Monetary Easing, Investment and Financial Instability*

Viral V. Acharya
Reserve Bank of India

Guillaume Plantin
Sciences Po

July 21, 2018

Abstract

This paper studies a model in which a low monetary policy rate lowers the cost of capital for firms, thereby spurring productive investment. Low interest rates however also induce firms to lever up so as to increase payouts to shareholders. Such leveraged share buybacks and productive investment compete for funds, so much so that the former may crowd out the latter. Below an endogenous lower bound, monetary easing generates only limited capital expenditures that come at the cost of large and destabilizing financial risk-taking.

Keywords: Monetary policy, financial stability, shadow banking, carry trades
JEL: E52, E58, G01, G21, G23, G28

*We are grateful to seminar and workshop participants at the World Econometric Society Meetings in Montreal, CREDIT Greta conference in Venice, Micro Foundations of Macro Finance workshop at New York University, New York University (NYU) Stern School of Business, NYU Economics at the Graduate School of Arts and Sciences, European Central Bank conference on the Transmission of Monetary Policy, Bank for International Settlements, the Federal Reserve Board, Bank of Italy, Bank of Portugal, Banque de France, University of Mannheim, Université Paris-Dauphine, Aarhus University, CREST, London Business School, University of Geneva, the Einaudi Institute for Economics and Finance, Bank of Spain, and NYU – ETH Zurich Law and Finance conference, for helpful comments and discussions. Hae Kang Lee provided excellent research assistance. All views expressed are those of the authors and do not reflect views of the Reserve Bank of India.

Introduction

Following the global financial crisis of 2007-08, most major central banks have embarked upon so-called unconventional monetary policies. These policies feature monetary easing aimed at keeping interest rates at ultra-low levels. Most notably, the Federal Reserve kept for over eight years interest rates at the zero lower-bound with large-scale asset purchases of Treasuries and mortgage-backed securities. European Central Bank followed suit with such purchases and so did the Bank of Japan.

These unconventional monetary policies have spurred risk-taking in financial markets. Notably, non-bank financial institutions have increasingly engaged into (unregulated) maturity transformation, rolling over short-term liabilities in order to fund flows into risky asset classes that include junk bonds and collateralized leveraged loans, residential mortgage-backed assets (Stein 2013), and emerging-market government and corporate bonds (Acharya and Vij 2016, Bruno and Shin 2014, Feroli et al. 2014). IMF GFSR (2016) documents that the presence of such a "risk-taking channel" in the non-bank finance (insurance companies, pension funds and asset managers) implies that monetary policy remains potent in affecting economic and financial outcomes even when banks face strict macroeconomic regulation.

Non-financial corporations have also increasingly engaged into financial risk-taking. The US corporate sector has raised \$7.8 trillion in debt over the 2010-2017 period, whereas net equity issuance has been negative due to payouts to shareholders that are at a high point compared with historical averages. As a result corporate leverage is close to historical highs for large firms[1], and has more broadly risen to levels exceeding those prevailing just

[1] There is significant heterogeneity across sectors, but median net debt across S&P 500 firms is close to an all-time maximum.

before the global financial crisis (IMF 2017).

Several observers and policymakers lament the disappointing impact of such financial risk-taking and of the resulting compression of risk premia on capital expenditures.[2] Investment has not returned yet to its pre-recession trends despite a large wedge between low interest rates and historically high realized rates of return on existing capital.[3] 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 (Furman 2015).

Motivated by these facts, this paper develops a simple model in which three features jointly arise in equilibrium: *i) a low policy rate, ii) a surge in leverage and maturity transformation ("carry trades") leading to the build-up of financial fragility, and iii) an increase in the fraction of firms' profits that are paid out at the expense of productive investment despite a marginal rate of return on capital above the policy rate.* Even though these three features have amplified following the 2008 crisis, they could actually be discerned earlier on. For example, Gutiérrez and Philippon (2017) 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

[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."

[3]Return on capital measured as private capital income divided by the private capital stock as in Furman (2015).

share buybacks.[4] Taylor (2011, 2012) traces the start of a "Great Deviation" around the same date, 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).

Gist of the argument

Consider an economy with two dates $t \in \{0; 1\}$ comprised of households and a unit mass of entrepreneurs. Competitive households inelastically supply savings S that they can invest in government bonds yielding a gross return r. They can also lend to entrepreneurs. Each entrepreneur is penniless and owns a technology that transforms I date-0 consumption units into $2\sqrt{I}$ date-1 units. Entrepreneurs have risk-neutral preferences $c_0 + c_1/R$, where R is their (gross) discount rate over future consumption, such that $SR^2 > 2$.

Entrepreneurs produce optimally at a marginal productivity of r reached when they invest $I = 1/r^2$ in their technology. Optimal consumption requires that entrepreneurs postpone consumption to date 1 if $r \geq R$, in which case households invest $S - I = S - 1/r^2$ in government bonds. If $r < R$, then entrepreneurs front-load at date 0 the consumption of their date-1 profits $2\sqrt{I} - rI = 1/r$, thereby borrowing a total date-0 amount $1/r^2 + I = 2/r^2$. Demand for government bonds thus shrinks to $S - 2/r^2$. If $r \leq \sqrt{2/S}$, entrepreneurs are however constrained. They borrow S and split it between consumption and productive investment so as to be marginally indifferent, in which case $I = 1/R^2$.

[4] Gutiérrez and Philippon (2017) argue that this evolution owes to a decline in the degree of competition in US product markets. We view this explanation as complementary to ours.

Borrowing by entrepreneurs against their future profits when $r < R$ admits a straightforward interpretation as leveraged share buybacks. The corporations set by entrepreneurs borrow in order to repurchase shares from these entrepreneurs and cancel the shares.

