Monetary Easing, Investment 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 excessive maturity transformation. As the interest rate becomes lower, firms not only invest more (produce more capital) but they also lever up more against their future profits holding capital fixed in order to increase early payout and buy shares back. If the resulting large corporate demand for funds is not met by sufficiently aggressive private and public spending, then share buybacks and productive investment compete for scarce funds. The model provides a framework to understand the puzzling phenomenon that the unprecedented post-2008 monetary easing has been associated with an increase in firms' payouts and below-trend real investment, even while return on capital has been historically high and interest rates historically low.

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Introduction

Motivation

Since the global financial crisis of 2007-08, most major central banks 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 followed suit with such purchases and so has the Bank of Japan. The ultimate 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.

These policies and the resulting "search for yield" among institutional investors have contributed to a sharp increase in the price of certain risky asset classes (e.g., high-yield corporate bonds, emerging-market debt and equities). Several observers and policymakers have highlighted, however, that this financial risk taking has had a disappointing impact on real investment.[1] Investment has not returned yet to its pre-recession trends in

[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

advanced economies despite a large wedge between historically low interest rates and historically high returns on existing capital. Rather than being reinvested, these high returns on capital have fuelled an increase in firms' payout to their shareholders, notably in the form of share repurchases (see, e.g., Furman 2015, 2016).

This paper develops a simple model in which these three features jointly develop in equilibrium: *i) accommodative monetary policy, ii) excessive financial risk taking, and iii) an increase in the fraction of firms' profits that are paid out at the expense of investment despite a high marginal excess return on capital*. Note that even though these three features have amplified following the 2008 crisis, they could actually be discerned earlier on. For example, Gutierrez and Philippon (2016) argue that starting in the early 2000s, US fixed investment has been a decreasing fraction of firms' profits despite a high Tobin's q, and that this coincided with an increase in share buybacks.[2] Taylor (2011, 2012) traces the start of a "Great Deviation" around the same time, whereby monetary policy became relatively more accommodative than in the previous decades, and prudential regulation looser. Taylor argues that this has significantly contributed to the build-up of financial fragility leading to the 2008 crisis. To be sure, this latter point is contentious (see, e.g., Bernanke, 2010, for an alternative viewpoint).

The goal of this paper is to develop a parsimonious model that simply ties together these three facts. To get a broad sense of the main mechanism at stake in our model, consider the elementary situation in which an agent

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."

[2]Gutierrez and Philippon (2016) argue that this evolution originates from an increase in firms' market power. We view this explanation as fully complementary to ours.

can borrow or lend at the risk-free rate in order both to smooth consumption and to invest in a storage technology with decreasing returns to scale. As the risk-free rate becomes small, the agent borrows large amounts in order both to invest large quantities, and to borrow against his future profits for early consumption. Early consumption out of future profits is akin to a leveraged share buyback. If a borrowing constraint binds at some point, then the agent will allocate his maximum borrowing capacity between investment and share buybacks up to the point at which the return on investment is equal to his intertemporal rate of substitution, and these rates will both be above the risk-free rate, reflecting the shadow cost of the borrowing constraint.

At the core of our analysis is a related mechanism in a model of the interest-rate channel of monetary policy. In our setup, as the policy rate becomes lower, firms not only invest more (produce more capital) but they also lever up more against their future profits holding capital fixed in order to increase early payout and buy shares back. If the resulting large corporate demand for funds is not met by sufficiently aggressive private and public spending, then share buybacks and productive investment compete for scarce funds. The former crowd out the latter. Investment remains low despite a wedge between the interest rate and the return on capital. A large amount of maturity transformation develops to fund share buybacks. This creates financial instability and comes at no social benefits.

As detailed below, our insights are more subtle than merely suggested by this broad intuition. First, we take into account that the interest-rate channel of monetary policy implies maturity transformation, and study how such transformation can create excessive financial fragility. Second, the pat-

terns of large payouts relative to productive investment, financial fragility due to excessive maturity transformation, and a wedge between the interest rate and the return on capital need not reflect suboptimal investment nor a binding borrowing constraint in equilibrium. They are by-products of the efficient policy that we consider provided the stimulus needed for investment is sufficiently large. Yet, an inefficient, overly accommodative monetary policy makes these patterns more pronounced, and can lead to an inefficient collapse in productive investment.

Model

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

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. Analyzing the issues discussed above requires the introduction of of several ingredients in such a workhorse model, including capital goods of varying maturity and liquidity and investment, heterogeneous agents (so that those willing to enter into maturity transformation 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. We study an

economy in which two goods are produced, a numéraire consumption good and a capital good. A downward-rigid wage prevents the efficient reallocation of labor towards the production of the capital good when production of the consumption good becomes relatively less efficient. The capital-good sector being more interest-sensitive than the consumption-good sector, the monetary authority can restore the efficient allocation despite incorrect price signals in the labor market by temporarily lowering the interest rate.

