Monetary Easing and Financial Instability*

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Abstract

We study optimal monetary policy in the presence of financial stability concerns. We build a model in which monetary easing can lower the cost of capital for firms and restore the natural level of investment, but does also subsidize inefficient maturity transformation by financial intermediaries in the form of "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, 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 the unprecedented post-2008 monetary easing has been associated with below-trend real investment, even while returns to real and financial capital have been historically high.

Keywords: Monetary policy, quantitative easing, financial stability, financial fragility, shadow banking, maturity transformation, carry trades

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"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.[1]

[1] This lowering of the cost of capital can arise, for instance, due to a reduction in the liquidity premium in markets, that in turn, enables cheaper leveraged financing of investments (Drechsler et al. 2016). Increase in investment can also arise because a lower real rate mitigates agency-driven financial constraints (Farhi and Tirole, 2012).

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 sharp asset-price inflation in certain risky asset classes (e.g., high-yield corporate bonds, emerging-market debt and equities) that did not induce significant real investments by the issuing entities.[2] 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 on 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

[2] 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."

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 transformation 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.[3] 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

[3]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). IMF (2014) documents that the composition of flows tilted from the pre-2009 50:50 between developed and emerging markets to post-2008 80:20 in favor of emerging markets. However, the net monthly outflow during June-Aug 2013 after the taper announcement represented a three to six standard deviation shock for the emerging markets.

with the up-lift.

When monetary easing is sufficiently aggressive that it generates excess returns on carry trades despite such transformation risk, financial intermediaries allocate economy's savings away from real investment into carry trades until the marginal return on investment rises to compensate for the opportunity cost of the carry. In other words, low interest rates induce carry trades that crowd out real-sector 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).

Furthermore, monetary easing translates into lower rates for corporate borrowing until it is sufficiently aggressive that carry trades become profitable. At interest rates below a critical rate, the transmission channel of monetary policy breaks down; in fact, as carry trade returns increase with further easing, a lower interest rate leads to a *higher* corporate cost of borrowing, an important manifestation of the crowding-out effect.

Model

We capture these economic insights in a simple and tractable model that integrates the standard rationale for monetary easing with the financial instability risk and crowding-out of real investment that arise from carry trades.

Our modelling strategy is as follows. In the workhorse new Keynesian model, optimal monetary policy reaches two simultaneous goals, anchoring inflation expectations and setting the real interest rate at the natural level that would prevail under flexible prices. Adding the possibility of inefficient carry trades discussed above in this workhorse model raises significant modelling challenges. This requires the introduction of assets of varying maturity and liquidity, heterogeneous agents (so that carry traders find counterparts), and imperfect liquidity in financial markets.

Our strategy is to introduce these ingredients in a simple model of optimal monetary policy that focusses on the steering of the real rate by the central bank while abstracting from price-level determination. Following Benmelech and Bergman (2012) or Farhi and Tirole (2012), we simply assume that the public sector controls the real interest rate. We study an economy in which households find two goods desirable, a numéraire good and the output produced by an interest-sensitive sector. We suppose that goods prices are too rigid to track the evolution of households' marginal rate of substitution. In the case of temporary positive preference shocks for the output, monetary easing — by temporarily lowering the interest rate — spurs investment by the interest-sensitive sector and can restore the first-best allocation despite incorrect price signals.

This model of optimal monetary easing is sufficiently tractable that it lends itself to the addition of the ingredients needed to study financial instability risk. We proceed by supposing that financial intermediaries are in charge of collecting the short-term resources that fund productive investment by the interest-sensitive sector. These financial intermediaries can direct these resources towards an alternative use, however. They can buy outstanding long-term cash flows from long-term investors, rolling over short-term debt until these cash flows pay off. Maturity transformation in the form of such "carry trades" is privately beneficial 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. If, in addition, the supply of long-term assets is sufficiently large that financial intermediaries extract rents from carry trades, then this raises the opportunity cost of productive investment and crowds it out.

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 sufficiently that the return on carry trades no longer compensates for the associated rollover risk.[4] Interestingly and importantly, such a tightening not only discourages carry trades, but also spurs productive investment as this reduces the crowding-out effect.

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 optimal monetary easing. Section 3 introduces financial intermediaries and derives (i) the carry-trade incentives at the 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

[4]While our motivation focused on the more recent monetary easing, the financial instability risk we highlight has manifested itself 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 during the subprime crisis.

