remain in the bank"—tries to balance these benefits with the cost of implementing such an intervention; i.e., targeting those with the largest impact on strategic complementarities in the most cost-effective way (e.g., Shen and Zou 2020; Sakovics and Steiner 2012; Martin, Puri, and Ufier 2018). How should they implement such policies?

There is a large theoretical literature in banking that provides guidance on this front by categorizing depositor withdrawals due to (i) liquidity needs of depositors, (ii) deteriorating fundamentals related to bank solvency or currency risk, and (iii) expectations about withdrawal behavior of other depositors due to strategic complementarities. Although there is some seminal empirical work that investigates these categories (see Iyer and Puri 2012; Iyer, Puri, and Ryan 2016), it provides little guidance on how large the "compensation to remain" in the bank is for each of these categories, especially when banks face large uncertainty that could induce a panic run. This paper fills this important gap. It develops a new approach to identify different categories of depositors during periods of heightened uncertainty and quantify their compensation to remain in the bank. In doing so, we are able to provide insights that go beyond banking and also apply to nonbank financial institutions and investment funds that face similar nature of withdrawals.[2]

One obstacle in credible research design is identifying whether withdrawals are a direct consequence of deteriorating fundamentals or an indirect consequence due to strategic complementarities between depositors (e.g., see Morris and Shin 2004; He and Manela 2016). It is also difficult to estimate what compensation might be sufficient to induce different kinds of depositors to remain in the bank, and whether such compensation is homogeneous. We exploit a unique setting in Greece that heightened uncertainty for the banking system and construct a research design that allows us to isolate reasons for depositor withdrawal. This is made possible due to rich microdata from a large bank, at the individual level and at daily frequency, where we can track withdrawals of time deposits.

1. Several theories have also been proposed on the advantages that such (stable) deposits provide to financial institutions and the financial system (e.g., Hanson et al. 2015).

2. For life insurance, see Foley-Fisher, Narajabad, and Verani 2020; for money market mutual funds, see Kacperczyk and Schnabl 2013; Schmidt, Timmermann, and Wermers 2016; and for asset-backed commercial paper, see Schroth, Suarez, and Taylor 2014.

The variation in the cost of withdrawal induced by the maturity expiration of time deposits allows us to identify the compensation to remain for different depositors.

Time deposit microdata and our research design provide two key ingredients necessary for achieving our goals. First, withdrawals of time deposits before maturity carry a measurable monetary penalty. By design, this penalty drops discontinuously at the maturity date, and such dates are distributed evenly over our sample period. This allows us to estimate a withdrawal elasticity with respect to the cost of withdrawing before maturity and credibly quantify compensation for depositors to remain in the bank. Second, our unique institutional setting allows us to exploit the surprise announcement of policies that could—with some uncertainty—adversely impact fundamentals of the bank after a specific implementation date. We construct a group of depositors whose time deposits mature before and after the implementation date to isolate withdrawals due to deteriorating fundamentals. In addition, we focus only on depositors that mature before the implementation date—and therefore are not directly exposed to deteriorating fundamentals—and exploit their differential exposure to possible withdrawals by other depositors to isolate withdrawals due to strategic complementarities. These elements allow us to isolate and quantify heterogeneous depositor compensation to remain in the bank during periods of uncertainty.

We start with a motivating framework that maps existing theoretical work to our setting (e.g., Goldstein and Pauzner 2005; He and Xiong 2012). We use this framework to focus on the drivers of time deposit withdrawals, both in quiet times and in periods with deteriorating fundamentals, and design our empirical strategy. A depositor chooses to withdraw before maturity if the payoff from withdrawal exceeds the expected value of the time deposit at maturity. Withdrawal payoffs depend on an idiosyncratic, depositor-specific shock (i.e., liquidity needs) and a monetary cost (i.e., a penalty for withdrawing before maturity). On the other hand, the expected value of a time deposit at maturity depends directly on fundamentals of the bank (i.e., any factor affecting the probability of getting a haircut), as well on withdrawals by other depositors (i.e., strategic complementarities). Following the global games literature, the latter is a function of fundamentals.[3] This framework allows us to think through the effects of changes in deteriorating fundamentals on withdrawal behavior. We then exploit the institutional features of our setting to construct groups of depositors with different maturities, some of whom are directly exposed to deteriorating fundamentals, and some of whom are not.

We implement our research design using daily deposit-level data with detailed contract characteristics on the entire universe of time deposit accounts for retail customers of a large Greek bank from 2014–2015. During this period, there was a surprise announcement of an election that increased the risk of radical left-wing policies being implemented at a future date. The event was clearly important, since it led to a 30% decline of deposits in the banking system. As discussed, we focus on time deposits in our empirical analysis. They are an economically relevant source of funding in Greece,

3. The notion is that if a sufficiently large number of depositors withdraw early due to deteriorating fundamentals (at present or expected in the future), the bank may become insolvent. Consequently, the remaining depositors who did not withdraw may get a haircut on their deposits. Therefore, these depositors may also decide to withdraw if they expect other depositors to do the same.

representing 62% of all Greek bank deposits by households.[4] Our inferences based on these deposits are not unique to Greece. This high prevalence of time deposits by households is a feature that exists in banking systems of most developed countries. For instance, in euro-area country banks, close to 50% of domestic private nonfinancial deposits are time deposits with a maturity over 1 year.[5]

We start by establishing new stylized facts on time deposit withdrawal behavior in *quiet times*, the earlier period of our sample period when uncertainty (measured as the default risk of the bank and of Greek sovereign bonds) was at its lowest. This was also a period when aggregate banking sector deposits (and the deposits at our bank) were increasing. Consequently, we use this period as a benchmark for depositor behavior when withdrawals due to deteriorating fundamentals (and in turn strategic complementarities) were negligible. We can then use withdrawals during this period to characterize withdrawal behavior motivated by depositors' liquidity needs. On average, about 0.04% of depositors withdraw time deposits before maturity on a daily basis. Extrapolating this over a year implies that 10.12% of time deposits are withdrawn due to liquidity reasons.[6] The cost paid by depositors for such withdrawals during quiet times, measured as a forgone annualized return over the deposit amount, is on average 17% and can be as high as 65% for some depositors. These magnitudes imply that depositors exhibit a high willingness to pay when withdrawing for liquidity reasons.

Next, we use the surprise announcement of a large policy uncertainty event in the second half of our sample to measure deposit withdrawals due to deteriorating fundamentals and strategic complementarities. In particular, the announcement of a presidential election in parliament occurred on December 8, 2014, increasing the likelihood of the opposition party taking control and implementing radical left-wing policies at a future date. The policies included in the opposition party's agenda were likely to lead to deterioration in fundamentals that would adversely impact the value of deposits (e.g., due to Greece leaving the euro zone and the conversion of deposits from euros to a new Greek currency, as well as nationalization of the banking sector). The impact of the increased risk on the financial system after the announcement was large, with the price of the 6-month credit default swap (CDS) on Greek sovereign bonds increasing by 136% and the stock market dropping by 12%.

We exploit an additional wrinkle related to the timing of policy implementation. Such policies could be implemented only when (and if) the opposition party came to power. The predetermined nature of parliamentary process implied that the earliest the opposition party could take control of the government was in late January 2015—i.e., 6 weeks after the announcement. Thus, the announcement of election in parliament was followed by a 6-week interim period during which none of the policies affecting the fundamental value of deposits could take place. Our empirical strategy exploits this feature across depositors with different maturities to disentangle different reasons for withdrawals.[7]

4. See the Bank of Greece report on deposit markets, available at https://www.bankofgreece.gr/Pages/en/Statistics/rates_markets/deposits.aspx.

5. See, for example, European Central Bank's report *Changes in Bank Financing Patterns*, available at: https://www.ecb.europa.eu/pub/pdf/other/changesinbankfinancingpatterns201204en.pdf?3afe7cf6dc78e23e1c8b5201d0dc51ae.

6. Yearly deposit withdrawals equal 0.04% times 253 days in which the bank was open in 2014.

7. More precisely, as we discuss in Section IV, there is another layer in our identification strategy. In particular, there is another (unexpected) announcement that allows us to sharpen our analysis and strengthen our identification. For simplicity,

Deposits that matured during the interim period faced no change in the value of their deposits directly due to deterioration in fundamentals after the announcement. These deposits could be held to maturity and withdrawn without penalty before new policies could be implemented. On the other hand, deposits maturing after the interim period could only avoid changes in the value of their deposits due to deteriorating fundamentals by withdrawing before maturity. Thus, deteriorating fundamentals directly induce withdrawals of deposits that mature after the interim period but do not induce withdrawals for deposits that mature within it. Notably, while there is differential exposure to fundamentals deteriorating in our research design, all depositors—regardless of their maturity date—are exposed to strategic complementarities: the possibility that a large enough number of *other* deposits are withdrawn and the bank fails.

To identify withdrawals due to the direct effect of deteriorating fundamentals, we measure the change in withdrawals around the announcement for two groups of depositors: (1) those with deposits that mature after the new policies could be implemented (i.e., had reasons to withdraw due to deterioration of fundamentals and strategic complementarities), and (2) those with deposits that mature during the interim period (i.e., had reasons to withdraw only due to strategic complementarities). Differencing across the two groups identifies the change in withdrawals due to deteriorating fundamentals. We implement this as a triple difference that accounts for time-series patterns in withdrawals due to idiosyncratic reasons, using depositor behavior in quiet times as the placebo group.

We find that the deterioration of fundamentals directly induced depositors to increase withdrawals by 200% relative to the quiet times baseline. Interestingly, withdrawals directly due to deteriorating fundamentals do not exhibit significant heterogeneity: There is little variation in the cross section of depositors, contract characteristics, or geography relative to its average level. This finding is reassuring since there is no a priori rationale to expect deteriorating fundamentals to have a heterogeneous effect on value of time deposits and therefore on withdrawal behavior.

To identify withdrawals due to strategic complementarities, we measure changes in withdrawals during the 3 weeks before and after the announcement of elections that could result in policy change in the future. We estimate this on the subsample of deposits maturing in the 6-week interim period before policy changes could potentially take place and impact these depositors directly. Our difference-in-difference specification accounts for time-series patterns in withdrawals due to idiosyncratic reasons using depositor behavior in quiet times as the placebo group. The identifying assumption is that withdrawals due to idiosyncratic reasons and bank fundamentals do not change during the interim period after the announcement, for which we provide supporting evidence.

Our estimates imply that strategic complementarities following the announcement increased depositors' withdrawals by 70% relative to the quiet times baseline. This is almost one-third the effect of a deterioration of fundamentals on withdrawal probabilities. The magnitude of withdrawals due to strategic complementarities varies in the cross section of depositors and contract characteristics, with

we discuss our empirical strategy around one announcement here. As will become evident, similar reasoning underlies our analysis that uses the second announcement.

effects driven by (1) male depositors, (2) deposits with larger balances, and (3) withdrawals outside of Athens. A possible interpretation of these results is that depositors with more extensive information networks and greater incentives to monitor might have withdrawal behavior that is more sensitive to strategic complementarities. This heterogeneity is in contrast to withdrawals induced by fundamentals. Stated differently, all the cross-sectional heterogeneity in withdrawal behavior of depositors in the period of heightened uncertainty is due to strategic complementarities. These findings lend support to theories that purport to design cost-effective intervention programs that target coordination failures among depositors (Shen and Zou 2020; Sakovics and Steiner 2012). Moreover, this ability to predict withdrawals due to strategic complementarities using ex-ante observable characteristics is potentially a useful input in optimal design of intervention programs.

We next quantify depositor "willingness to remain" in the bank in terms of additional compensation in periods of uncertainty.[8] Given our results, it is clear that such compensation is heterogeneous and depends on the reasons for depositor withdrawal. To back out a measure of monetary compensation, we first estimate a cost elasticity of withdrawals in quiet times. We use the discontinuity around interest payment dates for identification because the cost of withdrawal drops to zero around these dates. We estimate a cost elasticity of withdrawing deposits before maturity of 1.54. The estimate implies that a decline in the penalty for withdrawal equivalent to 1% of the deposit amount increases withdrawals by 120%. Using this estimate, we ask the question: How much would the bank have to pay depositors to prevent withdrawals from increasing during the high uncertainty period (relative to quiet times)? We find that preventing withdrawals from increasing for a 3-week period would have cost the bank 2.38% of the value of deposits, which would have implied a cost of capital (at an annualized rate) exceeding 50%. About two-thirds of this effect is driven by direct exposure to deteriorating fundamentals, with the remainder due to changes in expectations of withdrawal behavior of other depositors. Notably, this cost of stabilizing the bank by compensating the depositors to remain in the bank is small relative to the very high social costs of declining output that follows bank runs (see Reinhart and Rogoff 2014; Laeven and Valencia 2012).

We conclude by conducting two exercises that allow us to gauge external relevance of our estimates, as well as to assess their plausibility. First, we compare the deposits' demand elasticity implied by our quiet times estimates to those obtained in other settings. Our estimates imply an interest rate demand elasticity of time deposits of 0.48, very close to the insured deposit demand elasticity of 0.56 obtained in Egan, Hortaçsu, and Matvos 2017 using U.S. deposit data. Second, we consider how well our characterization of depositor behavior under aggregate uncertainty extrapolates to other settings. We scale the magnitude of withdrawals to other high-uncertainty events using sovereign bond CDS

8. An alternative policy to address withdrawals (instead of depositor compensation) in periods of heightened uncertainty is to impose haircuts or freezes on deposit withdrawals. Haircuts and freezes are typically considered bad signals about the prospects of the bank. They might also distort trust of depositors in the banking sector. Supporting this idea is the observation that capital controls and haircuts are usually in place for a long period of time whenever they are implemented. This is due to worries that reversing them in the short run could trigger a capital flight. Notably, if depositor withdrawal elasticity with respect to interest rates is constant, policymakers can reduce deposit withdrawals by increasing rates rather than imposing penalties (via haircuts).

prices for calibration. Our estimates imply that a 1% increase in the 6-month sovereign default risk is associated with a 0.25% increase in withdrawal probability due to strategic complementarities and a 0.71% increase in withdrawals due to deterioration of fundamentals. Using these elasticities, we find that our estimates predict a significant fraction of deposit withdrawals in (1) other high-uncertainty episodes in Greece during our analysis period, (2) a prominent episode of policy uncertainty in Italy (spring and summer 2018), and (3) well-known episodes of high uncertainty over bank fundamentals in other countries (e.g., Northern Rock in the UK and Washington Mutual in the United States). This lends credence to the argument that our approach and estimates might have relevance outside the setting we use in this paper.

Our estimates are likely to be a lower bound on the cost of stabilizing deposits through prices, given that deposit interest increases can signal trouble to depositors, decreasing "willingness to remain" and triggering further withdrawals. The cost of deposit stabilization through interest rate increases during periods of high policy uncertainty is likely to be very high, even before a full-fledged, panic-induced deposit run occurs.[9] Moreover, all our estimates are short-run deposit withdrawal elasticities. Depositor withdrawals due to deteriorating fundamentals or strategic complementarities plausibly intensify as bank deposits shrink. Finally, our estimates pertain to the withdrawal of time deposits before maturity, which entails an all-or-nothing decision that carries a monetary penalty. Regular deposits, in contrast, can be partially withdrawn with no penalty. Thus, our estimates are likely a lower bound on the withdrawal elasticity of regular deposits over longer horizons.

Our paper is related to recent empirical work using microdata to characterize runs on banks (Iyer and Puri 2012; Iyer, Puri, and Ryan 2016) and other financial institutions (Schmidt, Timmermann, and Wermers 2016).[10] Broadly, this line of work has focused on highlighting the importance of strategic complementarities in run episodes. Our work complements this influential work by developing a new approach to identify and quantify the compensation to remain in the bank for different categories of depositors during periods of heightened uncertainty. We differentiate between deposit withdrawals due to deteriorating fundamentals and those due to strategic complementarities *before* a full-scale panic run. This is important because, as emphasized in recent work (e.g., see He and Manela 2016; Ahnert and Kakhbod 2017; Schliephake and Shapiro 2018), real-life bank run episodes slowly move into full-scale panic, allowing policymakers a window of time to reduce deposit withdrawals as uncertainty heightens.[11] Overall, our estimates provide guidance to theoretical literature that has focused

9. There is recent evidence indicating that banks do attempt to prevent deposit withdrawals by changing deposit rates (Acharya and Mora 2015; Chavaz and Slutzky 2018; Martin, Puri, and Ufier 2018). In our setting, such attempts either did not occur or were insufficient: 6 months after our analysis period, the newly elected government imposed a €60/day withdrawal limit to slow down deposit outflows.

10. Runs on repo and asset-backed commercial paper (ABCP) for shadow banks have also been documented (e.g., see Gorton and Metrick 2012; Acharya, Schnabl, and Suarez 2013; Covitz, Liang, and Suarez 2013; Schroth, Suarez, and Taylor 2014).

11. Outside bank runs, Lorenzoni and Werning 2019 theoretically rationalize the slow-moving dynamics commonly observed around debt crises. With counted exceptions (e.g., Angeletos, Hellwig, and Pavan 2007), most of the literature on bank runs and coordination failures ignores the time dimension. For some salient examples of a theoretical discussion of information-based runs, see Bryant 1980; Diamond and Dybvig 1983; Postlewaite and Vives 1987; Rochet and Vives 2004;

on optimal design of intervention policies to prevent bank runs by targeting appropriate depositors (see Shen and Zou 2020; Sakovics and Steiner 2012).

Our paper also contributes to the empirical literature on economic and policy uncertainty. Recent work has focused on measurement of economic and policy uncertainty (e.g., Jurado, Ludvigson, and Ng 2015; Baker, Bloom, and Davis 2016; Fernández-Villaverde et al. 2015; Kelly, Pástor, and Veronesi 2016; Dew-Becker, Giglio, and Kelly 2018) and its impact on firms (Bloom, Bond, and Van Reenen 2007; Bloom 2009; Bachmann, Elstner, and Sims 2013; Bloom et al. 2018) and households (e.g., see Giavazzi and McMahon 2012). Our paper contributes to this literature by analyzing depositors' reactions to policy uncertainty. Our focus is on understanding and quantifying withdrawal behavior of depositors due to deteriorating fundamentals and strategic complementarities in periods of heightened uncertainty. We contribute to this literature by demonstrating how policy uncertainty might get transmitted to the real economy through its impact on stability of banks.

The rest of the paper proceeds as follows. Section II develops a motivating framework. Section III describes the data and the institutional setting for both quiet and uncertain times. Section IV describes our empirical strategy to estimate withdrawals driven by fundamentals and strategic complementarities. Section V presents our results. Section VI uses our estimates to quantify depositor compensation. Finally, Section VII presents our discussion and conclusions.

II Motivating Framework

In what follows, we introduce a framework to formalize depositor motives for withdrawals in our setting. We use it to describe the elasticities that we then isolate in our empirical strategy.

II.A Setting

There is a continuum of small depositors and a representative bank offering time deposits. Depositors hold time deposits, indexed by i. Time deposits are characterized by a principal, an interest rate, and a maturity date (T_i). Every period t before maturity T_i, depositors can decide to withdraw their time deposits from the bank. They choose to withdraw if the payoff of withdrawing before maturity is greater than the expected value of waiting until maturity.

II.A.1 Payoff from Withdrawing Before Maturity

Let W_{it} denote the payoff from early withdrawal of time deposit i at time t ($< T_i$). This payoff depends on a depositor-specific *idiosyncratic* shock, denoted by ϵ_{it}. This shock accounts for factors motivating depositors to withdraw before maturity (e.g., liquidity needs and better investment opportunities). Larger idiosyncratic shocks increase depositors' payoffs from early withdrawal (i.e., $\frac{\partial W_{it}}{\partial \epsilon_{it}} > 0$). Payoffs are also a function of early withdrawal penalties, κ_{it}, capturing both monetary

Goldstein and Pauzner 2005. For examples of a theoretical analysis of runs based on coordination problems, see Jacklin and Bhattacharya 1988; Chari and Jagannathan 1988; Calomiris and Kahn 1991; Chen 1999; Diamond and Rajan 2001.

and nonmonetary costs of withdrawing before maturity.[12] Higher penalties from early withdrawals decrease depositors' payoffs (i.e., $\frac{\partial W_{it}}{\partial \kappa_t} < 0$).[13]

II.A.2 Expected Value at Maturity

Let V_{it} denote the expected value (at maturity) of time deposit i with maturity date T_i. This value is a function of the principal P_i and the interest rate R_i.[14] It is also a function of the probability that the bank fails before maturity (i.e., the probability that the bank cannot repay its liabilities). This probability depends on both *fundamentals* and *strategic complementarities*.

