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Optimal Inflation with Corporate Taxation and Financial Constraints

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Abstract

How does inflation affect the investment decisions of financially constrained firms in the presence of corporate taxation? Inflation interacts with corporate taxation via the deductibility of i) capital expenditures and ii) interest payments on debt. Through the first channel, inflation increases firms' taxable profits and further distorts their investment decisions. Through the second, expected inflation affects the effective real interest rate and stimulates investment. When debt is collateralized, the second effect dominates. Therefore, present a tax-advantage to debt financing, positive long-run inflation enhances welfare by mitigating or even eliminating the investment distortion.

Keywords: optimal monetary policy, Friedman rule, credit frictions, tax benefits of debt. *JEL codes:* E31,E43, E44, E52, G32.

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1 Introduction

A large body of literature supports the idea that long-run inflation reduces welfare.[1] In particular, it has been argued that inflation exacerbates the distortionary effects of corporate taxation, thereby providing a further argument in favor of low (if not negative) rates of inflation.[2] Our paper revisits this statement by showing that, in the presence of collateral constraints, expected inflation actually *raises* equilibrium welfare — the opposite of the common presumption. For a given tax structure, eliminating inflation to achieve price stability might thus be a bad idea.

Corporate taxation distorts firms' investment and tax deductions are usually introduced to mitigate these distortions, absent more granular tax systems. As deductions are formulated in nominal terms, the rate of inflation can affect the effective tax burden, thus creating a source of monetary non-neutrality. This is notably the case for two common corporate tax deductions: investment expenditures and interest payments on debt.

When *investment expenditures* are computed at their historical value, as is often the case, inflation reduces the real value of the deduction. This raises the firm's net-of-depreciation taxable profits and consequently increases the distortionary effects of corporate taxes—an often-made argument for low inflation (e.g. Feldstein, 1999).

The deductibility of *interest payments* on debt changes the effective real rate of interest faced by firms and the tightness of their financial conditions, i.e. inflation acts as a subsidy to borrowers. If borrowing is collateralized by the firm's capital, inflation ultimately stimulates capital accumulation and brings the return to capital closer to the first best. This last channel, neglected by previous literature, turns out to dominate. The overall effects of inflation on equilibrium welfare are thus reversed compared to the frictionless model.

We make these points by proceeding in two steps. First, we show the interaction between corporate taxes and borrowing constraints in a simple two-period model. We establish the optimality of positive inflation in the presence of interest rate deductions only, and its impact on corporate tax revenues. Second, we assess the quantitative relevance of the central mechanism of this paper using a calibrated dynamic version of the model featuring corporate taxes and a collateral constraint à la Kiyotaki and Moore (1997). The stylized tax code presented in the model captures the two main tax/inflation distortions mentioned above and highlighted by Feldstein and Summers (1978): i) corporate taxes with deductibility of interest payments on debt and ii) deductibility of investment expenditures at historical values. Last, we examine optimal inflation in an extended version of the model that includes costly price rigidities.

The main quantitative results of the paper can be summarized as follows. In a world with perfectly competitive markets and flexible prices, for a given tax structure, a positive and relatively large long-run inflation rate (5.67%) is optimal. The Friedman rule (i.e., deflation at the real rate of interest) is optimal only in the limit

[1] See, for instance, Cooley and Hansen (1991); Lucas (2000); Lagos and Wright (2005); Schmitt-Grohe and Uribe (2010)

[2] Feldstein (1983) collects a number of studies on the interaction of inflation and existing tax rules in the U.S., Feldstein (1999) gathers cross-country analyses.

case of full deductibility of investment. Introducing price stickiness and monopolistic competition does not completely offset our results. If price adjustments are costly also in the long run, the optimal inflation rate is reduced but remains positive (2.7%). Furthermore, the optimal long-run inflation is an increasing function of the degree of monopolistic distortion. This contrasts with the standard New-Keynesian literature, which finds that the optimal long-run inflation in the presence of sticky prices is zero, independently of the degree of monopolistic competition (see King and Wolman, 1999; Woodford, 2003).

It is important to note that we take the tax system as exogenous. We are mindful of the possibility that an opportunely chosen set of taxes could bring about the first best with zero inflation as in Fischer (1999, p.42). Nevertheless, the ideal configuration differs from the *observed* constellation of taxes—for reasons that are beyond the scope of this analysis.[3] Our paper should thus be taken as invalidating, under the current system of corporate taxation, conventional wisdom on the detrimental effects of inflation.

The paper is organized as follows. Section 2 illustrates the interaction between corporate taxes, inflation and firms' investment decisions in a simple two-period model. Section 3 describes the general equilibrium dynamic model. Section 4 assesses the quantitative relevance of our mechanism. Section 5 introduces price rigidity and monopolistic competition. Section 6 discuss our financial frictions assumption. Section 7 examines the robustness of preceding results to different fiscal policy assumptions. Section 8 concludes. Most proofs and model details are gathered in the Appendix.

