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Independent central banks and banking crisis liquidity

Michael A. Gavin[1]

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Abstract
This study develops and tests a formal model that shows why central banks protected from direct government borrowing supply a larger financial safety net for commercial banks during a crisis. This result is derived from a novel model of central bank independence grounded in the rules governing access to the central bank's balance sheet, rather than in the politics of inflation. Subsequent analysis shows that this result is mediated by the degree of leverage in the banking system, but only in democracies where government borrowing restrictions are credible. Supporting quantitative evidence comes from an event study on a large sample of emerging market banking crises between 1980-2009.

Keywords Central bank independence · Political economy · Banking crises · Financial safety nets · Game theory · Event study

JEL classification C23 · C51 · C60 · E58 · G21

1 Introduction

In the decades following the breakdown of the Bretton Woods system, a consensus slowly emerged that financial crises had become more frequent, especially in the world's emerging market economies (Bordo et al. 2001; Calomiris and Haber 2014). At the same time a second consensus also emerged, that if the genie of financial globalization could not be put back in its bottle, then an independent central bank should lead the management of a banking crisis because they are best placed to reduce its ex-post costs (Wheately 2009; Larraín 2012). Yet the literature provides few clear answers on exactly which mechanism independence works through as

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✉ Michael A. Gavin
michael.gavin@mail.utoronto.ca

[1] Department of Political Science, The University of Toronto, Sidney Smith Hall, Room 3018, 100 St. George Street, Toronto, ON M5S 3G3, Canada

independent central banks are overwhelmingly viewed as inflation averse institutions of monetary restraint that alone can credibly commit to a conservative monetary policy. Such frameworks make for an awkward fit for studies on the politics of banking crisis management because it is not straightforward to derive expectations for central bank behavior during a crisis from an institutional bias in favor of monetary restraint during times of stability.

This study argues that a central bank's crisis management efforts are grounded in the political economy of financial safety nets, and central bank liquidity provision in particular. The argument is supported by a formal model and quantitative evidence that advance the literature in two ways. First, to the best of my knowledge, the paper builds the first formal model of central bank independence derived from the rules governing access to the lending resources of the central bank. Following Rogoff (1985), existing models have incorporated these rules only indirectly since the motivating politics in these studies is over a preferred rate of inflation. The model shows that the size of a central bank's financial safety net, which sets its crisis management capabilities, is determined in part by the politics over which institutions have borrowing privileges from the lender of last resort. The primary finding of the model is that when a government faces a binding restriction on borrowing from the central bank, the central bank attains independence and provisions a larger financial safety net for commercial banks during a crisis. Numerous political and distributional implications follow from this approach to the politics of central bank independence, all of which are found in the Online Supplementary Material. These include a lower *ex-ante* probability of a banking crisis, an unambiguously higher expected welfare for commercial banks, and an uncertain effect on the welfare for households.

The model is supported by an event study on a large sample of emerging market banking crises between 1980-2009. Results show that a statutory limit on the amount a government can borrow directly from its central bank leads to higher central bank liquidity support to their banking system during a crisis. However, as also predicted by the model, in democratic states this result is mediated by the degree of leverage in the banking system. This result does not hold in non-democracies where institutions may be weak and government borrowing restrictions may not be credible. A placebo analysis also indicates that the expansionary effect of government borrowing restrictions holds only during banking crises and not during times of stability. The quantitative findings are robust to the inclusion of many control variables, alternative event study windows, and numerous alternative econometric specifications that address concerns over endogeneity, dynamics, and omitted variable bias.

The results of this study offer new insights into the domestic sources of financial stability in emerging market economies. In particular, by showing that central banks which are shielded from potential direct government borrowing supply greater liquidity to their banking system in a crisis, this study supports the notion that emerging market economies which have made such reforms are not as vulnerable to the whims of international capital markets as implied by many recent studies (Fratzscher 2012; Forbes and Warnock 2012; Bruno and Shin 2014; Rey 2015; Bauerle D. et al. 2017). The reason is because such reforms equip emerging market economies with a greater capacity to not only manage banking crises but also the negative spillovers from international financial markets more generally (Alessandri and Haldane 2009). While

such reforms are only one tool available to states in a world of global finance and cannot ensure perpetual domestic financial stability on their own, this study contends that the existence of more robust financial safety nets, and not an enduring credible commitment to monetary restraint, may explain, in part, the relative resilience of financial systems in emerging market economies in the post-global financial crisis era.

2 Government access to central bank lending

To a survival-minded government financing public spending with loans directly from their central bank is tempting (Nordhaus 1975; Maxfield 1994; Akyüz and Boratav 2003). While such a strategy can distribute benefits to favored constituencies, it generally sacrifices short-term price stability. If policymakers nonetheless maintain a preference for long-term price stability, monetary policy is said to suffer from a time-inconsistency problem because policymakers have dynamically inconsistent preferences over the rate of inflation (Barro and Gordon 1983; Cukierman 1992; Maxfield 1998; Bodea and Hicks 2015b). Solving the time-inconsistency problem typically requires that policymakers send a costly signal to financial markets that their commitment to a restrained monetary policy is credible. Although a fixed exchange rate can send such a signal, the desire to maintain an independent monetary policy has led policymakers to favor the signal embedded in the delegation of monetary policy to an independent central bank (Fischer 1995).

The origins of independent central banks have been well studied.[1] While studies vary in their details, they share a common view that central banks are powerful institutions and the ends to which a central bank should be put are politically contestable. In one way or another, competing preferences over a preferred rate of inflation feature in nearly all accounts of central bank independence, although there are numerous interpretations of how these preferences feed into the political process. A preference for inflation aversion has been argued to emerge from the preferences of the financial sector (Posen 1995), domestic party politics (Bernhard 1998; Bernhard et al. 2002; Crowe 2008), competition for international capital (Maxfield 1998; Bodea and Hicks 2015a), a cultural logic of appropriateness (McNamara 2002), or from having a career background in finance (Adolph 2013). However, there is a widespread consensus that a preference for a conservative monetary policy is insufficient on its own for an independent central bank to achieve its preferred inflationary outcome. Numerous studies argue that an independent central bank needs to operate in an institutional context that reinforces the credibility of that independence if it is to achieve its policy goals (Franzese 1999; Keefer and Stasavage 2003; Bodea and Hicks 2015b).