Fundamentals are factors impacting the bank's solvency and the performance of its loan portfolio and investments (e.g., house price growth, unemployment, currency risk, redenomination risk, and capital controls). Each period t ($< T_i$), depositors form expectations about fundamentals at their maturity date. Let θ_{it} capture these expectations at time t for time deposit i with maturity date T_i. The distribution of θ_{it} across all time deposits (and maturity dates) is public knowledge. Lower values of θ_{it} represent worse (expected) fundamentals at maturity and a higher probability of the bank failing. Changes to (expected) fundamentals will have heterogeneous effects on depositors, depending on the maturity dates of their time deposits.

Strategic complementarities are factors affecting the probability of the bank failing through depositors' withdrawal behavior. If a sufficiently large number of depositors withdraw their time deposits, the bank (having limited reserves) can become illiquid and fail. Strategic complementarities at time t are denoted by γ_t and affect all maturities. Similar to previous work on this topic, strategic complementarities are affected by fundamentals (e.g., see Goldstein and Pauzner 2005). Worsening fundamentals can cause more depositors to withdraw before maturity just because they fear others might. This dependency between fundamentals and strategic complementarities could be captured by allowing γ_t to be a function of fundamentals for all maturities (θ_t). Worse (expected) fundamentals result in greater strategic complementarities across depositors (i.e., $\frac{\partial \gamma_t}{\partial \theta_t} < 0$). This implies that every period t, depositors face the same strategic complementarities, regardless of their maturity dates.

In this framework, changes in fundamentals θ_{it} have a *direct* effect on time deposits with maturities T_i (i.e., $\frac{\partial V_{it}}{\partial \theta_{it}} > 0$). They also have an *indirect* effect on time deposits of other maturities for which fundamentals $\theta_{i't}$ do not change (i.e., time deposits with maturities $T_{i'} \neq T_i$). The indirect effect is driven by changes in strategic complementarities. The intuition is that payoffs of withdrawing before maturity at time t increase with the number of other depositors withdrawing early (captured by γ_t). Note that the expected value of time deposits with maturity $T_{i'}$ decreases as fundamentals for time deposits of maturity T_i worsen (i.e., $\frac{\partial V_{i't}}{\partial \theta_{it}} = \frac{\partial V_{i't}}{\partial \gamma_t} \frac{\partial \gamma_t}{\partial \theta_{it}} > 0$).

12. When liquidated prematurely, time deposits have a monetary cost (e.g., breakup fee or forgone interests). Depositors also face nonmonetary costs associated with early liquidation (e.g., time spent in the bank closing the account).

13. Policies imposing a haircut on deposit withdrawals would effectively increase κ_{it} and reduce withdrawal payoffs. Similarly, policies imposing a freeze on deposit withdrawals imply an infinite value of κ_{it}.

14. Interest rates are not essential in our framework. However, we decided to include them because our empirical strategy quantifies the necessary compensation that would induce a depositor to remain in the bank in terms of interest payments (as an alternative policy to haircuts).

II.B Early Withdrawal Decision

Depositors withdraw before maturity if the payoffs from doing so are higher than the expected value at maturity. Therefore, a depositor holding time deposit i decides to withdraw at time t such that:

$$Withdrawal_{it} = \begin{cases} 1 & \text{if } V_{it}\left(R_i, \theta_{it}, \gamma_t(\theta_t)\right) \leq W_{it}\left(\kappa_{it}, \epsilon_{it}\right) \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where $Withdrawal_{it}$ is a dummy equal to one if the time deposit is withdrawn before maturity date T_i, and zero otherwise. $V_{it}\left(R_i, \theta_{it}, \gamma_t(\theta_t)\right)$ is the expected value at maturity, as defined in Section II.A.2, and $W_{it}\left(\kappa_{it}, \epsilon_{it}\right)$ is the payoff from early withdrawal, as defined in Section II.A.1.

Using Equation (1), the aggregate share of withdrawals at any time t is:

$$s_{\,t} = \frac{\sum_i Withdrawal_{it}}{Total\ Deposits_t} = \frac{\sum_i \mathbb{1}[V_{it}\left(R_i, \theta_{it}, \gamma_t(\theta_t)\right) \leq W_{it}\left(\kappa_{it}, \epsilon_{it}\right)]}{Total\ Deposits} \tag{2}$$

where $Total\ Deposits_t$ is the number of time deposits in the bank at time t.

II.C Heterogeneous Changes in Fundamentals

As in Goldstein and Pauzner 2005, we consider different scenarios depending on the level of fundamentals. When fundamentals are sufficiently high for all time deposits (i.e., high values of θ_t), the probability of the bank failing is negligible. Strategic complementarities are also negligible, such that withdrawal decisions are independent across depositors. In such cases, changes in idiosyncratic shocks ϵ_{it} are the only driver of withdrawals before maturity (see Equation 1). This region with high fundamentals captures "quiet times." When fundamentals are sufficiently low for all time deposits (i.e., low values of θ_t), the probability of the bank failing at maturity is sufficiently high such that the payoffs of early withdrawal exceed the expected value of waiting until maturity for all time deposits. In this case, all depositors withdraw before maturity, independently of other depositors' withdrawal behavior. This region with low fundamentals captures "doomsday." Finally, there is a middle region in the value of fundamentals, between "quiet times" and "doomsday," where depositors' withdrawal decisions depend on the strategies of other depositors.

We now explore the effects on depositor withdrawal behavior of a deterioration of fundamentals such that we transition from "quiet times" (i.e., high fundamentals) to this middle region with strategic complementarities. We consider a heterogeneous shock to fundamentals affecting some time deposits, but not others, depending on their maturity dates. There is a deterioration of fundamentals for maturities T_i, but other maturities $T_{i'}(\neq T_i)$ are not directly affected (i.e., θ_{it} goes down, but $\theta_{i't}$ remains unaffected). However, these changes to fundamentals affect *all* time deposits via strategic complementarities (i.e., γ_t is common to all maturities). Our empirical strategy, we use a similar shock to fundamentals with heterogeneous effects on time deposits depending on their maturity dates.

II.C.1 Example with Two Maturities and a Shock to Fundamentals

This section discusses the case with only two time deposits, which is useful in connecting with our identification strategy in Section IV. These are identical, except for their maturity dates: short-run (T_{SR}) and long-run (T_{LR}) maturities. Panel A in Figure 1 plots the expected value at maturity for both maturities in "quiet times," when fundamentals for all maturities are high and strategic complementarities are negligible. Since both deposits have identical principal and interest rates, expected values are the same and constant over time. Panel B in Figure 1 plots the fraction of withdrawals for both maturities, assuming the same fundamentals as Panel A and constant payoffs for withdrawals.[15] In "quiet times," withdrawal behavior is similar for both types of maturities.

Consider an (unexpected) announcement at t_0 of an event occurring at a future date t_E. In our empirical strategy, this corresponds to an unexpected announcement of an election date at a future date. Assume the event takes place before long-run maturity dates but after short-run maturity dates (i.e., $t_E > T_{SR}$ and $t_E < T_{LR}$). After the announcement, time deposits maturing *after* the event suffer a deterioration of fundamentals (i.e., $\theta_{LR}^{post-t_0} - \theta_{LR}^{pre-t_0} < 0$, where $pre - t_0$ and $post - t_0$ are periods before and after the announcement at t_0). However, fundamentals for time deposits maturing *before* the event remain unchanged. Thus, time deposits face heterogeneous changes in fundamentals depending on their maturity dates.

Figure 2 plots changes in expected values at maturity and fraction of withdrawals for both types of time deposits. After the announcement at t_0, expected values for long-run maturities decrease in anticipation of worse fundamentals at maturity (i.e., downward shift of the green line in Panel A in Figure 2). These time deposits are *exposed* to the aftermath of the event at t_E. Lower expected values at maturity increase the fraction of withdrawals for time deposits with long-run maturities increase (i.e., upward shift of the green line in Panel B in Figure 2). This change in withdrawals of *exposed* depositors captures the "total effect" of the change in fundamentals after the announcement. As outlined in our earlier discussion, the total effect includes both the direct effect of worsening fundamentals and the indirect effect of strategic complementarities resulting from other depositors' contemporaneous withdrawal behavior.

After the announcement, time deposits with short-run maturities do not experience a change in fundamentals. Because their maturity dates are before the event, they are *not exposed* to changes in fundamentals after the event. If the bank had full reserves, these depositors would have no reason to withdraw. However, because there are limited reserves, time deposits with short-run maturities are still subject to strategic complementarities. Because *exposed* depositors may start withdrawing their deposits—due to worsening fundamentals for them—other depositors may choose to preemptively withdraw their deposits as well. This indirect effect decreases the expected value of (*nonexposed*) depositors with short-run maturities (i.e., downward shift of the blue line in Panel A in Figure 2).

15. For simplicity and without loss of generality, we assume constant cost of withdrawal (i.e., $\kappa_{it} = \kappa_i$ for all t) and a distribution of idiosyncratic shocks (ϵ_{it}) with constant mean and variance. Appendix A discusses how payoffs and withdrawal probabilities change if these assumptions are relaxed.

Once again, lower expected values at maturity increase the fraction of withdrawals for *nonexposed* depositors (i.e., upward shift of the blue line in Panel B in Figure 2). This change in withdrawals of *nonexposed* maturities captures the indirect effect of strategic complementarities.[16]

The key assumption in Figure 2 is that there is no direct effect on time deposits maturing before the event (i.e., fundamentals for short-run maturities remain unaffected, such that $\theta_{SR}^{post-t_0} - \theta_{SR}^{pre-t_0} = 0$). Therefore, changes in their expected values and withdrawal behavior are exclusively driven by the indirect effect of having depositors with maturities after the event withdrawing after the announcement. We can then isolate the direct effect of a change in fundamentals on withdrawal behavior by differencing the fraction of withdrawals of time deposits with long-run (*exposed*) and short-run (*nonexposed*) maturities. In Figure 2, this direct effect is captured by the difference between the shifts of the green and blue lines. This result relies on both types of deposits experiencing *the same* indirect effects due to strategic complementarities (i.e., γ_t is common across all maturities).

III Data, Institutional Setting, and Descriptive Statistics

III.A Data

Our data set consists of time deposit accounts for the universe of retail customers of a large Greek bank. Standard contracts for time deposits are characterized by a fixed maturity period over which depositors cannot withdraw funds without incurring a monetary penalty. Time deposit contracts in our bank do not allow for the possibility of partial withdrawals. Each day, a time depositor faces two choices: do nothing (and keep waiting until maturity) or withdraw the entire deposit amount before maturity. In case of a withdrawal before maturity, depositors lose all accrued interests since the last interest payment. This forgone income is deposit-specific and varies over time, being a function of interest rates, deposit amounts, and the number of days left to maturity.[17]

We observe each time deposit account daily from January 1, 2014, to March 31, 2015. Each observation has information on account features (interest rate, currency, and origination and maturity dates) and depositor characteristics (gender, age, relationship with the bank, income, and education). There are additional details on the branch that originated each deposit (postcode and branch ID). Table 1 shows summary statistics describing the key variables in our data. The average deposit amount is €57,281 and the average interest rate is almost 2%. Time deposits in our sample have an average

16. In our empirical strategy, *exposed* deposits have maturity dates after an (unexpected) election date, and *nonexposed* deposits have maturity dates before. After the election, there is positive probability that the party running ahead in the polls will—once in power—implement new measures affecting fundamentals of depositors (e.g., capital controls). Such policies can only be passed and implemented after the election date t_E. Until that event, under the normal course, the bank is solvent and able to meet its obligations. This discontinuity in the implementation of new policies generates differential exposure of time depositors to fundamentals, depending on their maturity dates. Put another way, time deposits with maturity dates after the election (*exposed*) face worse fundamentals than time deposits maturing before the election (*nonexposed*).

17. This feature of time deposits is not unique to Greece. Depositors in most countries face similar restrictions. For example, in the United States, certificates of deposit and some savings accounts face a penalty for large withdrawals before an agreed period.

maturity of almost 6 months, with the most popular contracts having a maturity length of 1, 3, 6, or 12 months. Finally, 77% of accounts are denominated in euros.

Time depositors have an average age of 65 years and are 45% female.[18] The average income of time depositors (as declared in their tax return) is €25,363, while the average income in Greece in 2013 was €8,879 for individuals and €17,270 for households. Thus, time depositors tend to be among the high earners. Almost one-third of time depositors have at least another credit product with the bank, mainly a mortgage, consumer loan, or credit card. Depositors tend to hold their time deposits for over 2 years, renewing them an average of five times. Finally, our bank operates at a national level and has an extensive branch network, covering almost all provinces in the country, with only 34% of deposits originating in Athens.

III.B Deposit Withdrawals in Quiet Time Period

Our analysis includes periods of both (relative) tranquility and turmoil in Greek financial markets. We now present stylized facts from depositor withdrawal behavior when uncertainty regarding economic fundamentals is low. We then proceed to analyze periods of greater uncertainty.

From January to November 2014 (our *quiet time* period), Greece was experiencing a decline in economic uncertainty, which had been high since the financial crisis. For example, during this time, the country returned to international markets. Figure B.1 in Appendix B shows the CDS prices on sovereign bonds and the sovereign bond spreads from 2008 to 2015. Spreads during early and mid-2014 were at their lowest since the financial crisis. We take this period as a benchmark to characterize depositor behavior in a quiet time period.

III.B.1 General Withdrawal Pattern (Quiet Time Period)

Panel B of Table 1 shows that, on average, 0.04% of time deposits are withdrawn (before maturity) each day, adding up to an annualized rate of 10.12%.[19] Time depositors withdrawing before maturity incur a monetary cost by forgoing all accrued interest rates.

Withdrawal behavior is also heterogeneous across depositors and account characteristics. Figure D.1 plots (1) the distribution of time deposits in our sample across subgroups based on deposit and depositor characteristics, and (2) the fraction of withdrawals for the same subgroups. Withdrawals are more common in accounts with lower interest rates and longer maturity length. Depositors with more products with the bank (e.g., mortgages, loans, credit cards) are also more likely to withdraw before maturity. We do not find a differential effect in withdrawal behavior across education and age groups. Female and male depositors also have the same fraction of withdrawals. We also do not observe differential patterns across origination and maturity dates. Figure 3 plots the total number of

18. We do not observe whether the account has multiple depositors. All depositor characteristics in our data correspond to those of the main account holder. Given the average age of depositors and the large presence of our bank in rural areas, it seems likely that when there is a couple owning the time deposit, the main holder is male.

19. We classify as early withdrawals those withdrawals that occur at least 5 days before maturity. This gap of at least 5 days is because whenever a time deposit matures on a day that is weekend or holiday, the withdrawal is recorded on the earliest business day close to the maturity day.

time deposits originated in a given week and the total number of time deposits maturing during the same period. Importantly, depositor behavior related to choosing when to open a time deposit and when this deposit matures does not seem to be timed or manipulated for some reason, on average.

III.B.2 Withdrawals Closer to Maturity Dates (Quiet Time Period)

Another new stylized fact is that time deposit withdrawals exhibit a non-monotonic behavior over the duration of the contract. Figure 4 shows the fraction of withdrawals as a function of days to maturity for the most common maturity lengths: 6 and 12 months. The relationship between withdrawals and time to maturity has an inverted U-shape. Depositors are less likely to withdraw at the beginning and end of their maturity period. The non-monotonic withdrawal behavior over the life of the time deposit likely reflects the benefits and costs of liquidity-motivated deposit withdrawals. Depositors make deposits when they do not foresee the need for the cash in the very short run, which explains why withdrawals are infrequent early in the life of a deposit. The probability of unexpected liquidity needs increases over time, consistent with withdrawals increasing over the initial life of the deposit.

The opportunity cost of withdrawing a time deposit, on the other hand, increases as the maturity date approaches. Withdrawing a deposit is equivalent to taking a loan for the remaining maturity of the deposit, at a monetary cost equal to the promised interest. For example, suppose a depositor makes a 6-month term deposit of €100 at a 2% annualized interest rate. If she holds the deposit until maturity, in 6 months she receives €101. Withdrawing the deposit 2 weeks before maturity is equivalent to paying €1 of interest to borrow €100 for 2 weeks, or borrowing at an annualized rate close to 30%. If the depositor withdraws 1 week before maturity, the implied interest rate of the loan approaches 70%.[20] These higher costs reduce withdrawals as the deposit approaches maturity.

The forgone annualized return from withdrawals before maturity is on average 17% and can be as high as 65% (especially for deposits closer to maturity and large accrued interests). As the example illustrates, withdrawals closer to the deposit maturity date can only be rationalized if depositors exhibit very high discount rates. Interest rates exceeding 50% are not uncommon in pawnbrokers, payday lenders, or other high-cost lenders that serve liquidity-constrained borrowers. The difference is that, whereas typical high-cost loans are for small amounts usually below €1,000, the average time deposit in our sample exceeds €50,000. This implies that the opportunity cost of withdrawals can be substantial, especially when it occurs during the last month of the deposit maturity.

III.B.3 Withdrawals around Biannual Interest Payments (Quiet Time Period)

Aside from paying time deposit interest at maturity, our bank also pays accrued interests at two calendar dates in the year: January 1 and July 1. On these dates, all accounts receive all the interest accrued up to that date. To frame how this might impact withdrawal decisions, consider the following example. Suppose a depositor makes a 1-year time deposit on March 1 of year t and holds it to

20. Implied interest rates increase nonlinearly as depositors approach maturity, reaching 63% and 58% 2 and 3 weeks before maturity, respectively.

maturity until February 28 of year $t + 1$. During the length of her contract, the depositor receives three interest payments. The first consists of all accrued interests between March and June and will be paid on July 1 of year t. The second payment, on January 1 of year $t + 1$, accounts for all accrued interest between July and December of year t. Finally, at maturity on February 28 in year $t + 1$, the depositor receives accrued interests for January and February of year $t + 1$, plus the principal.

If a depositor decides to withdraw her balance before maturity, she loses all the interest accrued since the latest of three dates: deposit origination date, July 1 of year t, or January 1 of year $t + 1$. Accrued interest is calculated using a nonlinear formula that depends positively on interest rates, Euribor rates, deposit amount, and time since origination or last repayment (whichever date happened last). Since the only penalty from withdrawing a time deposit is the forgone interest, the interest payment schedule implies that the cost of withdrawals drops to zero on January 1 and July 1 of every year. Consider a time deposit that has accumulated €100 of accrued interest by June 30. If the depositor decides to withdraw on that day, she will receive only the principal. If she withdraws a day later, on July 1, she receives the principal plus €100.

The central conjecture behind the empirical research design in this paper is that depositors' withdrawal behavior is sensitive to the monetary penalty associated with withdrawals. If this conjecture is true, we should find that deposit withdrawals change discontinuously around interest payment dates. Figure 5 illustrates the discontinuity by plotting accrued interests (in euros) and the fraction of time deposits withdrawn each week during the 4 weeks before and after interest payments on July 1, 2014. In the left panel, we observe that the cost of withdrawal drops from an average of €500 (equivalent to 28% of time depositors' median monthly income) during the week before the interest repayment date to €0 the day after. Deposit withdrawals exhibit a similar discontinuous pattern: The percentage of depositors withdrawing, which is relatively stable during the 4 weeks prior to the interest payment date, increases by 40% during the week following the interest payment date.

The right panel in Figure 5 plots the cost of withdrawal expressed as a forgone annualized rate of return. The plot shows that the forgone return due to withdrawal increases exponentially as the interest payment date approaches and drops to zero after the date. The magnitude of the drop is large: The average forgone return falls from 50% to zero on July 1, which provides depositors with an incentive to postpone withdrawals until after accrued interests are paid. Aside from validating our main conjecture, we use this discontinuity to evaluate depositors' willingness to pay to withdraw.

III.C Institutional Setting: Events with Policy Uncertainty

We focus on depositor behavior in response to the policy uncertainty surrounding the snap national elections in January that resulted in the rise of the anti-austerity, left-wing party Syriza to the Greek government. We exploit two events that occurred in relatively rapid succession in the 6 weeks preceding the national election date. Figure 6 summarizes the key events taking place during this period.

The first event was the *unexpected* announcement by the incumbent prime minister, on December 8, 2014 (hereafter t_1), to bring the presidential election forward from February 11, 2015. This announcement was unprecedented, as it was the first time a presidential election in Greece had taken place before the end of the incumbent's term. This announcement increased political uncertainty. If the election failed (as it did on December 29, 2014, after a third round of unsuccessful voting), the government would be forced to call for a national election.[21]

The second event occurred the next day, on December 30, 2014 (hereafter t_2), when the incumbent prime minister announced that the snap national election would occur on January 25, 2015 (hereafter t_E). Importantly, both the timing of the announcement (t_2) and the selected date for the national election (t_E) were earlier than expected.[22] Despite his party trailing in polls, Prime Minister Samaras selected the earliest possible election date (t_E) to minimize the gap without government, while the country was on critical negotiations with its creditors. As a result, the announcement at t_2 implied that the snap election would occur at a date sooner than expected.