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 with that in recent related contributions. 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 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 not to "bailing out" short-term claims removes the market discipline, inducing excessive illiquidity-seeking by banks. They 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. In contrast to these papers, in our model the central bank faces no commitment problem; it finds low rates attractive up to a point for stimulating productive investment but lowering rates beyond triggers inefficient maturity transformation in the financial sector and crowds out productive real investment.

Acharya and Naqvi (2012a, b) develop 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. Easy monetary policy only exacerbates this problem. Stein (2012) explains that the prudential regulation of banks can partly rein in incentives to engage in maturity transformation that is socially suboptimal due to fire-sale externalities; however, there is always some unchecked growth of such activity in shadow banking and monetary policy that leans against the wind can be optimal as it raises the cost of borrowing in all "cracks" of the financial sector (this is indeed our model's insight too). The key difference between our model and these two papers is that excessive maturity transformation arises in our model not due to agency problems in the financial sector nor due to fire-sale externalities, but from excessive monetary easing aimed at stimulating aggregate output.[5] Brunnermeier and Koby (2016) show, like us, that monetary easing can lead to a contraction in lending. Whereas this stems from heightened incentives to finance inefficient speculation in our setup, this stems from eroded lending margins in an environment of imperfectly competitive banks in theirs.

As we set up the modeling ingredients and extensions in the paper, we relate our modeling of (i) the public sector controlling the real interest rate to recent papers making a similar assumption (e.g., Benmelech and Bergman 2012, or Farhi and Tirole 2012); and, (ii) the public sector's crowding out of carry trades and short-term deposits of the financial sector through asset purchases, as in Krishnamurthy and Vissing-Jorgensen (2015), Caballero and Farhi (2016), and Greenwood, Hansen and Stein (2016).

[5] 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.

Finally, the empirical literature supporting some of our model's implications and economic forces is discussed in Section 3.3.

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.[6]

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.

Relationship to new Keynesian models

This setup can be described as a much simplified version of a new Keynesian model in which money serves only as a unit of account ("cashless economy") and monetary policy consists in enforcing the short-term nominal interest rate. Such monetary policy has real effects in the presence of nominal rigidities. We entirely focus on these real effects, and fully abstract from price-level determination by assuming extreme nominal rigidities in the form of a fixed price level for one good that we therefore deem the numéraire good. This simple real model enables us to study inefficient speculation in Sections 3 and 4 in a tractable framework. In the online appendix, we sketch a nominal ver-

[6]Note also that restricting corporate securities to risk-free bonds is only to fix ideas. This comes at no loss of generality given that production is deterministic and entrepreneurs face no financial frictions.

sion of the model with endogenous price level. The public sector determines both the price level using an interest-feedback rule, and the real interest rate using an appropriate mix of open-market operations and taxes similar to that described above.

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.

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

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

maximized at

$$f'(I^*) = r^* = 1. \qquad (5)$$

In this elementary environment, condition (5) rephrases the standard "golden rule" according to which steady-state consumption is maximum when the return on capital 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 $f'(y) < \rho$.[7] We first check that, unsurprisingly, this preference shock does not affect the optimal policy rate when the output price is flexible. We

[7]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.

then introduce price rigidity.

Flexible price benchmark

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 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.

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.[8] 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

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

cohort is:

$$\underbrace{\frac{f(I_0)}{\rho} - \rho I_0}_{\text{Entrepreneurs' profits}} + \underbrace{\rho(y - I_0)}_{\text{Public bonds return}} + \underbrace{\rho I_0}_{\text{Private bonds return}} + \underbrace{y - I^* - \rho(y - I_0)}_{\text{Date-1 public rebate}}$$

$$= \underbrace{\frac{f(I_0)}{\rho} - I_0 + y}_{\text{Surplus created by the date-0 cohort}} + \underbrace{I_0 - I^*}_{\text{Subsidy from other cohorts}} . \quad (7)$$

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

Nominal rigidities and optimal monetary policy

We now create room for monetary easing at date 0 by introducing price 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.[9] 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. Suppose to fix ideas that savers have absolute priority over entrepreneurs when the output good is rationed, and that y is sufficiently large that they consume the entire output.[10] 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

[9] We could also assume a partial price adjustment without affecting the analysis.
[10] Alternative rationing rules would not qualitatively affect the analysis.