Figure 1 illustrates how savings S are used towards productive investment, leveraged share buybacks, and investment in government bonds as r varies:

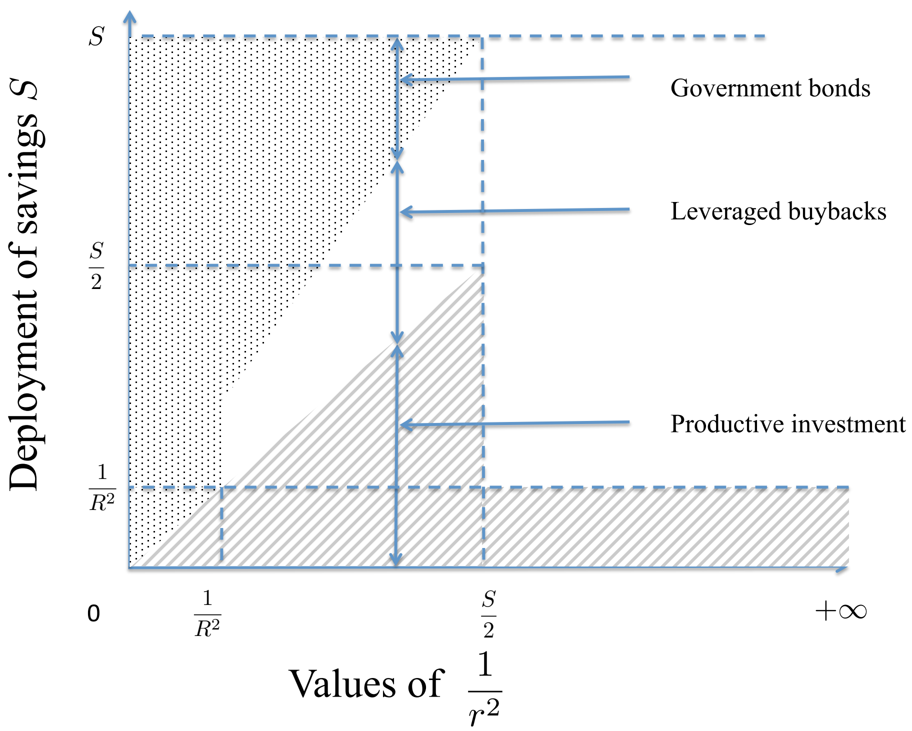

Figure 1: Deployment of savings as r varies

For $r \geq R$ ($1/r^2 \leq 1/R^2$), savings are only channeled towards productive investment (dashed area) and government bond purchases (dotted area). As $r < R$ ($1/r^2 > 1/R^2$), every unit of productive investment is matched by a unit of leveraged share buybacks. Entrepreneurs' demand for funds thus grows twice as fast with $1/r^2$ as when $r \geq R$. This implies that productive investment reaches a maximum $S/2$ when all savings are directed towards the private sector. Past this maximum, productive investment drops back to $1/R^2$ as the required return on it reflects entrepreneurs' borrowing constraints, and residual savings fuel a large amount of leveraged share buybacks.

The paper formalizes such a crowding out of productive investment by leveraged payouts to shareholders in a richer model that includes the following ingredients.

1. *General equilibrium.* Quantities of consumption goods and assets are endogenous equilibrium outcomes.

2. *Constrained-efficient public policy.* A central bank with full fiscal backing controls the real rate on public bonds. It seeks this way to mitigate the distortions induced by rigid (fixed) prices in order to maximize a standard social welfare function.

3. *Imperfect enforcement.* It is easy to see in the above elementary model that an appropriate cap on entrepreneurs' debt-to-assets ratio implements more productive investment than in the unregulated case by precluding leveraged share buybacks. Our main model by contrast posits the key assumption that it is not possible to regulate private leverage this way. This simply captures the existence of a large shadow-banking system that can fund corporate debt outside the scope of banking regulation. *In other words, we argue in this paper that the rise of a large shadow-banking system is a major reason monetary easing has led to less investment and more financial risk-taking over the last decades.*

4. *Maturity transformation and liquidity risk.* The main model also features market incompleteness. Entrepreneurs can only issue debt that has a shorter maturity than that of their projects. This implies that they must expose themselves to rollover risk when investing or buying

shares back. This is a double-edged sword. On the one hand, rollover risk makes leveraged share buybacks less appealing to them for moderate levels of monetary easing, thereby mitigating the crowding out of productive investment. On the other hand, when the policy rate is sufficiently low that entrepreneurs find such carry trades profitable, the monetary authority must implement a lending of last resort policy in order to avoid inefficient liquidation of entrepreneurs' projects.

5. *Redistributive implications.* Finally, as in the above elementary model, monetary easing channels savings from public bonds towards the private sector in the main model. In an overlapping-generations environment, the public sector makes up for its resulting smaller resources by taxing old households. Leveraged share buybacks thus lead to transfers to young entrepreneurs from old households. Whereas we posit that such transfers are welfare-neutral for simplicity, our results would be reinforced if the social welfare function was penalizing them (for example for political-economy reasons).

The paper is organized as follows. As a stepping stone, Section 1 presents a simple version of our model without maturity transformation. Section 2 tackles the full-fledged model and derives our main results. Section 3 discusses some extensions. Section 4 presents the concluding remarks.

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, leading it to collapse. Whereas the zero lower bound has arguably been the important binding constraint in the couple of years following the 2008 crisis, we believe that the endogenous lower bound that we obtain may have played a central role in the build-up of financial fragility leading to the 2008 crisis. This endogenous lower bound may also help understand the current patterns of reduced investment rates, increased payouts to shareholders, and growing leverage and maturity transformation.

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, 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.

Several recent contributions suggest alternative channels for the limited impact of low interest rates on investment. Brunnermeier and Koby (2018) show that this may stem from eroded lending margins in an environment of imperfectly competitive banks. 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. Quadrini (2017) develops a model in which monetary easing in the form of private asset purchases may have a contractionary impact on investment. In his setup, firms use deposits to hedge productivity shocks. The claims of the public sector against private assets crowd out those of the corporate sector thereby reducing the corporate sector's ability to take on productivity risk. A distinctive feature of our approach is that we jointly explain low investment, high payouts, and the growth of maturity transformation within the shadow-banking sector.

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.

Finally, as we argue in Section 3.2, our results are reinforced if redistributive concerns reduce the public sector's fiscal space. This is our point of contact with the literature that studies how real-rate manipulation by a monetary authority affects the real economy via redistributive effects (see, e.g., Auclert 2017 and the references herein).

1 An elementary model of monetary easing

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 be combined with labor at date $t+1$ in order to deliver the consumption good is for analytical simplicity, and plays no material role in our results. This also entails that the capital good can alternatively be interpreted as a durable good such as housing. 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, and are risk-neutral over consumption. Each worker supplies inelastically one unit of labor when young in a competitive labor market. Each worker also 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. This capital delivers $f(l)$ units of the consumption good at the next date $t+1$. The function f satisfies the Inada conditions.

Public sector. The public sector does not consume. It maximizes the sum of the utilities of agents in 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 trade bonds.

Fiscal policy. The public sector can tax workers as it sees fit. It can, in particular, apply lump-sum taxes. On the other hand, it cannot tax entrepreneurs nor regulate them. This latter assumption is made stark in order to yield a simple and clear exposition of our results.

