Monetary Easing, Investment and Financial Instability*

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Abstract

This paper studies a model of the interest-rate channel of monetary policy in which a low policy rate lowers the cost of capital for firms thereby spurring investment, but also induces destabilizing "carry trades" against their assets. If the public sector does not have sufficient fiscal capacity to cope with the large resulting private borrowing, then carry trades and productive investment compete for scarce funds, and so the former crowd out the latter. Below an endogenous lower bound, monetary easing generates only limited investment at the cost of large and socially wasteful financial risk taking.

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Introduction

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.

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 high-yield corporate bonds, 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). Non-financial corporations also have increasingly engaged into financial risk taking. The US corporate sector has raised $7.8 trillion in debt since 2010, 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, and has more broadly risen to levels exceeding those prevailing just 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.[1] Investment has not returned yet to its pre-recession

[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

trends despite a large wedge between historically low interest rates and historically high realized rates of return on existing capital.[2] 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.* Note that even though these three features have amplified following the 2008 crisis, they could actually be discerned earlier on. For example, Gutiérrez 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.[3] 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

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."

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

[3]Gutiérrez and Philippon (2016) argue that this evolution owes to a decline in the degree of competition in US product markets. We view this explanation as fully complementary to ours.

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).

To get a broad sense of the simple mechanism at stake in the model, consider an economy in which agents can borrow or lend at a (real) risk-free rate controlled by the public sector 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, agents borrow large amounts in order both to invest large quantities and to consume early against the future profits from such investment. This latter early consumption against future profits is akin to leveraged share buybacks. If the public sector sets the risk-free rate too low, such "storing and destoring" results in an excess private demand for funds. Rationed agents then allocate their maximum borrowing capacity across investment and share buybacks up to the point at which the marginal return on investment is equal to their intertemporal rate of substitution. 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 yet more subtle 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. Incomplete markets force them to borrow at a shorter maturity than that of their projects when doing so, and these "carry trades" expose them to rollover risk. The monetary authority correctly anticipates that setting the policy rate too low would generate an excess demand for loanable funds, and thus would lead to the resulting counterproductive credit rationing mentioned above. It optimally responds by accommodating less than it would if it could directly control carry-trade activity, and by using punitive rates when acting as a lender of last resort, very much in line with Bagehot's dictum. The important implication from this policy is that credit is *not* rationed in equilibrium. Each firm's capital budgeting and financing problem has an interior solution. Yet, in equilibrium, this second-best policy generates financial fragility in the form of large carry-trade activity, and marginal indifference between share buybacks and productive investment in the use of corporate resources despite a large wedge between the policy rate and the marginal return on capital. This wedge reflects the cost from taking on liquidity risk on carry trades.

An important driver of this outcome is our assumption that the central bank cannot directly control the quantity of leverage and maturity transformation in which the private sector engages. This captures the rise over the last decades of a large shadow-banking system that refinances the economy with the rollover of short-term liabilities outside the scope of licensed banking. The public sector can indirectly and partially affect the shadow-banking sector size in practice through the management of its expectations regarding the public response to its liquidity crises. This simply boils down to (credibly) announcing a punitive rate of last-resort lending in our model. Overall, the model makes the case that more unregulated maturity transformation in the financial system implies that monetary easing, even when constrained-efficient, induces more financial risk taking (carry trades) and less economic risk taking (capital expenditures).

Model

We introduce these ingredients in a simple model of optimal monetary policy that focusses on the steering of the real rate by the central bank. 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 however firms to enter into carry trades against their future profits despite the associated rollover risk that may induce inefficient early liquidation. Carry trades are socially costly not only as such a source of financial fragility, but also because they increase the private sector's overall demand for funds. At some point, productive investment and carry trades compete for finite resources, and the latter crowd out the former.

The best policy response to these two costs of carry trades is for the central bank to offer lending of last resort at the highest rate at which firms prefer to borrow rather than liquidating their assets in case of distress. This way, there is no inefficient asset liquidation, and the amount of maturity transformation per unit of capital created is kept to a minimum. Still, the central bank may be constrained and set the policy rate above the natural rate in the economy if this natural rate is sufficiently low and the assets that lend themselves to carry trades are sufficiently liquid. In other words, if lending of last resort is not crucial to the agents engaging into unregulated maturity transformation, the central bank has a very limited ability to spur investment while keeping financial risk taking under control.

The paper is organized as follows. As a first step, 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 binding 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 the fragility leading to the 2008 crisis. It is also a natural candidate to explain 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, 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.