Leading up to the snap election, the incumbent and challenging political parties had radically different stances regarding the bailout conditions imposed on Greece by the European Union and the International Monetary Fund. The incumbent conservative party, New Democracy, argued in favor of continuing austerity measures and Greece's continuation in the European Union. The opposition party, Syriza, supported the renegotiation of Greece's debt and, if better conditions were not agreed upon, proposed the nationalization of the banking sector, Greece leaving the eurozone, and return to a national currency (*Grexit*). In the national elections of January 25, Syriza won and was able to form a new government through a coalition with a smaller party.

The timing and close proximity of the events provide useful variation in exposure of time deposits to fundamentals. During the period between the announcement of the early presidential election (t_1) and the national elections date (t_E), there was absolute certainty that no new policy could be implemented. However, there was substantial uncertainty about the type of policy that would be implemented after t_E, due to the high likelihood that the anti-austerity, left-wing party would rise in government. In this setting, a time deposit maturing after t_E could only avoid this policy uncertainty by withdrawing early and paying the cost. Deposits with such maturities were *exposed* directly to a deterioration in fundamentals as their expected values were directly affected. On the other hand, a time deposit that matured before t_E could avoid policy uncertainty at no cost. Such depositors could simply wait until maturity and withdraw their deposits with no penalty before the new set of policies could be implemented. These maturities were *not* directly exposed to a change in fundamentals. However, as motivated in Section II.C.1, these deposits would also see their expected values affected because of strategic complementarities: the possibility that enough depositors withdrew before t_E, triggering a bank run. Thus, the only way for these depositors to avoid a reduction in expected value

21. According to the Greek constitution, the election of the president by the parliament requires a supermajority to motivate the nomination of candidates that are endorsed by the entire political spectrum. If the parliament is not able to achieve a supermajority and elect a president in three rounds, then it is dissolved and national elections are called.

22. If the parliament fails to elect a president, the government has 10 days to announce the date of national elections, which have to take place within 30 days of the announcement. In our setting, this means that the snap elections could be called as late as February 8, 2015.

would be to withdraw as early as possible, even if doing so would mean incurring some penalty.

In Section IV, we describe how we use the timing of the announcements and the maturity dates of deposits to construct a research design to isolate withdrawals due to deteriorating fundamentals and strategic complementarities. Before doing so, we provide some stylized facts around the policy uncertainty events we discuss in this section.

III.D Stylized Facts around Policy Uncertainty Events

The aforementioned events described in Figure 6 led to significant political turmoil in Greece and were a surprise not only to depositors, but also to other market participants.[23] The 6-month CDS price on Greek sovereign bonds increased by 136% after the announcement at t_1 (see left panel in Figure 7). CDS prices rose even further 3 weeks later, at t_2, when the presidential election failed and the national election date was announced. The right panel in Figure 7 shows that there was a significant drop in Athens Stock Exchange returns relative to FTSE Euro 100 on the day of the announcement (t_1) and a subsequent decline afterward. Moreover, the Athens Stock Exchange dropped 13% on t_1, its biggest one-day fall since December 1987.

Depositor withdrawal behavior changed significantly after the surprise announcement at t_1. The left panel in Figure 8 plots the daily percentage of withdrawals over our sample period. Before t_1, withdrawals account for an average of 0.04% of total time deposits per day. After t_1, the percentage of withdrawals rises steadily, and average daily withdrawal rates reach 0.28% of total accounts, seven times the rate during the quiet period before the announcement.

The flight of time deposits was not exclusive to our bank. The right panel in Figure 8 plots the relative decline in the level of deposits of our bank and of the entire Greek banking sector. Both series follow the same trend, indicating that systemwide deposit withdrawals followed the announcement. The plot for the banking system deposits is always below the plot for our bank, indicating that the rest of the banking system lost deposits at a rate faster than our (large) bank after t_1.

The characteristics of deposits and depositors withdrawing also changed after t_1. Table 1 summarizes depositor characteristics and account features for the average withdrawal before and after t_1. During the uncertainty period after t_1, withdrawals are for deposits with larger amounts and lower rates, and a higher proportion are denominated in euros. Depositors with longer relationships with the bank are also more likely to withdraw. Finally, a larger fraction of withdrawals in the uncertainty period are bank employees. These changes suggest that the rise in policy uncertainty increased depositors' willingness to pay for the cost of withdrawing.

IV Quantifying Depositor Withdrawals

Our empirical approach uses the staggered maturity dates of time deposits to disentangle the different motivations for deposit withdrawals during the uncertainty period that followed the events described

23. See, for example: http://www.bbc.co.uk/news/world-europe-30495578.

in the previous section. The goal is to distinguish empirically how policy uncertainty affects deposit withdrawals due to (i) direct exposure to deteriorating fundamentals, (ii) strategic complementarities, and (iii) idiosyncratic liquidity needs.

IV.A Mapping Empirical Strategy to Framework

We now map our empirical strategy to the framework described in Section II. There are two key elements we need to match: (1) an unexpected change in fundamentals, and (2) a group of deposits directly exposed and another not directly exposed to this change in fundamentals.

We exploit two shocks to fundamentals. The first is the surprise announcement at t_1. The second is the announcement at t_2 of the election date t_E. Effectively, both (unexpected) announcements directly exposed depositors maturing after the election date t_E to a deterioration of fundamentals. As discussed before, because some depositors are directly exposed, the nonexposed depositors can also be impacted due to strategic complementarities (i.e., γ_t in our framework).

Exposed deposits mature after t_E and see fundamentals deteriorated after t_1 and t_2. This decreases the expected value of their deposits. *Nonexposed* deposits mature before t_E and see their expected values drop after t_1 and t_2 exclusively because of strategic complementarities. Panel A in Figure 9 plots these changes, similarly to Section II. Announcements t_1 and t_2 changed the election date to t_1^E and t_2^E, respectively. These unexpected changes in the election date made some depositors who were previously *nonexposed* to now be *exposed*. The change in expected values of *exposed* maturities is captured by the difference between the green lines before and after the announcements. These changes capture both direct and indirect effects. The change in expected values of *nonexposed* maturities is measured by the difference between the blue lines before and after the announcements. These changes represent the (indirect) effect of strategic complementarities.

We can back out the change in expected values due exclusively to the direct effect of fundamentals as the difference between expected values of *exposed* and *nonexposed*. Recall that in our framework, an (unexpected) shock to fundamentals is depicted as a deterioration in θ_{it} affecting time deposits with maturities T_i.[24] More specifically, we identify the depositor withdrawals due to direct effect as the change in withdrawals for *exposed* depositors after a change in their own fundamentals (i.e., those facing total effect) minus the change in withdrawals for *nonexposed* depositors after a change in fundamentals for long-term maturities (i.e., those facing only indirect effect):

$$\beta_{fundamental} \equiv -\frac{\partial Share\,Withdrawals_t^E}{\partial \theta_E} - \frac{\partial Share\,Withdrawals_t^{NE}}{\partial \theta_E}$$

We can identify depositor withdrawals due to strategic complementarity as the change in withdrawals for *nonexposed* depositors after a change in fundamentals for exposed depositors. We capture this by:

$$\beta_{strategic} \equiv \frac{\partial Share\,Withdrawals_t^{NE}}{\partial \theta_E}$$

24. In the empirical strategy, we quantify the magnitude of deterioration of fundamentals θ_{it} using changes in CDS prices.

Similar to Section II, Panel B in Figure 9 plots how announcements at t_1 and t_2 changed the shares of withdrawals for *exposed* and *nonexposed* deposits. In this case, to match the data, we allowed for heterogeneous withdrawal costs (κ) and heterogeneous idiosyncratic shocks (ϵ) across depositors (see additional details in Appendix A).

Panels A and B in Figure 9 assume that the deterioration of fundamentals for *exposed* deposits after the announcements t_1 and t_2 happened *all things equal*. In order to maintain the ceteris paribus assumption in the empirical strategy, we need to control for deposit patterns described in Subsection III.B. We showed that depositor withdrawal behavior follows an inverted U-shape with deposit maturity and that withdrawals jump discontinuously semiannually on interest payment dates. To account for these patterns, we select the "quiet times" benchmark to have the same time to maturity and time to interest payment relative to deposits that are affected by the uncertainty episodes we study. We describe the details of how we construct these counterfactuals below.[25]

IV.B Identification of Fundamental-Related Withdrawals

To identify effects only due to changes in fundamentals, we examine changes in withdrawal behavior before and after the announcement at t_2. We compare the withdrawal behavior of deposits maturing during the 2 weeks after t_E (i.e., those *exposed* to both changes in fundamentals and strategic complementarities) with the withdrawal behavior of deposits maturing during the 2 weeks before t_E (i.e., those *unexposed* and facing only strategic complementarities). Because the exact date of t_E was announced 3 weeks earlier, on t_2, we consider withdrawal behavior in a 3-week window around t_2.

The starting point for our estimation is a difference-in-differences specification around t_2 comparing nonexposed and exposed groups maturing before and after t_E, respectively. To account for the time series variation induced by time to maturity and time to interest-payment, as explained in Section III.B.3, we construct a counterfactual group of deposits (placebo). We do so by selecting a sample of deposits around another interest payment date, July 1, 2014. Since t_2 occurs the same day as an interest payment date, we set $t_2^{Placebo}$ to July 1, 2014. Similarly, since t_E occurs 3 weeks after t_2, we set $t_E^{Placebo}$ to a date 3 weeks after $t_2^{Placebo}$.

We implement this research design estimating the following triple-differences specification:

$$\begin{aligned} Withdrawal_{it} \; = \; & \beta_0 + \beta_1\, Uncertainty_i + \beta_2\, Exposed_i + \beta_3\, Post_t \\ & + \beta_4\, Uncertainty_i \times Exposed_i + \beta_5\, Uncertainty_i \times Post_t \\ & + \beta_6\, Post_t \times Exposed_i \\ & + \beta_{Fundamental}\, Uncertainty_i \times Exposed_i \times Post_t \\ & + \gamma' X_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

25. It is worth pointing out that if t_2 had fully been unexpected just after quiet times, we could have potentially calculated both $\beta_{strategic}$ and $\beta_{fundamental}$ from only t_2. However, because there is an interim period between quiet times and t_2, we need an additional shock t_1.

where the dependent variable $Withdrawal_{it}$ is a dummy equal to one if deposit i is withdrawn before maturity in day t, and zero otherwise. $Exposed_i$ is a dummy equal to one if deposit i is maturing within 2 weeks after t_E (or $t_E^{Placebo}$ in the placebo group), and zero if maturing 2 weeks before t_E (or $t_E^{Placebo}$ in the placebo group). $Post_t$ is a dummy equal to one in the 3 weeks after t_2 (or $t_2^{Placebo}$ in the placebo group), and zero in the 3 weeks before this date. $Uncertainty_i$ is an indicator variable equal to one for deposits maturing in the period of heightened uncertainty, and zero for the deposits maturing in the quiet times placebo period. Maturities in the heightened uncertainty period are in a 2-week window around t_E. Correspondingly, maturities in the quiet times placebo period are in a 2-week window around $t_E^{Placebo}$. X_{it} is a set of covariates controlling for depositor and account characteristics, and ε_{it} is an error term. The coefficient $\beta_{Fundamental}$ is the triple-differences estimate of deteriorating fundamentals in a period of heightened uncertainty on deposit withdrawals.

Panel A in Table 2 shows the percentage of withdrawals for the various groups of depositors used in our triple-differences estimation. In the pre-period ($Post_i = 0$), there is a similar trend in withdrawals across exposed and nonexposed deposits for both the heightened uncertainty period ($Uncertainty_i = 1$) and the placebo period ($Uncertainty_i = 0$). This is expected, since the maturity of these deposits was decided months in advance, while the date t_E is revealed a few weeks before maturity (consistent with the patterns described in Figure 3).

As another check of our identification, we assess whether interest payments in the period of heightened uncertainty are the same as in the placebo period. This is important because differences in the interest rates could affect the size of the penalty for withdrawals. Table 2, Panel B shows that the interest payments do not vary across different groups of depositors in the pre-period ($Post_i = 0$). Note that for identification, we need to assume that withdrawals due to idiosyncratic liquidity reasons remain the same across exposed and nonexposed deposits in both the pre- and post-periods. We also need to assume that withdrawals due to strategic complementarities did not change differentially for exposed and nonexposed depositors.

IV.C Identification of Strategic Complementarity-Related Withdrawals

To identify the depositor withdrawals due to strategic complementarities, we exploit the (unexpected) announcement at t_1. We consider deposits that mature 3 weeks before t_E and were not exposed to changes in fundamentals due to policy changes after t_E. We then compare changes in withdrawals in these deposits during a 3-week window around t_1.[26] Similar to Section IV.B, we account for time series variation induced by time to maturity and time to interest payment by constructing a placebo group of deposits. Deposits in the placebo group mature in a period with no policy uncertainty. We evaluate withdrawals of the placebo group around a placebo date $t_1^{Placebo}$. Since t_1 occurs 3 weeks before an interest payment date (January 1, 2015), the placebo date $t_1^{Placebo}$ is set 3 weeks before

26. Even though date t_E was uncertain at t_1, we showed in Section III.C that t_E occurred 2 weeks before it was expected to occur. This implies that depositors at t_1 would have correctly inferred that they could withdraw deposits with no penalty before the policies were implemented.

an interest payment date as well (July 1, 2014). Similarly, since t_E is 6 weeks after t_1, $t_E^{Placebo}$ is 6 weeks after $t_1^{Placebo}$.

We implement the estimation using the following difference-in-differences specification:

$$Withdrawal_{it} = \delta\, Uncertainty_i + \lambda\, Post_t + \beta_{Strategic}\, Post_t \times Uncertainty_i + \gamma' X_{it} + \epsilon_{it} \quad (4)$$

where $Post_t$ is a dummy equal to one for the 3 weeks after t_1 (or $t_1^{Placebo}$ for the placebo group) and zero for the 3 weeks before this date. $Uncertainty_i$ is an indicator variable equal to one for deposits maturing in the period of heightened uncertainty and zero if maturing in the quiet times placebo period. Deposits in the heightened uncertainty period mature in the 3 weeks before t_E. Correspondingly, deposits in the quiet times placebo period mature in the 3 weeks before $t_E^{Placebo}$. X_{it} is the set of covariates accounting for depositor and account characteristics, and ϵ_{it} is an error term. The coefficient $\beta_{Strategic}$ is the difference-in-differences estimate capturing the change in withdrawals due to strategic complementarities.

Panel A of Table 4 shows the percentage of withdrawals in the pre- and post-periods (before t_1 and $t_1^{Placebo}$). When $Post_i = 0$, withdrawals for both groups of deposits are similar. Our interpretation of $\beta_{Strategic}$ assumes that any additional withdrawals after t_1 (in the heightened uncertainty period) are driven exclusively by strategic complementarities. To rule out alternative interpretations, we need to test whether during the 3 weeks following t_1 there are (1) changes in the banks' fundamentals, and (2) changes in idiosyncratic liquidity withdrawals. Appendix C reports that measures of liquidity, maturity mismatch, and funding costs remained constant during our sample period. Appendix D verifies that unemployment rates and pension payments remained constant during the analysis period.

V Results

We first present the estimates of depositor withdrawals due to strategic complementarities and deterioration in fundamentals. For both sets of results, we perform heterogeneity analysis across account, depositor, and regional characteristics. For brevity, we discuss the results but include detailed tables on heterogeneity analysis in Appendix E.

V.A Strategic Complementarities and Fundamental-Related Withdrawals

Fundamental-Related. Table 3 reports estimates from Equation 3. The triple-differences point estimate is 0.012, significant at the 1% level. It is robust to conditioning on a rich set of account (deposit amount, maturity, interest rate, and currency) and depositor (age, gender, bank employee, other products with the bank, and previous renewals) characteristics. The coefficient effectively captures the difference in withdrawals between depositors that face fundamental and strategic complementarities and those that face strategic complementarities only. The magnitude reflects a 3-week withdrawal and implies a 192% increase relative to the quiet times baseline.

Strategic Complementarities-Related. The estimation results from the specification in Equation 4 are presented in Panel B in Table 4. The point estimate of the difference-in-differences estimate is 0.0027, significant at the 10% level. It is robust to conditioning on a rich set of account and depositor characteristics. The estimate captures the change in withdrawals during 3-week periods before and after the announcement of the increased policy uncertainty in the future. As discussed before, these effects are estimated on deposits that mature before the new policies can take place relative to the counterfactual in quiet times. The baseline 3-week withdrawals in the pre-period is 0.4% (Panel A in Table 4). Relative to the baseline, the estimate implies that depositors are 68% more likely to pay the penalty and withdraw because of strategic complementarities.

Magnitudes. Our two estimates on increases in withdrawals are additive. Their combined total effect implies an increase in the 3-week withdrawals of 1.3 percentage points, or 22.7% in annual terms (assuming that the estimate remained constant over the year). Notably, by construction, we can only capture the short-run effects on withdrawals. This is likely to be an underestimate of the overall effect over a longer period if uncertainty of the kind we consider persists, especially in lieu of strategic complementarities. As the deposit base deteriorates, the risk of further withdrawals leading to a bank failure increases, which in theory should induce more withdrawals due to strategic complementarities. The magnitudes of combined total effects, although inherently partial equilibrium since they are based on difference-in-differences, closely represent the magnitude of the overall decline in deposits faced by the bank during the analysis period. During the 6 weeks following the announcement, withdrawals of all time deposits of the bank increased by 300% relative to the quiet times baseline. In comparison, the combined short-run effect of fundamental and strategic complementarities on increased depositor withdrawals is 270%, about 90% of the total increase in withdrawals.

Account and Depositor Heterogeneity. Panel A in Tables D.1 and D.3 present estimates for subsamples based on account and depositor characteristics. Columns (1) and (2) split the sample by gender. Withdrawal behaviors across men and women are only statistically different when they are related to strategic complementarity: men, on average, are more likely to withdraw their deposits before maturity. One interpretation of this result is that men have more extensive networks, which might give them additional information on other depositors withdrawing. Columns (3) and (4) split the sample by deposit size (above or below the median deposit amount of €35,000). Accounts with greater deposit amounts have higher withdrawals that are due to strategic complementarities than those with smaller deposit amounts. This is intuitive, since depositors with larger accounts might have greater incentive to monitor activity in the bank and react quicker to observing congestion/larger queues at the bank. Finally, Columns (5) and (6) show that there is no differential effect of deposits in euros and foreign currencies across both categories.

Panel B in Tables D.2 and D.3 show estimates for subsamples defined on the basis of depositor-bank relationships. Columns (1) and (2) compare depositors who have other financial products with the bank (mortgages, loans, and credit cards) with those who have no other products with the bank. Depositors with other products are significantly more likely to withdraw for fundamental reasons than those with no additional products, though this effect is economically small. This result highlights possible information channels in depositor-bank relationships. Columns (3) and (4) look at the number of years the depositor has at least one time deposit with the bank. Depositors who have held a time deposit with the bank for less than 2 years are significantly more likely to withdraw for both reasons. These depositors are probably less brand-loyal to the bank and more elastic in their withdrawals. Finally, Columns (5) and (6) consider the number of times the time deposit account has been previously renewed. This characteristic has no differential effect in any of the specifications.

Regional Heterogeneity. Table D.5 compares results for Athens (Greece's capital, and more densely populated) with the rest of the country. This split of the data does not show a significant heterogeneity in withdrawals related to fundamentals. However, there is substantial geographical heterogeneity for withdrawals due to strategic complementarities: Most of the effect on this margin is driven by depositors outside Athens. Table D.6 differentiates between large and small branches. Once again, withdrawal behavior related to fundamentals does not vary significantly across branches. In contrast, withdrawal behavior due to strategic complementarities is higher in large branches. Although suggestive, these results are consistent with the economics underlying the reasons for depositor withdrawals. If all depositors observe the deterioration of fundamentals, it could explain similar withdrawals due to fundamentals in the cross section. In contrast, observing congestion/lines (more likely in larger branches) could trigger more withdrawals due to strategic complementarities.[27]

We also consider whether the geographical patterns of withdrawal behavior due to strategic complementarities may be driven by differences in depositors' views about the left-wing policies that could be implemented in the future. Table D.7 shows results across municipalities that favored Grexit versus those that did not. We find no differential withdrawal behavior across these types of regions. In line with the results on borrower heterogeneity, observable characteristics do not seem to drive the differences in withdrawals due to strategic complementarities.