Figure 2 summarizes the timing of events for a typical cohort.

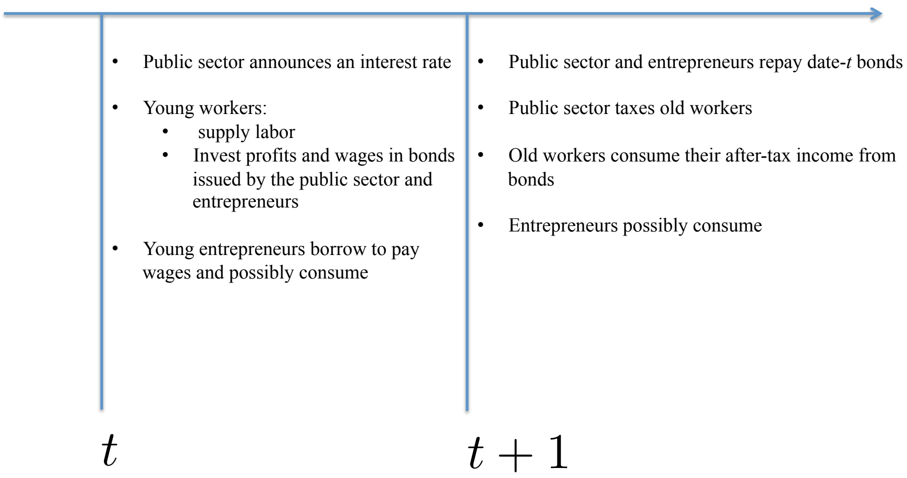

Figure 2: Timeline

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 the following. In recent contributions, Benmelech and Bergman (2012), Caballero and Simsek (2017) or Farhi and Tirole (2012) also focus on the financial-stability implications of monetary policy abstracting from price-level determination as we do.

Steady state

We study steady states in which the public sector announces a constant gross 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 workers. We denote w the market wage, and $l \in [0,1]$ the quantity of labor that young workers supply to young entrepreneurs. The steady-state values of r, w and l determine the respectives surpluses of entrepreneurs and workers as follows:

Entrepreneurs. Young entrepreneurs borrow wl to pay the corresponding wages.[5] If $r < 1$, entrepreneurs borrow the additional amount $(f(l) - rwl)/r$ against their next-date profit $f(l) - rwl$ in order to consume when young. They consume this profit $f(l) - rwl$ when old if $r \geq 1$.

Workers. Young workers' income is comprised of labor income in the capital-good sector wl, labor income in the consumption-good sector $w(1-l)$, and profits from the consumption-good sector $g(1-l) - w(1-l)$. Workers invest the resulting total income $g(1-l) + wl$ in private and public bonds thereby receiving a pre-tax income $r[g(1-l) + wl]$ when old. The share of their income that young workers invest in public bonds is equal to their total income $g(1-l) + wl$ net of young entrepreneurs' borrowing $wl + \mathbb{1}_{\{r<1\}} (f(l)/r - wl)$. The government rebates to old workers at each date this investment in public bonds by contemporaneous young workers net of the repayment of maturing bonds.

The surplus of a given cohort is therefore:

[5] This is just a convention and not a wage-in-advance constraint: the analysis is verbatim if entrepreneurs pay wages by directly granting units of capital to their employees.

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

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

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

Furthermore, profit maximization by all firms implies:

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

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

Expression (2) implies that the public sector optimally maximizes total output per cohort. This requires the consumption-good and capital-good sectors to be equally productive at the margin. This corresponds in turn to an employment level l^* in the capital-good sector such that

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

From (3) and (4), 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 an interest rate equal to the (unit) growth rate of the population is of course akin to the "golden rule" maximizing steady-state utility in overlapping-generations models.

Comments

Welfare irrelevance of leveraged share buybacks. As mentioned in the introduction, borrowing by young entrepreneurs against their future profits $f(l) - rwl$ admits a straightforward interpretation as leveraged share buybacks.[6] These leveraged share buybacks merely transfer consumption from workers to entrepreneurs and are thus welfare-neutral given the assumed preferences and social objective. Abstracting from redistributive concerns in this way enables us to focus on the sole impact of leveraged share buybacks on the aggregate private demand for funds. Importantly, as discussed in Section 3.2, redistributive concerns would only reinforce our results.

Private demand for funds. We characterize the steady state assuming that entrepreneurs face no borrowing constraints at the prevailing interest rate r. From Walras' Law, a necessary and sufficient condition for this to hold is that the public sector has enough fiscal capacity to balance its budget given the net demand for public bonds at each date: The tax on old workers that balances the budget cannot exceed their pre-tax income. By inspection of (1), this is always the case when $r \geq 1$, and so in particular at the optimal rate $r^* = 1$, as old workers receive a positive rebate in this case. 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.[7] We will discuss in detail this situation of potential disequilibrium in the bond

[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.

[7] 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 $(1 - r)f(l) \leq r[wl + g(1 - l)]$.

market in the more general model of Section 2. For brevity, we suppose in this Section 1 that parameters are such that private agents face no such borrowing constraints.

Monetary easing

Suppose now that one cohort of workers — the one born at date 0, say — has 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 $\rho \in (0,1)$.[8] We first check that unsurprisingly, this productivity shock does not affect the optimal policy rate $r^* = 1$ when the wage is flexible. We then introduce a 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.

[8] Note that whether this shock and the associated policy response are anticipated or not by the predecessors of the date-0 cohort is immaterial.

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, and that the public sector cannot regulate it in the short run. It is worthwhile stressing that wage rigidity is short-lived: It lasts for one date only.[9]

Given that the capital-good sector is interest-rate sensitive whereas the consumption-good sector 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.

[9]We could also assume a partial adjustment without affecting the analysis. Note also that the analysis would be similar if the date-0 productivity shock was permanent ("secular stagnation"). All that would matter in this case would be the number of periods it takes for the wage to adjust to the level w_0 that is optimal given the productivity shock.

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 temporarily reduced funding.[10] Again, the case in which this does not hold will be tackled in the more general context of the following 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 the intertemporal rate of substitution of a representative consumer here (consumers are heterogeneous), but rather by the relative marginal productivities of two sectors.

This Section 1 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.

[10] Formally, the required taxes are lower than old workers' pre-tax 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.