Conservative monetary policy preferences have been used to explain an apparent preference for relative monetary restraint during banking crises. Rosas (2006, 2009) argues that democratic states and those with independent central banks have a lower propensity for supplying generous liquidity provision during a banking crisis. However, the generalizability of these findings is questionable because crises are unique periods where day-to-day policy preferences need not apply (Posen 1995). For

[1] See Fernández-Albertos (2015) for a recent literature review on the politics of central bank independence.

example, Lohmann (1992) argues theoretically that an independent central bank may abandon its conservative stance and overreact to negative shocks in order to avoid having their independence re-appropriated by political authorities. Klomp and de Haan (2009) find supporting evidence for this view as independent central banks are found to enhance financial stability by acting more quickly and decisively during the early stages of a crisis when stabilizing intervention is politically unpopular (Thirkell-White 2009). However, the mechanism that brings about this superior result is unclear as a greater willingness to support commercial banks has also long been argued to be destabilizing as it induces greater moral hazard (Solow and Laffargue 1982).

The ambiguity of inferring central bank crisis management behavior from inflation preferences, which are salient during times of relative financial stability, leads this study to focus on the rules governing access to the central bank's balance sheet. The politics over these rules, and in particular the politics over the imposition of restrictions on direct government borrowing from the central bank, are salient in many studies on central bank independence where public deficit monetization has been identified as the culprit of high inflation (Öniş and Rubin 2003; Maman and Rosenhek 2007; Taylor 2009). The question motivating this paper is whether and how central bank financial safety nets for commercial banks change when a government can no longer borrow directly from its central bank.[2]

2.1 A model of the politics of financial safety nets

The model below is an extension of previous work by Repullo (2005). The motivation for the model developed by Repullo (2005) is to study how bank risk taking changes in response to central bank financial safety nets and various regulatory policies. The model developed here extends this previous work in numerous ways in order to study the politics structuring central bank financial safety nets. The two most pertinent changes include the addition of a government responsive to the welfare of households and the introduction of a new means to model the effects of central bank independence. These extensions allow the model to not only study how independence alters the central bank's commitment to provisioning a financial safety net for commercial banks, but also the effect independence has on the probability of a banking crisis and the expected welfare of commercial banks and households.[3]

The model is a full information three period sequential game consisting of interactions between three risk-neutral agents: a commercial bank, and two institutions that support national welfare. The first institution is a central bank that acts as a lender of last resort by lending newly printed money to commercial banks in crisis. The second is a government which, as the fiscal authority, makes transfers to households. Although households also appear in the model, they do not behave strategically as their welfare comprises the objective of the government. An outline of the timing of the game is shown in Fig. 1.

[2] Anecdotal evidence found in Drechsler et al. (2016) and Crosignani et al. (2017) show that restrictions on lending to Eurozone sovereigns may have indirectly and unwittingly led the European Central Bank to expand its liquidity support to Eurozone banks.

[3] These three implications are found in the Online Supplementary Material.

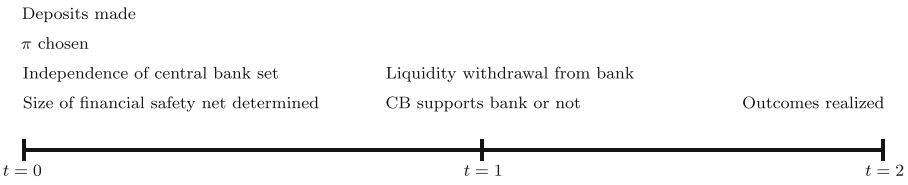

Fig. 1 Game timing

In period 0 the bank collects a unit of deposits from households. A random fraction w of these are retail deposits that can be withdrawn on demand and the remaining $1 - w$ comprise long-term debt contracts that mature at the end of period 2. The interest rate on retail deposits is normalized to zero and debt contracts pay interest rate r. The more the bank relies on long-term debt to fund its investment, the greater the bank's leverage and the greater prospect for household losses should the bank fail.

In period 0 the bank invests the full amount of its deposits in a risky project.[4] A successful investment returns R while a failed investment returns zero and sparks a banking crisis. The bank chooses the level of investment risk, π, where the investment succeeds with probability π and fails with probability $1-\pi$. Once invested, each unit of the risky investment can be liquidated in period 1 at a cost λ per unit. In period 2 the investment is sunk and has a liquidation value of 0. As in Repullo (2005), the following simplifying assumption is made about the behavior of investment returns.

Assumption 1 $R = R(\pi)$, where R(π) is decreasing and concave, with $R(1) \geq w + r(1 - w)$ and $R(1) + R'(1) < 0$.

Assumption 1 implies that safer investments yield a lower expected return but that even the safest investment still yields a positive profit for the bank. However, the condition $R(1)+R'(1) < 0$ ensures that choosing the safest investment is not optimal for the commercial bank as its expected profit is maximized at $\hat{\pi}$ when $R(\hat{\pi}) + \hat{\pi} R'(\hat{\pi}) = 0$. Collectively these assumptions on R ensure that the bank's expected profit is maximized when $\hat{\pi} \in (0, 1)$ and that for a given level of equilibrium bank risk, π^*, the bank's expected profit is decreasing in π when $\pi^* > \hat{\pi}$ and increasing in π when $\pi^* < \hat{\pi}$.

In period 1, households withdraw a random fraction v of their retail deposits where $v \in (0, 1]$.[5] The total amount withdrawn is therefore wv which equals the liquidity shortfall of the bank. If the central bank does not support the liquidity shortfall of the commercial bank, the commercial bank is forced to liquidate wv of the risky asset and incur the cost $\lambda wv > 0$. This leaves the bank with $w - \lambda wv$ in retail

[4] Assuming the commercial bank holds no capital is without loss of generality. As shown in Repullo (2005), adding a capital requirement to the model reduces the central bank's liquidity provision threshold, but such an effect is independent of the variables studied here.