A sufficiently aggressive reduction in the interest rate induces firms to enter into leveraged share buybacks despite the associated liquidity risk. The monetary authority optimally insures firms against such liquidity risk at a punitive rate. As a result, these trades redistribute resources from savers to borrowers but do not affect social welfare per se. They do so indirectly, however, by increasing firms' overall demand for funds. At some point, productive investment and leveraged share buybacks compete for resources, and a wedge between the return on capital and the policy rate reflects that the opportunity cost of investment is the associated foregone early consumption against future profits. The return on productive investment must therefore match that on leveraged share buybacks, and thus feature a compensation for liquidity risk.

Overall, this parsimonious model delivers, as mentioned above, that an accommodative monetary policy, possibly constrained-optimal, generates financial instability and a preference towards share buybacks relative to investment in the use of corporate funds despite a high marginal return on existing capital.

The paper is organized as follows. Section 1 describes the related literature

and our contributions relative to it. As a first step, Section 2 presents a simple version of our model without maturity transformation. Section 3 tackles the full-fledged model and derives our main results. Section 4 discusses some extensions. Section 5 presents the concluding remarks.

1 Related literature

Caballero and Farhi (2017) also build a model in which disequilibrium in the market for the risk-free asset plays a central role. Combined with borrowing constraints, it leads to an inefficiently low output in their setup. One important difference between their setting and ours is that disequilibrium in their model stems from an exogenous lower bound on the risk-free rate (the zero lower bound). By contrast, we exhibit an endogenous lower bound on the risk-free rate, below which leverage share buybacks crowd out productive investment and lead it to collapse. Whereas the zero lower bound has admittedly played an important role in the years following the 2008 crisis, we believe that the endogenous lower bound that we obtain may play a central role *ex ante*, in the build-up of fragility leading to crises. In particular a breach of this lower bound may contribute to explain the patterns of reduced investment rates, increased payouts to shareholders, and growing maturity transformation that developed before the crisis.

Other recent contributions that study the negative impact of low policy rates on financial stability rely on the lack of commitment of the public sector. In Farhi and Tirole (2012), the central bank 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 maturity transformation beyond socially useful levels, 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. 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 monetary easing rightly aimed at stimulating aggregate output.[3]

Brunnermeier and Koby (2016) show, like us, that monetary easing can lead to a contraction in investment. Whereas this stems from heightened incentives to increase payouts to shareholders in our setup, this stems from eroded lending margins in an environment of imperfectly competitive banks in theirs. Finally, Coimbra and Rey (2017) study a model in which the financial sector is comprised of institutions with varying risk appetites. Starting from a low interest rate, further monetary easing may increase financial instability, thereby creating a trade-off with the need to stimulate the economy as in our model.

2 An elementary model of monetary easing

2.1 Setup

Time is discrete. There are two types of private agents, workers and entrepreneurs, and a public sector. There are two goods that private agents find desirable: a perishable consumption good that serves as numéraire and a capital good.

Capital good. One unit of capital good produced at date t generates one unit of the consumption good at date $t+1$. That the capital good need not

[3] 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.

be combined with labor at date $t+1$ in order to deliver the consumption good is for analytical simplicity, and plays no role in our results. As a result, the capital good can alternatively be interpreted as a durable consumption good. We deem date-t investment the number of units of capital goods produced at this date.

Workers. At each date, a unit mass of workers are born and live for two dates. They derive utility from consumption only when old, at which point they are risk neutral over consumption. Each worker supplies inelastically one unit of labor when young in a competitive labor market. Each worker owns a technology that transforms l units of labor into $g(l)$ contemporaneous units of the consumption good, where the function g satisfies the Inada conditions.

Entrepreneurs. At each date, a unit mass of entrepreneurs are born and live for two dates. They are risk neutral over consumption at each date and do not discount future consumption. Each entrepreneur born at date t is endowed with a technology that transforms l units of labor at date t into $f(l)$ contemporaneous units of the capital good. The function f satisfies the Inada conditions.

Public sector. The public sector does not consume and maximizes the total utility of the private sector, discounting that of future generations with a factor arbitrarily close to 1.

Bond market. There is a competitive market for one-period risk-free bonds denominated in the numéraire good.

Monetary policy. The public sector announces at each date an interest rate at which it is willing to absorb any net demand for bonds.

Fiscal policy. The public sector can tax workers as it sees fit, and can,

in particular, apply lump-sum taxes. It cannot tax entrepreneurs. This latter assumption yields a simple and clear exposition of our main results. We will discuss its implications and relaxation in the following.

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 the consumption good. This will enable us to introduce ingredients that are typically absent from mainstream monetary models in a tractable framework. In recent contributions, Benmelech and Bergman (2012) or Farhi and Tirole (2012) also focus on the financial-stability implications of monetary policy abstracting from price-level determination as we do.