2 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.[11]

Capital good. A unit of capital good produced at date t yields one unit of consumption good at date $t+2$. Alternatively, this unit of capital 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 risk-free bonds.[12] An entrepreneur born at date t has access to the bond market at date $t+1$ with probability $1-q$ 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 $x \in (0,1)$,[13]

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

Lending of last resort. In addition to monetary and fiscal instruments

[11] Assuming that entrepreneurs do not value consumption when middle-aged slightly simplifies the exposition. Section 3.5 below explains how the introduction of interim consumption actually reinforces our results.

[12] 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 would be the case if, for example, a fraction of workers incurred high transaction costs when selling long-term bonds to consume after one period.

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

identical to that in the previous section, the public sector can act as a lender of last resort (LOLR) or emergency lender, offering credit to the entrepreneurs who are excluded from the bond market at whichever conditions it sees fit. So, the public sector announces both a rate at which it is willing to trade in the bond market, and a rate at which it acts as a LOLR. We deem the former rate the "policy rate" and the latter the "LOLR rate" in the balance of the paper.

These modifications introduce the minimum set of ingredients required to enrich the model of Section 1 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 the LOLR.

Important remark: Financial intermediaries and non-financial firms. In our model, the same type of agents, "entrepreneurs," both enter into maturity transformation and buy shares back for simplicity. To be sure, each activity is carried out by different types of agents in practice. In recent episodes of monetary easing, increases in maturity transformation have mostly taken place through the shadow-banking sector taking on maturity risk in order to finance long-term corporate debt or real-estate investments.[14] Non-financial corporations have levered up issuing such long-term-debt in order to increase payouts to shareholders. Section 3.1 shows that splitting the private sector this way into financial intermediaries that engage into maturity transforma-

[14] Traditional banks of course perform maturity transformation, yet the size of their balance sheets is significantly less sensitive to financial conditions than that of shadow institutions.

tion and firms that do not does not affect our results.

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 the consumption-good technology at date 0.

2.1 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 the same unit LOLR rate, and without any restriction on quantities. At this unit rate, leveraged share buybacks are unappealing, and the generous lending of last resort prevents entrepreneurs from inefficiently liquidating assets in order to repay the debt that finances wages in case they are excluded from the market at the interim date. 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.[15] 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 the steady state.

2.2 Monetary easing

As in Section 1, 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.[16]

[15] In addition, all the cohorts of workers but the initial one are rebated the reimbursements of these emergency loans by old entrepreneurs.

[16] Section 3.6 discusses how the anticipation of this shock would affect the analysis.

We study the best policy response to this shock. 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 LOLR 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 LOLR rate. We thus only need to determine how the public sector optimally sets these two rates. We denote by r the date-0 policy rate and by Λ the date-1 LOLR rate, and solve for an optimal policy (r, Λ).

For each $\rho \in (0, 1]$ we define $r_0(\rho)$ and $l_0(\rho)$ as in (7) and (8):

$$\rho g'(1 - l_0(\rho)) = f'(l_0(\rho)) = r_0(\rho) w^*. \tag{11}$$

The labor supply to entrepreneurs $l_0(\rho)$ that corresponds to the first-best output by the date-0 cohort, $f(l_0) + \rho g(1 - l_0)$, is strictly decreasing in ρ. The rate $r_0(\rho)$ is a strictly increasing function of ρ.

Policy Selection. We will see below that whenever the public sector can implement the first-best output by the date-0 cohort, there are in general several policies (r, Λ) that lead to this outcome. These policies imply different distributions of consumption across agents, which is welfare neutral by assumption. To lift this indeterminacy, we will suppose that the public sector selects in this case the policy that transfers as little income as possible from old workers to young entrepreneurs at date-0. This would be the unique optimal policy if such transfers came at an arbitrarily small cost.

Assumption. ***(Policy selection)*** *Among all policies* (r, Λ) *that maximize the output of the date-0 cohort, the public sector selects the one that minimizes entrepreneurs' early consumption.*

We now present the important steps of the analysis leading to the optimal policy (r, Λ), relegating more technical parts to the appendix.

Note first that an entrepreneur who is excluded from the market at date 1 may either tap the LOLR funds, or liquidate its assets. It cannot be optimal for the public sector to let entrepreneurs liquidate their assets at date 1. It is socially preferable to grant them emergency lending at the rate $\Lambda = 1 + \lambda$ as it saves inefficient output destruction without affecting entrepreneurs' decisions.[17] Thus one can without loss of generality restrict the analysis to the case in which $1 \leq \Lambda \leq 1 + \lambda$ and there are no asset liquidations.

Suppose that a date-0 entrepreneur has one unencumbered unit of the capital good. Given our assumption that only risk-free debt trades,[18] this entrepreneur can borrow for early consumption against a fraction $1/\Lambda$ of this unit—thereby consuming $1/r\Lambda$ when young—and consume from the residual at date 2 if he has not been excluded from the market at date 1. This dominates waiting until date 2 to consume the entire unit if and only if:

$$\frac{1}{r\Lambda} + \left(1 - \frac{1}{\Lambda}\right)(1 - q) > 1, \tag{12}$$

or

$$r < \frac{1}{1 + (\Lambda - 1)q}. \tag{13}$$

[17] We show in the appendix that the public sector always has enough fiscal space to do so at date 1.

[18] The analysis carries over if entrepreneurs can issue contingent claims.

The term $(\Lambda - 1)q$ represents the expected cost of liquidity risk. Define $\overline{\rho}$ as

$$r_0(\overline{\rho}) = \frac{1}{1 + \lambda q}. \tag{14}$$

From (13), if $\rho \geq \overline{\rho}$, then the public sector can simply set the policy rate at $r = r_0(\rho)$ and offer emergency lending at the rate $\Lambda = 1$ but in rationed quantities $r_0(\rho)l_0(\rho)w^*$ to each entrepreneur at date 1. This maximizes output and entails that young entrepreneurs do not consume at all at date 0 (they borrow only to fund wages).