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. ■

More on the relationship to new Keynesian models

In the workhorse new Keynesian framework, monetary policy serves both to pin down inflation and to set the real interest rate at the "natural" level that would prevail under flexible prices. Whereas we abstract from price-level determination, monetary policy in our framework plays the very same latter role of mitigating distortions induced by nominal rigidities. In our setup in which agents consume at one date only, there is no such thing as a natural intertemporal rate of substitution, and monetary policy tracks instead its equivalent here, the natural marginal rate of substitution between the output and the numéraire good.

The preference shock $\rho < 1$ at date 0 introduces a simple motive for monetary easing, equivalent to the exogenous temporary increase in households' desire to save introduced in the new Keynesian models that study deflation risk (see, e.g., Eggertsson and Woodford 2003, or Wiederholt 2015). For a concrete interpretation of this shock, one can view the entrepreneurs as representing the most interest-sensitive 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 durable prices would be relatively more affected in a deflationary episode and thus relatively more mispriced, as seems to be empirically the case (see Klenow and Malin 2011).

It is worthwhile stressing that nominal rigidities in our model create mispricing and market disequilibrium that are very short-lived: They last for one date only (date 1). We show in the following section that the corresponding monetary response can be conducive to financial instability for several periods down the road. This occurs if the public sector does not control the amount of maturity transformation implemented by the financial sector.

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 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 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 can participate in 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 $A \geq 0$ at a random future date with arrival probability $p \in (0, 1)$.[11] 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. These long-term claims held by LT investors could be modelled as long-term public debt issued in the past, as rents paid by entrepreneurs to use a fixed factor of production owned by LT investors (e.g., land), or as rents that would be paid by the producers of the numéraire good if we were explicitly modelling its production. The nature of this claim is irrelevant. All that matters is that LT investors hold a long-term claim to consumption.

Finally, we suppose that banks' 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

[11] 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.

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.

3.1 Inefficient carry trades

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

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

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 asset pays off and the trade is unwound. 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.

Condition (8) describes an economy in which the pool of LT assets that can be refinanced by rolling over short-term debt this way is very large. As detailed in Section 3.3, we find this condition to be consistent with the fact that maturity and liquidity transformation are now pervasive in the financial system, and performed by many institutions that are not subject to prudential regulation.

To fix ideas, we suppose that banks extract all the gains from such carry trades with LT investors: A long-term claim to one unit of future consumption trades at a price of one between banks and LT investors at date 0. This is only for expositional simplicity. As detailed in Section 3.2, our results rely only on the assumption that banks extract at least some surplus from carry trades.[12] Note that this assumption that LT assets trade in a buyer's market is consistent with condition (8) which implies that there is excess supply in the market for LT assets.

Formally, suppose that a bank finances the purchase of a claim to a unit 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.[13]

[12] Also, the online appendix discusses more general surplus sharing between banks and LT investors.

[13] For simplicity, we suppose that banks have an initial endowment in LT assets against which they do not find desirable to borrow but that they can liquidate together with

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 $1 - \rho\Lambda$:

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

In other words, banks earn a fixed return of $1 - \rho\Lambda$ on carry trades when borrowing at the rate ρ; thus, they lend to entrepreneurs at the same rate $1 - \rho\Lambda$, that pins down the demand of capital by the entrepreneurs. 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 $t \geq 1$.[14]

The following proposition summarizes these results.

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the assets bought from LT investors when excluded from markets. This way they never default.

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

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 government surplus.[15] 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 produc-

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

tive 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 Robustness

Alternative surplus-sharing rules

Three simple assumptions about the sharing of gains from trade between the different types of agents ease the exposition: i) savers are kept at their reservation utility by banks in the deposit market; ii) LT investors are kept at their reservation utility by banks in the market for LT assets; and iii) banks are kept at their reservation utility by entrepreneurs in the loan market. All that is needed to obtain our qualitative results—in particular, the crowding out of productive investment by carry trades—is much more parsimonious, however. *It suffices that banks or/and date-*0 *depositors extract some surplus from carry trades.* As soon as banks extract some surplus, then this raises their opportunity cost of loans to entrepreneurs, thereby reducing lending activity as shown above. If competition for deposits leads banks to raise deposit rates up to the point at which they pass on all their surplus from carry trades to depositors, then there is still crowding out: The higher hurdle rate on loans stems in this case from the higher deposit rates.

Again, this important assumption that LT investors do not achieve full surplus extraction from carry trades is in line with the assumption that there are many LT assets up for sale relative to date-0 investable funds.

Liquidity risk management in an 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.