Dynamics. We also adapt our main specifications for strategic complementarities and fundamental-related withdrawals in Equations 3 and 4 to account for weekly withdrawal patterns. Figure F.1 plots estimates for these weekly coefficients. A few observations emerge. First, as a test of our empirical design, these weekly estimates confirm that there are no pre-trends in the treatment group relative to the control group. We also find that fundamental-related withdrawals react immediately and are high in the weeks following t_2. By the third week after the event, it is likely that most elastic depositors have already withdrawn, and additional withdrawals are no longer significantly different from zero. Withdrawals due to strategic complementarities, on the other hand, follow a different pattern that is non-monotonic over the weeks following t_1. These patterns are consistent with more variation in

27. To further explore this effect, we test for the presence of clusters in withdrawal behavior across nearby branches. Figure D.2 plots the spatial autocorrelation across branches, measured by local Moran's I_i and using the inverse of the distance between branches as a weighting matrix. We find that after the surprise announcement at t_1, there was a significant change in spatial autocorrelation in the northern region of Greece (more densely populated region with large branches). This spatial autocorrelation during the period when withdrawals due to strategic complementarities were stronger can be interpreted as suggestive evidence supporting our tests in Table D.5.

withdrawals across account, depositor, and regions due to strategic complementarities.

VI Depositor Compensation

So far, we have not taken advantage of the fact that time deposit withdrawals incur a monetary penalty. We now use this monetary cost to provide estimates of depositor compensation when they withdraw due to deteriorating fundamentals and strategic complementarities. We would like to estimate how much the bank should increase interest rates on its time deposits after a deterioration in fundamentals, in the hope of preventing withdrawals that might propel the bank toward a run. Since there are different reasons for withdrawals, these estimates might be different for depositor behavior changing due to fundamentals or strategic complementarities. Our analysis allows us to speak to cost-benefit of policies focused on preventing bank runs by targeting a subset of depositors in times of deteriorating fundamentals (see Shen and Zou 2020; Sakovics and Steiner 2012; Ennis and Keister 2009).

VI.A Cost-Elasticity Estimation

We estimate an elasticity of withdrawals with respect to the cost of withdrawing in quiet times. This elasticity can be interpreted as a quantification of the depositors' "willingness to remain." To estimate this elasticity, we exploit the discontinuity in accrued interests on July 1, 2014, described in Subsection III.B.3, and the corresponding drop in the cost of withdrawing.[28] We consider time deposits maturing in the 3 weeks before and after July 25, 2014. This allows us to construct groups similar to our analysis in Sections IV.B and IV.C. We then compare withdrawals in these groups in response to interest payments on July 1, 2014, in the 3-week window around this date.

Similar to our previous analysis, we cannot use a simple before-and-after comparison of withdrawals because withdrawals have a non-monotonic relationship with time to maturity (see Subsection III.B.2). To account for these patterns, we define a placebo group with the same time to maturity in a period with no interest payment. For this purpose, we use October 1, 2014, as a placebo date for interest payments.[29] Deposits in the placebo group mature in the 3 weeks before and after October 25, 2014. Notably, all deposits in this analysis mature in a quiet time period, when fundamentals are high and strategic complementarities are negligible.[30]

The estimation follows the difference-in-differences specification:

$$Withdrawal_{it} = \delta\, InterestPay_i + \lambda\, Post_t + \beta\, InterestPay_i \times Post_t + \gamma' X_{it} + \epsilon_{it} \qquad (5)$$

28. We express the cost of withdrawing either in euros or as an annualized forgone return on the deposit amount.

29. Our results are also robust to choosing March 1, 2014, as a placebo date.

30. Panel A of Table 5 shows the fraction of withdrawals as a percentage of total time deposits for the interest payment and the control subsamples. We observe that withdrawal behavior is not significantly different across subsamples before July 1 and October 1, with 0.54% of depositors withdrawing in the interest payment subsample and 0.56% in the control subsample. The percentage of withdrawals in the interest payment subsample increases substantially after July 1. The percentage of withdrawals rises to 0.86% after the interest payment date. In the control subsample, withdrawals drop after October 1 to 0.46%. This fall in the control group matches the inverted U-shape pattern we described in Subsection III.B.2.

where *InterestPay* is a dummy equal to one if a deposit matures in the period of interest payments and zero if it matures in the placebo period with no interest payments. *Post* is a dummy equal to one in the 3 weeks after interest payments on July 1 (or October 1 in the placebo group). X_{it} is a vector of covariates of observable depositor and account characteristics. β is a difference-in-differences estimate. It gives us the effect of a drop in the monetary cost of withdrawing on withdrawals.

Results from estimating Equation 5 are reported in Table 5, Panel B. Column (1) shows estimates for the baseline specification without covariates. The estimated coefficient β is 0.0088, significant at the 1% level and robust to the inclusion of controls. It captures the increase in withdrawals when the cost of withdrawal drops to zero (a drop of -100%—or, on average, €494—or 1.29% of the deposit amount) and represents an increase of 154% relative to the baseline.[31] Equivalently, this implies that a reduction in the cost of withdrawal of 1% of the deposit amount increases withdrawals by 119%. Alternatively, a reduction of €100 in the cost of withdrawal increases depositor withdraws by 31.2%.

It is worth noting that baseline withdrawals are high to begin with: The baseline implies that over 14% of time deposits are withdrawn over a year. Moreover, the size of the penalty tends to understate depositors' willingness to pay to withdraw for idiosyncratic reasons (or to overstate the sensitivity of withdrawal probabilities to changes in the cost). This is because they ignore the opportunity cost of waiting.[32] Our estimates imply a demand elasticity of deposits to changes in the cost of withdrawal of 1.5 (154/100). This translates into an interest rate demand elasticity of time deposits of 0.48 for the average deposit balance and rate.[33] These figures are inside the very large range of demand elasticity estimates in other settings. For example, Dick 2008, using U.S. Call Report data for the period 1993-–1999, finds a demand elasticity of deposits to the interest rate between 2 and 3. Egan, Hortaçsu, and Matvos 2017, using data for 16 of the largest U.S. banks over the period 2002-–2013, obtain demand elasticity estimates of 0.56 for insured deposits and 0.16 for uninsured deposits.

VI.B Depositor Compensation to Remain in the Bank

The elasticities we have computed are useful for estimating the monetary costs paid by depositors for withdrawing before maturity. These estimates—which we can rephrase as the compensation that depositors are willing to accept to *not* withdraw before maturity—can guide policymakers when determining the cost of stabilizing deposits when confronted with uncertainty that might trigger a bank run. Such policies might involve increasing rates being offered on deposits (i.e., increasing benefits of not withdrawing). Alternatively, these policies might involve imposing haircuts on deposit with-

31. Notably, forgone interest payment of €494 is equivalent to almost 28% of the median monthly income of time depositors of the bank.

32. Recall from the discussion in Subsection III.B.2 that withdrawing shortly before the maturity date implies depositors use very large discount rates. For example, withdrawing a deposit of value D 1 week before maturity for a penalty of 1% of D is equivalent to paying an interest of $0.01 \times D$ to borrow $0.99 \times D$ for a week. This corresponds to an annualized interest rate of 68%. The average cost of withdrawal during the 3 weeks before the interest payment date, expressed in terms of forgone returns, is 41%.

33. A 75% change in the cost of withdrawal expressed as an annualized rate—a decline of 10 percentage points of a baseline of 41—leads to a 37% decline in deposits. The cost semi-elasticity using this figure implies that a 10-percentage-point drop in the forgone return from withdrawing induces a 37% increase in the withdrawal probability.

drawals during such times (i.e., increasing the cost of withdrawal). Our estimates apply to both of these scenarios and can help determine the size of these interest rate increases or haircuts required to prevent depositor withdrawals.

At a broad level, we use our empirical design and estimate the change in interest rates (or costs of withdrawing) that would have induced similar change in withdrawals during quiet times as we observe after the deterioration of fundamentals. Consequently, we compute additional depositor compensation that is required to keep them from withdrawing in response to a deterioration of fundamentals.

We find that the cost of withdrawal must drop by €293 (0.77% of deposit amount, or 26% in forgone return) to generate the same increase in withdrawals during quiet times as the increase in withdrawals due to strategic complementarities (Subsection V.A). Similarly, to generate the increase in fundamental-related withdrawals, we estimate the cost of withdrawal would have to drop by €612 (1.61% of deposit amount, or 72% forgone return) in quiet times. Combined, these estimates imply that the bank would have to offer depositors a payment of 2.38% of the value of their deposits. A large fraction of this compensation (2/3 = 1.61/2.38) is attributed to preventing fundamental-related withdrawals. This rate premium would prevent withdrawals from increasing during the 3-week period after the event that triggered the heightened uncertainty. As a calibration, the implied annualized return exceeds 50%, and the rate vastly exceeded our bank's marginal cost of funding from the European Central Bank at the time (below 5%).

Notably, the cost of preventing withdrawals is very high, in part because we are assuming similar willingness to withdraw across depositors. However, as noted earlier, there is heterogeneity in withdrawal elasticities of depositors, with some types of depositors being more susceptible to withdrawing due to strategic complementarities. Thus, this high cost occurs partly due to transferring rents to inframarginal depositors. In other words, the cost of preventing withdrawals during times of heightened uncertainty could vary and potentially be lower if policymakers were able to target those with the highest propensity to withdraw (see Sakovics and Steiner 2012). Finally, even at the high end, the cost of stabilizing the bank by compensating the depositors to remain in the bank is small relative to the very high social costs of declining output that follow bank runs (see Reinhart and Rogoff 2014; Laeven and Valencia 2012).

VI.C Quantification Using CDS Prices

Our approach to separate withdrawals due to strategic complementarities and fundamentals is not specific to Greece. We can potentially implement our methodology when analyzing other bank run episodes where there is an unexpected event that deteriorates fundamentals and may cause depositors to withdraw for reasons we have explored in this paper. To perform such an extrapolation, we need to scale the magnitude of the aggregate uncertainty increase during the Greek episode that gives us our estimates. A natural candidate for a measure of the aggregate uncertainty increase is the change in the Greek sovereign bond CDS price. To implement this, we consider the magnitude of CDS price changes after events at t_1 and t_2.

During our uncertainty period, the 6-month CDS price increased by 271%. Recall that we estimated a 68% increase in withdrawals due to strategic complementarities. Thus, when we extrapolate this estimate to other settings, we assume the elasticity of withdrawals driven by strategic complementarities to the CDS price to be 0.25 (68/271). In other words, a 1% increase in CDS price leads to a 0.25% increase in withdrawals due to strategic complementarities. Similarly, we estimated a 192% increase in withdrawals directly due to deterioration of fundamentals. Thus, for other episodes, we assume the elasticity of withdrawals driven by fundamentals to the CDS price to be 0.71 (i.e., a 1% increase in CDS price leads to a 0.71% increase in withdrawals due to fundamentals).

Combined, these two elasticities imply that a 1% increase in the 6-month sovereign default risk is associated with a 0.96% increase in withdrawals, with a larger component that is directly driven by deterioration of fundamentals. These elasticities suggest that for a change in CDS prices, depositors withdrawing due to strategic complementarities are less elastic than depositors withdrawing directly due to deteriorating fundamentals (1/4 vs. 3/4). This has implications for policies trying to keep depositors in the bank in periods of high uncertainty. For a given CDS shock, strategic depositors are less likely to react than those withdrawing for deteriorating fundamentals. In other words, they have a higher willingness to remain for the same CDS shock.

Extrapolating to Other Episodes. To assess the plausibility of the magnitude of our estimates and their external validity, we perform a series of extrapolation exercises to other episodes where there was a change in fundamentals after a surprise announcement. We can use our estimated elasticities of deposit withdrawals with respect to changes in CDS prices to test whether our approach and estimates have relevance outside our setting. In particular, we evaluate whether using our elasticities can predict a significant fraction of actual deposit withdrawals in the Greek banking sector (see Appendix G) and other recent bank run episodes (namely, the Italian crisis in the summer of 2018 and the runs on Northern Rock and Washington Mutual in Appendix I). We find that although we underestimate the magnitude of withdrawals in all four events, extrapolation using our estimates comes reasonably close to observed outcomes (see Appendix G for details on our quantification exercise).

VII Discussion and Conclusion

We develop a new approach to identify and quantify the compensation to remain in the bank for depositors during periods of uncertainty. Our innovative empirical design allows us to compute a "willingness to remain" separately for deposit withdrawals due to direct exposure to deteriorating fundamentals and those due to expectations about withdrawal behavior of other depositors. After a policy uncertainty shock that doubled the short-run CDS price of Greek sovereign bonds, we find that deposit withdrawals quadrupled. According to our estimates, two-thirds of this increase is due to direct exposure to fundamentals, while the remainder is driven by the indirect effect of strategic complementarities. We estimate that in order to prevent the increased deposit withdrawals, our bank would have to increase the rate offered to depositors by 2.38 percentage points over a 3-week period—an annualized rate of over 50%.

When the fundamentals around a bank deteriorate, policymakers and banks are confronted with several choices to address a potential bank run during periods of heightened uncertainty. On one hand, they might increase rates being offered on deposits. Indeed, we often observe banks increasing their deposit rates to attract depositors at the beginning of periods with abnormally high levels of deposit withdrawals (see Martin, Puri, and Ufier 2018). On the other hand, they might impose haircuts on withdrawals, hoping to arrest the run.[34] Regardless of the choice, our paper provides quantitative guidance to policymakers as they face an environment where uncertainty might trigger a bank run.

Our findings also provide new insights into the design of interventions to prevent runs by targeting depositors with the largest propensity to withdraw due to strategic complementarities (see Shen and Zou 2020; Sakovics and Steiner 2012). Our results on "heterogeneity" (see Section V), with some types of depositors being more susceptible to withdrawing due to strategic complementarities, suggest that such targeting could be customized based on depositor characteristics such as gender, deposit amounts and maturities, and previous relationships of depositors with the bank. In contrast, we find no heterogeneous behavior when estimating withdrawals that are directly due to deteriorating fundamentals. Together, these findings also provide guidance to policies that follow from theoretical work that argues that once a run starts, it might be ex post efficient to freeze (or convert demand deposits to time deposits) some but not all deposits (see Ennis and Keister 2009).

Our novel empirical design exploits staggered maturities of time deposits and multiple announcements that had the potential to impact fundamentals in the future. These key ingredients allow us to estimate the willingness to pay to keep depositors who might be withdrawing for different reasons. However, our inferences apply more generally, including instances when depositors have homogeneous contracts (e.g., demand deposits with no maturities) and when fundamentals change adversely and impact all the depositors at the same time. Having said that, we should be cautious in extrapolating our estimates to scenarios where uncertainty and deterioration of fundamentals are longer-run and permanent in nature. Moreover, we might not be able to use these estimates as-is for smaller banks, since we study the depositor behavior for a large important bank in the economy.

Finally, we provide supporting evidence for economic forces behind theoretical work on global games in banking. We find that depositor withdrawals due to strategic complementarities are quantitatively important and—unlike withdrawals that are directly due to deteriorating fundamentals—exhibit heterogeneity within the depositors and over time. These inputs can be useful for designing policy interventions that hope to address bank runs. They are also useful in understanding runs in nonbanks and financial funds—given the close nature of withdrawals they face relative to our study—that now moderate a significant part of economic activity around the world (for life insurance, see Foley-Fisher, Narajabad, and Verani 2020; for money market mutual funds, see Kacperczyk and Schnabl 2013; Schmidt, Timmermann, and Wermers 2016; and for asset-backed commercial paper, see Schroth,

34. Policymakers and banks have typically not followed this strategy, likely because of the strong negative signal it might send about the prospects of the bank/economy and because of the possibility of reduced future trust in the banking sector. Supporting this idea is the observation that capital controls and haircuts are usually in place for a long period of time whenever they are implemented. This is due to worries that reversing them in the short run could trigger a capital flight.

Suarez, and Taylor 2014). We leave exploration of these avenues for future research.

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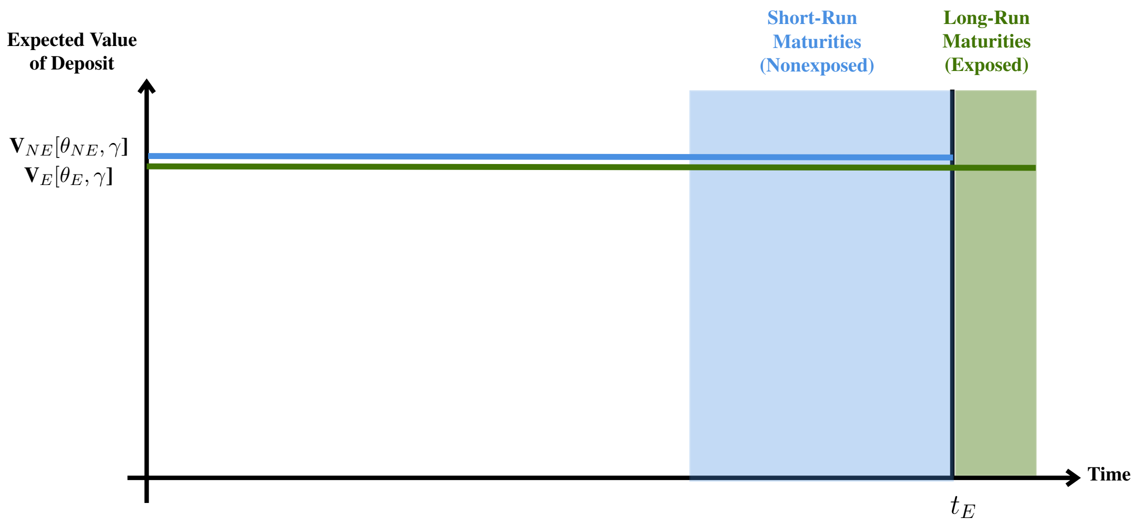
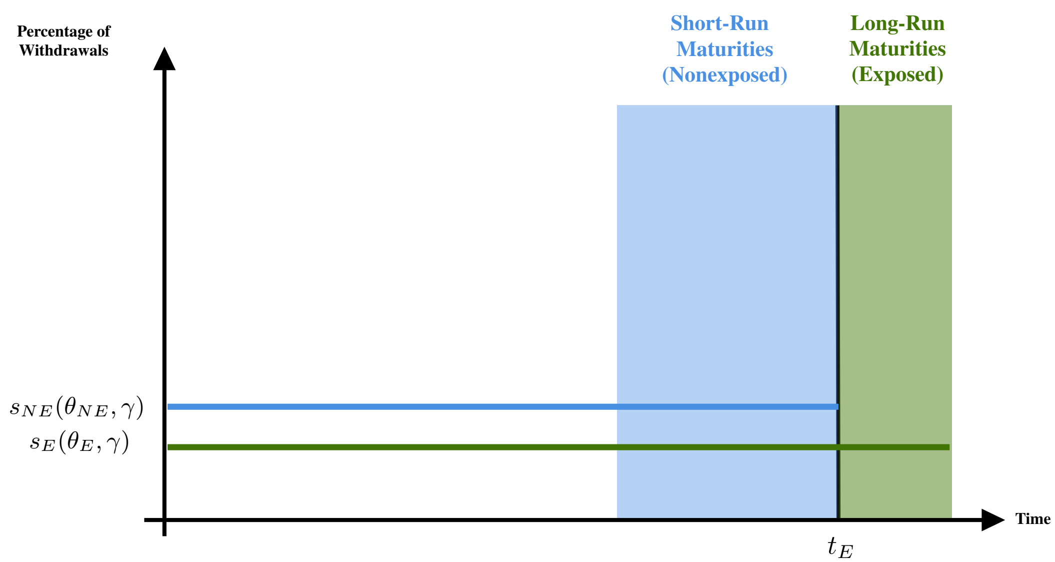
Figure 1: Framework in Quiet Times

PANEL A: Expected Value of Deposit for Depositors with Exposed and Nonexposed Maturities