[5] In a seminal paper, Gorton (1988) shows that banking panics occur because households respond to exogenous events such as unexpected macroeconomic shocks rather than bank specific fundamentals. Thus, while banking panics are explainable non-random events, they may be considered random from the perspective of individual banks experiencing a liquidity withdrawal.

deposits but households still hold retail deposit claims of $w - wv$ on the bank. This liquidity shortfall, equal to the liquidation cost λwv, leads to a run on the bank by households. This causes the bank's failure in period 1. In order to avoid this fate, the bank seeks to borrow wv from the central bank, which charges an interest rate equal to the retail deposit rate (i.e., zero). When the bank borrows wv from the central bank and its investment is successful, its payoff equals $R(\pi)$, minus the repayment of its liability to depositors and the central bank. Therefore the bank's payoff equals $R(\pi) - 1 - r(1 - w)$ when the investment is successful. By limited liability, the bank receives a payoff of zero if it becomes insolvent, either because there was a bank run in period 1 or the investment fails in period 2. Therefore, in period 0 the bank chooses the level of investment risk, π, that maximizes its profit according to the following equation.

$$\pi[R(\pi) - 1 - r(1 - w)] + (1 - \pi)[0] \tag{1}$$

Differentiating (1) with respect to π, the bank chooses the level of investment risk in equilibrium that solves the following condition.

$$R(\pi^*) + \pi R'(\pi^*) = 1 + r(1 - w) \tag{2}$$

Recalling that the bank's expected profit is highest when its choice of π satisfies $R(\hat{\pi}) + \hat{\pi} R'(\hat{\pi}) = 0$, it follows that π^* is below the optimal $\hat{\pi}$ and that the bank assumes too much risk in equilibrium.

When no banking crisis occurs, household welfare is composed of their retail deposits and a return on their debt contracts, leaving households with a net payoff of $r(1 - w)$. When a banking crisis does occur, households keep their withdrawn deposit wv, but lose their remaining deposit of $1 - wv$. To ensure that households receive at least wv back, it is assumed that the liquidation of the investment is not so costly that wv cannot be recovered. That is, $(1 + \lambda)wv \leq 1$.[6] Households losses are offset by the consumption of central bank financed fiscal stimulus of $g(x)$, where x is the amount a government borrows from its central bank. While nothing in the model precludes the government from borrowing from the central bank and passing it on to the commercial bank, the financial history of emerging market economies suggests that direct government borrowing has primarily been used to fund transfer payments to households[7] (Calomiris and Haber 2014). Indeed, such transfers have typically been a major source of inflation in emerging market economies and explain why the rules on direct government borrowing comprise 50% of widely used central bank independence indices (Cukierman et al. 1992; Garriga 2016). When the bank

[6]This assumption is made without loss of generality and serves two functions in the model. First, it is necessary for a liquidity shortfall in period 1 to have a possibility of producing a banking crisis in period 1. Second, it simplifies the household's payoff when the central bank does not lend to the bank (i.e., the right hand side of the inequality that produces (3)).

[7]Moreover, all the results of the model continue to hold if the government incorporates commercial bank payoffs into its own utility function because commercial bank payoffs are independent of x.

fails households receive a net payoff of $wv - 1 + g(x)$ where $g(x)$ behaves according to the following assumption.

Assumption 2 $g(x) \geq 0$ if $x > 0$, with $g(x)$ increasing and concave in x and $g(0) = 0$.

Although the model assumes no upper limit on the nominal amount of stimulus a government can leverage from their central bank, the government incurs a cost, c, for every unit of the government's borrowing. This cost is interpreted generally and can include costs to the government's reputation, a higher rate of inflation, and losses to economic efficiency. Moreover, this cost is weighted by a state's level of democracy as democratic governments are assumed to be more sensitive to the long-term costs of central bank financed fiscal stimulus.[8] The total cost from direct government borrowing is therefore cxD. This condition implies that a government implementing a central bank financed fiscal stimulus will set its borrowing according to $g'(x) = cD$ in equilibrium.

The central bank's strategy is to devise a rule governing its willingness to support a liquidity constrained commercial bank. As the lender of last resort the central bank commits to unconditionally support the commercial bank, but only if their liquidity shortfall is below a critical threshold. As in Repullo (2005), this strategy emerges from the lending rule being set in period 0, prior to the realized value of the liquidity shortfall in period 1. If the realized liquidity shock faced by the commercial bank is below or equal to this threshold, the central bank supports the liquidity constrained commercial bank. Liquidity shortfalls above this threshold go unsupported by the central bank and the commercial bank fails.

The central bank devises its lending rule to maximize expected period 2 national welfare. This approach follows much of the central bank independence literature by grounding a central bank's objective in a weighted average of competing sources of national welfare.[9] National welfare is defined as the aggregated period 2 welfare of the bank and households. Given that the central bank can print currency at will, their own solvency is not a strategic consideration since a negative equity position can always be covered through inflationary government transfers (Buiter 2008). Having the capacity to print new money also implies that there is no upper limit on the amount of support it may offer the commercial bank. However, a strategy of unlimited support to the commercial bank will not be generally optimal. The reason is because although such support gives the commercial bank reassurance that it will avoid failing in a liquidity crisis and therefore have a better chance at capturing $R(\pi^*)$, this benefit is offset by a reduction in the probability that households will capture crisis-triggering transfers $g(x)$. Therefore, following the deposit withdrawal by households, the central bank's strategy is to lend wv to the commercial bank if the expected aggregate welfare from doing so is larger than the certain welfare from not

[8] See Kono (2006) for an example of this approach to modelling democracy.

[9] For example, even in Rogoff (1985) the optimal central bank strategy places a non-zero weight on employment stabilization.

lending and letting the bank fail.[10] This leads to the central bank's lending decision.

$$\pi[R(\pi) - 1 - r(1-w) + r(1-w)] + (1-\pi)(wv - 1 + g(x)) \geq wv - 1 + g(x)$$

which simplifies to the equilibrium decision rule

$$\bar{v}^* \leq \frac{R(\pi^*) - g(x^*)}{w} \tag{3}$$

The central bank supports the liquidity shortfall of the bank if the liquidity shock falls below a threshold $\bar{v}$. In this model $\bar{v}$ measures the size of a state's financial safety net because it sets the maximum liquidity shock that the central bank is willing to support.[11] Analyzing (3), $R(\pi)$ enters positively and indicates that when the bank expects a higher return on their investment the central bank will be more likely to lend to them when they face a liquidity shortfall. Second, the financial safety net is decreasing in $g(x)$. The reason is because $g(x)$ moderates the cost of a banking crisis for households. It follows from this result that the introduction of government borrowing restrictions (i.e., $g(x) = 0$) expands the financial safety net for the commercial bank. Although the central bank still incorporates household welfare into its decision rule, without a channel for direct household transfers the central bank is only able to contribute to household welfare by supplying larger liquidity support to the commercial bank. Lastly, the financial safety net is increasing in the credit to deposit ratio, $\frac{1}{w}$, which is a common measure of banking sector leverage. When this ratio increases, the cost of a bank failure increases, and this prompts the central bank to extend a more generous financial safety net to the commercial bank.