2.2 Steady-state

We study steady-states in which the public sector announces a constant interest rate r. We suppose that the public sector offsets its net position in the bond market at each date with a lump-sum tax or rebate on current old households.

This elementary model lends itself to a simple analysis. We denote w the market wage, and $l \in [0, 1]$ the quantity of labor that workers supply to

entrepreneurs. Entrepreneurs then borrow wl to pay wages. If $r < 1$, they borrow the additional amount $(f(l) - rwl)/r$ against their next-date profit $f(l) - rwl$.[4]

Workers invest in bonds both their labor income w and their profit $g(1-l) - w(1-l)$.

The consumption of a given cohort is then:

$$\underbrace{\left[1 + \mathbf{1}_{\{r<1\}}\left(\frac{1}{r} - 1\right)\right](f(l) - rwl)}_{\text{Entrepreneurs' income}} + \underbrace{rwl + rg(1-l)}_{\text{Old workers' pre-tax income}}$$

$$+ \underbrace{(1-r)\left[g(1-l) - \mathbf{1}_{\{r<1\}}\left(\frac{f(l)}{r} - wl\right)\right]}_{\text{Rebate to old workers}} \tag{1}$$

$$= f(l) + g(1-l). \tag{2}$$

Further, profit maximization by all firms implies:

$$g'(1-l) = w, \tag{3}$$

$$f'(l) = rw. \tag{4}$$

Two remarks are in order:

Absence of borrowing constraints. We make here the implicit assumption that the public sector always has the sufficient tax capacity to accommodate bond trading by private agents at the prevailing policy rate r.

[4]We adopt the convention that entrepreneurs hold on to the capital good that they produce and borrow against it. Such borrowing is of course equivalent to a partial or total sale of the capital good to the young workers in this environment in which control rights are immaterial.

By inspection of (1), this is always the case when $r \geq 1$. On the other hand, this might not hold when r is sufficiently small other things being equal, because young entrepreneurs' borrowing might exceed the income that young workers and the public sector (via taxation of old workers) can lend.[5] We will discuss in detail this situation in the more general model of Section 3. For brevity, this Section 2 focusses on values of r such that private agents face no such borrowing constraints.

Irrelevance of leveraged share buybacks. The borrowing against their future profit $(f(l) - rwl)/r$ by young entrepreneurs when $r < 1$ in order to consume admits a straightforward interpretation as a leveraged share buyback. The corporations set by young entrepreneurs borrow in order to repurchase shares from these entrepreneurs and cancel the shares. Absent any borrowing constraint, such leveraged share buybacks are immaterial given the objective of the public sector. They merely transfer income from workers to entrepreneurs as they are offset by taxes. For the balance of the paper we use the terminology that entrepreneurs "enter into leveraged share buybacks" whenever they borrow beyond the need to finance investment wl in order to consume when young.[6] In the general model of the next section, such leveraged share buybacks will transfer income from workers to entrepreneurs at the cost of risky maturity transformation by entrepreneurs.

Expression (2) shows that surplus is maximized when production is efficient, which occurs when the consumption-good and capital-good sectors are

[5]Formally, the tax on old workers that covers the public sector's net issuance must be smaller than their pre-tax income, which simplifies into $(1-r)f(l) \leq r(wl + g(1-l))$.

[6]To be sure, nothing distinguishes share repurchases from dividends in our setting. We prefer the interpretation of share buybacks because they better correspond in practice to the one-shot large payouts that we will study in our main model.

equally productive. This corresponds in turn to an employment level l^* in the capital-good sector such that

$$g'(1-l^*) = f'(l^*). \tag{5}$$

The public sector can reach this outcome by setting the interest rate to $r^* = 1$. In this case, the market wage w^* solves

$$w^* = g'(1-l^*) = f'(l^*) = r^* w^*, \tag{6}$$

net bond issuance by the public sector and thus taxes are equal to zero.

The optimality of a unit interest rate is obviously a version of the "golden rule" stating that steady-state consumption in OLG models is maximum when the interest rate matches the growth rate of the population (which is one here).

2.3 Monetary easing

Suppose now that one cohort of workers — the one born at date 0, say — have a less productive technology than that of its predecessors and successors. Unlike the other cohorts, their technology transforms x units of labor into $\rho g(x)$ contemporaneous units of the consumption good, where $\rho \in (0,1)$.[7] We first check that, unsurprisingly, this preference shock does not affect the optimal policy rate $r^* = 1$ when the wage is flexible. We then introduce a

[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.

downward-rigid wage.

Flexible-wage benchmark

When the wage is flexible, the steady-state unit interest rate is still optimal at all dates in the presence of such time-varying productivity. The date-0 wage adjusts to a level $w_0 < w^*$ such that the employment level in the capital-good sector $l_0 > l^*$ leads to more investment:

$$w_0 = \rho g'(1 - l_0) = f'(l_0), \tag{7}$$

and productive efficiency prevails at every date. Time-varying productivity only has a redistributive effect across cohorts as the old workers at date 0 must be taxed $g(1-l^*)-\rho g(1-l_0)$ to balance the date-0 public-sector budget, whereas old workers at date 1 receive the corresponding rebate.

