Monetary Easing and Financial Instability*

Viral Acharya
New York University

Guillaume Plantin
Sciences Po

October 28, 2016

Abstract

We build a model to study optimal monetary policy in the presence of financial stability concerns. Rigid output prices preclude optimal real investment in response to preference (or productivity) shocks. Monetary easing, by lowering the cost of capital for firms, can restore output to the efficient level, but also subsidizes inefficient maturity transformation by financial intermediaries - "carry trades" that borrow cheap at the short-term against illiquid long-term assets. Carry trades not only lead to financial instability in the form of rollover risk from short-term debt, but also crowd out real investment since intermediaries equate the marginal return on lending to firms to that on carry trades. Optimal monetary policy trades off any stimulative gains against these costs of carry trades. The model provides a framework to understand the puzzling phenomenon that monetary easing is associated with low real investment, even while returns to real and financial capital are high.

Keywords: Monetary policy, ultra-low interest rates, quantitative easing, financial stability, financial fragility, shadow banking, maturity transformation, carry trades

JEL: E52, E58, G01, G21, G23, G28

*We are grateful to seminar and workshop participants at the World Econometric Society Meetings, Montreal, August 2015; CREDIT Greta conference, Venice, October 2015; Micro Foundations of Macro Finance workshop, New York University, April 2016; London Business School, June 2016; and, University of Mannheim, June 2016, for helpful comments and discussions. Hae Kang Lee provided excellent research assistance.

"In the absence of economic rents, the return on corporate capital should generally follow the path of interest rates, which reflect the prevailing return to capital in the economy. But over the past three decades, the return to productive capital generally has risen, despite the large decline in yields on government bonds." – Jason Furman, Chairman of the Council of Economic Advisors, United States, in "Productivity, Inequality and Economic Rents," June 13, 2016.

Introduction

Motivation

Since the global financial crisis of 2007-08, central banks in the Western economies have embarked upon the so-called unconventional monetary policies. These policies feature monetary easing aimed at keeping interest rates at ultra-low levels. Most notably, the Federal Reserve has kept interest rates at the zero lower-bound with large-scale asset purchases of Treasuries and mortgage-backed securities. European Central Bank has now followed suit with such purchases and so has the Bank of Japan. The objective of such aggressive easing has been to restore some of the abrupt and massive loss in aggregate demand that followed the crisis by lowering the cost of capital for the real sector with the objective of stimulating investment and credit to "normal" levels.

Several academics and policy-makers have highlighted, however, that such monetary policies have had unintended consequences that have limited the effectiveness of the policies in achieving the intended goals. In particular, they have highlighted the "search for yield" among institutional investors and the resulting asset-price inflation in certain risky assets such as high-yield corporate bonds and emerging-market debt and equities.[1] Others, notably Furman (2015, 2016) (see the introductory quote), have argued that coincident with low rates has been a *high* marginal return to capital, *low* fixed real investment, and *high* returns to shareholder capital in the form of share buy-backs. Indeed, if extended periods of low rates were successful at restoring investment, the marginal return of capital would end up low and fixed real investment high. Furman considers this an important puzzle facing economic theory and the practice of monetary policy.

One way of understanding these consequences in a unified way is that keeping interest rates low allows financial institutions to fund long-term assets with relatively short-term claims, hoping that these claims can be refinanced until the long-term assets mature, resulting in a "carry." A potential rollover risk arises with such carry trades when the availability of future funding liquidity is uncertain, and early liquidation of the long-term assets backing the trades is costly and inefficient. In this case, the maturity trans-

[1]See, in particular, Rajan (2013): "If effective, the combination of the "low for long" policy for short term policy rates coupled with quantitative easing tends to depress yields. ... Fixed income investors with minimum nominal return needs then migrate to riskier instruments such as junk bonds, emerging market bonds, or commodity ETFs. ... [T]his reach for yield is precisely one of the intended consequences of unconventional monetary policy. The hope is that as the price of risk is reduced, corporations faced with a lower cost of capital will have greater incentive to make real investments, thereby creating jobs and enhancing growth. ... There are two ways these calculations can go wrong. First, financial risk taking may stay just that, without translating into real investment. For instance, the price of junk debt or homes may be bid up unduly, increasing the risk of a crash, without new capital goods being bought or homes being built. ... Second, and probably a lesser worry, accommodative policies may reduce the cost of capital for firms so much that they prefer labor-saving capital investment to hiring labor."

formation that monetary easing induces in the financial sector creates private gains in the sector – resulting from transfers from savers to borrowers – but also results in expected social costs in the form of inefficient liquidations of long-term assets when this rollover risk materializes.

For instance, when the "taper" of its expansionary monetary policy was announced by the Federal Reserve in May 2013, several emerging market debt securities experienced liquidations by foreign institutional investors, causing severe price volatility in their debt markets as well as in the currency exchange rates.[2] The "taper tantrum" required massive interventions by emerging market central banks and was ultimately calmed down only when the Federal Reserve indicated a few months later that it would not in fact taper as quickly as it might have suggested in May 2013. Recently, as the Federal Reserve appears to be moving closer to "up-lift" of the rates, similar liquidation concerns have been raised about. In particular, there is the mention of "illusory liquidity" that the financial sector has been relying on for funding of positions in high-yield corporate debt, structured products, and emerging market debt and equities, and that this liquidity may vanish with the up-lift.

Importantly, as returns to carry trades become positive when interest rates are low, financial intermediaries allocate economy's savings away from real investment into paying out of carry until the marginal return on investment rises to compensate for the opportunity cost of giving up the carry. In other words, low interest rates induce carry trades that crowd out real-sector

[2]See Feroli et al.(2014), who document that Emerging Market Bond Funds had started receiving steady inflows since 2009, with a peak of around $3.5 bln per month that promptly reversed to outflows of similar magnitude in the months immediately after the "taper" announcement. See also the discussion of Feroli et al. by Stein (2014).

investment. This leads to the coincidence of low rates with high marginal return on real capital, low real investment, and high shareholder return on capital (due to paying out of the carry), as documented in Furman (2015, 2016).

Model

We capture these rich economic insights in a simple and tractable framework that can provide a building block for a fuller model of monetary policy that faces a "penalty" when interest rates are too low. In particular, we present a model that integrates the stimulative rationale of monetary easing with the financial instability risk and crowding-out of real investment that arise from carry trades induced in the financial sector by monetary easing. Our main result is that when the stimulative gains from monetary policy are weak and the potential for financial carry trades large, optimal monetary policy should "lean against the wind" by tightening and discouraging carry trades.[3] Interestingly, and equally importantly, the discouraging of carry trades by keeping interest rates not too low is essential to raising aggregate demand as this reduces the crowding-out effect.