In period 0 the government also decides whether to grant their central bank independence by passing a law prohibiting themselves from borrowing from the central bank. The government passes such a law if doing so increases the expected household welfare net of the costs associated with direct central bank borrowing. Therefore, the central bank will be granted its independence if

$$\bar{v}_i^*[\pi^*(r(1-w)) + (1-\pi^*)(wv-1)] + (w - \bar{v}_i^*)(wv - 1) \geq$$
$$\bar{v}_n^*[\pi^*(r(1-w)) + (1-\pi^*)(wv-1+g(x^*)-cxD)] + (w-\bar{v}_n^*)(wv-1+g(x^*)-cxD) \tag{4}$$

where $\bar{v}_n^*$ is the financial safety net provided by a non-independent central bank and $\bar{v}_i^*$ is the financial safety net provided by an independent central bank. Simplifying (4), we see that a central bank will be made independent if

$$(w-\pi^*\bar{v}_n^*)(g(x^*)-cxD) \leq (\bar{v}_i^* - \bar{v}_n^*)[\pi^*(r(1-w)) + (1-\pi^*)(wv-1) - (wv-1)] \tag{5}$$

Equation 5 contains four components, two probabilities and two payoffs. The left hand side of Eq. 5 is composed of the probability that the government will resort to fiscal stimulus, $w - \pi^*\bar{v}_n^*$, and the benefits to households and the government when they do so, $g(x^*) - cxD$. Note that the net benefits of government financed fiscal

[10] The model assumes zero opportunity cost to the central bank from its liquidity operations. This assumption is without loss of generality. Indeed, it is trivial to add such costs to the model. See Repullo (2005).

[11] Since financial safety nets cannot be negative, it is assumed that $\bar{v} \geq 0$.

stimulus are decreasing in a state's level of democracy. The right hand side is also composed of two terms, the probability that an expanded financial safety net will be used, $\bar{v}_i^* - \bar{v}_n^*$, and the extra benefit households receive when an independent central bank does so, $\pi^*(r(1-w)) + (1-\pi^*)(wv-1) - (wv-1)$.[12]

The basic model outlined above contains three equilibrium conditions. The first is the choice of risk, π^*, by the commercial bank. The second is the government's decision whether to grant the central bank independence. As case studies on the political economy of central bank independence show, such decisions are complex and subject to international and domestic pressures. Nevertheless, while two of the political variables animating the decision in Eq. 5, $g(x)$ and c, are treated abstractly in the model, a fruitful avenue for future research would be to endogenize these terms. For example, although the model assumes the government does not have meaningful access to international capital markets, incorporating this into a model of c is clearly possible. Likewise, modelling the distributional allocation of $g(x)$ rather than its level would add an interesting dynamic to the model. However, while a richer treatment of the politics driving the central bank independence decision are possible, and indeed desirable, these considerations are secondary to the task of this article and are therefore left to future research. The third choice is over the size of the financial safety net provided by the central bank $\bar{v}^*$. Three implications regarding the political and economic effects of central bank independence are noteworthy and are found in the Online Supplementary Material. These include a lower *ex-ante* probability of a banking crisis, an unambiguous increase in the welfare of the commercial bank, and an uncertain effect on the welfare of households.

2.2 Testable implications

Five testable hypotheses are derived from the model. The first three concern the lending behavior of central bank's during crises and are derived from various components of Eq. 3. The first considers the effect of government borrowing restrictions on the financial safety net for commercial banks. As discussed in the literature review, some studies predict that independent central banks are forces for monetary restraint during times of crisis and stability alike. The model above predicts distinct lending behavior to emerge during a crisis. In particular, during a crisis independent central banks that are legally protected from an obligation to lend to the government will provide more support to the banking system. This leads to the first hypothesis.

> *H1 (Restrictions):* Following a banking crisis liquidity provision will be higher when a government cannot borrow directly from its central bank.

The second hypothesis states that a banking system with higher leverage will receive greater support from the central bank during a crisis. This prediction is corroborated by the performance of various financial systems during the global financial

[12]Note that since the decision over central bank independence is made in period 0, the government's decision is based on the equilibrium, and not observed, values of $\bar{v}_n^*$, $\bar{v}_i^*$, and π^*.

crisis (Ratnovski and Huang 2009). In the model this hypothesis relates to the fraction $\frac{1}{w}$ in Eq. 3 which predicts that commercial banks funding themselves with more debt (i.e., a lower w) will receive more central bank support during a crisis. Formally the second hypothesis is stated as follows.

H2 (Leverage): Following a banking crisis liquidity provision will be higher when a banking system is more leveraged.

The third hypothesis concerns the interaction between government borrowing restrictions and the leverage of the banking system. In particular, it says that the strength of the effect of borrowing restrictions will be conditioned by the degree of leverage in the banking system. When a crisis occurs and an independent central bank judges how decisively to act to stabilize markets, their initial actions will likely be informed by how fragile they perceive the banking system to be. Measures of leverage are one such indicator, which leads to the prediction that the strength of the government borrowing restrictions effect will be mediated by the degree of leverage in the banking system. This interaction effect can be seen in the second order partial derivative of Eq. 3.

$$\frac{d\bar{v}}{dx}\frac{d\bar{v}}{dw} = \frac{g'(x)}{w^2} \tag{6}$$

Moreover, in line with findings that show why the credibility of a central bank's independence is contingent on a state's broader institutional context, this interaction effect is expected to be particularly salient in democracies.[13] Intuitively, if democratic states are less likely to erode the independent status of their central bank, the interaction effect between the banking system's leverage and government borrowing restrictions will be enhanced. Given that $g'(x) \geq 0$ by assumption and $g'(x) = cD$ in equilibrium, it follows that the interaction effect of $\frac{g'(x^*)}{w^2}$ is expected to be higher in democracies. The third hypothesis is stated as follows.

H3 (Interaction): Following a banking crisis, in democracies the strength of the effect of government borrowing restrictions will increase at higher credit to deposit ratios.

The final two hypotheses concern central bank lending outside of a crisis context. In particular they test whether the effects of government borrowing restrictions and banking system leverage are also observed during non-crisis times. The model contains no predictions regarding the behavior of central banks during times of stability because it is concerned only with crisis lending. Therefore, consistent with the existing literature it is expected that concerns over inflation will be high on the agenda of independent central banks which leads them to act as agents of monetary restraint. However, because banking system fragility correlates with its leverage, higher banking system leverage is still expected to exert a positive effect on central bank liquidity provision outside of a crisis context. Formally the final two hypotheses are stated as follows.