Rigid wage and optimal monetary policy

We now introduce nominal rigidities in order to create room for monetary easing at date 0:

Assumption. ***(Downward rigid wage)*** *The wage cannot be smaller than w^* at any date.*

In other words, we suppose that the wage is too downward rigid to track the transitory productivity shock that hits the date-0 cohort.

It is worthwhile stressing that nominal rigidities in our model are short-lived: They last for one date only.[8] Note also that the analysis would be

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

similar if the date-0 productivity shock was permanent. All that matters is the number of periods it takes for the wage to adjust to the level w_0 that is optimal given the productivity shock.

Given that the capital-good sector is interest-sensitive whereas the consumption-good one is not, the public sector can make up for the absence of appropriate price signals in the date-0 labor market by distorting the date-0 capital market. By setting the date-0 policy rate at

$$r_0 = \frac{w_0}{w^*}, \tag{8}$$

the public sector restores productive efficiency. Entrepreneurs invest up to the optimal level l_0 since

$$f'(l_0) = r_0 w^* = w_0. \tag{9}$$

Each worker accommodates by applying in his own firm the residual quantity of labor that the other firms are not willing to absorb at the prevailing market wage w^*. He does so at a marginal return below wage ($\rho g'(1-l_0) = w_0 < w^*$), and produces at the socially optimal level by doing so.

Note that since $r_0 < 1$, date-0 entrepreneurs enter into leveraged share buybacks. This channels young workers' funds out of public bonds into such trades. As noticed before, the public sector must then have sufficient tax capacity to make up for this reduced funding.[9] Again, the case in which this does not hold will be tackled in the more general context of the following

[9]Formally, the required taxes are lower than old workers' income at date 0 if parameters are such that $f(l_0) \leq r_0(w^* l_0 + w^* l^* + \rho g(1-l_0))$. This holds if, for example, ρ is sufficiently close to 1 and entrepreneurs' profits are smaller than workers' income in the steady-state.

section. Absent such borrowing constraints, we have,

Proposition 1. ***(Monetary easing)*** *Setting the interest rate at $r_0 < 1$ at date 0 and at $r^* = 1$ at other dates implements the flexible-wage outputs at all dates 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. Monetary policy in our framework plays the very same latter role of mitigating distortions induced by nominal rigidities by gearing real variables towards their "natural" levels. The natural level is not defined by an intertemporal rate of substitution here, but rather by the relative marginal productivities of two sectors.

This section 2 has derived optimal monetary policy in our elementary model of the interest-rate channel of monetary policy. Building on this framework, the following section studies a richer environment in which entrepreneurs need to take on liquidity risk in order to take advantage of low short-term interest rates when investing and buying shares back.

3 Monetary policy and financial instability

This section leaves the modelling of the public sector and that of workers unchanged, but modifies the modelling of entrepreneurs and that of their

capital-good technology so that both investment and share buybacks involve taking on liquidity risk.

Entrepreneurs' preferences. We now assume that entrepreneurs live for three dates, and value consumption at the initial and last dates of their lives. They still are risk-neutral and do not discount future cash flows.[10]

Capital good. A unit of capital good produced at date t yields one unit of consumption good at date $t+2$. Alternatively, this unit can be liquidated at date $t+1$, in which case it generates $1/(1+\lambda)$ units of consumption at this date, where $\lambda > 0$.

Liquidity risk. We still assume that agents can trade only one-period bonds.[11] An entrepreneur born at date t has access to the bond market at date $t+1$ with probability q only, where $q \in (0,1)$. Such market exclusions are independent across entrepreneurs of the same cohort. This simple modelling of liquidity risk follows Diamond (1997). We assume that for all $x \in (0,1)$,[12]

$$\frac{f(x)}{x} \geq [1+\lambda(1-q)]f'(x). \tag{10}$$

Lending of last resort. In addition to monetary and fiscal instruments identical to that in the previous section, the public sector can act as a lender of last resort or emergency lender, offering credit to the entrepreneurs who are excluded from the bond market at whichever conditions he sees fit.

[10] Assuming that they do not value interim consumption slightly simplifies the exposition. We discuss how the introduction of interim consumption reinforces our results in the following.

[11] All that we need is that issuing two-period bonds against the capital good does not dominate rolling over one-period bonds beyond some leverage ratio. This could stem, for example, from prohibitive transaction costs for some workers when they need to sell long-term bonds to consume after one period.

[12] This ensures that entrepreneurs' debt capacity always exceeds their wage bill.