LT investors can invest

We could assume that in addition to holding LT assets, LT investors have access to efficient investment opportunities similar to that of entrepreneurs. This would not affect the analysis. Again, as long as banks or/and depositors earn some surplus from carry trades, then carry trades would crowd out these efficient investments as well.

3.3 Interpretation and Implications

Interpretation of $A \geq y$: Shadow Banking

We interpret condition (8) as essentially stating that maturity/liquidity transformation by the financial system—short-term borrowing against long-term assets—is not constrained by prudential regulation, i.e., a large quantity of long-term assets (in the global economy) can be potentially funded with short-term claims (of a given economy). 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 gradual evolution of an important shadow banking system that by 2007 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 (i) junk bonds and collateralized leveraged loans (Stein, 2014), (ii) emerging market government and corporate bonds (Feroli et al. 2014 and IMF, 2014), facilitating implicitly carry trades by these governments and corporations (Bruno and Shin, 2014, and Acharya and Vij, 2016); and, (iii) funding of residential mortgage-backed assets by real estate investment trusts (REITs) using short-term repo (sale and repurchase agreements), as discussed in Stein (2013). 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) 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"

Our setup predicts several of the stylized facts described in the introduction (Furman, 2015, 2016). Suppose that p is large and q small, other things being equal, i.e., carry trades face low rollover risk. Then $1 - \rho\Lambda$ is large and crowding out is important:

(1) 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.[16]

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.

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).

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

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, 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.[17]

3.4 Optimal monetary policy

We thus far 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 by the financial sector. We now study optimal monetary policy in the presence of such behavior. Note first that it is clearly optimal to maintain the policy rate $r^* = 1$ at all dates other than 0. Any attempt at affecting date-0 carry-trades incentives by committing to different rates at dates $t \geq 1$ distorts investment at these dates. It is therefore strictly more efficient to affect carry-trade incentives with the date-0 rate only. The public sector thus faces a static problem and its ability to commit is immaterial.

We characterize the optimal date-0 policy rate. 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

[17]Indeed, Acharya, Eisert, Eufinger and Hirsch (2015) document a rise in borrowing costs for non-zombie firms in Italy and Spain since 2012.

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 to an even lower investment level at date 0.*

Proof. See discussion above. ■

Lack of transmission of monetary policy

An important manifestation of the crowding-out effect of carry trades highlighted in Figure 1 is that once interest rate is low enough for their returns to be profitable ($r < 1/(1+\Lambda)$), the transmission of monetary policy to the real sector breaks down. Not only do further reductions in interest rates not get passed onto as lower corporate lending rates by the financial sector, in fact the lending rates rise with such reductions as the carry trade returns increase and intermediaries equate the marginal lending rate to these returns.

An interesting corollary is that optimal interest rate in the carry-trade region (second case of Proposition 3) is one up to which monetary easing is transmitted one for one to the corporate lending rates and below which transmission reverses (or more generally, becomes weaker). The optimal interest rate is also the one below which there would be a growth in shadow banking, i.e., a surge in the creation of private money by intermediaries in the form of short-term deposit-like claims (crowding out public money) to engage in maturity transformation in unregulated or weakly regulated parts of the financial sector. If undertaken on traditional banking balance-sheets, then the optimal interest rate is the one below which banking sector growth is driven by non-traditional banking: growth in carry trades at the expense of real-sector lending.

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 public bonds trade. We deem it the "policy" rate, now denoted r_P.[18] The second one

[18] It is easy to see that it is still optimal to set this policy rate to 1 at all dates other than 0.