The key ingredients of our model are as follows. We study an economy in which the relative price of output is fixed ("nominal rigidity"), and thus cannot reflect shocks to consumer preferences (alternatively, shocks to pro-

[3] While our motivation focused on the more recent monetary easing, the financial instability risk we highlight has manifested also in the past episodes of monetary easing in the form of destabilization of long-term government bond markets (see http://fortune.com/2013/02/03/the-great-bond-massacre-fortune-1994/) and the materialization of rollover risk in mortgage-related maturity transformation by the financial sector.

duction costs). Corporations issue bonds and so does the public sector, all at the going rate of interest which the central bank (assumed to be managing debt for the public sector) can set through sale or repurchase of public sector bonds through open market operations. Any such central bank actions in bond markets are immediately met with tax increase or rebate. To start with, we consider a benchmark model without the financial intermediaries.

In the case of temporary positive preference shocks for the real sector's output, monetary easing – by temporarily lowering the interest rate – reduces the corporate cost of capital and can restore the first-best allocation that is out of reach under *laissez-faire* because of missing price signals for the real sector output. Effectively, as the nominal price is rigid, the central bank by setting the nominal rate is able to set the real rate of interest to the desired level or the natural rate.

We then introduce financial intermediaries. We assume that financial intermediaries can issue short-term debt to savers at the going rate of interest and intermediaries choose how much to lend to the corporations (assumed to be short-term) versus lending against long-term assets held by long-term investors (capturing some or all of these assets' returns in the process, or equivalently, intermediaries have legacy long-term assets of their own). Funding of long-term assets by issuing short-term debt gives rise to rollover risk if long-term assets' cash flows are delayed and intermediaries face a freeze in the short-term funding markets; in such case, long-term assets are liquidated at a cost that is socially inefficient. If long-term assets' cash flows are, however, realized early, then intermediaries receive a carry that compensates for the rollover risk undertaken.

Maturity transformation in the form of such "carry trades" is privately beneficial to financial institutions, but socially costly. It implements a transfer from households to borrowing financial institutions at the social cost of inefficient early liquidation of long-term assets when rollover risk materializes. There is, in addition, a more subtle social cost from the carry trades. Intermediaries reduce lending to corporations until the marginal return on corporate investment earned by intermediaries equals the carry-trade returns, a crowding-out effect that is increasing in the attractiveness of carry-trade, which in turn, increases the lower is the interest rate set by the central bank.

We then show that optimal monetary policy that incorporates these two social costs of carry trades operates in the following way. In general, it does not involve monetary easing up to the point in the benchmark model as this induces carry trades and crowds out real-sector investment. Instead, the optimal monetary policy sets the interest rate to a point that discourages carry trades and prevents such crowding-out. In other words, it stops at a point beyond which further monetary easing results in financial instability of the financial sector and depression of real investment.

Finally, we extend the model to endogenize the rollover risk of the long-term assets when funded with short-term debt. In particular, we assume that the rollover risk is due to cash inlays required by long-term assets to retain their value. The central bank can provide liquidity to meet such inlays at its lender-of-last-resort (LOLR) rate to maintain ex-post real efficiency from keeping these assets as ongoing instead of their being liquidated. We then obtain an interesting tradeoff between the monetary policy rate and the LOLR rate. Carry trades become only more attractive with a low LOLR rate, so that optimal policy either features (i) a low monetary policy rate combined with a high LOLR rate ("aggressive" policy that discourages of carry trades at the cost of ex-post efficiency), or (ii) a high monetary policy rate combined with a low LOLR rate ("conservative" policy that discourages carry trades at the cost of lower ex-ante investment).

The model, in turn, also provides implications for when quantitative easing programs may be efficient and succeed without inducing financial instability. If the aggressive policy above cannot be implemented due to time-inconsistency problem in setting the LOLR rate, then the central bank can compensate by reducing the supply of long-term assets in the economy that facilitate carry trades. In particular, it would not help with financial stability to purchase assets with high rollover risk that are not attractive for carry trades in the first place, but safer and more liquid long-term assets that lend themselves to carry-trade profits when short-term funding costs are low.

The paper is organized as follows. Section 1 describes the related literature and our contributions relative to it. Section 2 presents the benchmark model of monetary easing with nominal rigidity. Section 3 introduces financial intermediaries and derives (i) the carry-trade incentives for optimal rate in the benchmark model, (ii) implications of the carry trades, and, (iii) the optimal monetary policy taking account of carry trades by the financial sector. Section 4 extends the model to a lender-of-last-resort (LOLR) policy, so that the central bank sets the ex-ante policy rate as well as the ex-post LOLR rate when rollover risk materializes, and also discusses implications for quantitative easing programs. Section 5 presents the concluding remarks.

1 Related literature

It is interesting to contrast the role of monetary easing in creating financial instability in our model from the current literature that models this role. In Farhi and Tirole (2012), the central bank faces a commitment problem which is that it cannot commit not to lower interest rates when financial sector's maturity transformation goes awry. In anticipation, the financial sector finds it optimal to engage in maturity transformation to exploit the central bank's "put." In contrast, in our model the central bank faces no commitment problem as such, but it finds low rates attractive from the standpoint of stimulating productive investment and must weigh this benefit against the cost that low rates also stimulate inefficient maturity transformation in the financial sector.

In Diamond and Rajan (2012), the rollover risk in short-term claims disciplines banks from excessive maturity transformation, but the inability of the central bank to commit to "bailing out" short-term claims removes the market discipline, inducing excessive illiquidity-seeking by banks. They too propose raising rates in good times taking account of financial stability concerns, but so as to avoid distortions from having to raise rates when banks are distressed. Again, the contrast with our model is that central bank in our model has no commitment problem but its attempts to boost activity by lowering rates induce carry trades.

Acharya and Naqvi (2012a) develops a model of internal agency problem in financial firms due to limited liability wherein liquidity shortfalls on maturity transformation serve to align insiders' incentives with those of outsiders. When aggregate liquidity at rollover date is abundant, such alignment is restricted accentuating agency conflicts, leading to excessive lending and fueling of asset-price bubbles. Acharya and Naqvi (2012b) argue that monetary policy being easy only exacerbates this problem and that it should instead lean against the wind to get around the limited-liability induced distortions in bank lending. Our model features, in contrast, carry trade behavior that is entirely due to moral hazard created by the monetary policy, even absent agency problems within the financial sector.