Proposition 2. ***(Monetary response to small productivity shocks)*** *If $\rho \geq \overline{\rho}$, then the public sector optimally sets the policy rate at $r_0(\rho)$ at date 0. It acts as a LOLR 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:

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

Proof. See the appendix. ■

Conversely, if $\rho < \overline{\rho}$, then the public sector cannot set the date-0 policy rate at $r_0(\rho)$ and ration emergency lending this way. This would induce share buybacks and inefficient liquidation of excluded entrepreneurs' assets at date 1 from condition (13). Attaining the first-best output requires setting a date-0 policy rate r that induces share buybacks. This is not problematic per se as long as it does not lead to a binding borrowing constraint for date-0 entrepreneurs. We now determine the values of $\rho < \overline{\rho}$ for which the first-best output level can be attained without hitting such a borrowing constraint. From (12), if a policy (r, Λ) is conducive to share buybacks, a young date-0 entrepreneur solves if unconstrained:

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

The first-order condition reads:

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

Condition (10) ensures that the date-0 borrowing of the young entrepreneur $f(l)/r\Lambda$ more than covers the wage $w^{*}l$. We solve for a policy (r,Λ) that implements the first-best output while minimizing date-0 entrepreneurs' demand for funds. Such a policy (r,Λ) solves

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

s.t.

$$\frac{r\Lambda}{1+r(\Lambda-1)(1-q)}=r_{0}(\rho), \tag{19}$$

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

We show in the appendix that the solution is attained at $\Lambda=1+\lambda$ and $r=r_{\lambda}(\rho)$ defined by

$$r_{0}(\rho)=\frac{r_{\lambda}(\rho)(1+\lambda)}{1+r_{\lambda}(\rho)\lambda(1-q)}. \tag{21}$$

Note that $r_{0}(\rho)>r_{\lambda}(\rho)$. We show in the appendix that there exists $\underline{\rho}$ such that for all $\rho\in[\underline{\rho},\overline{\rho}]$, entrepreneurs do not face borrowing constraints when the public sector uses this policy $(r_\lambda(\rho), 1+\lambda)$.[19] Thus we have for such intermediate shocks:

Proposition 3. ***(Monetary response to intermediate productivity shocks)*** *There exists $\underline{\rho} \leq \overline{\rho}$ such that for all $\rho \in [\underline{\rho}, \overline{\rho})$, the public sector can implement the first-best output, 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:*

$$\frac{f'(l_0)}{w^*} = r_0 > r_\lambda. \tag{22}$$

Proof. See the appendix. ■

For any $\rho \in (\underline{\rho}, \overline{\rho})$, there are a continuum of policies that implement the first-best. Any policy (r, Λ) such that i) (19) holds and ii) there is no binding borrowing constraint for date-0 young entrepreneurs implements the first-best. In addition to the policy that Proposition 3 singles out, there are policies with higher date-0 rates and lower LOLR rates that satisfy both conditions. In accordance with our assumed selection criterion, the policy that Proposition 3 selects is the one among those that minimizes entrepreneurs' borrowing, and thus makes the date-0 borrowing constraint as slack as possible. All the policies that implement the first-best but this one are eliminated as ρ decreases sufficiently: Formally, as $\rho \downarrow \underline{\rho}$, the set of optimal policies shrinks until it reduces to the singleton $\{(r_\lambda(\underline{\rho}), 1+\lambda)\}$ at $\rho = \underline{\rho}$.

If the shock is large ($\rho < \underline{\rho}$), then any policy $(r, 1+\lambda)$ that would implement the first-best output absent borrowing constraint would generate a

[19] Parameters may be such that $\underline{\rho} = \overline{\rho}$. See proof of Proposition 3 in the appendix for a formal characterization of this situation.

borrowing constraint. Hitting such a constraint is very counterproductive as a constrained entrepreneur allocates his borrowing capacity B between investment w^*l and early consumption $B - w^*l$ so as to maximize, up to a constant,

$$f(l) + B - w^*l \tag{23}$$

and thus chooses l such that

$$f'(l) = w^*. \tag{24}$$

Thus investment snaps back to the non-stimulated level. As a result, the public sector cannot implement the first-best output level. It cannot do better than the policy $(r_\lambda(\underline{\rho}), 1 + \lambda)$.

Proposition 4. ***(Monetary response to large productivity shocks)*** *If $\rho < \underline{\rho}$, then the public sector cannot implement the first-best output level. It cannot spur more investment than the optimal level $f(l_0(\underline{\rho}))$ corresponding to a policy rate $r_\lambda(\underline{\rho})$. There are leveraged share buybacks and emergency lending at a punitive rate $1 + \lambda$. If the public sector mistakenly sets the date-0 rate at a level below $r_\lambda(\underline{\rho})$, then investment snaps back to the steady-state level $f(l^*)$.*

Proof. See the appendix. ■

In this case in which the shock is so large that the first-best is out of reach, the optimal policy is unique. It exhibits an endogenous lower bound $r_\lambda(\underline{r})$ below which monetary accommodation is counterproductive as carry trades crowd out investment.[20] It is worthwhile stressing that entrepreneurs

[20] That this bound $r_\lambda(\underline{r})$ is smaller than 1 is only due to the normalization of the growth rate of the economy and of entrepreneurs' intertemporal rate of substitution to 1.

are individually unconstrained at this lower bound $r_\lambda(\underline{\rho})$ in the sense that their investment/consumption problem admits an interior solution.

To be sure, a rational public sector should never set the policy rate below the level $r_\lambda(\underline{\rho})$ that triggers credit-market disequilibrium, entrepreneurs' rationing, and a contraction of investment to non-stimulated levels. In an open-economy extension of the model, such interest-rate levels could however be induced by capital flowing out of economies in which the rate is below $r_\lambda(\underline{\rho})$. Plantin and Shin (2018) study such situations of destabilizing monetary spillovers.

Figure 3 summarizes the findings in Propositions 2, 3, and 4:

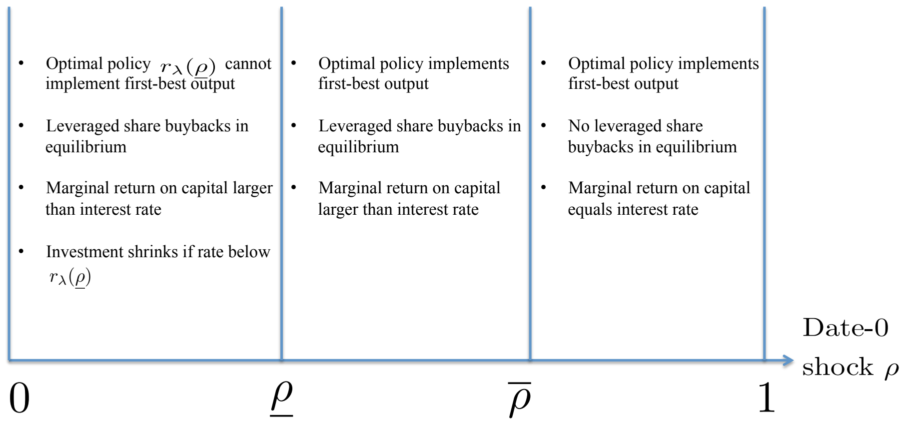

Figure 3: Optimal policy and equilibrium patterns as the date-0 shock varies

For small shocks ($\rho \geq \overline{\rho}$), the output is at its first-best level, liquidity risk discourages share buybacks, and the marginal return on capital is equal to the interest rate. Such an implementation of the first-best without share buybacks for early consumption is out of reach as shocks become larger ($\rho < \overline{\rho}$). In this case, as claimed in the introduction, we predict that monetary accommodation induces excessive maturity transformation, and indifference between share buybacks and capital expenditures at the margin despite a wedge between interest rate and marginal return on capital that actually reflects liquidity risk. Interestingly these patterns are not necessarily a symptom of inefficient investment. They may arise even if investment is at the first-best (case $\rho \in [\underline{\rho}, \overline{\rho})$). If parameters are however such that $\underline{\rho} = \overline{\rho}$, then this intermediate region vanishes and entrepreneurs enter into leveraged share buybacks exactly in the situations in which investment is below the first-best level, that is, for any $\rho < \underline{\rho} = \overline{\rho}$.

The role of asset liquidity. It is transparent from (14) that the threshold $\overline{\rho}$ above which there are no leveraged share buybacks in equilibrium is decreasing in λ. 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 $\underline{\rho}$, below which aggregate borrowing is constrained and investment is suboptimal, is also decreasing in λ. Higher liquidation costs reduce the amount $f(l_0)/(1 + \lambda)$ against which shares are bought back and thus eases financial constraints. In sum, large liquidation costs make it easier for the public sector to stimulate investment by deterring socially inefficient financial risk taking.

3 Extensions

3.1 Explicit modelling of shadow banks

As mentioned above, "entrepreneurs" in our model aggregate both the shadow-banking sector and non-financial firms for expositional simplicity. All our results carry over if we split entrepreneurs into these two categories of agents for more realism. Suppose for example that a subset of entrepreneurs—firms—have access to the capital-producing technology but cannot tap workers. The residual entrepreneurs—shadow banks—cannot produce but they can intermediate between workers and firms subject to rollover risk. Competitive shadow banks make zero profit by borrowing short-term from workers in order to fund firms' investments and leveraged share buybacks (if any). Firms issue long-term bonds underwritten by shadow banks. We now interpret λ as the cost for a shadow bank of refinancing such long-term bonds with other shadow banks if it is excluded from retail markets at the interim date.[21] It is easy to see that the analysis is then unchanged. Shadow banks charge firms a spread that reflect the expected costs associated with rollover risk. Firms therefore face the exact same cost of funds as in the baseline model and have the same demand for funds. In particular, they enter into leveraged share buybacks under the same circumstances ($\rho \leq \overline{\rho}$).

3.2 Political-economy constraints

The goal of the paper is to present a novel explanation for the low investment and high payouts induced by monetary easing in the simplest possible framework with a minimum set of ingredients. In particular the absence of any costs to workers' taxation or entrepreneurs' bailouts, and a social objective ignoring redistributive issues imply that the first-best output fails to be implemented only when entrepreneurs' demand for loans exceeds the entire supply of funds in the economy. This is an extreme view that stacks the deck against obtaining our endogenous lower bound.

It is straightforward to add to this setup a constraint on the magnitude of the transfer from old workers towards young entrepreneurs at date 0—for example as a fraction of workers' pre-tax income. The tighter the constraint,

[21]The institutions involved in the rescue may for example not be able to extract as much from the lending relationship as the original lender.

the higher the threshold $\underline{\rho}$ below which the first-best output is out of reach. On the other hand, the threshold $\overline{\rho}$ would not be affected by such a constraint since it is determined by the expected return on carry trades only (by (14)). So a tighter redistributive constraint makes it more likely that $\underline{\rho} = \overline{\rho}$ other things being equal, in which case the optimal policy either implements the first-best output without any carry trades (case $\rho \geq \overline{\rho}$ corresponding to Proposition 2) or fails to implement the first-best (case $\rho < \overline{\rho}$ corresponding to Proposition 4).

3.3 Prudential regulation

An important ingredient of our model is the assumption that the public sector cannot keep a check on leverage in the private sector. Using for brevity the elementary model sketched in the introduction, this section shows that the appropriate combination of a policy rate and a prudential regulation for entrepreneurs can implement investment levels beyond $1/R^2$ without inducing leveraged share buybacks.[22] Suppose thus that in this model, the public sector can enforce an interest rate r and a capital requirement stipulating that entrepreneurs cannot borrow beyond a fraction Δ of their total asset

[22]The interest rates that induce investment below $1/R^2$ are not conducive to leveraged share buybacks even in the unregulated case studied in the introduction.

value. Subject to such a capital requirement, entrepreneurs then solve:

$$\min_{B,I} \left\{ c_0 + \frac{c_1}{R} \right\} \tag{25}$$

$$s.t. \quad c_0 + I \leq B, \tag{26}$$

$$c_1 + rB \leq 2\sqrt{I}, \tag{27}$$

$$B \leq \frac{2\Delta\sqrt{I}}{r}, \tag{28}$$

$$c_0 \geq 0. \tag{29}$$

The variables B and I respectively denote total borrowing and investment by entrepreneurs. The case $\Delta = 1$ corresponds to the unregulated case studied in the introduction. (In this case (28) simply imposes that c_1 be positive.)

Proposition 5. ***(Prudential regulation curbs inefficient risk-taking)*** *The public sector can implement investment $I \in [1/R^2, 4/R^2)$ without triggering any leveraged share buybacks ($B = I$) by setting (r, Δ) such that:*

$$\frac{\Delta}{r} = \frac{1}{r+R} = \frac{\sqrt{I}}{2}. \tag{30}$$

Proof. See the appendix. ■

Condition (30) shows that the policy rate r unsurprisingly decreases with respect to I. The capital requirement becomes in turn tighter as monetary policy is more accommodative: Δ decreases with I. Intuitively, inframarginal productivity is larger than r and so unconstrained debt capacity grows faster than investment I as r decreases. A tightening capital requirement keeps this debt capacity at the minimum level $B = I$ that allows for optimal investment but not for early consumption.