Brunnermeier and Koby (2017) 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. 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. Quadrini (2017) develops a model in which monetary easing by the public sector in the form of private asset purchases may have a contractionary impact on investment as in our environment. 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 its ability to take on productivity risk.

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.[4]

Finally, as we argue in Section 3.1, our results are reinforced if redistributive concerns limit the public sector's willingness to tax old agents in order to accommodate the large borrowing induced by share buybacks. 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

[4] 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. 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, 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. This capital delivers $f(l)$ units of the consumption good at the next date. 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. 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.

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 workers.

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.[5] If $r < 1$, they borrow the additional amount $(f(l) - rwl)/r$ against their next-date profit $f(l) - rwl$. 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:

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

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

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

Expression (1) states that entrepreneurs consume their profits when young if $r < 1$ and when old otherwise. Old workers receive the proceeds from their loans to entrepreneurs wl and to the public sector $g(1-l)$, and the public

[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.

sector adds to/substracts from this income a lump-sum rebate or tax equal to its net proceeds in the bond market. From (2), consumption per cohort is equal to output in the steady-state.

Furthermore, profit maximization by all firms implies:

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

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

Expression (2) shows that the public sector optimally maximizes the output per cohort, which 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

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

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 welfare in OLG models is maximum when the interest rate matches the growth rate of the population (which is one here).

Comments

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) or Farhi and Tirole (2012) also focus on the financial-stability implications of monetary policy abstracting from price-level determination as we do.

Welfare irrelevance of leveraged share buybacks. Borrowing by young entrepreneurs against their future profits $f(l) - rwl$ admits a straightforward interpretation as leveraged share buybacks. The corporations set by young entrepreneurs borrow in order to repurchase shares from these entrepreneurs and cancel the shares.[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 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 3.1, redistributive concerns would only reinforce our results.

Private demand for funds. 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. By inspection of (1), this is always the case when $r \geq 1$. On the other hand, this might not

[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.

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 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 — 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 $\rho \in (0, 1)$.[8] In a more elaborate model in which capital does not fully depreciate over one period and must be combined with labor to generate consumption, such a shock on the relative productivity of capital could stem from an exogenous destruction of the capital stock.

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

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

[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 because this does not affect their investment decisions given the assumed environment.

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.[9] 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 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 mar-

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

ket. 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.[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

[10] 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.

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 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.

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 $\lambda > 0$.

[11] Assuming that they do not value interim consumption slightly simplifies the exposition. Section 3.4 below shows how the introduction of interim consumption reinforces our results.

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).[13] We assume that for all $x \in (0,1)$,[14]

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

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 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 lender of last resort.[15] 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

[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]The analysis would carry over to the case in which entrepreneurs may also be excluded from markets when young at the cost of some additional complexity.

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

[15]Equivalently, the public sector announces a rate at which it is willing to borrow and a rate at which it is willing to lend since only excluded entrepreneurs need to borrow from him in equilibrium.

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.

Financial intermediaries and non-financial firms. There is no room for financial intermediation in our model, and so 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, maturity transformation has mostly taken place through the shadow-banking sector taking on maturity risk in order to finance long-term corporate debt or real-estate investments. Non-financial corporations have levered up using longer and more standard maturities and increased their payouts to shareholders.

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.

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 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.[16] 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.[17]

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

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

[17] Section 3.5 discusses how the anticipation of this shock would affect the analysis.

$g(1 - l_0)$, is strictly decreasing in ρ.

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.[18] Thus one can without loss of generality restrict the analysis to the case in which $\Lambda \leq 1+\lambda$ and there are no asset liquidations.

We will see in the following that whenever the public sector can implement the first-best output by the date-0 cohort, there are 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 suppose that the public sector selects in this case the policy that transfers as little income as possible from date-0 old workers to young entrepreneurs.

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 solve for such optimal policies. We develop the important steps of the analysis in the body of the paper and relegate more technical parts to the appendix. Suppose that a date-0 entrepreneur has one unencumbered unit of the capital good. Recall our assumption that only risk-free debt trades.[19] The entrepreneur can thus borrow for early consumption against a fraction $1/\Lambda$ of this unit, and consume from the residual at date 2 if he has not been

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

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

excluded from the market at date 1. This dominates waiting until date 2 to consume the entire unit if and only if:

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

or

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

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 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:

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

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 $(r_\lambda(\rho), 1 + \lambda)$. 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.[20] Any policy (r, Λ) such that i) (19) holds and ii) there is no

[20] Parameters may be such that this set is empty because $\underline{\rho} = \overline{\rho}$. This occurs when capital

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. As a result, all the policies that implement the first-best but this one are eliminated as ρ decreases: 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 $\rho = \underline{\rho}$. This policy with the largest feasible LOLR rate follows Bagehot's dictum: lending without limit to solvent firms at a punitive rate.