Stein (2012) explains that while prudential regulation of banks and systemically important financial firms can partly rein in the attempts to engage in excessive maturity transformation, there is always some unchecked growth of such activity in shadow banking. He argues for a monetary policy that leans against the wind as raising the cost of borrowing which reaches all "cracks" of the financial sector. Finally, Acharya (2015) proposes a leaning-against-the-wind interest-rate policy in good times for a central bank to reduce the extent of political interference that can arise in attempting to deal with quasi-fiscal actions during a financial crisis. These explanations are both consistent with the considerations for financial stability in our model, but our objective is to deliver a stylized model that can serve as a building block for a fuller model of monetary policy that accounts for such considerations.

2 An elementary model of monetary easing

2.1 Setup

Time is discrete. There are two classes of agents: households and the public sector. Households are of two types, savers and entrepreneurs, that share similar preferences but differ along their endowments. There are two goods that households find desirable: a numéraire good and entrepreneurs' output.

Households' preferences. At each date, a mass 2 of households are born and live for two dates. Each cohort is equally split into savers and entrepreneurs. Both types of households derive utility from consumption only when old. Entrepreneurs' output and the numéraire good are perfect substitutes for them, although an entrepreneur cannot consume his own output. Households are risk neutral over consumption.

Households' endowments. Each saver receives an endowment of y units of the numéraire good at birth, where $y > 0$. Each entrepreneur born at date t is endowed with a technology that transforms an investment of I units of the numéraire good at date t into $f(I)$ units of output at date $t+1$. The function f satisfies the Inada conditions and is such that

$$f'(y) < 1. \tag{1}$$

Public sector. The public sector does not consume and maximizes total households' utility, discounting that of future generations with a factor arbitrarily close to 1. At each date, the public sector matches net bond issuances described below with lump sum rebates/taxes to current old households.

Bond markets. There are two markets for one-period risk-free bonds denominated in the numéraire good. The public sector and savers trade in the public-bond market. Savers and entrepreneurs trade in the corporate-bond market. Note that this implies in particular that the public sector cannot lend to entrepreneurs.[4]

[4]Note also that restricting corporate securities to risk-free bonds is only to fix ideas.

Monetary policy. The public sector announces at each date an interest rate at which it is willing to meet any (net) demand for public bonds by savers.

Finally, households are price-takers in goods and bonds markets.

Comments

This setup is a much simplified version of the workhorse monetary model in which money serves only as a unit of account ("cashless economy") and monetary policy boils down to enforcing a short-term nominal interest rate. In the workhorse model, the presence of nominal rigidities implies that the monetary policy also affects the real interest rate. Below, we dramatically simplify this workhorse framework by assuming extreme nominal rigidities in the form of a fixed price level for one good that we therefore deem the numéraire good. Beyond obvious gains in tractability, our motivation for this simplification is that it is useful to study how financial-stability concerns stand in the way of a central bank in a benchmark model in which the monetary authority would otherwise have a free hand at controlling the real economy.

2.2 Steady-state

We study steady-states in which the public sector announces a constant interest rate $r > f'(y)$, and the price of firms' output (in terms of the numéraire good) is at its equilibrium level of one.

This comes at no loss of generality given that production is deterministic and entrepreneurs face no financial frictions.

The structure of the model lends itself to simple analysis. Savers need to store their endowment for consumption. They have access to two risk-free stores of value, public and corporate bonds. Equilibrium therefore requires that the return on corporate bonds is equal to that announced by the public sector on public bonds, r. At such a rate r, entrepreneurs optimally invest I such that

$$f'(I) = r, \tag{2}$$

and make a net profit

$$f(I) - rI. \tag{3}$$

Savers invest I in corporate bonds and $y - I$ in public bonds. At each date, current old households receive a lump sum from the government equal to the net issuance $(1-r)(y-I)$. The utility of a generic cohort of households is therefore equal to

$$\begin{aligned} &\underbrace{rI}_{\text{Savers' return on corporate bonds}} + \underbrace{r(y-I)}_{\text{Savers' return on public bonds}} \\ &+ \underbrace{f(I) - rI}_{\text{Entrepreneurs' profits}} + \underbrace{(1-r)(y-I)}_{\text{Rebated public surplus}} \\ &= f(I) - I + y, \end{aligned} \tag{4}$$

maximized at

$$f'(I^*) = r^* = 1. \tag{5}$$

In this elementary environment, condition (5) rephrases the standard "golden rule" according to which steady-state consumption is maximum when the return on savings equates the growth rate of the economy (zero here). Net public debt issuance is zero at each date at this optimal unit interest rate.

2.3 Monetary easing

Suppose now that one cohort of households — the one born at date 0, say — do not have the same preferences as that of their predecessors and successors. Unlike the other cohorts, they value the consumption of one unit of output at date 1 as much as that of $1/\rho$ units of numéraire, where $\rho \in (0, 1)$ is such that $f'(y) < \rho$.[5]

Flexible prices

When the output price is flexible, the steady-state unit interest rate is still optimal at all dates in the presence of such time-varying preferences. The date-1 market-clearing price of the output (in terms of the numéraire good) is $1/\rho$, whereas it remains equal to one at every other date. At this date-1 price, the steady-state unit interest rate leads to a date-0 corporate borrowing I_0

[5]Note that whether this shock and the associated policy response are anticipated or not by the predecessors of the date-0 cohort is immaterial because this does not affect their investment decisions given the assumed environment.

such that

$$\frac{f'(I_0)}{\rho} = 1, \tag{6}$$

that exceeds the level I^* prevailing at other dates. The objective of the public sector is reached at this unit rate because production is efficient at each date.

Redistributive implications of the preference shock

The exceptionally high date-0 productive investment level $I_0 > I^*$ has redistributive consequences across cohorts that are immaterial given the public sector's objective. At date 0, the public sector faces a bond payment of $y - I^*$ to the date-(-1) cohort but raises only $y - I_0$ from the date-0 cohort. It therefore must collect a lump sum tax $I_0 - I^*$ from old date-(-1) households.[6] At date 1, the public sector repays only $\rho(y - I_0)$ to the date-0 cohort whereas it collects $y - I^*$ from the date-1 cohort. Overall, the utility of the date-0 cohort is:

$$\begin{aligned} &\underbrace{\frac{f(I_0)}{\rho} - \rho I_0}_{\text{Entrepreneurs' profits}} + \underbrace{\rho(y - I_0)}_{\text{Public bonds return}} + \underbrace{\rho I_0}_{\text{Private bonds return}} + \underbrace{y - I^* - \rho(y - I_0)}_{\text{Date-1 public rebate}} \\ = &\underbrace{\frac{f(I_0)}{\rho} - I_0 + y}_{\text{Surplus created by the date-0 cohort}} + \underbrace{I_0 - I^*}_{\text{Subsidy from other cohorts}} . \end{aligned} \tag{7}$$

The subsidy from other cohorts $I_0 - I^*$ matches the tax paid by the date-(-1) cohort at date 0.