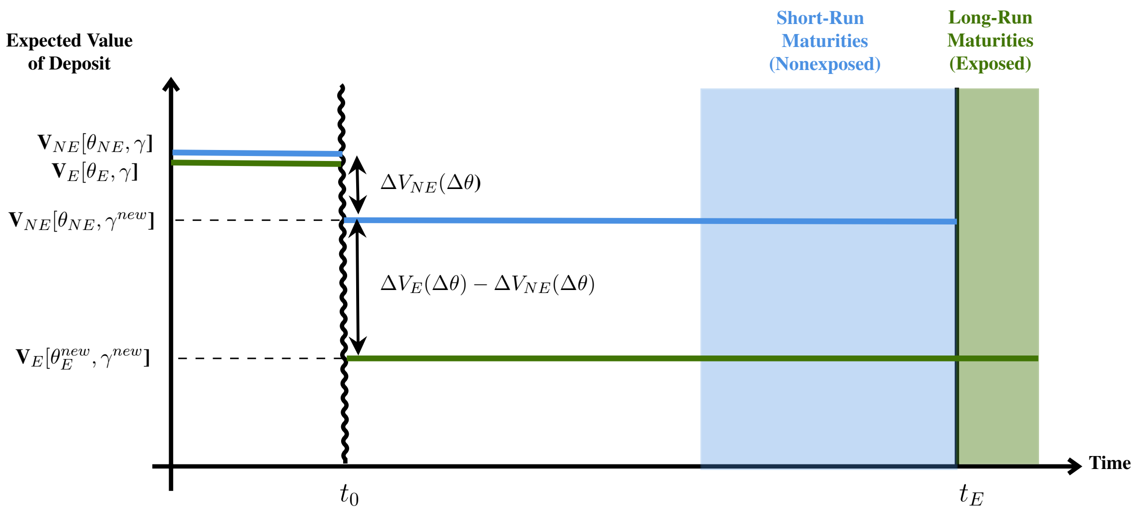
PANEL B: Percentage of Withdrawals for Depositors with Exposed and Nonexposed Maturities



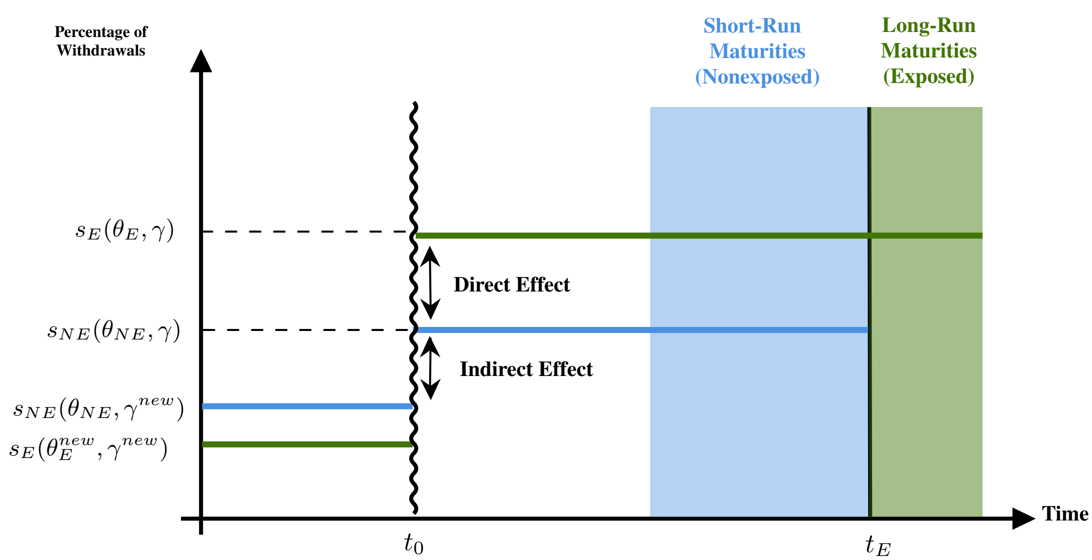
Notes: Panel A plots the expected value of deposits ($V[.]$) in quiet times in our motivating framework in Section II. Panel B illustrates the percentage of withdrawals ($s[.]$) associated with those expected values of deposits. Both panels plot separately deposits with exposed and nonexposed maturities, depending on whether they mature before or after t_E (i.e., short- versus long-run maturities). The x-axis in both panels plots time. The green lines in both panels refer to time deposits with exposed maturities, while the blue lines in both panels represent time deposits with nonexposed maturities.

Figure 2: Framework with Deteriorating Fundamentals for Depositors with Exposed Maturities

PANEL A: Expected Value of Deposit for Depositors with Exposed and Nonexposed Maturities

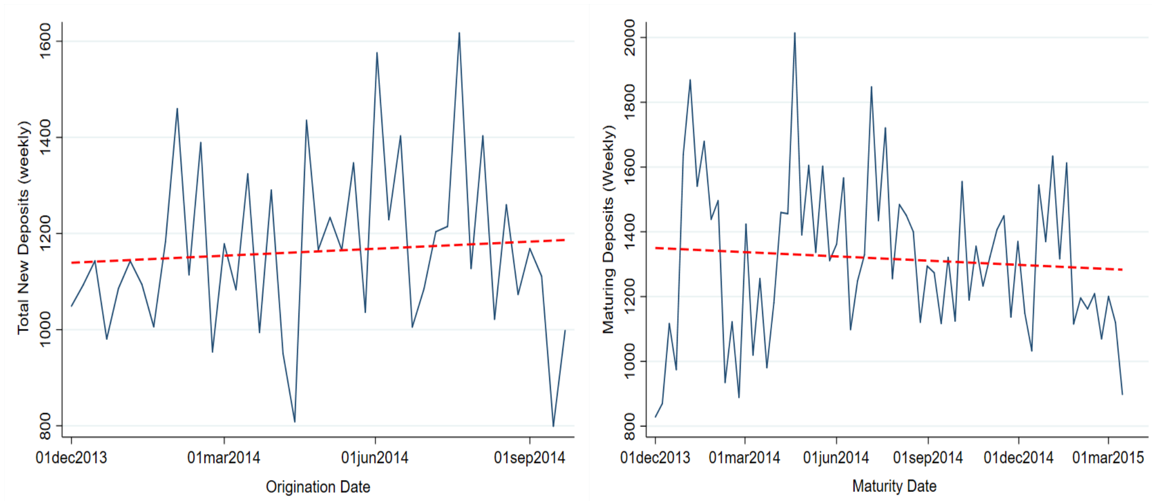


PANEL B: Percentage of Withdrawals for Depositors with Exposed and Nonexposed Maturities



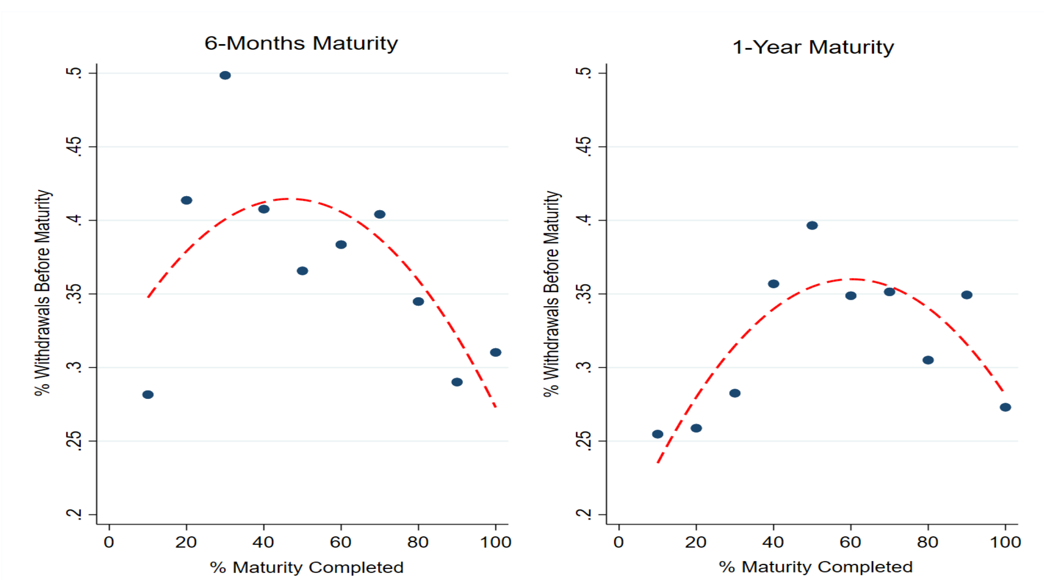
Notes: Panel A plots the expected value of deposits ($V[.]$) after a deterioration of fundamentals in our motivating framework in Section II. Panel B illustrates the percentage of withdrawals ($s[.]$) associated with those expected values of deposits. Both panels plot separately deposits with exposed and nonexposed maturities, depending on whether they mature before or after t_E (i.e., short- versus long-run maturities). The x-axis in both panels plots time. The green lines in both panels refer to time deposits with exposed maturities, while the blue lines in both panels represent time deposits with nonexposed maturities. The curly line at t_0 represents an unexpected deterioration of fundamentals affecting long-run, but not short-run maturities. $\Delta[.]$ describe the change before and after t_0. *Direct* and *Indirect* effects are those described in Section II.

Figure 3: Deposits' Origination and Maturity Dates



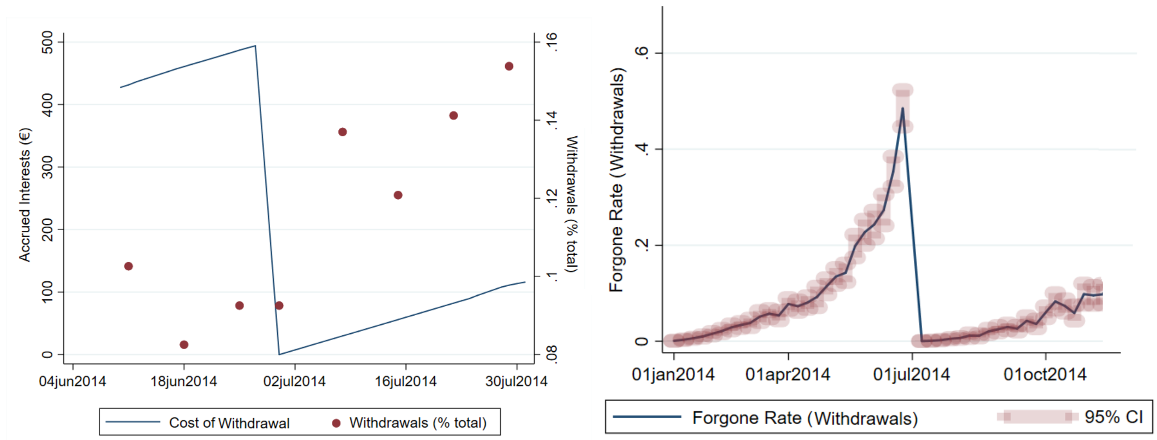
Notes: The left panel plots weekly originations, measured by total new time deposits at our bank in a given week. The right graph plots the total number of time deposits maturing in a given week. The red dashed lines fit a linear trend using fitted values from an OLS regression of new and maturing time deposits over a weekly trend. Both trends are not significantly different from zero.

Figure 4: Withdrawals and Time to Maturity



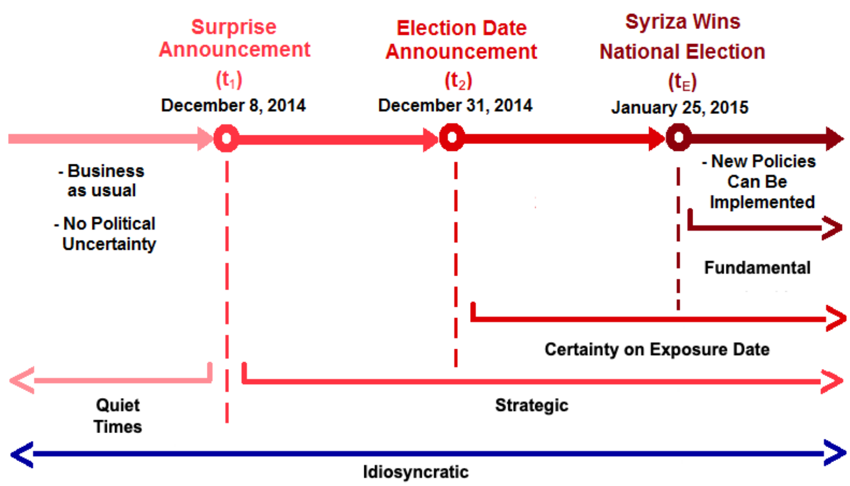
Notes: The figure plots time deposits maturing between January and October 2014. The left panel plots deposits with six month maturities, and the right panel plots deposits with one yer maturities. The y-axis represents the percentage of withdrawals. The x-axis is the percentage of maturity completed at the time of withdrawal. For example, a time deposit with a six-month maturity that is withdrawn two months after origination has completed 33% of its maturity. The red dashed lines are fitted values from a regression of percentage of withdrawals over percentage of maturity completed and percentage of maturity completed squared.

Figure 5: Payment of Accrued Interests and Foregone Returns for Deposits Withdrawn Before Maturity



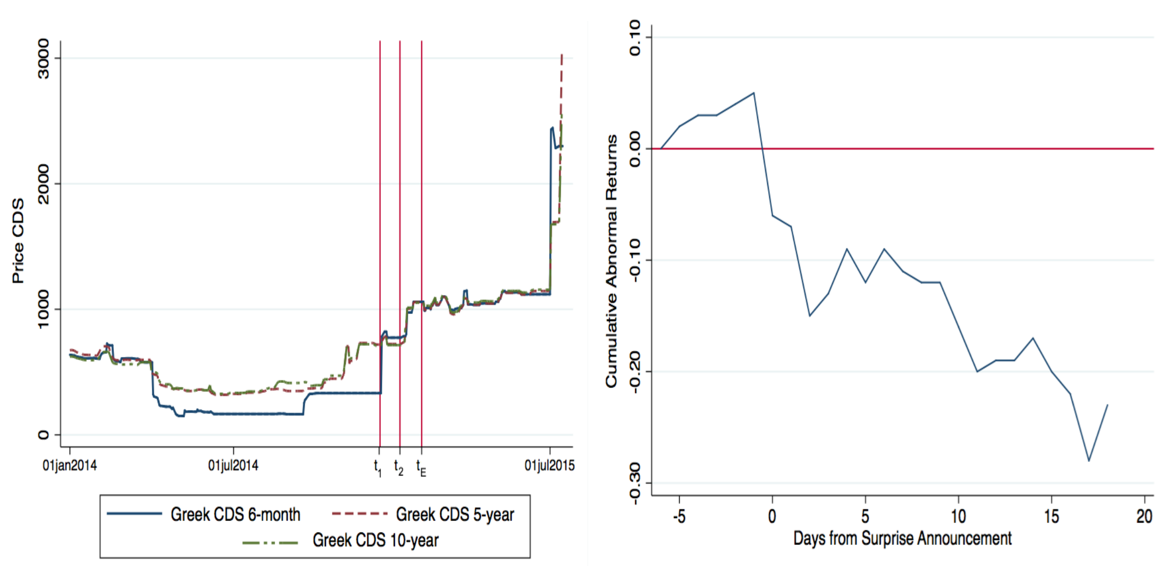
Notes: The solid line in the left panel plots average accrued interests for all time deposits at a weekly frequency between June 7 and July 31, 2014. The dots correspond to the percentage of deposits withdrawn before maturity each week for the same time period. The right panel plots the foregone rate of return for time deposits at a weekly frequency between January 1 and December 1, 2014. We calculate foregone interests as *(Interest Forgone/Interest Received)ˆ(365/Days to Maturity)*, where *Interest Forgone* is accrued interests at the time of withdrawal and *Interest Received* is interest payments at maturity. The shaded area in the right panel represents 95% confidence intervals.

Figure 6: Main Events



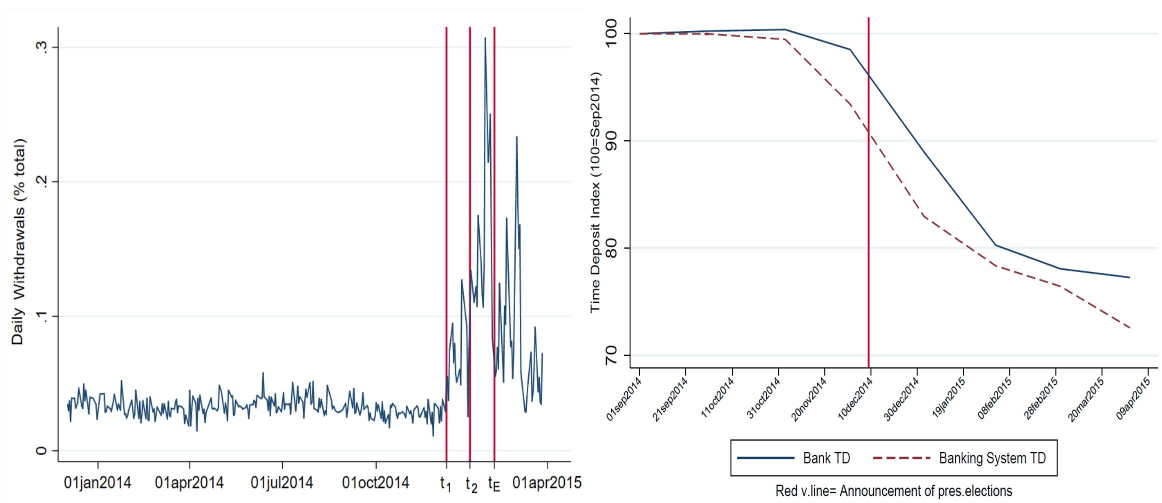
Note: The diagram depicts our three main events (t_1, t_2 and t_E). Before t_1, withdrawals are due to idiosyncratic reasons. After t_1, depositors with maturities after that date also face strategic complementarities, driven by changes in their expectations of other depositors' withdrawal behavior. After t_2, depositors with maturities after that date receive news about their exposure to policy uncertainty. Finally, after t_E depositors with maturities after that date also face deteriorating fundamentals in the form of new policies being implemented by the new government.

Figure 7: CDS Prices and Cumulative Abnormal Returns



Notes: The left graph plots CDS prices for Greek sovereign bonds with six-month, five-year and ten-year maturities. The red vertical lines correspond to our key events in our empirical analysis (see Figure 6). The right graph plots cumulative abnormal returns for Athens Stock Exchange with respect to FTSE Euro 100 over an event window starting 5 days prior to the surprise announcement on December 8, 2014 (t_1) until 17 days after.

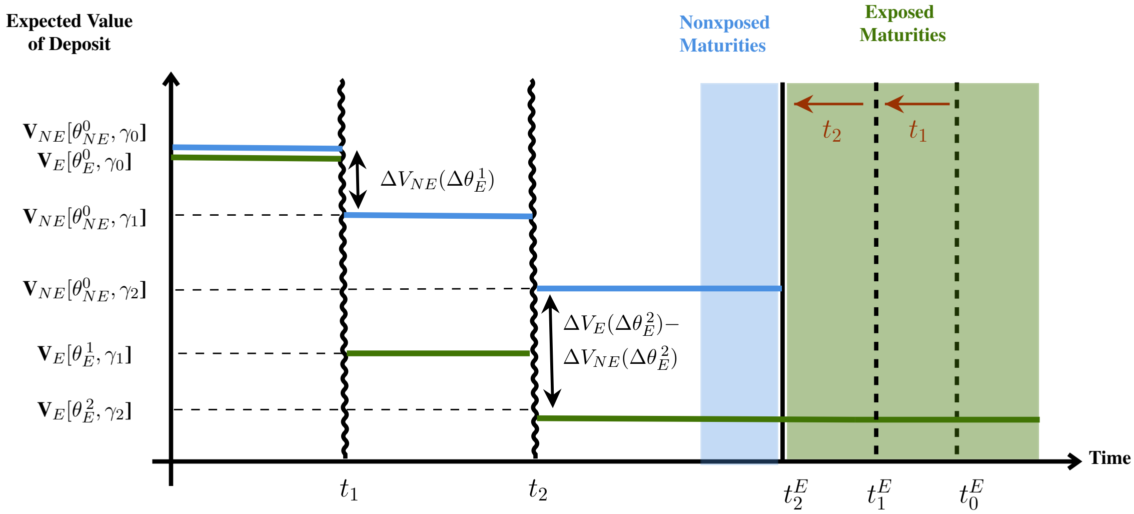
Figure 8: Daily Percentage of Time Deposits Withdrawn Before Maturity



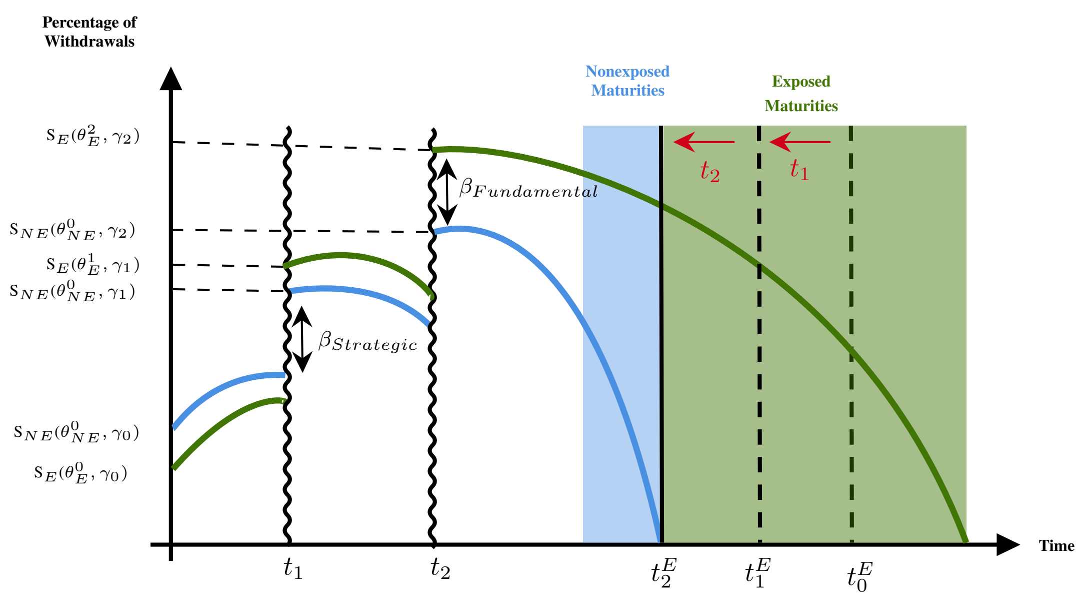
Note: The left panel plots time deposits withdrawn before maturity expressed as a percentage of total time deposits between January 1, 2014 and March 31, 2015. The red vertical lines correspond to our key events (see Figure 6). The right panel plots changes in total time deposits between September 2014 (normalized to 100) and April 2015. The solid blue line represents changes in our bank's time deposits, while the dashed red line plots changes in time deposits (relative to September 2014) in the overall Greek banking system. The vertical red line corresponds to t_1.