[13] I thank an anonymous reviewer for suggesting this hypothesis.

H4a (Asymmetry (a)): Government borrowing restrictions reduce liquidity provision during non-crisis times.

H4b (Asymmetry (b)): Higher banking sector leverage increases liquidity provision during non-crisis times.

3 Empirical design

In a banking crisis a significant fraction of a state's banking system experiences a rapid deterioration in its financial health. The suddenness of most banking crises leaves a clear demarcation between the pre-crisis period and the crisis proper, which can be exploited in an event study to estimate the amount of central bank liquidity attributable to the crisis. An event study is a unique before-and-after research design that takes advantage of a discontinuity in the data generating process (Kothari and Warner 2008).

The dependent variable is constructed in three steps. The first step estimates a linear trend in liquidity provision in state i using observations in the twelve-month period prior to the crisis. The second step projects this trend into the event window, which consists of the date of the banking crisis plus twelve months. This projection forms a counterfactual series of central bank liquidity provision assumed to approximate what central bank liquidity would have been were it not for the crisis. The final step subtracts the projected series of liquidity provision from actual liquidity provision.[14] The result is a measure of the "abnormal" amount of liquidity supplied by a central bank due to the crisis.[15]

3.1 Data and methodology

Banking crisis dates spanning 1980-2009 are taken from Laeven and Valencia (2013). An event is coded as a systemic banking crisis if the banking system is experiencing financial distress and states are responding with significant remedial policy intervention.[16] Although the database lists 147 banking crises, the short-term nature of central bank liquidity provision requires a focus on the 38 crises in emerging market economies where dates include a month and where sufficient data on covariates can be obtained. A list of the banking crises included in the estimations is found in the Online Supplementary Material. Following Laeven and Valencia (2013), liquidity

[14] This step implies that the dependent variable will be measured with error, imparting a well-known downward bias in the estimated regression coefficients (Green 2003, p. 84).

[15] In a very small number of instances the trend in central bank liquidity prior to a banking crisis predicts negative central bank liquidity in the event window. When this occurs the projected series of claims is set to zero. Although the dataset contains twenty-nine observations of negative central bank liquidity provision (i.e., commercial banks were *net lenders* to central banks), this possibility is precluded in the analysis by restricting projected liquidity to be non-negative. This prevents situations where low levels of liquidity result in positive abnormal liquidity because projected liquidity is negative.

[16] See Laeven and Valencia (2013) for detailed criteria defining a distressed banking system and the list of remedial state interventions.

provision is measured by central bank claims on the banking sector. Using the International Monetary Fund's International Financial Statistics (IFS), the dependent variable is measured as central bank claims on depository corporations (line 12e) normalized by the total deposit base of the banking system, defined as the sum of transferable deposits (line 24) and time, savings, and foreign currency deposits (line 25). Normalizing central bank claims in this way implicitly controls for the massive expansion in banking systems in the post-Bretton Woods era and permits meaningful comparisons of liquidity provision over time.

The main independent variables include a measure of government borrowing restrictions from Garriga (2016) and the credit to deposit ratio from Beck et al. (2010). The former comprises an index of legal measures that place limitations on central bank lending to the public sector.[17] Restrictions cover the volume, maturity, interest rates, and conditions for direct advances and securitized lending. Increases in this index imply greater government borrowing restrictions. Increases in the credit to deposit ratio indicate that a banking system relies less on retail deposits to fund its loans. A greater reliance on wholesale funding has been shown to increase banking system leverage and therefore the degree of banking sector fragility (Copelovitch and Singer 2017). Various control variables have been included. The unified democracy score from Pemstein et al. (2010) provides a measurement of a state's level of democracy. Two control variables measure the size and presence of a financial safety net. A dummy variable indicating the presence of formal deposit insurance is taken from Demirgüc-Kunt et al. (2014) and a state's foreign exchange reserves as a share of GDP are taken from the World Development Indicators. Additional control variables include a measure of economic openness and net capital inflows as a share of GDP. Economic openness is defined as the sum of imports and exports over GDP and this measure is taken from the World Development Indicators. Observations on net capital inflows are from Bluedorn et al. (2013). A variable counting the number of contemporary crises occurring has been constructed using the full sample of banking crises found in Laeven and Valencia (2013). This variable measures the degree to which banking crises are occurring around the world at any given moment. Lastly, decade dummy variables have been included to control for the three waves of emerging market banking crises, which broadly comprise those associated with the debt crises of the 1980s, the crises of liberalization associated with the 1990s, and those associated with the global financial crisis. Variables measured at an annual frequency have been linearly interpolated to produce monthly observations when necessary. A linear interpolation is justified in all cases as the variables are "sluggish" and change only gradually over time. Summary statistics for all variables are included in the Online Supplementary Material.

The estimation strategies for the event study are driven by concerns over potential endogeneity, omitted variable bias, dynamics, and the "large N, small T" structure of the data, where N is the number of units and T is the number of time periods. Moreover, the sluggishness of the independent variables combined with a very short thirteen-month time span for each banking crisis episode leave very little within-unit

[17] What this article refers to as government borrowing restrictions, Garriga (2016) labels as central bank financial independence.

variation to exploit. Thus, estimators that utilize variation across units are preferred. As there exists no estimation strategy that can address all of the above-mentioned concerns simultaneously, a variety of estimation strategies have been chosen. Support for the hypotheses therefore comes not from the reliance on any particular modelling strategy, but from a broad set of models, each with their own shortcomings, telling a similar story. Estimators that meet this criteria include pooled OLS, random effects, and between effects, and specifications utilizing each method are presented below.[18] Concerns over dynamics have been addressed in each specification, despite the limitations imposed by the short time span of the event study. The effects of time have been addressed through various strategies including clustering errors by country and time, accounting for AR(1) disturbances, and including multiple lagged dependent variables.