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 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 $(r_\lambda(\underline{\rho}), 1+\lambda)$.

output is large relative to consumption-good output (sufficiently large capital share).

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 shares 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.[21] It is worthwhile stressing that entrepreneurs are individually unconstrained at this lower bound in the sense that their investment/consumption problem admits an interior solution.

Figure 1 summarizes the findings in Propositions 2, 3, and 4:

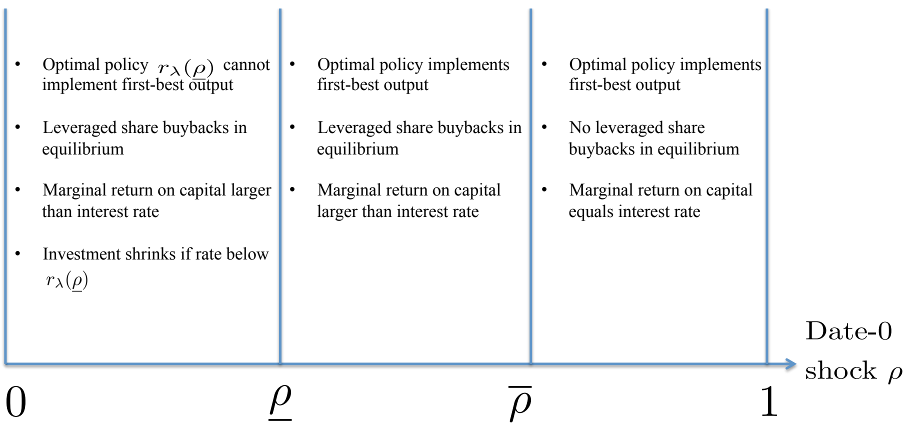

Figure 1: Optimal policy and equilibrium patterns as the date-0 shock varies

[21]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.

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 $\rho < \underline{\rho} = \overline{\rho}$.

Shadow banking and maturity transformation outside banks

A clear-cut implication of our framework is that aggressive monetary easing must spur a strong demand for "carry trades" in an economy in which maturity transformation is not strictly regulated because it can arise outside the scope of traditional banks. 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 that collapsed in 2008. Also in line with the model, as mentioned in the introduction, carry trades and more generally unregulated maturity transformation appear to have recently moved over to asset management industry flows into junk bonds and collateralized leveraged loans, emerging market government and corporate bonds, and funding of residential mortgage-backed assets. 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 (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.

3 Extensions

3.1 Political-economy constraints

The goal of the paper is to present a novel explanation for the low investment and high financial risk taking 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, 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).

3.2 Taxing/regulating 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 nor regulating entrepreneurs. 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 (lump-sum) taxation of date-0 consumption by entrepreneurs, by the (lump-sum) taxation of their future profits, or by an upper bound on their leverage ratio so that they borrow only to finance wages. An interesting route for future research consists in studying the intermediate situation in which the taxation of capital or the regulation of leverage can only be imperfectly enforced, and examining the interplay of this imperfection with the crowding out of investment by financial risk taking.[22]

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

3.3 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 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) between the public sector and the entrepreneurs. 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.

3.4 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.

In sum, our assumption that assets fully depreciate after one period so that there are no outstanding legacy assets that can back carry trades at date 0 strongly stacks the deck against our results.

3.5 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.

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 the agents with the highest borrowing capacity in the economy exceeds the policy rate, ii) the public sector has limited control over maturity transformation by these agents. 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 borrowers. The model gives a compact explanation for the increase in maturity transformation and share buybacks that has recently accompanied 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).