Figure 9: Mapping Framework to Empirical Strategy

PANEL A: Expected Value of Deposit for Depositors with Exposed and Nonexposed Maturities



PANEL B: Percentage of Withdrawals for Depositors with Exposed and Nonexposed Maturities



Panel A plots the expected value of deposits ($V[.]$) after a deterioration of fundamentals in our motivating framework in Section II. Panel B illustrates the percentage of withdrawals ($s[.]$) associated with those expected values of deposits. Both panels plot separately deposits with exposed and nonexposed maturities, depending on whether they mature before or after t_E (i.e., short- versus long-run maturities). The x-axis in both panels plots time. The green lines in both panels refer to time deposits with exposed maturities, while the blue lines in both panels represent time deposits with nonexposed maturities. The curly lines at t_1 and t_2 represent unexpected changes in t_E, such that some deposits with nonexposed maturities becomes expose. $\Delta[.]$ describe the change before and after t_1 and t_2. $\beta_{Fundamental}$ and $\beta_{strategic}$ are our coefficients of interest in our empirical analysis in Section IV. In our empirical strategy, we use t_1 to identify strategic complementarities, and t_2 for fundamental-related withdrawals.

Table 1: Descriptive Statistics

PANEL A: Entire Sample

	Mean (1)	S.D (2)	Min (3)	Median (4)	Max (5)	N (6)
Depositor Characteristics						
Age (years)	65	15	18	66	100	>300,000
Female	0.45	0.5	0	0	1	>300,000
Income (€)	25,363	20,880	1,103	21,137	197,609	>40,000
Education (years)	12	3	0	12	20	>200,000
Other Products (mortgage, credit card, loan)	0.3	0.46	0	0	1	>300,000
Years Holding Time Deposits	2.3	2.7	0.06	1	56	>300,000
Bank Employee	0.04	0.2	0	0	1	>300,000
Athens	0.34	0.47	0	0	1	>300,000
Account Characteristics						
Interest Rate (%)	1.94	0.95	0.01	2.2	8.19	>300,000
Balance (€)	57,281	65,490	687	36,000	500,000	>300,000
Currency Euros	0.77	0.42	0	1	1	>300,000
Maturity (days)	164	119	21	130	365	>300,000
Previous Renewals	6.5	10.6	1	3	1513	>300,000

PANEL B: Withdrawn Before Maturity

	Mean (1)	S.D. (2)	Min (3)	Median (4)	Max (5)
Quiet-Times (January to November 2014)					
Daily % Withdrawals	0.04	0.01	0.01	0.03	0.06
Days to maturity	136	104	6	114	364
Maturity (days)	257	117	21	360	365
Balance (€)	41,188	49,364	2,828	23,500	500,000
Interest Rate (%)	1.86	0.85	0.01	2.1	4
Currency Euros	0.88	0.32	0	1	1
Age (years)	64	16	18	64	100
Female	0.47	0.5	0	0	1
Education (years)	12	3.23	0	12	1 20
Income (€)	24,450	18,678	1,900	20,433	149,569
Bank Employee	0.03	0.18	0	0	1
Years Holding Time Deposits	2.2	2.5	0.08	2.7	47
Previous Renewals	3.5	4.7	1	2	97
Other Products (mortgage, credit card, loan)	0.34	0.47	0	0	1
Forgone Interest Payment	308	493	0	175	8,180
Uncertainty Period (Dec 2014 to Feb 2015)					
Daily % Withdrawals	0.12	0.07	0.02	0.10	0.28
Days to maturity	129	96	6	105	364
Maturity (days)	240	109	21	183	360
Balance (€)	58,583	63,591	687	37,000	500,000
Interest Rate (%)	1.67	0.49	0.01	1.75	3.25
Currency Euros	0.93	0.26	0	1	1
Age (years)	63	15	20	63	100
Female	0.45	0.5	0	0	1
Education (years)	13	3.17	0	12	1 20
Income (€)	25,697	19,304	1,900	21,748	193,491
Bank Employee	0.07	0.26	0	0	1
Years Holding Time Deposits	2.8	3.5	0.08	1.8	56
Previous Renewals	4.9	6.5	1	3	82
Other Products (mortgage, credit card, loan)	0.39	0.49	0	0	1
Forgone Interest Payment	385	531	0	211	8,225

Note: Panel A presents summary statistics for all time deposits in our sample. We need to mask total observations to keep the identity of our bank confidential. Panel B reports summary statistics for time deposits withdrawn before reaching maturity, both in quiet times (January to November 2014) and uncertainty period (December 2014 to February 2015).

Table 2: Identifying Fundamental Related Withdrawals

PANEL A: Percentage of Time Deposits Withdrawn Before Maturity

	Uncertainty=1		Uncertainty=0	
	Exposed=0	Exposed=1	Exposed=0	Exposed=1
Post=0 (Before t_1 or $t_1^{Placebo}$)	0.40 %	0.49 %	0.40 %	0.41 %
Post=0 (Between t_1 ($t_1^{Placebo}$) and t_2 ($t_2^{Placebo}$)	1.00 %	1.07 %	0.66 %	0.64 %
Post=1 (After t_2 or $t_2^{Placebo}$)	0.39 %	2.78 %	0.37 %	1.40 %
Observations (N)	>8,000	>8,000	>8,000	>8,000

PANEL B: Interest Payments

	Uncertainty =1		Uncertainty=0)	
	Exposed=0	Exposed=1	Exposed=0	Ex[psed=1
Interest Payment (in Post=0)	€526 (680)	€478 (602)	€509 (707)	€475 (603)

Notes: Panel A reports the percentage of time deposits withdrawn before maturity. The first and second columns consider *exposed* and *nonexposed* time deposits with maturity dates after t_2 ($Uncertainty = 1$). The third and fourth columns refer to time deposits with maturity dates in the quiet period, after $t_2^{Placebo}$ ($Uncertainty = 0$). The first row reports percentage of time deposits withdrawn before maturity during the three weeks prior to t_1 and $t_1^{Placebo}$. The second row reports percentage of time deposits withdrawn before maturity during the three-weeks following t_1 and $t_1^{Placebo}$. The third row reports percentage of time deposits withdrawn before maturity during the three-weeks following t_2 and $t_2^{Placebo}$. We need to mask total observations to keep the identity of our bank confidential. Panel B reports average interest payments (in Euros) for the pre-period ($Post = 0$). Standard deviations of interest payments are reported in parentheses.

Table 3: Difference-in-Differences-in-Differences Estimation for Fundamental Related Withdrawals

Withdrawal (0/1)	(1)	(2)
DDD	0.0127***	0.0127***
	(0.0030)	(0.0030)
Uncertainty	0.0030**	0.0028**
	(0.00122)	(0.00126)
Exposed	-0.0016	-0.0016
	(0.0010)	(0.0011)
Post	-0.0028***	-0.0028***
	(0.0009)	(0.0009)
Uncertainty × Post	-0.0033**	-0.0033**
	(0.0015)	(0.0015)
Exposed × Uncertainty	0.0023	0.0025
	(0.0019)	(0.0019)
Post × Exposed	0.0104***	0.0104***
	(0.0017)	(0.0017)
Account Characteristics	No	Yes
Depositor Characteristics	No	Yes
Observations	>50,000	>50,000

Note: This table reports results from estimating Equation 3. The dependent variable $Withdrawal$ is a dummy equal to one for withdrawals. $Exposed$ is a dummy equal to one if deposits mature within two weeks after t_E (or $t_E^{Placebo}$ in the placebo group), and zero if maturing two weeks before t_E (or $t_E^{Placebo}$ in the placebo group). $Post$ is a dummy equal to one in the three weeks after t_2 (or $t_2^{Placebo}$ in the placebo group), and zero in the three weeks before this date. $Uncertainty$ is an indicator variable equal to one for deposits maturing in the period of heightened uncertainty, and zero for the deposits maturing in the quiet times placebo period. Maturities in the heightened uncertainty period are in a two-week window around t_E. Correspondingly, maturities in the quiet times placebo period are in a two-week window around $t_E^{Placebo}$. The coefficient of interest $\beta_f undamental$ is the one for the triple interaction of *Post*, *Uncertainty* and *Exposed* (labeled *DDD* in the table). Column (2) includes depositor characteristics (gender, age, bank employee, other products, previous relationship with the bank) and account characteristics (deposit amount, maturity, rate, currency). Robust standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1). We need to mask observations to keep the identity of our bank confidential.

Table 4: Identifying Strategic Complementarities Related Withdrawals

PANEL A: Percentage of Time Deposits Withdrawn Before Maturity

	Uncertainty=1	Uncertainty=0
Post=0 Before t_1 (or $t_1^{Placebo}$)	0.40 %	0.40 %
Post=1 After t_1 (or $t_1^{Placebo}$)	0.94 %	0.66 %
Observations (N)	>8,000	>8,000

PANEL B: Difference-in-Differences Estimation for Strategic Complementarities Related Withdrawals

Withdrawal (0/1)	(1)	(2)
DiD	0.0027*	0.0027*
	(0.0015)	(0.0015)
Uncertainty	0.000	0.000
	(0.001)	(0.001)
Post	0.0026***	0.0027***
	(0.0009)	(0.0009)
Account Characteristics	No	Yes
Depositor Characteristics	No	Yes
Observations	>30,000	>30,000

Note: Panel A reports the percentage of time deposits withdrawn before maturity. The first column considers time deposits with maturity dates after t_2 but before t_E ($Uncertainty = 1$). The second column refers to time deposits with maturity dates in the quiet period, before $t_2^{Placebo}$ but after $t_E^{Placebo}$ ($Uncertainty = 0$). The first row reports percentage of time deposits withdrawn before maturity during the three weeks prior to t_1 and $t_1^{Placebo}$ ($Post = 0$). The second row reports percentage of time deposits withdrawn before maturity during the three-weeks following t_1 and $t_1^{Placebo}$ ($Post = 1$). Panel B reports results from estimating Equation 4. The dependent variable $Withdrawal$ is a dummy equal to one for withdrawals. $Post$ is a dummy equal to one for the three weeks after t_1 (or $t_1^{Placebo}$ for the placebo group), and zero for the three weeks before this date. $Uncertainty$ is an indicator variable equal to one for deposits maturing in the period of heightened uncertainty, and zero if maturing in the quiet times placebo period. Deposits in the heightened uncertainty period mature in the three-weeks before t_E. Correspondingly, deposits in the quiet times placebo period mature in the three weeks before $t_E^{Placebo}$. DiD refers to the interaction between $Uncertainty$ and $Post$, and captures the coefficient $\beta_{Strategic}$. Column (2) in Panel B includes depositor characteristics (gender, age, bank employee, other products, previous relationship with the bank) and time deposit characteristics (deposit amount, maturity, interest rate, currency). Robust standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1). We need to mask observations in Panels A and B to keep the identity of our bank confidential.

Table 5: Estimating the Elasticity of Depositors to Interest Payments

PANEL A: Percentage of Time Deposits Withdrawn Before Maturity

	Interest Pay=1	Interest Pay=0
Post=0 Before July 1 (or Oct 1)	0.54 %	0.57 %
Post=1 After July 1 (or Oct 1)	1.26 %	0.40 %
Observations (N)	>8,000	>8,000

PANEL B: Difference-in-Differences Estimation Around Interest Payments

Withdrawal (0/1)	(1)	(2)
DiD	0.0088***	0.0088***
	(0.002)	(0.002)
Interest Pay	-0.00024	-0.00016
	(0.001)	(0.001)
Post	-0.0016	-0.0016
	(0.001)	(0.001)
Account Characteristics	No	Yes
Depositor Characteristics	No	Yes
Observations	>30,000	>30,000

Note: Panel A reports percentage of withdrawals in a period of interest payments ($InterestPay = 1$) relative to a period with no interest payments ($Interest = 0$). The first row shows percentage of time deposits withdrawn before maturity during the three weeks prior interest payments ($Post = 0$), while the second row reports withdrawal behavior in the three weeks following interest payments ($Post = 1$) Panel B reports results from estimating Equation 5. The dependent variable $Withdrawal$ is a dummy equal to one for withdrawals. $Interest\ Pay$ is a dummy equal to one if a deposit matures in the period of interest payments, and zero if it matures in the placebo period with no interest payments. $Post$ is a dummy equal to one in the three weeks after interest payments on July 1 (or October 1 in the placebo group). DiD refers to the interaction between $Interest\ Pay$ and $Post$, capturing our coefficient of interest. Column (2) in Panel B includes depositor characteristics (gender, age, bank employee, other products, previous relationship with the bank) and time deposit characteristics (deposit amount, maturity, interest rate, currency). Robust standard errors are in parentheses (*** p<0.01, ** p<0.05, * p<0.1). We need to mask observations in Panels A and B to keep the identity of our bank confidential.

For Online Appendix

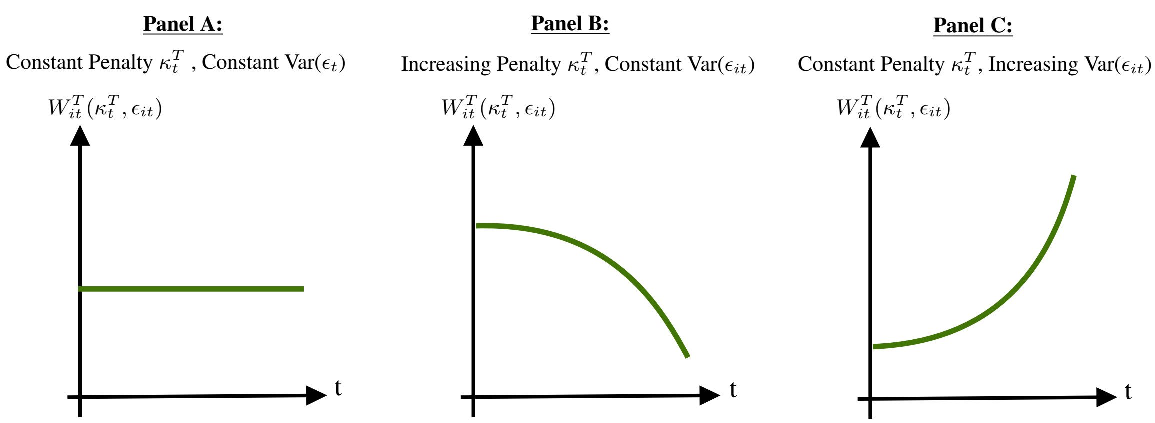
Appendix A Non-Monotonic Payoffs of Withdrawals

In the main text (Section II), for simplicity, we assumed that depositor's expected payoffs of withdrawal are constant over time (case illustrated in Panel A of Figure A.1). That is, $\frac{\partial W_{it}(\kappa_t^T,\epsilon_{it})}{\partial t} = 0$. In this section we consider the case in which depositors' expected payoffs of withdrawal can be non-monotonic. We consider this case, because non-monotonic payoffs of withdrawals can generate non-monotonic probabilities of withdrawal over time – which is what we observe in our setting. The reason to keep the simpler case in the text is that the economic intuition between the case discussed here and the simple one is identical.

In order to generate non-monotonicity, we combine two assumptions: time-varying monetary cost (κ_t^T) and time-varying variance of idiosyncratic shock (ϵ_{it}). We assume that the monetary penalty for early withdrawal increases as we get closer to maturity. That is, $\frac{\partial \kappa_t^T}{\partial (T-t)} < 0$. This assumption matches standard contracts for time deposits across countries. It is also consistent with cases in which there is no monetary penalty, but the depositor will lose all accrued interests in the event of early withdrawal. In this case, payoffs from early withdrawal are decreasing as we get closer to maturity, as illustrated in Panel B of Figure A.1.

We also assume that the the variance of the (unobserved) idiosyncratic shock increases as we get closer to maturity. That is, $\frac{\partial Var(\epsilon_{it})}{\partial (T-t)} < 0$. This assumption can be interpreted as liquidity shocks becoming more unpredictable as we get further away from origination. A person originating a time deposit is betting on not needing the money until maturity. The further into the future, the higher the variance on the person's liquidity needs. In this case, payoffs from early withdrawal are increasing as we get closer to maturity. That is, it is more likely that the depositor will get a larger liquidity shock such the she will need to withdraw the time deposit early, as illustrated in Panel C of Figure A.1.

Figure A.1: Expected Payoffs of Withdrawals



Combining time-varying monetary penalties and time-varying liquidity shock variances allows us to simply generate withdrawal probabilities that are an inverted U-shaped. As discussed in Section III.B.2, this matches the pattern we observe in the data. For completeness, consider Figure A.2 which extends the discussion on withdrawal probabilities in Section II with such non-monotonic withdrawal payoffs. The intuition for inverted U-shaped withdrawal probabilities is straight forward. Closer to origination, probability of withdrawal is low because it is unlikely depositor is hit with liquidity shock. As we move further form origination, liquidity shocks have a greater variance, and probability of getting a large enough shock goes up. Therefore, withdrawal probability increases. As we get closer to maturity, depositors are getting greater liquidity shocks, but they also have to pay a significant higher monetary penalty. So many of them decide to wait and withdrawal probability falls.

Figure A.3 shows how the change in long-term fundamentals explained in Section II.C will map to the non-monotonic payoff of early withdrawal case. We are able to separate between total, direct and indirect effects in the same way we did in the previous section. Key difference is that now we allow depositors to face a time-varying trade-off between the cost of early withdrawal and the expected value of deposit at maturity.