A between effects estimator has been included to address concerns over endogeneity and eliminates dynamics altogether as the independent variables in this estimator consist of group means. Given that one of the main independent variables concerns an institutional characteristic related to central bank independence, the weak instrument problem is almost surely binding. A recent study by Hauk (2017) advises that in such situations the choice among alternative estimators requires negotiating the trade-offs between various biases arising from endogeneity, omitted variable bias, dynamics, and others. In Hauk (2017) Monte Carlo simulations show that when endogeneity bias is a concern, average absolute bias is minimized with the random effects and between effects estimators. Lastly, a series of robustness checks for the first three hypotheses are found in the Online Supplementary Material. These include a set of alternative econometric specifications and alternative measures of some independent and control variables.[19]

A placebo analysis of 1,000 trials of the event study using randomly chosen dates is used to test H4a and H4b. To ensure selected dates did not fall around banking crises, the randomization process excluded dates twelve months before and after a banking crisis. The randomization process also excluded the first and last twelve months in the dataset. This placebo analysis tests whether the estimated effects of the independent variables on central bank liquidity are present outside of a crisis context. In addition to the placebo analysis, a complementary analysis of liquidity provision outside of a crisis context has also been included in the Online Supplementary Material.

[18]The large N, small T setting also precludes popular estimators that rely more on within-unit variation such as fixed effects, and the GMM estimators of Arellano and Bond (1991) and Blundell and Bond (1998). Moreover, simulations in Clark and Linzer (2015) show that in a panel with sluggish independent variables, many units, and few observations per unit, the preference for a fixed or random effects estimator hinges on the correlation between the unit effects and the within-unit mean of the independent variable. Given that across a wide range of specifications using the variables in Table 1 the highest correlation between the unit effects and the within-unit mean of government borrowing restrictions is 0.25, the random effects estimator outperforms the fixed effects estimator in terms of total root mean squared error (Clark and Linzer 2015, p. 406). Likewise, the highest correlation between the unit effects and the within-unit mean of the credit to deposit ratio is 0.10.

[19]For example, if the measure of capital account openness of Chinn and Ito (2008) is substituted for net capital inflows and the index of creditor rights from Djankov et al. (2007) is substituted for the democracy measure of Pemstein et al. (2010), results are very similar to the main event study.

3.2 Results

The results of the event study are shown in Table 1. In the three leftmost columns, coefficients on government borrowing restrictions have the expected positive sign and are statistically significant at either the 5% or 1% level. Given that government borrowing restrictions are measured on a zero to one scale, a one-unit increase in a government's borrowing restrictions score is too large to meaningfully interpret. Instead, given a one standard deviation increase, equal to 0.235 units, abnormal liquidity is expected to be higher by 3.7 percent of the deposit base of the banking system using the government borrowing restrictions coefficient from column (2).[20] Similar results are attained on tests of H2 as the coefficients on the credit to deposit ratio have the expected positive sign and are statistically significant at the 5% level or higher in all columns except (1) and (4). Using the coefficient on the credit to deposit ratio from column (2), a one standard deviation increase, equal to 44.3%, is expected to increase abnormal central bank liquidity by 2.1 percent of the deposit base of the banking system. Given that Laeven and Valencia (2013) report that median average liquidity support in emerging market economies following a banking crisis is 10.3 percent of the deposit base of the banking system, both coefficients impart a substantially significant effect on abnormal liquidity (Laeven and Valencia 2013, p. 244). These results support H1 and H2, that central banks protected by government borrowing restrictions and facing a highly leveraged banking system supply higher levels of abnormal liquidity during a banking crisis.[21]

Given the challenges that accompany identifying the effects of the key independent variables, it is notable that the results in favor of H1 and H2 hold across a broad range of models. For example, concerns over the dynamic nature of the data, whereby values of the dependent variable at $t - 1$ correlate with values at t, are addressed in columns (4) through (9) in various ways. Following the advice of Wilkins (2018), columns (4) and (5), are estimated with the inclusion of three lagged dependent variables.[22] Dynamics are also addressed in the random effects estimations in columns (6) and (7) by accounting for serial correlation in the disturbances.[23] Lastly, results continue to hold in columns (8) and (9) with a between effects estimator that addresses concerns over endogeneity, omitted variable bias, and dynamics.

[20] 0.235 units on the government borrowing restrictions index roughly corresponds to the difference in scores between Indonesia (0.212) and Malaysia (0.514) during their respective crises in 1997.

[21] These results were also found to be stable and statistically significant across a wide range of event window lengths. Details on this robustness check are available in the Online Supplementary Material.

[22] Lagged dependent variables not reported in Table 1, but are available upon request. Tests using the *actest* command in Stata 14 indicate that autocorrelation is purged from the model with the inclusion of three lagged dependent variables. Furthermore, support for the hypotheses hold up to and including the addition of five lagged dependent variables.

[23] The advice of Wilkins (2018) notwithstanding, in panel data settings the inclusion of a lagged dependent variable in a small T setting opens the possibility of Nickell bias (Nickell 1981). While this possibility led to the exclusion of lagged dependent variables in the random effects estimations in Table 1, the results of columns (6) and (7) continue to hold up to and including three lagged dependent variables. These results are available upon request. Estimations using Newey-West standard errors, which account for serial correlation of the error term, are also very similar to the main results and are found in the Online Supplementary Material.

Table 1 Abnormal central bank liquidity during banking crises

	OLS			OLS with three LDVs		Random effects		Between effects	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Government Borrowing Restrictions	0.096*	0.158***	0.171***	0.016***	0.014**	0.088**	0.086**	0.146***	0.146***
	(0.049)	(0.050)	(0.045)	(0.005)	(0.005)	(0.039)	(0.038)	(0.042)	(0.043)
Bank Credit (% Deposits)	0.041*	0.047**	0.056***	0.006*	0.007**	0.058***	0.067***	0.064***	0.064***
	(0.024)	(0.023)	(0.020)	(0.003)	(0.003)	(0.019)	(0.018)	(0.022)	(0.017)
Democracy	−0.009	−0.028**	−0.025**	−0.005**	−0.004*	−0.021	−0.016	−0.010	−0.022
	(0.018)	(0.013)	(0.012)	(0.002)	(0.002)	(0.018)	(0.017)	(0.018)	(0.015)
Deposit Insurance		−0.073***	−0.073***	−0.009***	−0.008**	−0.036**	−0.035**	−0.086***	−0.076***
		(0.019)	(0.022)	(0.003)	(0.004)	(0.014)	(0.014)	(0.019)	(0.021)
Reserves (% GDP)		−0.508**	−0.703***	−0.073***	−0.065**	−0.420***	−0.539***	−0.772***	−1.133***
		(0.193)	(0.223)	(0.021)	(0.024)	(0.127)	(0.135)	(0.233)	(0.258)
Net Capital Inflows (% GDP)			−0.612***		−0.009		−0.624***		−0.482***
			(0.116)		(0.041)		(0.129)		(0.147)
Floating Exchange Rate			−0.025		0.005		−0.004		−0.012
			(0.016)		(0.003)		(0.009)		(0.019)
Trade (% GDP)			0.045		−0.001		0.051		0.071*
			(0.047)		(0.007)		(0.032)		(0.038)
Crises Worldwide (count)	−0.005	−0.005*	−0.003	−0.001***	−0.001**	−0.003**	−0.002*	−0.005*	−0.005*
	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)	(0.003)
1990's Dummy	0.013	0.070***	0.022	0.008	0.006	0.037	−0.010	0.021	0.017
	(0.030)	(0.021)	(0.041)	(0.005)	(0.008)	(0.034)	(0.036)	(0.026)	(0.026)