These modifications introduce the minimum set of ingredients required to enrich the model of Section 2 as follows. First, both investment and share buybacks by entrepreneurs involve taking on liquidity risk. Entrepreneurs must fund their long-term cash flows with short-term debt ("carry trades"), and this entails rollover risk. Entrepreneurs must liquidate inefficiently their capital in case they are excluded from markets and need to refinance their short-term debt. Second, the public sector can avoid such inefficient liquidation by acting as a lender of last resort.

As in the previous section, we first characterize optimal monetary policy in the steady-state. We then study optimal monetary policy when a negative productivity shock hits workers' technology at date 0.

3.1 Optimal policy in the steady-state

It is easy to see that the public sector optimally sets the policy rate at $r^* = 1$ as in the previous section, and commits to refinance entrepreneurs who are excluded from the market at this same unit rate, and without any restriction on quantities. At this unit rate, leveraged share buybacks are unappealing, and such generous lending of last resort prevents entrepreneurs from inefficiently liquidating assets in order to repay the debt that finances wages at the interim date in case they are excluded from the market. These emergency loans can be funded with a lump sum tax on old workers equal to the amount qw^*l^* that distressed entrepreneurs owe them. The optimal wage and labor supply to the capital-good sector w^* and l^* are defined as in (6). In sum, the public sector can eliminate liquidity risk at no cost and implement productive efficiency in this case.

3.2 Monetary easing

As in Section 2, we now assume that a productivity shock $\rho \in (0,1)$ hits the consumption-good technology owned by date-0 workers. Whereas this was immaterial in the previous section, we now assume for simplicity that this shock is unanticipated by previous cohorts.[13] We define $r_0(\rho)$ and $l_0(\rho)$ as in (7) and (8). The rate $r_0(\rho)$ is an increasing function of ρ.

That $r_0(\rho) < 1$ may induce entrepreneurs to enter into leveraged share buybacks. They must now enter into carry trades—rolling over short-term debt— and take on liquidity risk to do so, however. On one hand, this liquidity risk deters carry trades as it reduces their expected return. On the other hand, if $r_0(\rho)$ is sufficiently low, entrepreneurs will enter into carry trades. In this case, they extract surplus from workers at a social cost as they may enter into financial distress and inefficiently liquidate capital by doing so.

We now study the best policy response to this situation. Note first that it is always optimal to set the policy rate at $r^* = 1$ at all other dates than 0, and to act as a lender of last resort at this unit rate without restrictions at all other dates than 1. It cannot be efficient to influence the behavior of the date-0 cohort of entrepreneurs by distorting investment by the other cohorts, and it is preferable to directly use the date-0 policy rate and the date-1 rate of last resort to do so.

We thus only need to determine how the public sector optimally sets the date-0 policy rate and the conditions at which it acts as a lender of last resort at date 1. To do so, we characterize as a first step the cut-off value

[13] We will discuss how the anticipation of this shock affects the analysis in the following.

of r_0 below which date-0 entrepreneurs enter into leveraged share buybacks. Suppose that a date-0 entrepreneur has one unencumbered unit of the capital good, and that the public sector does not offer any emergency lending to entrepreneurs excluded from the market at date 1. The entrepreneur can still borrow against a fraction $1/(1+\lambda)$ of this unit, and consume from the residual at date 2 if he has not been excluded from the market and forced to liquidate his unit at date 1. This dominates waiting until date 2 to consume the entire proceeds from the capital good if and only if:

$$\frac{1}{r_0(1+\lambda)} + \frac{\lambda(1-q)}{1+\lambda} > 1, \tag{11}$$

or

$$r_0 < \frac{1}{1+\lambda q}. \tag{12}$$

The term λq represents the expected cost of liquidity risk. Define $\underline{\rho}$ as

$$r_0(\underline{\rho}) = \frac{1}{1+\lambda q}. \tag{13}$$

We have:

Proposition 2. ***(Monetary response to mild productivity shocks)*** *If $\rho \geq \underline{\rho}$, then the public sector optimally sets the policy rate at $r_0(\rho)$ at date 0. It acts as a lender of last resort at date 1 by lending up to $r_0(\rho)l_0(\rho)w^*$ at a unit rate to each entrepreneur at date 1.*

There are no leveraged share buybacks in equilibrium, and the marginal

date-0 return on capital is equal to the interest rate:

$$\frac{f'(l_0)}{w^*} = r_0. \tag{14}$$

Proof. For such mild productivity shocks, $r_0(\rho)$ is such that entrepreneurs find liquidity risk too high to enter into share buybacks if they have to liquidate assets in case of market exclusion. The public sector thus only needs to ration its emergency lending so that entrepreneurs borrow only to fund investment and not to buy shares back. ■

In this situation of mild productivity shocks, the policy described above implements the first-best whereby productive efficiency is maximized for each cohort. Consider now the situation of severe productivity shocks in which $\rho < \underline{\rho}$. We have in this case:

Proposition 3. ***(Monetary response to severe productivity shocks)*** *Suppose $\rho < \underline{\rho}$. There exists $\rho_\lambda \leq \underline{\rho}$ such that:*