[6] Recall our convention that households are taxed when old only.

Nominal rigidities and optimal monetary policy

We now create room for active monetary policy at date 0 by introducing nominal rigidities:

Assumption. ***(Sluggish output price)*** *The output price remains constant at all dates at its steady-state level of one.*

In other words, we suppose that the price system is too rigid to track the exceptional and transitory preference shock that hits the date-0 cohort.[7] With sticky output price, the public sector can make up for the absence of appropriate price signals in the date-1 output market by distorting the date-0 capital market. Monetary easing in the form of an interest rate equal to ρ between dates 0 and 1 boosts date-0 productive investment to the optimal level I_0 because optimal date-0 investment by entrepreneurs then derives from the very same equation (6). The only difference with the case of flexible prices is that date-0 entrepreneurs' profit is reduced to $f(I_0) - \rho I_0$ because the consumers of their output extract a surplus $(1/\rho)f(I_0) - f(I_0)$ given the unit output price.

Proposition 1. ***(Monetary easing)*** *Setting the interest rate at ρ at date 0 and at one at other dates implements the flexible-price outputs and is therefore optimal.*

Proof. See discussion above. ■

This very stylized model of monetary easing shares with the New-Keynesian framework the broad view that monetary policy serves to mitigate welfare

[7]We could also assume a partial price adjustment without affecting the analysis.

losses due to the relative price distortions induced by nominal rigidities (see, e.g., chapter 4 in Galí, 2015). In our setup, however, the important price distortion occurs between sectors of varying interest-rate sensitivities. We naturally interpret the entrepreneurs as representing the most interest-sensitive (non-financial) sectors of the economy, such as construction and other durable goods manufacturers. Accordingly, the date-0 preference shock captures in a fixed-price environment the idea that durables would be relatively more affected in a deflationary environment, as seems to be empirically the case.[8]

3 Monetary policy and financial instability

We now introduce a financial sector in this economy. The financial sector is comprised of two types of agents, banks and long-term investors. Both banks and LT investors find only the numéraire good desirable. They are risk-neutral over consumption at each date. They discount future consumption using the same discount factor as that of the public sector. (Recall this discount factor is arbitrarily close to 1). Banks and LT investors play the following respective roles in the economy.

Banks. We shut down the corporate-bond market and suppose instead that the financing of entrepreneurs by savers must be intermediated by banks. To fix ideas, we suppose that savers are competitive in the market for deposits—one-period risk-free bonds issued by banks, and that banks are competitive in the market for loans—one-period risk-free bonds issued

[8]See Klenow and Malin (2011) for the empirical link between durability and price flexibility. In fact, we could equivalently assume time-invariant preferences and an exogenous date-0 drop in the output price.

by entrepreneurs. Savers still have direct access to government bonds. Following Diamond (1997), we model liquidity risk for banks as a simple form of market incompleteness. We suppose that each bank has access to capital markets with probability $1 - q$ only at each date, where $q \in (0, 1)$. Penalties from defaulting on deposits are so large that banks never find it optimal to do so.

LT investors. At date 0, LT investors hold claims to an asset that pays off A at a random future date with arrival probability $p \in (0, 1)$.[9] All or part of the asset can also be liquidated before this accrual date at a linear cost: It is possible to generate cash at the current date at the cost of giving up $1 + \lambda$ units at the accrual date for each currently generated unit, where $\lambda \geq 0$. LT investors cannot trade directly with households but can do so with banks.

Finally, we suppose that exclusions from markets are not perfectly correlated across banks, and that the exclusion dates are independent from the asset's payoff date.

The model studied in Section 2 can be viewed as the particular case in which $A = 0$ so that LT investors are immaterial. In this case, banks cannot remunerate deposits below the return on public bonds and entrepreneurs cannot borrow below the deposit rate. Banks' assets and liabilities therefore all earn the policy rate at all dates, banks make zero profit and are immaterial.

[9]This specification of a payoff date arriving at a constant rate is meant to obtain a simple time-homogeneous problem. All that matters is that the asset is long term ($p < 1$). We could also introduce heterogeneous assets of varying maturities without gaining significant insights.

3.1 Inefficient carry trades

The financial sector becomes relevant when $A > 0$. We focus on the most interesting case in which

$$A \geq y. \tag{8}$$

In this case, monetary easing at date 0 in the form of a policy rate equal to ρ between dates 0 and 1 opens up potential gains from trade between banks and LT investors. Banks have access to funds at a lower cost than the financial sector's discount factor, and LT investors own claims to future consumption against which it is possible to borrow. Thus banks can enter into profitable carry trades by buying assets from LT investors, financing their acquisitions by rolling over short-term debt until the accrual date at which the trade is unwound. To fix ideas, we suppose that banks extract all the gains from such trades with LT investors. Our results rely only on the fact that they extract at least some of these gains. Note that this assumption that LT assets trade in a buyer's market is consistent with condition (8) which states that there is little money chasing many assets.

Such carry trades involve risky maturity transformation. If a bank is excluded from markets before the asset pays off, then it must liquidate its LT assets in order to honor outstanding deposits. This illiquidity risk reduces the appeal of carry trades.[10]

Formally, suppose that a bank finances the purchase of a claim to a unit

[10]For simplicity, we suppose that banks have a sufficient initial endowment in assets identical to the ones they purchased from LT investors that they can always generate enough cash from early liquidation when cut from markets.

payoff from LT investors with the issuance of a unit deposit at date 0. The expected value of the associated liability is then:

$$\rho \sum_{k \geq 1} (1-q)^{k-1}(1-p)^{k-1}[p + (1-p)q(1+\lambda)] = \rho(1+\Lambda), \tag{9}$$

where

$$\Lambda = \frac{\lambda}{1 + \frac{p}{(1-p)q}}. \tag{10}$$

Expression (9) states that the bank rolls over the unit deposit until the first of two events occurs: the accrual date or an exclusion date. The latter event entails early liquidation of LT assets.

The parameter Λ defined in (10) is increasing in λ, $1-p$, and q. It thus measures the overall magnitude of the transformation risk induced by carry trades.

If $\rho(1+\Lambda) \geq 1$, then the carry trade is not profitable. LT investors hold on to their assets, and banks intermediate between savers and entrepreneurs the optimal investment I_0 at date 0 making zero profit.