Table 1 (continued)

	OLS			OLS with three LDVs		Random effects		Between effects	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2000's Dummy	−0.007	0.077**	0.029	0.005	0.004	0.038	−0.013	0.037*	0.034
	(0.045)	(0.032)	(0.042)	(0.006)	(0.008)	(0.041)	(0.041)	(0.021)	(0.022)
Constant	−0.001	−0.001	0.035	0.004	0.002	0.002	0.030	0.053	0.065**
	(0.030)	(0.031)	(0.029)	(0.004)	(0.006)	(0.036)	(0.035)	(0.043)	(0.033)
$Prob > F$	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R^2	0.15	0.33	0.42	0.94	0.94				
# Observations	444	436	436	332	332	436	436	452	452

Coefficients estimated with OLS. Standard errors in parentheses. Columns (1), (2), and (3) errors clustered by country and time

Columns (4), (5), (8) and (9) errors clustered by country. Columns (6) and (7) errors adjusted for AR(1) process. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Control variables behave as expected. Democracy enters negatively across all specifications, although they are only sporadically statistically significant. Other measures of financial safety nets, such as formal deposit insurance and foreign currency reserves also enter negatively and are generally statistically significant at conventional levels. This result supports the argument that other components of a state's financial safety net may reduce the need for compensating liquidity provision. Net capital inflows appear negative and are statistically significant in three out of four specifications, indicating that greater net capital inflows reduce liquidity provision into the banking system. Neither the presence of a floating exchange rate, a high level of trade openness, or the number of crises worldwide appear to impact central bank liquidity provision as these coefficients are either rarely statistically significant or are substantively small.

Figures 2 and 3 plot the marginal effects of government borrowing restrictions across a range of credit to deposit ratios in democracies and non-democracies, respectively.[24] Estimates of the marginal effects were obtained using the method of Hainmueller et al. (forthcoming), which uses local linear regressions using a binning procedure or a Gaussian kernel reweighting scheme. Both approaches relax the linear interaction effect assumption by estimating local conditional marginal effects of a treatment variable at different values of a moderating variable. Although both approaches yield the same results, the latter are shown in Figs. 2 and 3.[25] Using the specification in column (3) of Table 1, Figs. 2 and 3 show strong evidence in favor of H3. Two results stand out. First, in democracies the marginal effect of government borrowing restrictions is positive and statistically significant across essentially all credit to deposit ratios. No such effect is found in non-democracies. Second, in democracies the strength of the effect of government borrowing restrictions increases at higher credit to deposit ratios. This result supports the notion that central bank's that are *credibly* free from direct government borrowing respond more decisively at the onset of a crisis if a banking system is highly leveraged.[26]

In the placebo analysis used to test H4a and H4b the average coefficients on government borrowing restrictions and the credit to deposit ratio are -0.002 and -0.0004, respectively, which are substantively lower than their counterparts in column (5) of Table 1. Histograms showing the distribution of t-statistics over the 1,000 placebo trials for government borrowing restrictions and the credit to deposit ratio are listed in Figs. 4 and 5, respectively. As expected the distribution of t-statistics resembles a Student's t-distribution and in both figures the vast majority of t-statistics fail to reach conventional levels of statistical significance. In only 56 and 125 of the 1,000 trials did the government borrowing restrictions coefficients achieve statistical significance at the 5 percent and 10 percent levels, respectively. Not only are these results within

[24] States with a Unified Democracy Score above the average in the sample, equal to 0.35, are classified as democracies. Non-democracies are states with scores below 0.35.

[25] Results using the binning procedure are found in the Online Supplementary Material.

[26] The absence of a response by central banks to increased leverage in autocracies may reflect more than the absence of credible central bank independence. In particular, autocracies also tend to have weak institutions that are incapable of a quick, decisive response to a crisis irrespective of the degree of leverage in the banking system. I thank an anonymous reviewer for this suggestion.

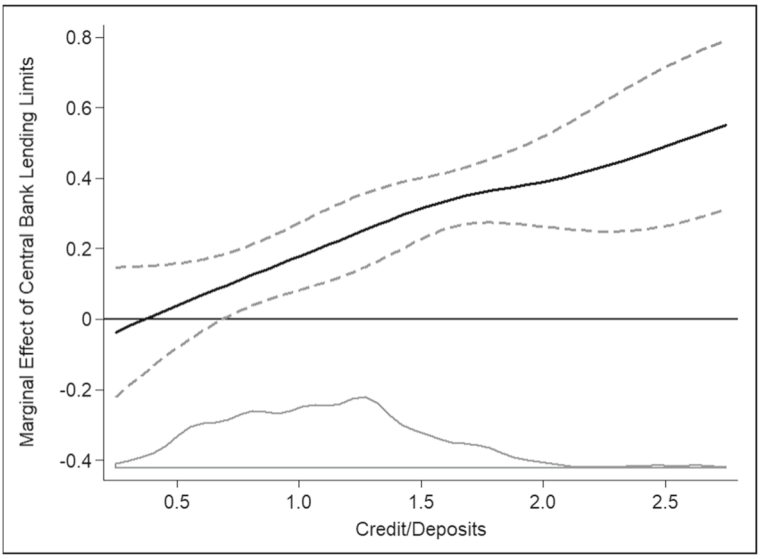

Fig. 2 Marginal effect of government borrowing restrictions on abnormal liquidity in democracies

the range of expected type II error rates, 34 of the 56 trials that achieved statistical significance at the 5% level did so with a negative coefficient. Overall the effect of government borrowing restrictions on liquidity provision appears to be significantly different during times of crisis and during times of stability.