- *If $\rho \in [\rho_\lambda, \underline{\rho}]$, then the public sector can implement productive efficiency, there are leveraged share buybacks at date 0, and emergency lending prevents inefficient liquidation of capital. The optimal policy consists in setting a date-0 rate $r_\lambda(\rho) < r_0(\rho)$. Emergency lending takes place at a rate $1+\lambda$ without any restriction on quantities. The marginal return on capital is strictly above the date-0 rate:*

$$\frac{f'(l_0)}{w^*} = r_0 > r_\lambda. \tag{15}$$

- *If $\rho < \rho_\lambda$, then the public sector cannot implement productive efficiency.*

It cannot spur more investment than the optimal level $f(l_0(\rho_\lambda))$ corresponding to a policy rate $r_\lambda(\rho_\lambda)$. Again, there are leveraged shares buyback and emergency lending at a punitive rate $1+\lambda$. If the public sector mistakenly sets the date-0 rate at a level below $r_\lambda(\rho_\lambda)$, then investment snaps back to the steady-state level $f(l^*)$.

Proof. See the appendix. ■

The intuition for these results is as follows. We have seen that if the date-0 rate is below $r_0(\underline{\rho}) = 1/(1+\lambda q)$, then date-0 entrepreneurs find leveraged share buybacks attractive even absent any emergency funding in case of market exclusion. The best the public sector can do in this situation is to avoid the deadweight loss of inefficient liquidations due to the share buybacks by offering emergency lending. The highest possible rate at which it can grant emergency loans is $1+\lambda$. At this rate, distressed entrepreneurs are indifferent between liquidating assets or tapping the public sector.

Whereas emergency lending prevents inefficient asset liquidations, leveraged share buybacks still are problematic because they can create financial constraints. As mentioned in Section 2, when entrepreneurs borrow against their entire firm value rather than only to finance wages, there might be an overall shortage of loanable funds. Setting emergency lending for share buybacks at the highest possible rate $1+\lambda$ at which entrepreneurs are willing to use it minimizes entrepreneurs' initial demand for funds. This high emergency lending rate is reflected in firms' opportunity cost of funds, which explains both why the policy rate $r_\lambda(\rho)$ has to be more aggressive than $r_0(\rho)$ and why the marginal return on capital is above this policy rate.

There is a level ρ_λ of ρ below which it is impossible to implement produc-

tive efficiency, because this would imply a date-0 rate at which the borrowing constraint binds. If this constraint binds, then investment snaps back to the steady-state level $f(l^*)$, which cannot be optimal. This is because constrained entrepreneurs borrow as much as possible and split the amount into date-0 consumption and investment. The marginal return on capital is thus equal to their unit discount rate. Figure 1 and Corollary summarize the findings in Propositions 2 and 3:

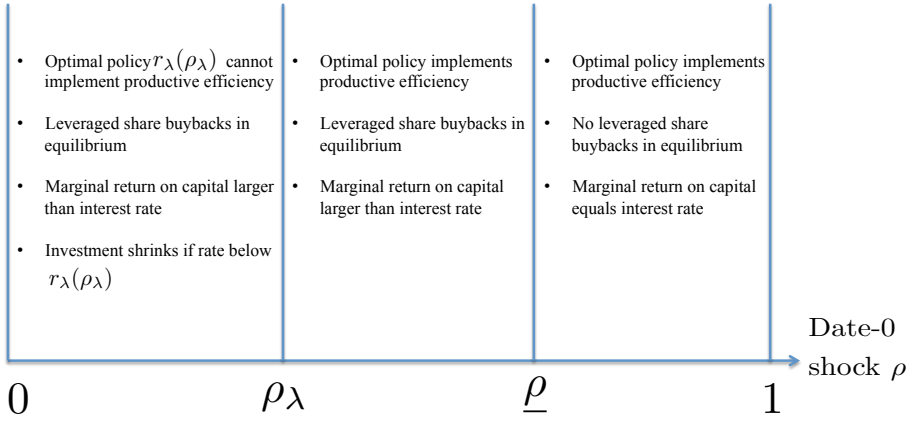

Figure 1: Optimal policy and equilibrium patterns as the date-0 shock varies

Corollary 4. ***(Summary of Propositions 2 and 3)***

- *As claimed in the introduction, we predict that monetary accommodation can induce excessive maturity transformation, and marginal indifference between share buybacks and investment in the use of corporate*

funds despite a wedge between interest rate and marginal return on capital. (Case $\rho \leq \underline{\rho}$).

- *These patterns may arise even if investment is at the efficient level and entrepreneurs are not constrained in equilibrium. (Case $\rho \in [\rho_\lambda, \underline{\rho}]$).*

- *These patterns are more pronounced if monetary accommodation is excessive, with an interest rate below the endogenous lower bound $r_\lambda(\rho_\lambda)$. In this case investment stays at the non-stimulated level $f(l^*)$ and monetary easing only spurs socially undesirable carry trades.*

The following comments are in order.