Conversely, if $\rho(1+\Lambda) < 1$, then banks have two valuable alternative uses of deposits. They may either lend to entrepreneurs, or engage in carry trades. The marginal return on carry trades is one minus the expected cost of failure to roll over $\rho\Lambda$. In equilibrium, the marginal return on loans to entrepreneurs must equate it. This implies that banks attract the entire date-0 savers' income y and split their investments into an aggregate lending to entrepreneurs I^{**} and a carry trade of size $y - I^{**}$, where I^{**} is the entrepreneurs' demand for funds when the cost of funds is $1 - \rho\Lambda$:

$$f'(I^{**}) = 1 - \rho\Lambda. \tag{11}$$

Note that banks, unless excluded from markets, have enough funds to both lend I^* to entrepreneurs and refinance the carry trade $y - I^{**}$ at all $t \geq 1$.[11]

The following proposition summarizes these results.

Proposition 2. ***(Monetary easing and inefficient carry trades)*** *If $\rho(1+\Lambda) \geq 1$, then banks do not enter into carry trades at date 0. They make zero profit and channel I_0 towards entrepreneurs at date 0.*

Otherwise, entrepreneurs invest only I^{**} such that $I^* < I^{**} < I_0$. Banks use the residual date-0 savings $y - I^{**}$ to enter into carry trades at date 0, where $f'(I^{**}) = 1 - \rho\Lambda$. In particular, the public sector has no resources at date 0.

Proof. See discussion above. ■

This setup captures the idea that imposing an unusually low interest rate creates room for socially inefficient carry trades. Carry trades are socially inefficient for two reasons: they create financial instability and they crowd out productive investment.

- *Financial instability.* The return on carry trade $1 - \rho(1 + \Lambda)$ can be decomposed in two parts, a "carry" $1 - \rho$ and an expected cost of financial distress $-\rho\Lambda$. The carry is a wash for social surplus as it is only a transfer from households to banks via the diversion of govern-

[11] This stems from $\rho(y - I^{**}) < y - I^*$ since $I^{**} > I^*$.

ment surplus.[12] On the other hand, the expected cost of the liquidity crises created down the road by maturity transformation is a social deadweight loss. In other words, banks extract rents at the social cost of financial instability.

- *Crowding out of productive investment.* The additional social cost of carry trades is that carry-trade returns raise the hurdle rate for loans to entrepreneurs, thereby leading to a suboptimally low level of productive investment. Note that this second source of inefficiency prevails only if the wealth to income ratio A/y of the economy is sufficiently large, as is the case under condition (8), so that the marginal deposit has two alternative uses in equilibrium, either carry trades or loans to entrepreneurs. A sufficiently small supply of assets against which banks find it profitable to rollover deposits would imply that the hurdle rate on loans would be ρ.

3.2 Model Interpretation and Implications

Interpretation of $A \geq y$

We interpret condition (8) as essentially stating that maturity/liquidity transformation by the banking system—short-term borrowing against long-term cash assets—is not constrained by prudential regulation. The public sector could in principle control carry-trade activity by banks by means of appropriate prudential rules. Assuming away such a binding regulation in the United States is in line with the existence of a shadow banking system prior

[12]Absent carry trades, the government rebates the carry $1-\rho$ to current old households.

to 2007 that was larger than the traditional banking system, and that was not subject to such rules. In line with our theory, the shadow banking system in the presence of stricter macro-prudential regulation since 2007 has sharply contracted, but the carry trades appear to have moved over to asset management industry flows into junk bonds and collateralized leveraged loans (Stein, 2014), and emerging market government and corporate bonds (Feroli et al. 2014). IMF GFSR (2016) documents that the presence of such a "risk-taking channel" in the non-bank finance (insurance companies, pension funds, and asset managers) to low rates implies that monetary policy remains potent in affecting economic outcomes – we argue, in potentially unintended and harmful ways – even when banks face strict macroeconomic regulation.

Crowding out by "carry trades": Empirical evidence

Our setup predicts several of the stylized facts described in the introduction (Furman, 2015, 2016):

(1) Suppose that p is large and q small, other things being equal, i.e., the long-term assets are relatively safe and face low rollover risk. Then $1 - \rho\Lambda$ is large and crowding out is important: There is limited real investment by entrepreneurs and the marginal return to real sector capital is high in equilibrium.

(2) It is likely that the refinanced asset pays off before a liquidity crisis (in which many banks become excluded from trading and get distressed). At this payoff date, the carry accrues to banks: The return on shareholder capital is high due to high payouts but carries the rollover risk.[13]

[13] An alternative interpretation of this payout is in the form of issuance of bonds by

Note that if banks and LT investors were splitting the surplus from carry trades, then payouts by banks would be smaller but there would be an initial boom in asset prices from LT assets at date 0. Alternatively, the LT assets can be interpreted as foreign assets chased by international capital flows searching for yield (Feroli et al. 2014).

Malinvestment

The mechanism that leads inefficient carry trades to arise and crowd out investment closely relates to the old notion of "malinvestment that is prominent in Austrian economics (Hayek, 1931, and von Mises, 1949, for example). The distortion of the real interest rate due to monetary easing may subsidize activities that are not socially desirable, e.g., excessive lending to the housing sector, but become privately profitable for banks due to the (socially inefficient) maturity transformation they offer, at the expense of more desirable investments such as loans to the real sector. Whereas rent extraction through inefficient maturity transformation or carry trades are a particularly relevant and topical form of "malinvestment," this distortion can and does take other forms such as zombie lending by banks which we discuss next.

Zombie lending

Inefficient speculation is not the only unintended consequence of monetary easing that observers have pointed out in recent crises. In some contexts,

corporations to engage in shareholder buy-backs without undertaking significant real investment. In other words, corporations can themselves engage in "carry trades" by tapping into bond markets, a financial "arbitrage" of sorts that creates value for shareholders on its own.

such as Japan in the 1990s following monetary easing by the Bank of Japan (Caballero, Hoshi and Kashyap, 2008, and Gianetti and Simonov, 2013), or Italy and Spain after European Central Bank's unconventional monetary policy actions in 2012 (Acharya, Eisert, Eufinger and Hirsch, 2015), the main concern has rather been that of zombie lending—the refinancing of highly distressed borrowers in order to defer credit losses at the risk of amplifying them down the road. It is straightforward to introduce this unintended consequence of monetary easing in our setup. Suppose for example that banks have legacy non-performing loans that can be either liquidated at date 0 or refinanced for one additional period, which creates an additional loss δ at date 1 for each dollar of refinancing. In other words, zombie lending is a storage technology with return $1 - \delta$. Investing deposits in this technology becomes appealing if the date-0 policy rate is lower than $1 - \delta$. This creates deadweight losses and crowding out of productive investment very much in the same way as in the case of maturity transformation or carry trades.