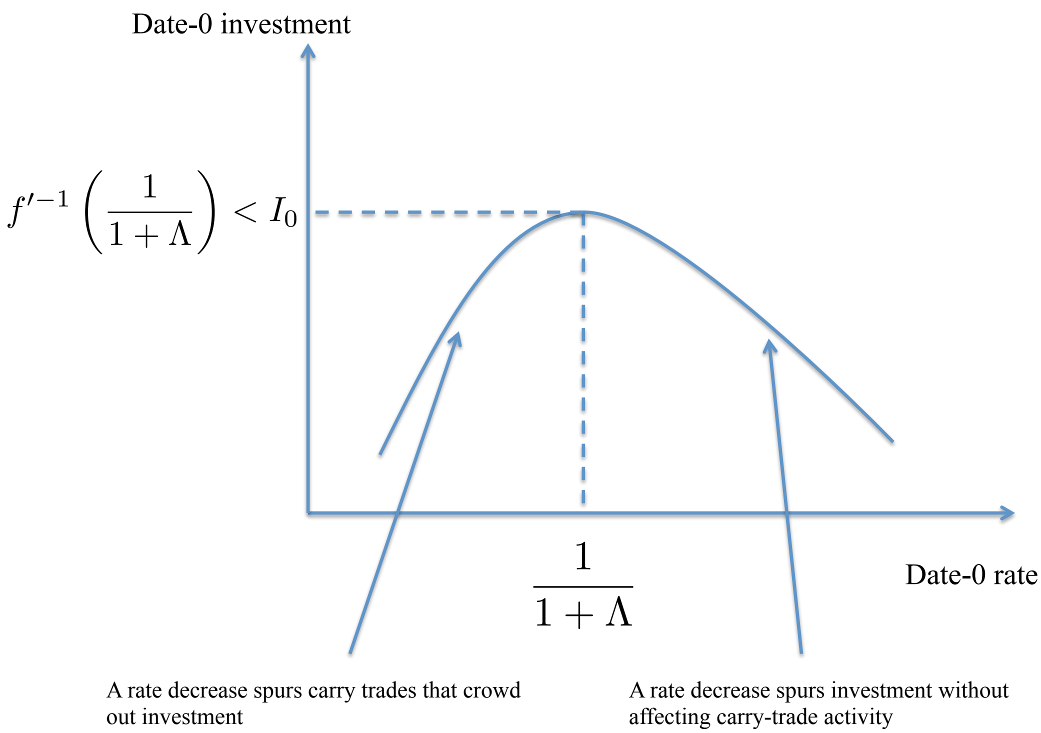

Figure 1: Entrepreneurial investment is not monotonic in the policy rate.

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.

Unlike in Section 3.4, the public sector now faces an intertemporal problem. We suppose that it can fully commit to a policy (r_P, r_L).

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.[19] 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 (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

[19] The LOLR rate must satisfy $\rho[1 + (r_L - 1)/(1 + pq/1 - p)] \geq 1$.

against some of their assets if these agents have a preference shock and put a premium d/l on current consumption at the date of the shock. 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 ex-post 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:

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

Condition (21) shows that the aggressive policy is globally optimal when $\rho\sigma(1-p)d/[\sigma(1-p)+p]$ is sufficiently small holding $\rho(l+d)/l)$ constant . This is so when σ or/and $1-p$ are sufficiently small other things being equal, or, when the ex-ante cost of an ex-post inefficient LOLR policy is sufficiently small.

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.

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. In Krishnamurthy and Vissing-Jorgensen (2015) too, private money and public money are substitutes: short-term debt issuance by the financial sector to meet the demand for safe assets by households renders them fragile, which is not the case if this demand is met by public debt issuance. Similarly, in our model, carry trades by the public sector crowd out carry trades by the private sector and can be desirable from a financial stability standpoint.

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.[20] This implication is consistent with the findings of Krishnamurthy and Vissing-Jorgensen (2011) that Federal Reserve actions to purchase mortgage-backed securities (MBS) from markets had a more favorable market reaction than operations "twist." Consistently, Darmouni and Rodnyansky (2016) document that while the Fed purchases of MBS resulted in a transmission to the real sector in the form of bank lending, operations "twist" did not.

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 undertak-

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

ing 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 financial-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 (opportunistic behavior) 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 financial sector. We could alternatively consider an adverse-selection framework in which there are two types of financial intermediaries: one, that only lends to the productive real sector, and another, that has excess to the carry-trade technology. We conjecture that this model with adverse selection would have implications broadly similar to the ones under 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.

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Online Appendix: Extensions

E.1 Sketch of a nominal model

We leave the entrepreneurs unchanged but now assume that savers consume both when young and old. The cohort of savers that is born at date t has quasi-linear preferences

$$u(c_t) + c_{t+1}, \tag{E.1}$$

where u is differentiable, strictly increasing and concave. Savers are endowed with L units of labor at birth that they supply inelastically when young to competitive firms that transform one unit of labor into one unit of the "numéraire" good (which no longer serves as numéraire). We suppose that savers value only the output produced by entrepreneurs of their own cohort, and so they do not seek to consume the output produced when they are young.

All agents use a common currency as unit of account. The public sector sets the nominal interest rate, issues one-period bonds, and taxes old households.

Steady-state

Suppose that prices are flexible. No-arbitrage then implies that the "numéraire" good and the output have the same price at all dates given that they are perfect substitutes, and that this price also corresponds to the wage.