Aggregate borrowing constraint. Our setup suggests that the patterns we seek to explain are foremost the symptoms of the limited supply of private or/and public investable funds that can accommodate corporate demand following the reduction in interest rates. Whereas the limited supply of funds stems from the overlapping-generations structure here, our results do not live or die on a particular form of constraint. An interesting avenue for future research consists in detailing the political-economy frictions, redistributive concerns, or any other frictions that could prevent the public sector from supplying enough funds to the economy so that the opportunity cost of investment is not foregone share buybacks.

It is worthwhile stressing that the relevant measure of spending capacity here is relative to the value of the outstanding assets that can back carry trades. Admittedly, financial deregulation, innovation and globalization over the last 30 years have significantly expanded the set of such assets, thereby weakening the link between monetary policy and investment. Such an evolu-

tion of the financial system can be broadly viewed in our model as a reduction in the parameter λ (see below).

Shadow banking and maturity transformation outside banks. A clear-cut implication of our framework is that aggressive monetary easing must spur an abnormally strong demand for "carry trades," or maturity transformation. This is clearly in line with the rapid growth of an important shadow-banking system that accompanied the "Great Deviation" identified by Taylor (2011) and collapsed in 2008.

Following post-2008 unconventional monetary policy, carry trades and more generally unregulated maturity transfomation 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.

The role of asset liquidity. It is transparent from (13) that the threshold $\underline{\rho}$ above which there are no leveraged share buybacks in equilibrium is decreasing in λ and q. As capital is less liquid, it takes a lower policy rate

to make carry trades profitable. We show in the proof of Proposition 3 that the second threshold ρ_λ, below which aggregate borrowing is constrained and investment is suboptimal, is decreasing in λ but increasing in q. Higher liquidation costs reduce the amount $f(l_0)/(1+\lambda)$ against which shares are bought back and thus eases financial constraints. An increase in q raises the routine emergency lending that is provided to firms at other dates than 1. This worsens borrowing constraints because this leaves less dry powder for leveraged share buybacks at date 0, as there is more emergency lending to refinance the debt w^*l^* of middle-aged entrepreneurs.

4 Extensions

We briefly discuss some interesting extensions of the model.

4.1 Taxing entrepreneurs

Whereas we assume that entrepreneurs cannot be taxed at all for expositional simplicity, our results rely only on the assumption that the public sector does not have a free hand at taxing entrepreneurs.[14] If this were the case, it would be easy to eliminate borrowing constraints by deterring leveraged share buybacks. This could be implemented either through the taxation of date-0 consumption by entrepreneurs, or by the taxation of their future profits. Note that such a taxation of capital is easy to implement in our model but would have to be very finely tuned in practice in order not to be counterproductive and deter investment.

[14] See e.g., Landier and Plantin (2017) for such a model of limited capital taxation.

4.2 Asset purchases

The large taxation of date-0 old workers in order to match the net supply of bonds by the private sector can be interpreted as an exceptionally large public asset-purchase program at date 0. Our case for a large public-sector balance sheet is reminiscent of the one made 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. 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 efficiently crowd out inefficient carry trades by the private sector.

4.3 Interim consumption by entrepreneurs

The assumption that entrepreneurs also value consumption when middle-aged would reinforce our results by further weakening the link between interest rate and productive investment. To see this, note that the fraction $1 - q$ of date-0 middle-aged entrepreneurs who are not excluded from markets at date 0 would borrow against their date-1 profit without taking any liquidity risk in the face of a date-0 interest-rate cut. This would suck more investable funds out of productive investment, and the public sector would have no way to prevent this with punitive emergency rates given the absence of maturity transformation. More generally, if entrepreneurs were living n periods and

capital goods delivered consumption over the same horizon, then a stock of legacy assets produced by the $n-1$ previous cohorts would lend themselves to carry trades that are less risky than that against newly produced (and thus longer-lived) assets at date 0. These carry trades would absorb a lot of date-0 savings and dramatically amplify the diversion of savings away from productive investment.

4.4 Anticipated productivity shock

If the date-0 productivity shock is perceived as sufficiently likely by date-(-1) entrepreneurs, then this adds another cost from a date-0 rate cut. The anticipation of such a cut would induce them to excessively invest, and possibly to enter into leveraged share buybacks if the probability of the cut is sufficiently large. Their refinancing at date 0 would drain more funds away from date-0 investment and thus put more constraints on productive investment at this date. Overall, the first-best could not be reached and the public sector would have to trade off the desirable distortions created for the date-0 cohort with the unintended ones created for the previous one.

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. Optimal monetary policy seeks to minimize

the crowding out of productive investment by carry trades, but there is a limit to what it can achieve in the form of an endogenous lower bound on the policy rate. Going below this bound has a negative impact on investment. The model helps understand the increase in maturity transformation and share buybacks that has recently accompanied monetary easing, together with a wedge between the marginal return on capital and interest rate.