Redistributive implications of carry trades

Recall that, absent carry trades ($\rho(1+\Lambda) \geq 1$), monetary easing entails that the date-0 cohort receives a subsidy $I_0 - I^*$ that is paid by the date-(-1) cohort when old at date 0. In the presence of carry trades, the date-(-1) cohort pays a larger tax $y - I^*$ to the public sector at date 0 because all fresh resources y are directed towards banks at this date. The public sector must essentially default on this cohort, which in this setting takes the form of a lump sum tax equal to the repayment owed. The counterpart of this tax is an equivalent public surplus paid to the date-0 cohort at date 1 since the government receives funds from young households and owes nothing to old households at this date 1. In addition, banks extract (at the cost of liquidity risk) a carry $(1-\rho)(y-I^{**})$. In sum, carry trades increase the loss to old households at date 0 at the benefit of banks.[14]

Interbank market

The assumption that banks lose all access to funds when excluded from the market simplifies the analysis but is rather strong. We could alternatively assume that banks may randomly lose direct access to retail deposits, but that they could still gain indirect access to funding via other banks in an interbank market, albeit at some cost. This way, banks would be able to insure each other against liquidity risk. Because this risk is the only force that reduces their incentives to enter into carry trades, the crowding-out effect of carry trades would be even stronger under this milder assumption. More generally, since intermediaries internalize the rollover risk of carry trades in our models, long-term assets with greater safety and liquidity such as government bonds, collateralized assets, and other fixed-income securities, become more attractive havens for carry trades, and the more liquid these assets are, the greater is the ex-ante crowding out of real investment.

3.3 Optimal monetary policy

Section 3.1 studied the situation in which the public sector naively sets the date-0 policy rate at the level ρ that is optimal absent opportunistic behavior

[14]These redistributive effects do crucially hinge on the assumption that only old households are taxed.

by the financial sector. We now characterize the optimal date-0 policy rate in the presence of such behavior. It is obviously equal to ρ when carry trades are not profitable because $\rho(1+\Lambda) \geq 1$.

Consider now the interesting case in which $\rho(1+\Lambda) < 1$. The date-0 investment in the productive technology I is not monotonic in the date-0 interest rate r set by the public sector (see Figure 1 for an illustration). For $r \in (1/(1+\Lambda), +\infty)$, the private sector does not enter into carry trades and I is a decreasing function of r given by

$$f'(I) = r. \tag{12}$$

Otherwise, there is carry-trade activity and I is an increasing function of r implicitly defined by

$$f'(I) = 1 - r\Lambda, \tag{13}$$

because a higher interest rate makes carry trades less attractive relative to productive investment. Thus the optimal rate set by the public sector is $1/(1+\Lambda) > \rho$, because it yields the highest possible level of investment in the productive technology, which is still lower than the first-best level. To sum up,

Proposition 3. ***(Optimal interest rate)*** *If* $\rho(1+\Lambda) \geq 1$*, then the optimal policy rate is* ρ *which implements the first-best date-0 investment level.*

Otherwise, the optimal policy rate is $1/(1+\Lambda)$*, leading to a smaller second-best level of date-0 productive investment. At a rate lower than this optimal rate, socially inefficient carry trades crowd out productive investment leading*

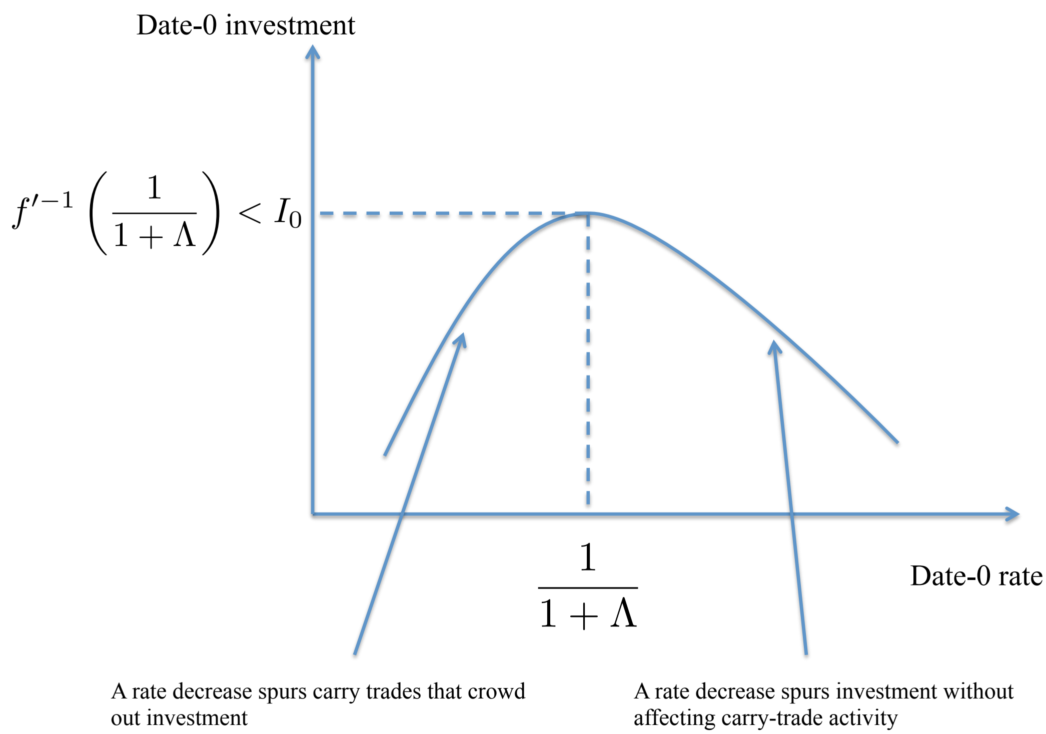

Figure 1: Entrepreneurial investment is not monotonic in the policy rate.

to an even lower investment level at date 0.

Proof. See discussion above. ■

4 Endogenous liquidity and optimal lending of last resort

Finally, we endogenize the cost $1+\lambda$ that banks incur when forced to liquidate the LT asset. We suppose that this cost is determined by the public sector acting as lender of last resort: It is the rate at which the public sector is willing to lend against these LT assets.