Figure A.2: Percentage of Withdrawals (Quiet Times, Non-Monotonic Payoffs)

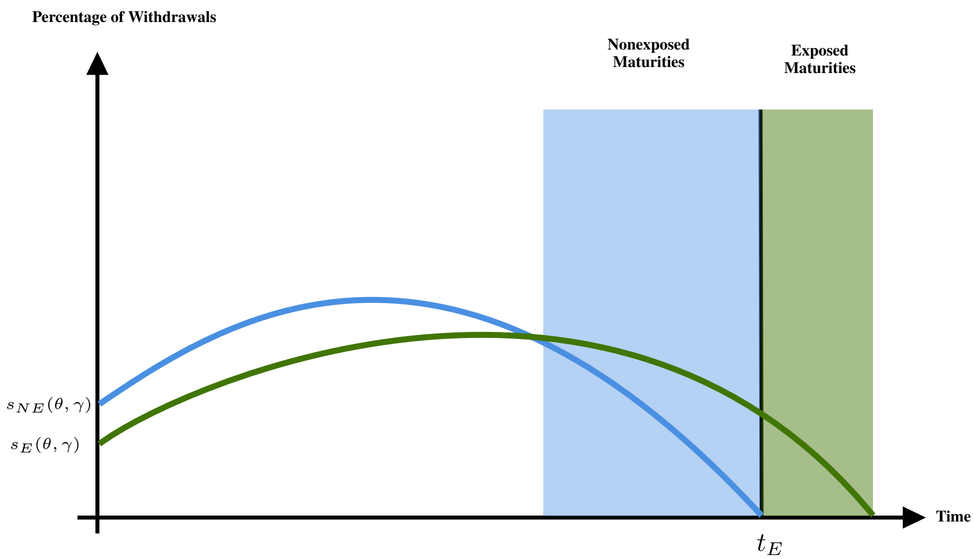
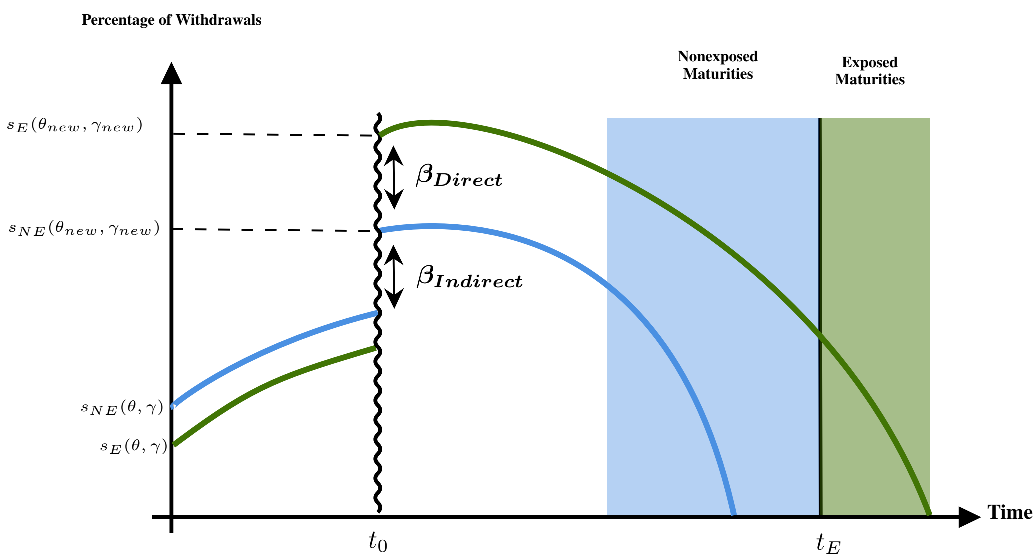


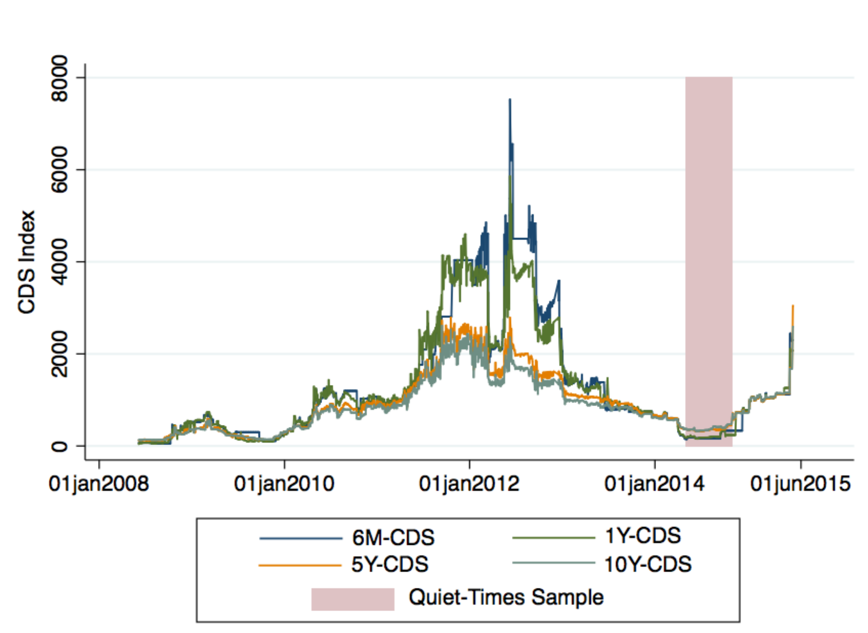
Figure A.3: Changes in Fundamentals (Non-Monotonic Payoffs)



Appendix B Greek CDS Index and Sovereign Bonds Spreads

Figure B.1: Greek CDS Index and 10-Year Bond Spread

Panel A: Greek CDS for Different Maturities (2010-2015)



Panel B: Greek Bond Spread with respect to German Bond (2010-2015)

Note: Panel A plots the Credit Default Swap Index for Greece, normalized to 100 for June 2008. The shaded area represents the sample period between March and November 2014. Panel B shows the 10-year Greek bond spread relative to the German 10-year bond.

Appendix C No Changes in Idiosyncratic Risk

Identification of our estimates for strategic complementarities assumes that there are no changes in liquidity-based, idiosyncratic withdrawals during the three weeks following the surprise announcement on December 8, 2014 (t_1). We now evaluate this assumption.

One potential concern is unemployment. If major layoffs took place immediately after the announcement, deposit withdrawals might be driven by liquidity reasons differing from those in quiet times. Unemployment rates remain stable during December 2014 and January 2015. Magnitudes were similar to those in previous months (accounting for seasonality).[35] Moreover, we find no correlation between changes in regional unemployment figures and changes in deposit withdrawals during this period.

Another concern, given the age of a large fraction of our depositors, is that after the announcement there was a change in payment of pensions. We found no evidence of pension amounts changing during our period or delays taking place after the announcement. There were also no changes in number of patient visits and hospitalizations during our sample period.

We have checked the interest rates offered by our bank's competitors before and after the announcement, and they are all similar to those we observed in quiet times. Therefore, there seem to be no changes in competition in the time-deposit market during our period. Even in regions where competition across banks was stronger, it is irrelevant for our exercise as along as competing banks did not offer a return higher than 17%, which is the average forgone return for early withdrawals of time deposits in our bank.

Appendix D No Changes in Bank Fundamentals

Identification of our estimates for strategic complementarities assumes that there are no changes in bank fundamentals during the three weeks following the surprise announcement on December 8, 2014 (t_1). We now evaluate this assumption.

Subsection IV.A Liquidity Measures

The bank tracks short-term liquidity through an index, the Liquidity Assets Ratio (LAR), defined as:

$$Liquidity\ Assets\ Ratio\ = \frac{Liquid\ Assets\ of\ \ up\ to\ 30\ days\ maturity}{Short\ \ term\ \ borrowing} \tag{B1}$$

where $Liquid\ Assets$ include cash, interbank placements with maturity up to 30 days, compulsory reserve requirements to Bank of Greece, unencumbered high quality liquid assets, excess collateral pledged to ECB, inflows from installment loans within 30 days and other assets with maturity up to 30 days; and $ShortTermBorrowing$ considers interbank deposits with maturity up to one year, time deposits with maturity up to one year, wholesale funding with maturity up to one year, and 80% of saving and current accounts.

The LAR index needs to be higher than 20% for our bank to be considered liquid. We have confirmed with our bank that the ratio was above the minimum threshold during the period for which we perform our analysis in Section IV. At that time, time deposits accounted for more than 15% of our bank's total liquidity.

Our bank also monitored another liquidity index, the Maturity Mismatch Ratio (MMR), given by:

35. See Eurostat Database for detailed figures at the NUTS 2 level, available at https://ec.europa.eu/eurostat/data/database

$$Maturity\,Mismatch\,Ratio\;=\;\frac{Assets-\;\;Liabilities\;\;of\;\;up\;\;to\;\;30\;\;days\;\;maturity}{Short\;\;term\;\;borrowing} \tag{B2}$$

This index needs to be higher than 20%. It was the case that during the three weeks following t_1 the index was significantly above this threshold and there were no significant changes in its values.

Both indexes deteriorated soon after the January elections, and this trend intensified in early 2015.

Subsection IV.B Funding Costs

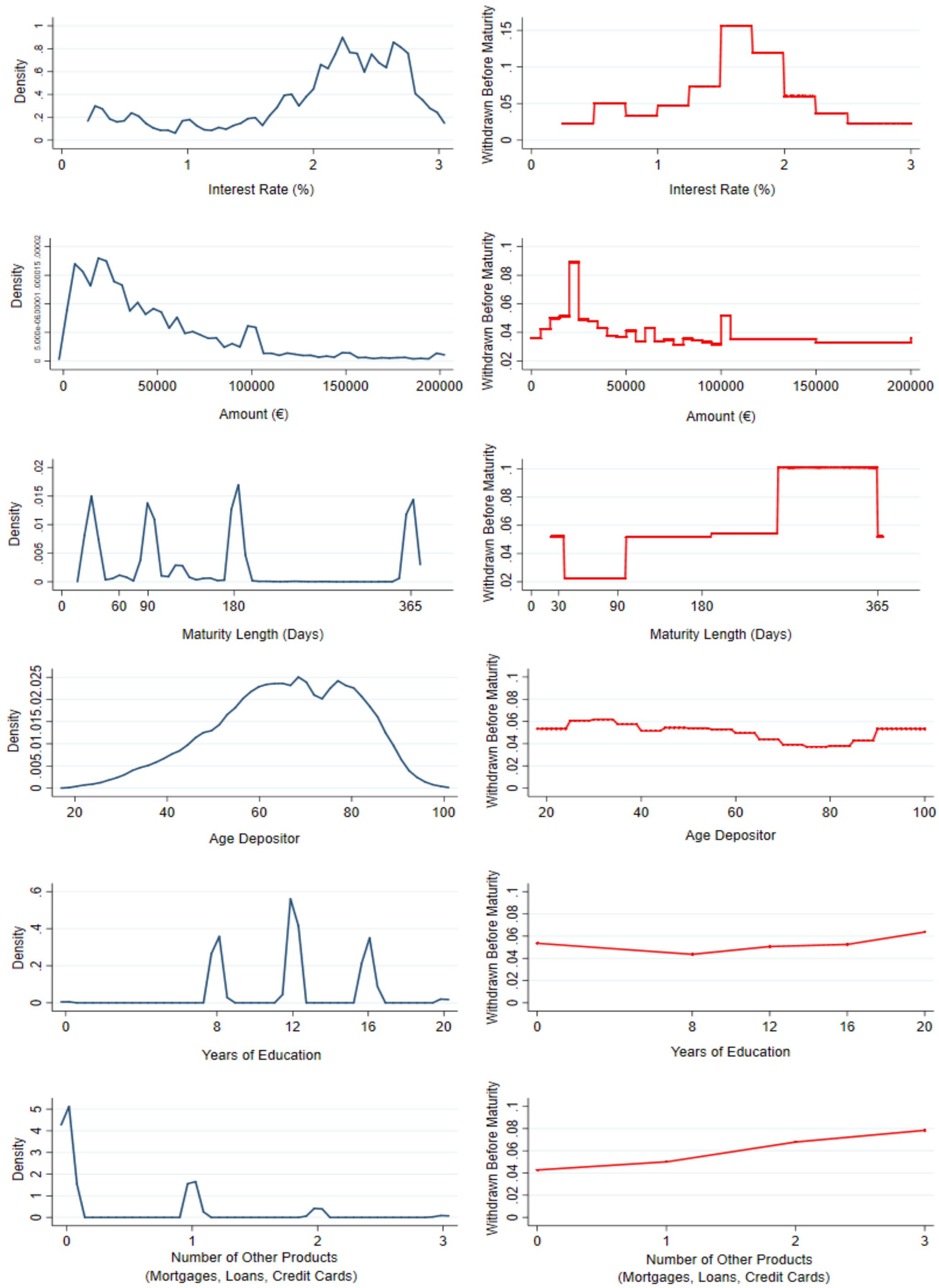
Despite the deposit outflow after the surprise announcement, our bank did not face any funding problems in the three weeks following t_1. Our bank was able to borrow from the ECB at similar rates in the weeks following the announcement (but before the election). Moreover, there were no changes on the interest rates on both time and demand deposits during this period. Finally, there was a slight decline on the value of our bank's collateral during this period. However, we confirmed with our bank that this fall did not pose a threat to the banks solvency.

Subsection IV.C Loan Repayment

We also checked that there were no changes in repayment behavior of our bank's customers in the six weeks after the surprise announcement in December 2014. To do so, we have information on the entire August 2014 loan portfolio. We observe payment delinquencies for all corporate and household loans. Every month between August 2014 and February 2015, over 80% of all personal loans and mortgages had no delays in their monthly payments. The fraction of corporate loans during these months also remained stable and high.

Appendix E Heterogeneity Across Deposit Withdrawals

Figure D.1: Distribution of Depositor Characteristics and Withdrawal Behavior (During Quiet Times)



Notes: Figures use daily data for all time deposits from a large Greek bank between January and November 2014. Figures on the left plot density distributions of characteristics for time deposits (interest rates, deposit amount, maturity length) and depositors (age, education, other products with the bank). Figures on the right plot the fraction of time deposits withdrawn before maturity across time deposit and depositor characteristics. We calculate the fraction of withdrawals before maturity by dividing the number of time deposits withdrawn prior to their maturity dates over the total number of deposits originated over this period (Jan-Nov 2014).

Table D.1: Heterogeneity Analysis for Fundamental-Related Withdrawals (Depositor and Account Characteristics)

Withdrawal (0/1)	Female	Male	Balance <35,000	Balance >35,000	Currency Euros	Foreign Currency
DDD	0.0136***	0.0119***	0.0106**	0.0148***	0.0129***	0.0106
	(0.0043)	(0.0042)	(0.0044)	(0.0042)	(0.0033)	(0.0065)
Uncertainty	0.001	0.004**	0.001	0.005**	0.003**	-0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
Exposed	-0.002	-0.001	0.001	-0.004***	-0.002*	0.002
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)
Post	-0.004***	-0.002	-0.003*	-0.003**	-0.003***	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Uncertainty × Post	-0.0017	-0.0046**	-0.0021	-0.0043**	-0.00368**	0.000552
	(0.0021)	(0.0021)	(0.0021)	(0.0021)	(0.0016)	(0.0030)
Uncertainty × Exposed	0.0033	0.0018	0.0014	0.0034	0.0032	-0.0030
	(0.0027)	(0.0026)	(0.0028)	(0.0025)	(0.0020)	(0.0037)
Exposed × Post	0.0107***	0.0101***	0.0091***	0.0116***	0.0112***	0.0035
	(0.0023)	(0.0023)	(0.0027)	(0.0020)	(0.0018)	(0.0045)
Depositor Characteristics	Yes	Yes		Yes	Yes	Yes
Yes						
Account Characteristics	Yes	Yes		Yes	Yes	Yes
Yes						
Observations	>20,000	>30,000	>25,000	>25,000	>45,000	>5,000
Baseline Prob. of Running	0.71	0.62	0.72	0.61	0.69	0.39
Baseline Cost of Running (% TD)	1.32	1.31	1.17	1.44 1.40	0.58	

Note: The table estimates Equation 3 separately across subsamples for heterogeneous depositor and account characteristics. Columns (1) and (2) differentiate by gender. Columns (3) and (4) split the sample by deposit amount (below and above €35K). Columns (5) and (6) separate the sample by accounts denominated in euros and those in foreign currencies. Robust standard errors are in parentheses (with *** p<0.01, ** p<0.05, * p<0.1). We need to mask observations to keep the identity of The Bank confidential.

Table D.2: Heterogeneity Analysis for Fundamental-Related Withdrawals (Depositor-Bank Relationship)

Withdrawal (0/1)	No Other Products	Other Products	Less than 2 years	More than 2 years	3 Renewals or Less	More than 3 Renewals
DDD	0.0068**	0.0283***	0.0197***	0.0044	0.0161***	0.0093**
	(0.0032)	(0.0070)	(0.0045)	(0.0038)	(0.0046)	(0.0039)
Uncertainty	0.001	0.008***	0.005***	0.000	0.004**	0.001
	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Exposed	-0.002	-0.002	0.002	-0.006***	0.001	-0.005***
	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Post	-0.002**	-0.004**	-0.002	-0.004***	-0.001	-0.004***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Uncertainty × Post	-0.0025	-0.0053	-0.0052**	-0.0009	-0.0056**	-0.0008
	(0.0016)	(0.0035)	(0.0021)	(0.0021)	(0.0022)	(0.0020)
Uncertainty × Exposed	0.0036*	-0.0004	0.0008	0.0049**	0.0011	0.0041*
	(0.0020)	(0.0042)	(0.0028)	(0.0023)	(0.0029)	(0.0024)
Post × Exposed	0.0093***	0.0134***	0.0090***	0.0122***	0.0097***	0.0111***
	(0.0019)	(0.0035)	(0.0024)	(0.0022)	(0.0025)	(0.0021)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>40,000	>10,000	>30,000	>20,000	>20,000	>30,000
Baseline Withdrawals	0.59	0.87	0.64	0.70	0.65	0.68
Baseline Cost of Withdrawing (% TD)	1.32	1.30	1.17	1.52	1.39	1.23

Note: This table estimates Equation 3 separately across subsamples for depositor-bank relationship. Columns (1) and (2) consider depositors with and without other products with the bank. Columns (3) and (4) split between depositors that have been less than two years and those that have been a customer for a longer period. Columns (5) and (6) separate depositors depending on whether they have renewed at least three times their deposit. Robust standard errors are in parentheses (with *** $p<0.01$, ** $p<0.05$, * $p<0.1$). We need to mask observations to keep the identity of The Bank confidential.

Table D.3: Heterogeneity Analysis for Withdrawals Due to Strategic Complementarities

PANEL A: Depositor and Account Characteristics

Withdrawal (0/1)	Female	Male	Balance <35,000	Balance >35,000	Currency Euros	Foreign Currency
DiD	-0.0000	0.0051**	-0.0000	0.0053***	0.0034**	-0.0037
	(0.0022)	(0.0020)	(0.0022)	(0.0019)	(0.0016)	(0.0035)
Uncertainty	0.002	-0.001	0.001	-0.001	0.000	0.002
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)
Post	0.0036***	0.0019	0.0014	0.0037***	0.0028***	0.0008
	(0.0013)	(0.0012)	(0.0015)	(0.0011)	(0.0010)	(0.0024)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>15,000	>15,000	>15,000	>15,000	>35,000	>5,000
Baseline Withdrawals	0.36	0.44	0.59	0.24	0.41	0.31
Baseline Cost of Withdrawing (% TD)	1.32	1.31	1.17	1.44	1.40	0.57

PANEL B: Depositor-Bank Relationship

Withdrawal (0/1)	No Other Products	Other Products	Less than 2 years	More than 2 years	3 Renewals or Less	More than 3 Renewals
DiD	0.0016	0.0059*	0.0046**	0.0002	0.0044**	0.0008
	(0.0016)	(0.0034)	(0.0021)	(0.0020)	(0.0022)	(0.0019)
Uncertainty	0.000	0.001	0.000	0.001	0.000	0.001
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Post	0.0023**	0.0037*	0.0011	0.0047***	0.0011	0.0044***
	(0.0010)	(0.0020)	(0.0013)	(0.0013)	(0.0013)	(0.0012)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>20,000	>10,000	>15,000	>15,000	>15,000	>15,000
Baseline Withdrawals	0.19	0.95	0.53	0.23	0.54	0.24
Baseline Cost of Withdrawing (% TD)	1.32	1.30	1.17	1.51	1.39	1.23

Note: Panel A estimates Equation 4 separately across subsamples for heterogeneous depositor and account characteristics. Columns (1) and (2) differentiate by gender. Columns (3) and (4) split the sample by deposit amount (below and above €35K). Columns (5) and (6) separate the sample by accounts denominated in euros and those in foreign currencies. Panel B estimates Equation 4 separately across subsamples for depositor-bank relationship. Columns (1) and (2) consider depositors with and without other products with the bank. Columns (3) and (4) split between depositors that have been less than two years and those that have been a customer for a longer period. Columns (5) and (6) separate depositors depending on whether they have renewed at least three times their deposit. Robust standard errors are in parentheses (with *** $p<0.01$, ** $p<0.05$, * $p<0.1$). We need to mask observations in Panels A and B to keep the identity of our bank confidential.