There are many directions in which we could extend our analysis fruitfully. For example, we could introduce uncertainty to the duration of the productivity shock experienced by the economy over time (instead of a one-period shock) 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).

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Appendix: Proof of Proposition 3

Suppose that the public sector sets the date-0 interest rate at r smaller than $r_0(\underline{\rho})$, and offers emergency lending at a rate $\Lambda \leq 1 + \lambda$. This is without loss of generality as entrepreneurs would rather liquidate their assets than borrow at date 1 at any higher rate than $1+\lambda$. A young date-0 entrepreneur then borrows l at date 0 so as to solve:

$$\max_{l} \left\{ \frac{f(l)}{r\Lambda} + \frac{(\Lambda - 1)(1-q)f(l)}{\Lambda} - w^* l \right\} \tag{16}$$

The first-order condition reads:

$$f'(l) = \frac{r\Lambda w^*}{1 + r(\Lambda - 1)(1-q)}. \tag{17}$$

From (17), condition (10) ensures that the date-0 borrowing of the young entrepreneur $f(l)/r\Lambda$ more than covers the wage $w^* l$.

For a given shock $\rho \leq \underline{\rho}$ an optimal policy (r, Λ) implements productive efficiency while minimizing entrepreneurs' demand for funds. It thus solves

$$\min_{r,\Lambda} \left\{ \frac{1}{r\Lambda} \right\} \tag{18}$$

s.t.

$$\frac{r\Lambda w^*}{1 + r(\Lambda - 1)(1-q)} = r_0(\rho), \tag{19}$$

$$\Lambda \leq 1 + \lambda. \tag{20}$$

Straightforward computations show that the solution is attained at $\Lambda = 1+\lambda$ and $r = r_\lambda(\rho)$ defined by

$$r_0(\rho) = \frac{r_\lambda(\rho)(1+\lambda)}{1 + r_\lambda(\rho)\lambda(1-q)} > r_\lambda(\rho). \tag{21}$$

This latter inequality reflects the wedge between the marginal return on capital and the interest rate.

It only remains to determine when date-0 borrowing by entrepreneurs exceeds the date-0 supply of loanable funds. For a date-0 rate r_λ and borrowing $w^* l_0$, we have at date 0:

- Income of old workers:

$$\underbrace{g(1-l^*) + w^* l^*}_{\substack{\text{Proceeds from having invested} \\ \text{the date } (-1) \text{ income at rate 1}}} - \underbrace{q w^* l^*}_{\substack{\text{Tax to fund emergency lending} \\ \text{for excluded middle-aged entrepreneurs}}} \tag{22}$$

- Funds invested in public bonds by young workers:

$$\underbrace{\rho g(1-l_0) + w^* l_0}_{\text{Profit and labor income}} - \underbrace{(1-q) w^* l^*}_{\substack{\text{Refinancing of} \\ \text{middle-aged entrepreneurs}}} - \underbrace{\frac{f(l_0)}{r_\lambda(1+\lambda)}}_{\substack{\text{Loans to} \\ \text{young entrepreneurs}}} \tag{23}$$

- Amount owed to old workers by the government from their investments in public bonds:

$$g(1-l^*) - (1-q) w^* l^* \tag{24}$$

The last term (24) stems from the fact young workers' investment in

public bonds at date -1 is their total income $g(1-l^*)+w^*l^*$ net of labor income w^*l and refinancing of middle-aged entrepreneurs $(1-q)w^*l^*$.

The date-0 borrowing constraint binds when the debt owed by the government net of new issuances is smaller than the taxable income of old workers:

$$(22) \leq (24) - (23), \tag{25}$$

and re-arranging yields

$$\frac{f(l_0)}{(1+\lambda)r_\lambda} - w^*l_0 \geq w^*l^*(1-q) + \rho g(1-l_0), \tag{26}$$

from the definition of r_λ this is equivalent to

$$\frac{f(l_0)}{r_0} - w^*l_0 \geq \rho g(1-l_0) + \frac{\lambda(1-q)f(l_0)}{1+\lambda}. \tag{27}$$

From the envelope theorem, the derivative of the left-hand side of (27) w.r.t. ρ is

$$-\frac{f(l_0)}{r_0^2}\frac{dr_0}{d\rho} \leq 0, \tag{28}$$

whereas that of the right-hand side is

$$g(1-l_0) - \rho g'(1-l_0)\frac{dl_0}{d\rho}\frac{1+\lambda q}{1+\lambda} \geq 0. \tag{29}$$

This implies that the borrowing constraint binds if and only if ρ is below a threshold ρ_λ, possibly equal to $\underline{\rho}$.

Finally, a simple inspection of (27) shows that this threshold ρ_λ is decreasing in λ and increasing in q.