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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:

- Income of old workers:

$$\underbrace{r_0\rho g(1-l_0)+r_0w^*l_0}_{\substack{\text{Proceeds from having invested}\\ \text{the date-0 income at rate } r_0}} - \underbrace{qr_0w^*l_0}_{\substack{\text{Tax to fund emergency lending}\\ \text{for excluded middle-aged entrepreneurs}}} \tag{25}$$

- Funds invested in public bonds by young workers:

$$\underbrace{g(1-l^*)}_{\text{Income not lent to young entrepreneurs}} - \underbrace{(1-q)r_0w^*l_0}_{\substack{\text{Refinancing of}\\ \text{middle-aged entrepreneurs}}} \tag{26}$$

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

$$r_0[\rho g(1-l_0)-(1-q)w^*l^*]-qw^*l^* \tag{27}$$

The latter term states that young date-0 workers invested $\rho g(1-l_0)-(1-q)w^*l^*$ in public bonds at date 0, and so this fraction of their date-1 income cannot be taxed and transferred to other agents. On the other hand the government rebates qw^*l^* paid by old firms at date 1 to old agents. No agent is constrained at date 1 if the public sector can balance its budget, or if (25) $\geq$ (27) $-$ (26), 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:

$$\min_{r,\Lambda} \left\{ \frac{1}{r\Lambda} \right\} \tag{28}$$

s.t.

$$\frac{r\Lambda w^*}{1 + r(\Lambda - 1)(1 - q)} = r_0(\rho), \tag{29}$$

$$\Lambda \leq 1 + \lambda. \tag{30}$$

That $1 > r(1 - q)$ implies that the l.h.s. of (29) 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

$$r_0(\rho) = \frac{r_\lambda(\rho)(1 + \lambda)}{1 + r_\lambda(\rho)\lambda(1 - q)} > r_\lambda(\rho). \tag{31}$$

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 and borrowing w^*l_0, we have at date 0:

- Income of old workers:

$$\underbrace{g(1-l^*)+w^*l^*}_{\substack{\text{Proceeds from having invested}\\ \text{the date }(-1)\text{ income at rate 1}}} \quad - \quad \underbrace{qw^*l^*}_{\substack{\text{Tax to fund emergency lending}\\ \text{for excluded middle-aged entrepreneurs}}} \tag{32}$$

- Funds invested in public bonds by young workers:

$$\underbrace{\rho g(1-l_0)+w^*l_0}_{\text{Profit and labor income}} - \underbrace{(1-q)w^*l^*}_{\substack{\text{Refinancing of}\\ \text{middle-aged entrepreneurs}}} - \underbrace{\frac{f(l_0)}{r_\lambda(1+\lambda)}}_{\substack{\text{Loans to}\\ \text{young entrepreneurs}}} \tag{33}$$

- Amount owed to old workers by the government from their investments in public bonds net of rebates from old date-(-2) entrepreneurs:

$$g(1-l^*)-(1-q)w^*l^*-qw^*l^* \tag{34}$$

  The last term (34) 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:

$$(32) \leq (34) - (33), \tag{35}$$

and re-arranging yields

$$\frac{f(l_0)}{(1+\lambda)r_\lambda} - w^* l_0 \geq w^* l^* + \rho g(1-l_0). \tag{36}$$

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

$$\frac{f(l_0)}{r_0} - w^* l_0 \geq \rho g(1-l_0) + \frac{\lambda(1-q)f(l_0)}{1+\lambda} + w^* l^*. \tag{37}$$

From the envelope theorem, the derivative of the left-hand side of (37) w.r.t. ρ is

$$-\frac{f(l_0)}{r_0^2}\frac{dr_0}{d\rho} \leq 0, \tag{38}$$

whereas that of the right-hand side is

$$g(1-l_0) - \rho g'(1-l_0)\frac{dl_0}{d\rho}\frac{1+\lambda q}{1+\lambda} \geq 0. \tag{39}$$

This implies that the borrowing constraint binds if and only if ρ is below a threshold $\underline{\rho}$, possibly equal to $\overline{\rho}$. A simple inspection of (37) 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:

$$\underbrace{r_0\rho g(1-l_0)+r_0w^*l_0}_{\substack{\text{Proceeds from having invested}\\ \text{the date-0 income at rate } r_0}} - \underbrace{\frac{qf(l_0)}{1+\lambda}}_{\substack{\text{Tax to fund emergency lending}\\ \text{for excluded middle-aged entrepreneurs}}} \tag{40}$$

- Funds invested in public bonds by young workers:

$$\underbrace{g(1-l^*)}_{\text{Income not lent to entrepreneurs}} - \underbrace{\frac{(1-q)f(l_0)}{1+\lambda}}_{\substack{\text{Refinancing of}\\ \text{middle-aged entrepreneurs}}} \tag{41}$$

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

$$r_0[\rho g(1-l_0)-(1-q)w^*l^* - \frac{f(l_0)}{r_0(1+\lambda)} + w^*l_0] - qw^*l^* \tag{42}$$

No agent is constrained at date 1 if the public sector can balance its budget, or if (40) $\geq$ (42) $-$ (41), 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.