An interesting route for future research consists in studying the intermediate situation in which the regulation of leverage—or/and the taxation of entrepreneurs' capital/consumption—can only be imperfectly enforced, and examining the interplay of such imperfect enforcement with the crowding out of investment by financial risk-taking highlighted here.[23]

3.4 Asset purchases

An important component of the post 2008 unconventional monetary policy is the purchase of mortgage-backed securities by the Federal Reserve. In our setup, such private-asset purchases would correspond to a swap between the public sector and the entrepreneurs of units of the capital good for public bonds akin to remunerated excess reserves (although reserves have an indefinite maturity whereas the public liabilities last one-period here). Such a swap could be an alternative way to spur investment at date 0. If the public sector kept the date-0 policy rate at $r^* = 1$ (for example because this is an exogenous lower bound given the alternative storages available, as is the case with the zero lower bound in practice) but accepted to trade $1/r_0$ bonds for each unit of capital produced at date 0, then this would also generate the first-best output without triggering any excess demand of funds due to carry trades at date 0. But the risk that such an excess demand of funds arises is only postponed to date 1 under this alternative policy, as overpaying for private assets creates the same need to transfer funds from old workers to young entrepreneurs once the public bonds mature at date 1.

[23]Plantin (2015) develops a model of leverage regulation under imperfect enforcement. Landier and Plantin (2017) offer a model of optimal capital taxation under imperfect enforcement.

3.5 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.

3.6 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 would not be reached over a larger parameter range 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.

4 Concluding remarks

Our attempt in this paper has been to embed financial-stability concerns in a workhorse model of the interest-rate channel of monetary policy. We study an economy in which i) the intertemporal rate of substitution of agents with the highest borrowing capacity in the economy exceeds the policy rate, ii) the public sector has limited control over maturity transformation by the private sector. Under these circumstances, monetary easing triggers a large amount of financial risk-taking at the expense of capital expenditures. Financial risk-taking is a socially costly rent extraction by entrepreneurs. The model gives a compact explanation for the increase in maturity transformation and share buybacks that has accompanied the recent phases of monetary easing, together with limited investment despite 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 an endogenous 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).

References

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

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

Acharya, Viral V. and Siddharth Vij. 2016. "External Commercial Borrowings of Corporations as Carry Trades: Evidence from India," Working Paper, New York University Stern School of Business.

Auclert, Adrien. 2017. "Monetary Policy and the Redistribution Channel," working paper.

Benmelech, Efraim and Nittai K. Bergman. 2012. "Credit Traps," *American Economic Review* 102 (6).

Bernanke, Ben S. 2010. "Monetary Policy and the Housing Bubble," Speech at the Annual Meeting of the American Economic Association, Atlanta, Georgia.

Brunnermeier, Markus K. and Yann Koby. 2018. "The Reversal Interest Rate," working paper, Princeton University.

Bruno, Valentina and Hyun-Song Shin. 2014. "Global Dollar Credit and Carry Trades: A Firm-level Analysis," *Review of Financial Studies,* forthcoming.

Caballero, Ricardo J. and Emmanuel Farhi. 2017. "The Safety Trap," *Review of Economic Studies,* forthcoming.

Caballero, Ricardo J. and Alp Simsek. 2017. "A Risk-centric Model of Demand Recessions and Macroprudential Policy," working paper.

Coimbra, Nuno and Hélène Rey. 2017. "Financial Cycles with Heterogeneous Intermediaries," working paper.

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

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

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

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

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

Gutiérrez, Germán and Thomas Philippon. 2017. "Investment-less Growth: An Empirical Investigation," *Brookings Papers on Economic Activity,* Fall.

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

International Monetary Fund. 2017. "Getting the Policy Mix Right," In *Global Financial Stability Report, April 2017.*

Landier, Augustin and Guillaume Plantin. 2017. "Taxing the Rich," forthcoming, *Review of Economic Studies* 84 (3).

Plantin, Guillaume. 2015. "Shadow Banking and Bank Capital Regulation," *Review of Financial Studies* 28 (1).

Plantin, Guillaume and Hyun Shin. 2018. "Exchange Rates and Monetary Spillovers," *Theoretical Economics* 13 (2).

Quadrini, Vincenzo. 2017. "Interest Rate Policies, Banking and the Macro-economy," working paper.

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

Stein, Jeremy C. 2012. "Monetary Policy as Financial-Stability Regulation," *Quarterly Journal of Economics* 127 (1).

Stein, Jeremy C. 2013. "Overheating in Credit Markets: Origins, Measurement, and Policy Responses," Speech delivered at the "Restoring Household Financial Stability after the Great Recession: Why

Household Balance Sheets Matter" research symposium sponsored by the Federal Reserve Bank of St. Louis, St. Louis, Missouri.

Taylor, John. 2011. "Macroeconomic Lessons from the Great Deviation," in Daron Acemoglu and Michael Woodford (Eds.) NBER Macroeconomics Annual, Vol. 25, The University of Chicago Press, 25.

Taylor, John. 2012. "Monetary Policy Rules Work and Discretion Doesnt: A Tale of Two Eras," *Journal of Money Credit and Banking* 44 (6).

Appendix

Proof of Proposition 2

For $\rho \geq \overline{\rho}$, (13) implies that a date-0 rate $r_0(\rho)$ 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 when the LOLR rate is 1. Since entrepreneurs borrow only wages from young workers they are not constrained at date 0. Furthermore, there are no borrowing constraints at date 1. We have indeed at this date 1:

- Pre-tax (and thus taxable) income of old workers:

$$r_0 \rho g(1 - l_0) + r_0 w^* l_0 \tag{31}$$

- Funds invested in public bonds by young workers:

$$\underbrace{g(1 - l^*)}_{\text{Income not lent to young entrepreneurs}} \quad - \quad \underbrace{(1 - q) r_0 w^* l_0}_{\substack{\text{Refinancing of} \\ \text{middle-aged entrepreneurs}}} \tag{32}$$

- Maturing public liabilities:

$$r_0[\rho g(1 - l_0) - (1 - q) w^* l^*] + q r_0 w^* l_0 - q w^* l^* \tag{33}$$

The first term in (33) states that young date-0 workers invested $\rho g(1 - l_0) - (1 - q) w^* l^*$ in public bonds at date 0. The second term represents the emergency funding to distressed middle-aged entrepreneurs. The third term is the reimbursement by old entrepreneurs of the emergency funding that they received when distressed at date 0.