Table D.4: Heterogeneity Analysis for Withdrawals Due to Idiosyncratic Reasons

PANEL A: Depositor and Account Characteristics

Withdrawal (0/1)	Female	Male	Balance <35,000	Balance >35,000	Currency Euros	Foreign Currency
Interest Pay	0.000	-0.000	-0.001	0.000	0.000	-0.000
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)
Post	-0.002	-0.001	-0.005**	0.001	-0.001	-0.006*
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)
DiD	0.0082***	0.0093***	0.0105***	0.0073***	0.0091***	0.0066
	(0.0024)	(0.0024)	(0.0030)	(0.0019)	(0.0019)	(0.0047)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>15,000	>15,000	>15,000	>15,000	>27,000	>3,000
Baseline Withdrawals	0.56	0.58	1.00	0.18	0.55	0.69
Baseline Cost of Withdrawing (% TD)	1.32	1.29	1.18	1.42	1.39	0.59

PANEL B: Depositor-Bank Relationship

Withdrawal (0/1)	No Other Products	Other Products	Less than 2 years	More than 2 years	3 Renewals or Less	More than 3 Renewals
Interest Pay	0.001	-0.002	0.001	-0.002	0.001	-0.002
	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Post	-0.0003	-0.0051**	-0.0028*	0.0000	-0.0025	-0.0005
	(0.00115)	(0.00241)	(0.0016)	(0.0013)	(0.0016)	(0.0013)
DiD	0.0067***	0.0144***	0.0092***	0.0083***	0.0103***	0.0070***
	(0.0019)	(0.0038)	(0.0026)	(0.0021)	(0.0027)	(0.0021)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>25,000	>5,000	>20,000	>20,000	>15,000	>15,000
Baseline Withdrawals	0.42	0.94	0.78	0.28	0.75	0.34
Baseline Cost of Withdrawing (% TD)	1.29	1.35	1.25	1.39	1.42	1.17

Note: Panel A estimates Equation 5 separately across subsamples for heterogeneous depositor and account characteristics. Columns (1) and (2) differentiate by gender. Columns (3) and (4) split the sample by deposit amount (below and above €35K). Columns (5) and (6) separate the sample by accounts denominated in euros and those in foreign currencies. Panel B estimates Equation 5 separately across subsamples for depositor-bank relationship. Columns (1) and (2) consider depositors with and without other products with the bank. Columns (3) and (4) split between depositors that have been less than two years and those that have been a customer for a longer period. Columns (5) and (6) separate depositors depending on whether they have renewed at least three times their deposit. Robust standard errors are in parentheses (with *** $p<0.01$, ** $p<0.05$, * $p<0.1$). We need to mask observations in Panels A and B to keep the identity of our bank confidential.

Table D.5: Heterogeneity Analysis Across Regions

Withdrawals(0/1)	(Strategic) City of Athens	(Strategic) Not Athens	(Idiosyncratic) City of Athens	(Idiosyncratic) Not Athens	(Fundamentals) City of Athens	(Fundamentals) Not Athens
Uncertainty (or Interest Pay)	0.003	-0.001	0.004*	-0.001	-0.001	0.004**
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Post	0.005***	0.002*	0.001	-0.003**	-0.004*	-0.001
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Uncertainty × Post	-0.0014	0.0048***	0.0060*	0.0101***	0.0022	0.0035
(DD)	(0.0027)	(0.0017)	(0.0032)	(0.0021)	(0.0034)	(0.0023)
Exposed					-0.0029	-0.0029***
					(0.0019)	(0.0010)
Uncertainty × Exposed					-0.0035	-0.0030*
					(0.0027)	(0.0018)
Exposed × Post					0.0104***	0.0105***
					(0.0033)	(0.0019)
DDD					0.0175***	0.0107***
					(0.0056)	(0.0036)
Depositor characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>10,000	>20,000	>10,000	>20,000	>15,000	>30,000
Baseline Withdrawals	0.38	0.40	0.29	0.70	0.66	0.67
Baseline Cost of Withdrawing (% TD)	1.22	1.37	1.30	1.32	1.35	1.31

Note: This table estimates our main specifications separately for depositors in Athens and in the rest of the country. Columns (1) and (2) report estimates for strategic complementarities in Equation 4. Columns (3) and (4) show estimates for idiosyncratic related withdrawals in Equation 5. Columns (5) and (6) present estimates for fundamentals in Equation 3. Robust standard errors are in parentheses (with *** $p<0.01$, ** $p<0.05$, * $p<0.1$). We need to mask observations to keep the identity of our bank confidential.

Table D.6: Heterogeneity Analysis for Small and Large Branches

Withdrawal (0/1)	(Strategic) Small Branches	(Strategic) Large Branches	(Idiosyncratic) Small Branches	(Idiosyncratic) Large Branches	(Fundamentals) Small Branches	(Fundamentals) Large Branches
Uncertainty (or Interest Pay)	0.003	-0.000	-0.002	0.000	-0.000	0.003**
	(0.003)	(0.001)	(0.003)	(0.001)	(0.003)	(0.001)
Post	-0.001	-0.002	0.001	0.003***	-0.001	-0.002
	(0.002)	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)
Uncertainty × Post	-0.0021	0.0037**	0.0091***	0.0060*	0.0031	0.0022
(DD)	(0.0036)	(0.0016)	(0.0046)	(0.0019)	(0.0043)	(0.0021)
Exposed					-0.0020	-0.0030***
					(0.0022)	(0.0010)
Uncertainty × Exposed					-0.0017	-0.0036**
					(0.0033)	(0.0017)
Exposed × Post					0.0071*	0.0112***
					(0.0039)	(0.0018)
DDD					0.0137**	0.0125***
					(0.0070)	(0.0034)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>7,000	>23,000	>7,000	>23,000	>10,000	>40,000
Baseline Withdrawals	0.49	0.38	0.70	0.53	0.66	0.67
Baseline Cost of Withdrawing Running (% TD)	1.35	1.31	1.34	1.30	1.35	1.31

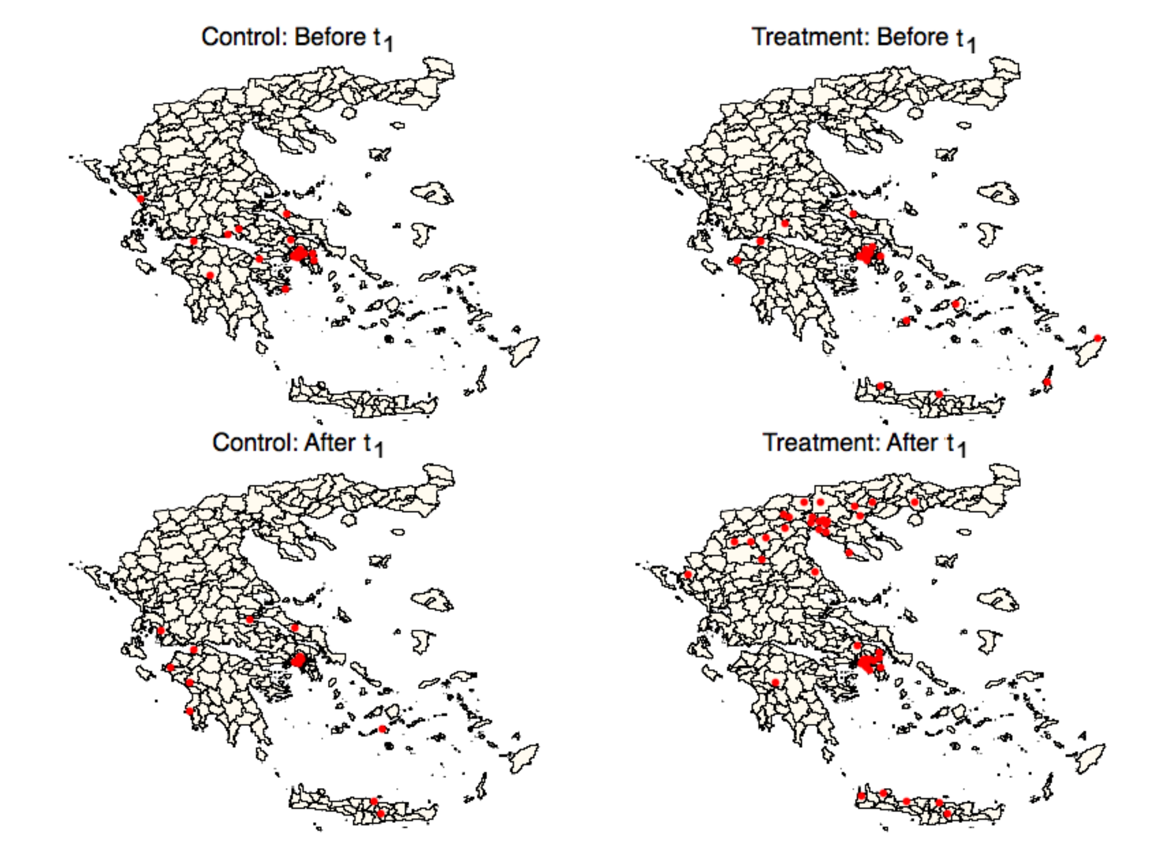
Note: This table estimates our main specifications separately for depositors in small and large branches. Columns (1) and (2) report estimates for strategic complementarities in Equation 4. Columns (3) and (4) show estimates for idiosyncratic related withdrawals in Equation 5. Columns (5) and (6) present estimates for fundamentals in Equation 3. Branch size is defined as those below and above the median in their number of time deposit accounts. Small branches are those with 200 or less daily time deposit accounts on average, and large branches are those with more than 200 daily time deposit accounts on average. Robust standard errors are in parentheses (with *** p<0.01, ** p<0.05, * p<0.1). We need to mask observations to keep the identity of our bank confidential.

Table D.7: Heterogeneity Analysis on Political Views

Withdrawal (0/1)	(Strategic) Against Grexit (<50%)	(Strategic) Pro-Grexit (>50%)	(Idiosyncratic) Against Grexit (<50%)	(Idiosyncratic) Pro-Grexit (>50%)	(Fundamentals) Against Grexit (<50%)	(Fundamentals) Pro-Grexit (>50%)
Uncertainty (or Interest Pay)	0.002	-0.000	-0.001	0.000	0.002	0.003*
	(0.002)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)
Post	0.002*	0.003**	-0.004**	-0.000	0.000	-0.003**
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)
Uncertainty × Post	0.0019	0.0032*	0.0094***	0.0086***	0.0028	0.0022
(DD)	(0.0024)	(0.0018)	(0.0029)	(0.0022)	(0.0032)	(0.0023)
Exposed					-0.0028**	-0.0028**
					(0.0014)	(0.0012)
Uncertainty × Exposed					-0.0041*	-0.0028
					(0.0023)	(0.0019)
Exposed × Post					0.0090***	0.0113***
					(0.0026)	(0.0021)
DDD					0.0167***	0.0103***
					(0.0051)	(0.0038)
Depositor Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Account Characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Observations	>10,000	>20,000	>10,000	>20,000	>15,000	>35,000
Baseline Withdrawals	0.32	0.45	0.75	0.46	0.55	0.73
Baseline Cost of Withdrawing (% TD)	1.34	1.31	1.32	1.30	1.34	1.30

Note: This table estimates our main specifications separately for depositors in areas according to their political views. Columns (1) and (2) report estimates for strategic complementarities in Equation 4. Columns (3) and (4) show estimates for idiosyncratic related withdrawals in Equation 5. Columns (5) and (6) present estimates for fundamentals in Equation 3. Odd (even) columns consider areas with a majority of voters against (in favor) Grexit. Robust standard errors are in parentheses (with *** $p<0.01$, ** $p<0.05$, * $p<0.1$). We need to mask observations to keep the identity of our bank confidential.

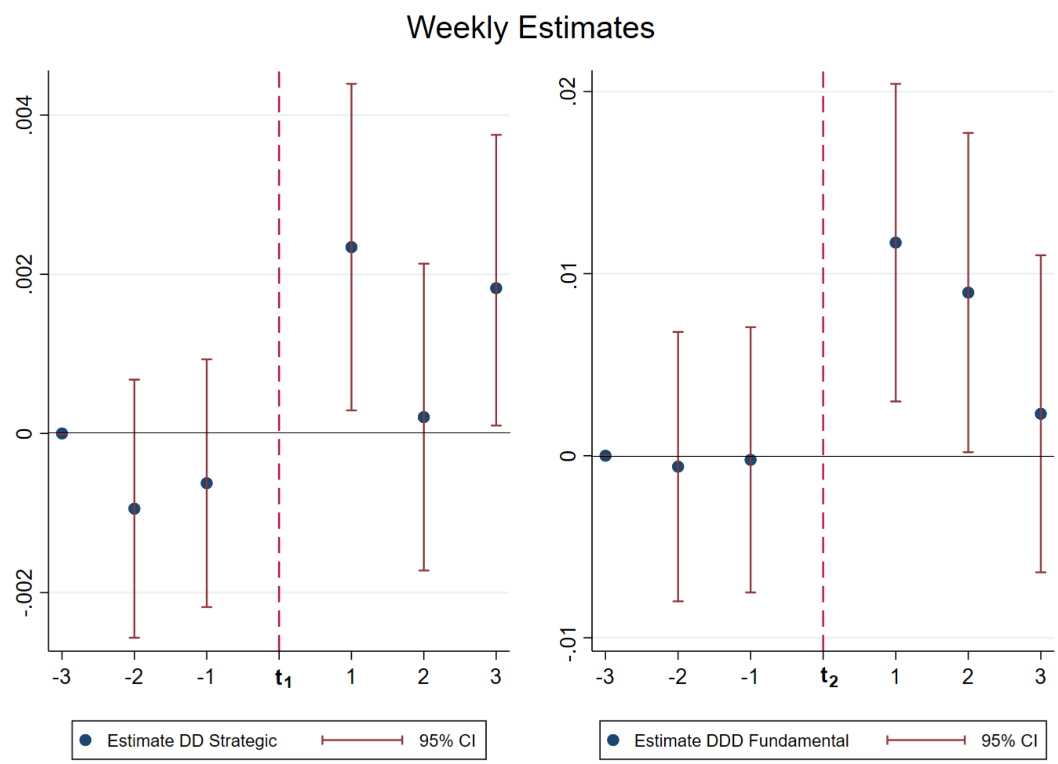
Figure D.2: Spatial Autocorrelation in Deposit Withdrawals across Branches



Note: The graphs plot spatial autocorrelation of deposit withdrawals across different areas of Greece. The red dots correspond to branches with deposit withdrawals exhibiting positive spatial autocorrelation with nearby branches, as measured by local Moran's I_i. This is a measure of the correlation of a variable with itself through space (in this case, withdrawal behavior in one branch relative to nearby branches). Positive spatial autocorrelation occurs when similar values occur near one another. The two maps to the left correspond to the control period with no news shock. The two maps to the right belong to the treatment period with the news shock at t_1. The two top maps represent the period before the announcement at t_1, while the two maps at the bottom correspond to the period after the surprise news at t_1. Unreported, after t_2 there is no differential spatial correlation across regions.

Appendix F Weekly Dynamics

Figure F.1: Weekly Estimates for Strategic and Fundamental-Related Withdrawals



Note: The left panel plots differences-in-differences coefficients for strategic withdrawals for weeks before and after the announcement at t_1. Same specification as in Panel B of Table 4, but estimating weekly DD coefficients. The right panel shows triple differences coefficients for fundamental-related withdrawals for weeks before and after the announcement at t_2. Same specification as in Table 3, but estimating weekly DDD coefficients. The whiskers represent 95% confidence intervals for each coefficient estimate.

Appendix G Extrapolation to Our Bank and the Greek Banking System

We evaluate whether our estimates can explain the overall decline of deposits at our bank and at the Greek banking sector during the time period. The combined increase in CDS prices between t_0 and t_1 (6-weeks) was 219%. Our estimates predict that during the same period there should be: 1) 1.68% of depositors withdrawing because of idiosyncratic reasons (0.04% daily $\times$ 42 days); 2) 1.14% of depositors withdrawing because of strategic complementarities (baseline of 1.68% withdrawals $\times$ 68% estimate); 3) 3.23% of depositors withdrawing because of fundamentals (baseline of 1.68% withdrawals $\times$ 192% estimate); and 4) 1.68% of depositors withdrawing because of interest payments on January 1st (using the elasticity, a lower cost of 0.83% leads to a 100% higher probability of withdrawal w.r.t the baseline of 1.68%).

Our estimates predict that an increase in CDS of 219% resulting in both strategic and fundamental uncertainty will lead 7.73% of depositors to withdraw their time-deposits. in the data, we observe that total time-deposits at our bank dropped by 8%, and total time-deposits in the Greek banking sector declined by 10%. Thus, the magnitude of our estimates of deposit-withdrawal sensitivities aligns well with the magnitude of the aggregate decline in deposits in Greece during the same time period.

Appendix H Extrapolation to Similar Episode in Italy

In this subsection we calibrate our estimates to changes in CDS prices taking place after events that indicated the (possible) exit of Italy from the Eurozone ('Italexit', 'Italeave', or—domestically—'Euroscita') in 2018. During this period there was an increase in aggregate policy uncertainty after an unexpected coalition to form government between two anti-Europe parties (populist Five Star Movement, the right-wing League). Prior to the March 2018 elections, both parties had antagonized each other and expressed no intention of cooperating when in government. Coalition negotiations between both parties became public in May, when a draft for a coalition agreement was leaked in the media.This draft reclaimed radical changes to the Stability and Growth Pact, along with €250 billion from the ECB. It also supported "the introduction of specific technical procedures for single states to leave the Eurozone and regain monetary sovereignty." These news increased policy uncertainty in the country.

When comparing the Italian episode to our analysis of the Greek elections, we can distinguish between two key events. The fist event took place on May 15, 2018, when the draft for a coalition agreement was leaked. The second event is the formation of a new government on May 29, 2018. The first event can be compared to our shock at t_0, since it created policy uncertainty for depositors with long-run maturity expiration, but not for short-run maturity deposits (since policies could not be implemented until after the appoint ment of government). Depositors with shorter maturity expiration only faced a change in their expectations on how other depositors will behave. The second event is comparable to our shock at t_1, when a new government is appointed and all depositors are exposed to policy uncertainty.

Over this 2-week period the CDS price on Italian sovereign bonds increased by 177% during this period of policy uncertainty. During that quarter, almost 4% of time deposits hold by households with maturities shorter than two years were withdrawn.[36] As in Greece, there were no bankruns, only a progressive leakage of depositors out of the system during that period. For an equivalent increase in CDS prices, our estimates predict that, in the month following the election, 5.31% of total time deposits with maturities shorter than one year will be withdrawn for an equivalent CDS change.

Appendix I Extrapolation to Other Bank Episodes

We end by evaluating how our estimates predict deposit withdrawals in recent episodes of bank runs.

The first is the bank run on Northern Rock in 2007. On September 14, 2007, Northern Rock sought and received a liquidity support facility from the Bank of England. The motive for such an emergency measure was the run on deposits of Northern Rock that took place Friday 14 and Monday 17 September, 2007. It all started in August 9, 2007, when interbank and other financial markets froze. Because of Northern Rock's funding model (requiring mortgage securitization), markets anticipated that there was a probability that the bank will run into trouble because of its next securitization being scheduled for September 2007. During August 10 and

36. See Bank of Italy's sectoral breakdown of MFI deposits as reported by the ECB

mid-September Northern Rock and the British government and regulators tried to find a solution to the liquidity crisis. The main three options under discussion were: 1) Northern Rock finding a solution to its liquidity crisis on its own by means of short-term money markets and securitization; 2) Northern Rock being taken over by another major retail bank; and 3) Northern Rock receiving a support liquidity facility from the Bank of England and guaranteed by the Government. [37]

After Northern Rock unexpectedly asked for liquidity to the Bank of England, its 5-year CDS price increased 180%. Northern Rock lost £10 billion of its £30 billion savings book (33% loss), with £4.4 billion in deposits withdrawn on September 14 (21% of total deposit amount).[38] Our model predicts that such an increase in the CDS will result in 11% of time depositors leaving the bank.[39]

We also consider deposit withdrawals during the bank-runs on Washington Mutual (WaMu). WaMu's first bank run took place on July 12, 2008, centered in Southern California after the federal government seized IndyMac following a $1.3 billion bank run. The second run started on September 11, 2008, when Moody's rated WaMu's financial strength at D+ and downgraded the company's debt rating to junk status. These news and Lehman Brothers' bankruptcy on September 15, 2008, sparked another bank run.

On September 26, 2008,Washington Mutual filed for bankruptcy. In the month prior to the first bank run, the 5-year CDS of WaMu increased by almost 100%. In September 16, 2008 (last day WaMu was traded on CDS markets), the CDS premium increased by more than 100%. Our estimates predict that such increases in CDS will result in 6% withdrawals of total deposits. During these episodes, WaMu depositors withdrew $16.7 billion out of their savings and checking accounts over the next 10 days after the bankruptcy announcement. These withdrawals accounted for 9% of WaMu's total deposits.

37. For details, see: https://publications.parliament.uk/pa/cm200708/cmselect/cmtreasy/56/5607.htm

38. See, e.g., Financial Times "Northern Rock fall sees outflow of savings," https://www.ft.com/content/2e3bc984-9a07-11dc-ad70-0000779fd2ac

39. One key difference between Greek and British deposits is the level of insurance. While Greek retail deposits are insured up to €100,000, the UK government only guarantees 100% of the first £2,000 and 90% of the next £33,000. That is, in the UK only £31,700 are insured per deposit.