Formally, the public sector now sets two interest rates. The first one, the only rate that we considered thus far, is the interest rate at which claims to future public surpluses trade at date 0. We deem it the "policy" rate, now denoted r_P.[15] The second one is the rate at which the public sector is willing to lend against LT assets, and we deem it the "lending-of-last-resort (LOLR)" rate, denoted r_L. These two rates are a stylized summary of monetary policies that consist in controlling both short-term nominal rates and the conditions under which each asset class is admissible collateral for the central bank.

Absent any commitment problem nor any other ingredient in the model, the public sector would easily implement the first-best by committing to $r_P = \rho$, and to a sufficiently high LOLR rate r_L that discourages carry trades in the first place.[16] Since banks use public refinancing only for the socially bad reason that they have entered into carry trades, such a high LOLR rate would come at no cost in equilibrium. We now consider a more interesting situation in which banks also have socially good reasons to resort to public refinancing, so that the public sector faces a trade-off when determining the liquidity of LT assets through its LOLR policy.

4.1 Optimal lending of last resort

We now suppose that, from date 1 on, banks may receive a profitable opportunity to lend against LT assets. The arrival rate of this opportunity is σ

[15]The policy rate is optimally set to 1 at all dates other than 0.
[16]The LOLR rate must satisfy $\rho[1 + (r_L - 1)/(1 + pq/1 - p)] \geq 1$.

(strictly) before the LT asset pays off, and 0 afterwards. This opportunity requires an investment l and generates a payoff $l+d$ at the date at which the LT asset pays off. There are several possible interpretations for this opportunity. First, it may be construed as the financing of a subset of LT investors against some of their assets if these agents have a preference shock and put a premium d/l on current consumption at the arrival date. Alternatively, it may be that a maintenance investment of l is required in order to avoid a reduction d in the LT asset's payoff. The public sector does not observe whether and when this opportunity arrives and thus cannot condition its policy on it.

For simplicity, we suppose in this section that

$$f(x) = \log x \tag{14}$$

and impose parameter restrictions:

$$\rho \left(\frac{l+d}{l} \right) < 1, \tag{15}$$

$$l \leq \frac{dy}{l+d}. \tag{16}$$

We will explain the respective roles of these restrictions in due course.

A trade-off now arises as a higher LOLR rate r_L makes a low date-0 policy rate r_P more conducive to entrepreneurial investment by discouraging carry trades, but may eliminate such socially desirable investment opportunities. This leads to the existence of two locally optimal policies (r_P, r_L):

Proposition 4. ***(Optimal policies)*** *There are two locally optimal policies*

(r_P, r_L). *First, an aggressive policy leads to optimal date-0 investment but comes at the cost of a strict LOLR policy that eliminates efficient subsequent lending. Formally, it consists in setting*

$$r_P = \rho, \tag{17}$$

$$r_L > 1 + \frac{1-\rho}{\rho}\left[1 + \frac{p}{(1-p)q}\right]. \tag{18}$$

The second one, more conservative, is such that

$$r_P = \frac{l}{l+d} > \rho, \tag{19}$$

$$r_L = 1 + \frac{d}{l}\left[1 + \frac{p}{(1-p)q}\right], \tag{20}$$

which leads to a suboptimal level of entrepreneurial investment at date 0 but maintains the socially desirable subsequent loans backed by the LT asset.

The former aggressive policy is preferable to the latter conservative one if and only if:

$$\log\left[\frac{\rho(l+d)}{l}\right] < \frac{\rho(l+d)}{l} - 1 - \frac{\rho\sigma(1-p)d}{\sigma(1-p)+p}. \tag{21}$$

Proof. The banks' subsequent lending opportunity has a private positive NPV if and only if

$$l + d \geq l\left[1 + \frac{r_L - 1}{1 + \frac{p}{(1-p)q}}\right]. \tag{22}$$

Condition (15) implies that if r_L satisfies this condition, then it is not possible to implement the investment level I_0 at date 0 because setting the policy rate at ρ would induce carry trades. There are therefore two local optima. The public sector may seek to reach entrepreneurial investment I_0 at date 0, in which case it must set $r_P = \rho$ and r_L sufficiently large to discourage carry trades (as given in (18)). Alternatively, the public sector may pick the lowest rate r_L at which banks invest l after date 1 whenever they have a chance, given by (20), which imposes r_P as given by (19) from Proposition 3. Condition (16) ensures that banks can raise enough funds from savers to finance this lending opportunity l when it occurs as well as the optimal unit loan to entrepreneurs.

Finally, (21) simply stems from noting that entrepreneurs invest $1/r_P$ when the date-0 policy rate is r_P and from re-arranging the condition:

$$\frac{\log\left(\frac{1}{\rho}\right)}{\rho} - \frac{1}{\rho} > \frac{\log\left(\frac{l+d}{l}\right)}{\rho} - \frac{l+d}{l} + \frac{\sigma(1-p)d}{\sigma(1-p)+p}. \tag{23}$$

■

4.2 Quantitative easing as a crowding-out strategy

The aggressive policy in Proposition 4 admits an alternative interpretation in terms of quantitative easing. Suppose that the public sector cannot commit to a LOLR rate other than, say, $r_L = 1$. The public sector can then purchase at date 0 a cash flow Q generated by the LT asset such that

$$Q \geq A + I_0 - y. \tag{24}$$

This eliminates the crowding out of entrepreneurial investment by carry trades by ensuring that the marginal entrepreneurial loan cannot be alternatively directed towards carry trades. The only remaining social cost of carry trades stems from the expected costs of financial distress for the carry trades that are backed by the assets left in the market. Note that if the public sector is unable to exploit the investment opportunity l available to the financial sector, then this public asset purchase comes at the same costs as that of a high LOLR rate that discourages such efficient investment.

Such a large-scale asset purchase can be financed either by taxation or by issuance of short-term debt. This latter arrangement closely matches, within our model, the one advocated by Greenwood, Hanson and Stein (2016), who argue that the central bank should "crowd out" the issuance of short-term debt by the financial sector by maintaining a large balance-sheet of government bonds funded by savers in the economy. Similarly, in our model, carry trades by the public sector crowd out carry trades by the private sector.

This rationale for QE has the interesting implication that large-scale asset purchases are most efficient when they withdraw assets that would lend themselves to carry trades from the market. In particular, QE strategies that consist in swapping assets, in particular illiquid or long-term ones for more liquid/shorter-lived ones, such as operations "twist" would be counterproductive here as they would raise the profitability of carry trades and thus lead to more crowding out of entrepreneurial investment.[17]

[17] Caballero and Farhi (2016) reach similar conclusions regarding the efficiency of asset swaps albeit for different reasons.