We posit that the public sector seeks to achieve a constant rate of inflation that we normalize to 1. We denote r_{t+1} and i_{t+1} the respective real and nominal gross interest rates between t and $t+1$, and π_{t+1} the gross rate of inflation over this period. Under perfect coordination between fiscal and monetary policies, the public sector can attain a constant price level together with a given path of real rates $\{r_t\}_{t\in\mathbb{N}}$ by combining an interest-feedback rule, open-market operations, and taxes on old households as follows. The interest-rate rule is a standard Taylor rule:

$$i_{t+1} = r_{t+1}\pi_t^{\Phi}, \tag{E.2}$$

with $\Phi > 1$. Rule (E.2) together with the Euler equation $i_{t+1} = r_{t+1}\pi_{t+1}$ defines a linear difference equation for the logarithm of inflation that has a unique non-exploding solution equal to 0 at all dates.

The public sector then imposes a real rate r_{t+1} by issuing at date t a claim to $y_{t+1} - I_{t+1}$ due next date, where $\{y_{t+1}; I_{t+1}\}$ solves:

$$u'(L - y_{t+1}) = r_{t+1}, \tag{E.3}$$

$$f'(I_{t+1}) = r_{t+1}, \tag{E.4}$$

where we suppose that u is such that the solution to this system exists and satisfies $y_{t+1} > I_{t+1}$. At the prevailing rate r_{t+1}, savers save a total amount y_{t+1} at date t, lending I_{t+1} to date-t entrepreneurs and investing the residual in public bonds.

Finally, a lump-sum tax $r_t(y_t - I_t) - y_{t+1} + I_{t+1}$ on old households at date $t + 1$ balances the budget of the public sector.

It is straightforward to check that, as in the body of the paper, the optimal interest rate has the "golden-rule" value of one in the steady-state.

Whereas a full-fledged treatment of monetary easing and financial instability in this nominal model is beyond the scope of this appendix, we can offer the following sketch.

Monetary easing

We suppose that entrepreneurs born at date 0 experience pessimistic "animal spirits," and wrongly believe that the date-1 price level for their output will be $\rho < 1$. This is the only date-0 shock: Unlike in the body of the paper, we assume constant preferences. The two goods still remain perfect substitutes at date 1. Savers who set the price level through their Euler equation have correct expectations.

Keeping the price level at one, the public sector can target a real rate $r_1 < 1$ between dates 0 and 1 by issuing claims to date-1 consumption

$y' - I'$, where $\{y'; I'\}$ solves:

$$u'(L - y') = r_1, \tag{E.5}$$

$$\rho f'(I) = r_1. \tag{E.6}$$

The optimal rate r_1 depends then on the weight that the social welfare function puts on savers and entrepreneurs as it trades off productive efficiency ($r_1 = \rho$) and efficient consumption/savings decisions ($u' = 1$).

Monetary easing and financial instability

The introduction, as in the body of the paper, of banks and LT investors with a constant intertemporal rate of substitution raises the issue that it is unclear which Euler equation, theirs or that of the savers, pins down inflation. A full-fledged nominal model should address this. If one assumes that savers pin down inflation, then the condition under which monetary easing triggers carry trades is identical to that in the body of the paper ($1 - r_0(1 + \Lambda) < 1$). The only difference with the main model is that the public sector has an additional strategy that can be optimal: lowering the interest rate below the optimal level in the absence of carry trades. This can reduce the size of the carry trade by spurring date-0 households' consumption, thereby depriving banks of deposits.

E.2 Surplus-sharing between banks and long-term investors

If a bank refinances a unit LT claim held by a LT investors by rolling over deposits starting at date 0, then the bank and the selling LT investors share a surplus $1-\rho(1+\Lambda)$. The price at which banks purchase such LT claims from LT investors regulate how they split this surplus. Suppose that a bank can purchase a unit claim at date 0 at a price $1+x$, where $x \in [0, 1/[\rho(1+\Lambda)]-1]$. Such an x could be further endogenized with a full-fledged model of imperfect competition between banks and LT investors. The body of the paper studies the case in which $x=0$.

Inequality (8) suffices to ensure that a bank always has the option to use its deposits in a carry trade. In this case, the hurdle rate on real investment is $1/(1+x)-\rho\Lambda$, and entrepreneurs' demand for loans $I(x)$, increasing in x, solves

$$f'(I(x)) = \frac{1}{1+x} - \rho\Lambda, \tag{E.7}$$

and the deposits invested in carry trades are

$$y - I(x). \tag{E.8}$$