No agent is constrained at date 1 if the public sector can balance its budget, or if (31) + (32) ≥ (33), which always holds. ■

Proof of Proposition 3

As stated in the body of the paper, implementing the first-best output while minimizing young entrepreneurs' consumption at date 0 amounts to solving:

$$\min_{r,\Lambda}\left\{\frac{1}{r\Lambda}\right\} \tag{34}$$

s.t.

$$\frac{r\Lambda w^*}{1+r(\Lambda-1)(1-q)} = r_0(\rho), \tag{35}$$

$$\Lambda \leq 1+\lambda. \tag{36}$$

That $1 > r(1-q)$ implies that the left hand side (l.h.s.) of (35) is increasing in $r\Lambda$ holding r fixed. It is also clearly increasing in r holding $r\Lambda$ fixed. So the largest feasible $r\Lambda$ that satisfies this equality corresponds to the smallest r and in turn to the largest feasible value of Λ, $1+\lambda$. This implies that the policy rate is $r = r_\lambda(\rho)$ defined by

$$r_0(\rho) = \frac{r_\lambda(\rho)(1+\lambda)}{1+r_\lambda(\rho)\lambda(1-q)} > r_\lambda(\rho). \tag{37}$$

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

We now show that given this policy, date-0 borrowing by entrepreneurs exceeds the date-0 supply of loanable funds when ρ is below a threshold $\underline{\rho}$. For a date-0 rate r_λ, we have at date 0:

- Pre-tax income of old workers (=proceeds from having invested their date-(-1) income at rate 1):

$$g(1-l^*)+w^*l^* \tag{38}$$

- Funds invested in public bonds by young workers:

$$\underbrace{\rho g(1-l_0)+w^*l_0}_{\text{Profits and labor income}} - \underbrace{(1-q)w^*l^*}_{\substack{\text{Refinancing of}\\ \text{middle-aged entrepreneurs}}} - \underbrace{\frac{f(l_0)}{r_\lambda(1+\lambda)}}_{\substack{\text{Loans to}\\ \text{young entrepreneurs}}} \tag{39}$$

- Maturing public liabilities:

$$g(1-l^*)-(1-q)w^*l^*+qw^*l^*-qw^*l^* \tag{40}$$

  The term $g(1-l^*)-(1-q)w^*l^*$ in (40) stems from the fact that young workers' investment in public bonds at date -1 is their total income $g(1-l^*)+w^*l^*$ net of loans to young entrepreneurs w^*l and refinancing of middle-aged entrepreneurs $(1-q)w^*l^*$. The two other terms cancel out as they represent the emergency lending to middle-aged entrepreneurs net of the reimbursement by old entrepreneurs of the date-(-1) emergency funds (lent at a unit rate).

The date-0 borrowing constraint binds when maturing liabilities exceed taxable income and investment in public bonds:

$$(38)+(39)\leq(40), \tag{41}$$

and re-arranging yields

$$\frac{f(l_0)}{(1+\lambda)r_\lambda} - w^* l_0 \geq w^* l^* + \rho g(1-l_0). \tag{42}$$

This is intuitive: the l.h.s. is the amount that date-0 young entrepreneurs seek to borrow beyond the financing of wages, and the right-hand side features the investable funds of young workers $\rho g(1-l_0)$ and the amount that firms owe to old workers which is taxable $w^* l^*$. From the definition of r_λ, this is equivalent to

$$\frac{f(l_0)}{r_0} - w^* l_0 \geq \rho g(1-l_0) + \frac{\lambda(1-q)f(l_0)}{1+\lambda} + w^* l^*. \tag{43}$$

From the envelope theorem, the derivative of the left-hand side of (43) w.r.t. ρ is

$$-\frac{f(l_0)}{r_0^2}\frac{dr_0}{d\rho} \leq 0, \tag{44}$$

whereas that of the right-hand side is

$$g(1-l_0) - \rho g'(1-l_0)\frac{dl_0}{d\rho}\frac{1+\lambda q}{1+\lambda} \geq 0. \tag{45}$$

This implies that the borrowing constraint binds if and only if ρ is below a threshold $\underline{\rho}$, possibly equal to $\overline{\rho}$ if (43) does not hold at $\rho = \overline{\rho}$. A simple inspection of (43) shows that this threshold $\underline{\rho}$ is decreasing in λ.

Finally, there are no borrowing constraints at date 1. We have at this date:

- Income of old workers (=Proceeds from having invested their date-0 income at rate r_0):

$$r_0 \rho g(1 - l_0) + r_0 w^* l_0 \tag{46}$$

- Funds invested in public bonds by young workers:

$$\underbrace{g(1 - l^*)}_{\text{Income not lent to entrepreneurs}} \quad - \quad \underbrace{\frac{(1 - q) f(l_0)}{1 + \lambda}}_{\substack{\text{Refinancing of} \\ \text{middle-aged entrepreneurs}}} \tag{47}$$

- Maturing public liabilities:

$$r_0 \left[\rho g(1 - l_0) + w^* l_0 - (1 - q) w^* l^* - \frac{f(l_0)}{r_0(1 + \lambda)} \right] + \frac{q f(l_0)}{1 + \lambda} - q w^* l^* \tag{48}$$

Again, the first-term is the repayment of public bonds purchased at date-0 by young workers, with their total income net of loans to young entrepreneurs and distressed middle-aged ones. The second term are emergency loans to distressed middle-aged entrepreneurs. The third term is the repayment of emergency loans by old entrepreneurs.

No agent is constrained at date 1 if the public sector can balance its budget, or if (46) + (47) $\geq$ (48), which always holds. ■

Proof of Proposition 4

By construction of $\underline{\rho}$, if $\rho < \underline{\rho}$, it is impossible to implement the first-best output, or in fact any output larger than the one associated with the policy $(r_\lambda(\underline{\rho}), 1 + \lambda)$ without triggering a borrowing constraint and thus investment at the non-stimulated level. ■

Proof of Proposition 5

That $I > 1/R^2$ implies that $r < R$ and so (28) is optimally binding: entrepreneurs maximize early consumption. Together with a binding condition (26) this yields a first-order condition for investment:

$$\sqrt{I} = \frac{\Delta}{r} + \frac{1-\Delta}{R.} \tag{49}$$

Imposing that $B = 2\Delta\sqrt{I}/r$ equal I implies $\sqrt{I} = 2\Delta/r$, which combined with (49) and re-arranged yields relations (30).

Note that for higher levels of investment $I \geq 4/R^2$, implementing $B = I$ is out of reach. It is possible to get arbitrarily close to the lower bound for B defined as

$$\frac{B-I}{I} = 1 - \frac{2}{R\sqrt{I}} \tag{50}$$

by setting Δ and r arbitrarily small and $\Delta/r = \sqrt{I} - 1/R$. ■