5 Concluding remarks

Our attempt in this paper has been to embed financial stability concerns in workhorse monetary policy models. In particular, we introduced the following tension in a monetary policy model with nominal rigidities: monetary easing, not only lowers the cost of capital for firms, but also subsidizes inefficient maturity transformation by financial intermediaries - "carry trades" that borrow cheap at the short-term against illiquid long-term assets. Optimal monetary policy trades off any stimulative gains against the costs of carry trades from rollover risk faced by the financial sector from undertaking carry trades and the crowding out of real investments. The model helps understand the puzzle raised by Furman (2015, 2016) as to why low nominal rates have been associated with low investment and high marginal returns to real capital while generating at the same time high returns to shareholder capital.

There are many directions in which we could extend our analysis fruitfully. One, we assumed that long-term assets are held by long-term investors and financial intermediaries lend against these by borrowing short-term, capturing in the process some or all of the long-term assets' returns. In general, there may be sales of some of these assets to financial intermediaries as well as the creation of new such long-term assets. Endogenizing ex-ante asset prices of long-term assets when carry trades are profitable is a promising direction to develop a theory of asset-price inflation and bubble-burst patterns arising as a finacial-sector response to monetary easing.

Second, we could introduce uncertainty to real-sector output or to preference shocks over time whereby monetary easing may continue for several periods and then be tightened at the cost of unwinding of financial sector carry-trades. Carry trades would then potentially build up in the economy over an extended period of monetary easing and face abrupt rollover risk when rates rise. Adding such a feature to the model would allow us to relate in a better fashion to phenomena in asset markets and financial flows as observed during the "taper tantrum" in 2013 (Feroli et al. 2014).

Finally, our model relied on moral hazard induced by monetary easing as a way of generating carry trades in equilibrium. Implicitly, we assumed that the central bank cannot perfectly observe and rule out inefficient maturity transformation or carry trades by the (shadow-banking) financial sector. It is straightforward to consider an adverse-selection framework in which there are two types of financial intermediaries: one, that only lend to the productive real sector, and another, that has excess to the carry-trade technology. The model with adverse selection has outcomes that are almost isomorphic to the one with moral hazard: optimal monetary policy under adverse selection uses higher interest rates or tightening to screen out the second type of financial intermediaries by making carry trades unattractive.

References

Acharya, Viral V. 2015. "Financial Stability in the Broader Mandate for Central Banks: A Political Economy Perspective." Brookings' Hutchins Center Working Paper Series.

Acharya, Viral V., Tim Eisert, Christian Eufinger, and Christian Hirsch. 2015. "Whatever it Takes: The Real Effects of Unconventional Monetary Policy." Working Paper, NYU Stern School of Business.

Acharya, Viral V., and Hassan Naqvi. 2012a. "The Seeds of a Crisis: A Theory of Bank Liquidity and Risk Taking over the Business Cycle." *Journal of Financial Economics* 106 (2): 349–366.

Acharya, Viral V., and Hassan Naqvi. 2012b. "Bank Liquidity and Bubbles: Why Central Banks Should Lean against Liquidity." In *New Perspectives on Asset Price Bubbles: Theory, Evidence and Policy*, edited by Douglas Evanoff, George Kaufman and A.G. Malliaris. New York: Oxford University Press.

Caballero, Ricardo J. and Emmanuel Farhi. 2016. "The Safety Trap," Working Paper, Harvard University.

Caballero, Ricardo J., Takeo Hoshi and Anil K. Kashyap. 2008. "Zombie Lending and Depressed Restructuring in Japan." *American Economic Review* 98 (5): 1943–77.

Diamond, Douglas W. 1997. "Liquidity, Banks, and Markets." *Journal of Political Economy* 105 (5): 928–56.

Diamond, Douglas W., and Raghuram G. Rajan. 2012. "Illiquid Banks, Financial Stability, and Interest Rate Policy." *Journal of Political Economy* 120 (3): 552–591.

Farhi, Emmanuel, and Jean Tirole. 2012. "Collective Moral Hazard, Maturity Mismatch, and Systemic Bailouts." *American Economic Review* 102 (1): 60–93.

Feroli, Michael, Anil K. Kashyap, Kermit Schoenholtz, and Hyun Song Shin. 2014. "Market Tantrums and Monetary Policy." U.S. Monetary Policy Forum.

Furman, Jason. 2015. "Business Investment in the United States: Facts, Explanations, Puzzles, and Policies." Council of Economic Advisers. Remarks at the Progressive Policy Institute.

Furman, Jason. 2016. "Productivity, Inequality, and Economic Rents." http://www.regblog.org/2016/06/13/furman-productivity-inequality-and-economic-rents/.

Galí, Jordi. 2015. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications.* Princeton: Princeton University Press.

Giannetti, Mariassunta and Andrei Simonov. 2013. "On the Real Effects of Bank Bailouts: Micro Evidence from Japan." *American Economic Journal: Macroeconomics* 5 (1): 135–67.

Greenwood, Robin, Samuel G. Hanson, and Jeremy C. Stein. 2016. "The Federal Reserve's Balance Sheet as a Financial-Stability Tool." Paper presented at the *Designing Resilient Monetary Policy Frameworks for the Future* Federal Reserve Bank of Kansas City Symposium, Jackson Hole, WY.

Hayek, Friedrich A. 1931. *Prices and Production.* New York: Augustus M. Kelley Publishers.

International Monetary Fund. 2016. “Monetary Policy and the Rise of Nonbank Finance.” In *Global Financial Stability Report, October 2016.*

Klenow, Peter J. and Benjamin A. Malin. 2011. “Microeconomic Evidence on Price-Setting.” In *Handbook of Monetary Economics,* Volume 3A, edited by Benjamin M. Friedman and Michael Woodford, 231–84, Amsterdam: Elsevier Science.

Mises, Ludwig von. 1949. *Human Action: A Treatise on Economics,* Chapter XX, Section 8. New Haven: Yale University Press.

Rajan, Raghuram G. 2013. “A Step in the Dark: Unconventional Monetary Policy after the Crisis.” Andrew Crockett Memorial Lecture, Bank for International Settlements.

Stein, Jeremy C. 2012. “Monetary Policy as Financial-Stability Regulation.” *Quarterly Journal of Economics* 127 (1): 57–95.

Stein, Jeremy C. 2014. Comments on Feroli, Michael, Anil K. Kashyap, Kermit Schoenholtz, and Hyun Song Shin, “Market Tantrums and Monetary Policy.” U.S. Monetary Policy Forum.