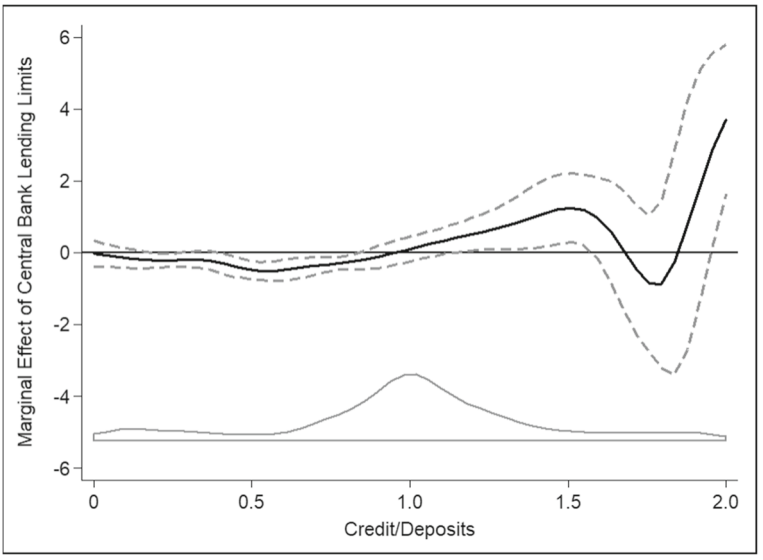

Fig. 3 Marginal effect of government borrowing restrictions on abnormal liquidity in non-democracies

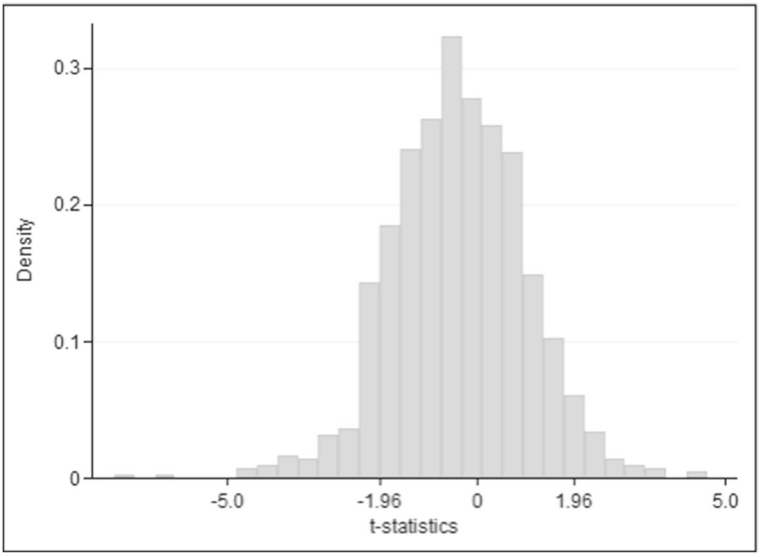

Fig. 4 T-statistics histogram for government borrowing restrictions

For the credit to deposit ratio 147 and 264 coefficients reached statistical significance at the 5% and 10% levels, respectively. These results are arguably not near expected type II error rates. Moreover, a clear majority, 103 of the 147 statistically significant trials, had a negative coefficient, the opposite of what was found in the event study. Overall, the prevalence of small effect sizes and the prevalence for

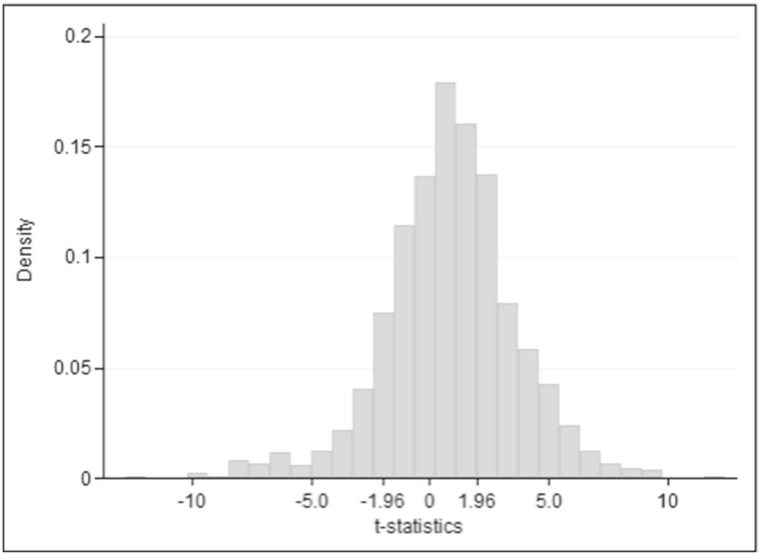

Fig. 5 T-Statistics histogram for bank credit (% deposits)

negative coefficients in the statistically significant trials indicates that liquidity provision appears to be significantly different during times of crisis and during times of stability.

4 Conclusion

With the development of a formal model and supporting quantitative evidence, this study showed that emerging market central banks that can refuse to lend directly to their government supply a larger financial safety net to commercial banks in crisis. A key secondary finding was that financial safety nets expand with the degree of leverage in the banking system. Moreover, the interaction between these two effects was important in democracies as the strength of the effect of independence increased with the degree of leverage in the banking system.

These effects were grounded in a novel approach to the politics of central bank independence that focused on the rules governing which loan requests a central bank may refuse. This approach offers new insights into the political and economic implications of central bank independence. For example, by showing that political structures are linked to the allocation of a central bank's last resort lending facilities, this study shows that central bank governance structures reach beyond market outcomes such as changes to aggregate prices and investment flows and effect the lending behavior of the central bank itself.

Future research would do well to focus on the links between the politics structuring central bank behavior and domestic financial stability. Section 2.1 identified a few potential extensions of the basic model developed here, but further extensions that incorporate international variables are possible. For example, many studies have identified liquidity conditions in the world's core economies as an important determinant of monetary conditions in emerging market economies (Pettis 2001; Fratzscher 2012; Bruno and Shin 2014; Rey 2015). The implication from this body of research is that when monetary conditions in the core tighten, the probability of crises in interdependent emerging market economies increases. While emerging market economies will remain sensitive to financial shocks originating beyond their borders for the foreseeable future, their institutional development and provision of financial safety nets may leave them less vulnerable than in the past. If true this growing institutional capacity may signal that international financial integration and banking crises may not be forever linked, at least not in an axiomatic way. Although this topic needs further research, the implication of this study is that this relationship hinges on the politics of financial safety nets.

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