Related literature

A consistent finding in the literature is that the optimal rate of long-run inflation should range between the Friedman Rule and numbers close to zero. Schmitt-Grohe and Uribe (2010) survey the literature on the optimal rate of inflation and show that positive inflation could be justified only in the absence of a uniform taxation of income (e.g. when untaxable pure profits are present). However, these authors conclude that for reasonably calibrated parameter values, tax incompleteness could not explain the magnitude of observed inflation targets. In this paper we show that, under plausible conditions, the interplay between borrowing constraints and distortionary taxes justifies a positive long-run target inflation. Importantly, the mechanism at play is not only theoretically plausible, but also quantitative relevant.

More recently, a number of studies have explored different channels that could lead to the optimality of a positive long-run inflation rate. For example, a positive inflation target could be useful to avoid the risk of hitting the zero lower bound (Coibion et al., 2012). Alternatively, inflation can be welfare enhancing in the presence of

[3]For about 100 years, interest payments on debt has been fully deductible in the U.S. In the aftermath of the recent financial turmoil, it has become a hotly debated topic in the fiscal-reform debate together with other policies aiming at discouraging the use of debt to finance business activities. For example, the Wyden-Coats Tax Fairness and Simplification Act proposes to limit interest deductions to their non-inflationary component. However, no changes to the tax code have been implemented up to now.

downward nominal rigidities as it can "grease the wheel of labor market" (see Tobin's 1971 AEA presidential address and Kim and Ruge-Murcia, 2009). However, these distortions are usually of secondary importance and only small deviations from price stability are optimal. Recent work by Venkateswaran and Wright (2013) also finds that inflation is welfare improving in the presence of distortionary taxes and collateral constraints. Despite the strong similarities with our results, their mechanism differs from ours in many respects. In both models, distortionary taxation generates under-accumulation of assets. In Venkateswaran and Wright (2013), positive inflation is beneficial because it induces *households* to shift from real balances to the real asset, i.e. capital (Mundell-Tobin effect). In our model, inflation spurs capital accumulation by easing *firms'* financing conditions via its effect on the interest tax shield. Thus, our results crucially depend on the (empirically motivated) deductibility of interest payments, absent in Venkateswaran and Wright (2013).

Our work draws on the growing literature addressing macro-financial linkages (see Kiyotaki and Moore, 1997; Bernanke et al., 1999; Jermann and Quadrini, 2012 among others). The novelty of our approach is to focus on the interaction between corporate taxes and the firms' financing conditions, and its implications for optimal monetary policy.

2 Inflation, financial frictions and corporate taxes: inspecting the mechanism

How do corporate taxes and inflation affect the investment decision of the firm and its capital structure in the presence of financial frictions? To answer this question, we start from a bare-bones model of the firm and establish that positive inflation can be used, when the interest expenditure on debt is deductible, to eliminate the investment distortion stemming from the taxation of corporate profits.

Consider a firm that maximizes, over two periods, the present value V of current and future dividends discounted at the net real interest rate ρ.[4] The firm produces output Y with capital k and labor l with a constant-returns-to-scale, increasing and concave production function. It may choose to issue b nominal bonds promising to pay a net nominal rate of interest r. The gross inflation rate is π, so that $1+r = (1+\rho)\pi$. For simplicity, there is no capital depreciation.

2.1 No corporate taxation, no financial constraints

By accumulating one extra unit of capital today, reduces dividends by one unit today. This extra unit of capital survives undepreciated until tomorrow when it produces extra output Y_k. At the optimum, and after discounting, marginal costs and benefits

[4] This real interest rate can be thought of, and the trade-offs we describe below can be interpreted as, resulting from the modified golden rule steady state of a Ramsey model in which the long-run real interest rate equals the rate of time preference of consumers.

must balance out, providing the intertemporal condition for the firm:

$$V_k = -1 + \frac{1 + Y_k}{1 + \rho} = 0, \tag{1}$$

so that the undistorted investment decision sets $Y_k = \rho$.

In accordance with the Modigliani-Miller theorem, debt does not affect the value of the firm: an extra bond issued today raises dividends today by 1 but requires a nominal repayment $1 + r$ tomorrow to bondholders, with a resulting zero net effect, after discounting of nominal flows at the nominal rate, on the value of the firm:

$$V_b = -1 + \frac{1 + r}{1 + r} = 0. \tag{2}$$

2.2 Corporate taxation, nominal interest deductibility, no financial constraints

Now suppose corporate profits are taxed at the constant proportional rate $\tau \in (0, 1)$ but that the firm is allowed to deduct a fraction $\varkappa_r \in (0, 1)$ of its nominal interest payments on debt from its taxable profits.

The taxation of corporate profits discourages investment by lowering the after-tax marginal product of capital since the investment decision of the firm satisfies

$$V_k = -1 + \frac{1 + (1 - \tau)Y_k}{1 + \rho} = 0. \tag{3}$$

The deductibility of nominal interest payments provides a shield from the taxation of corporate profits: for each extra bond promising a nominal interest payment r tomorrow, the firm can deduct $\varkappa_r r$ from its taxable profits and reduce its corporate tax bill by $\tau \varkappa_r r$ in nominal terms. Each unit of debt thus enhances the value of the firm by the present value of this nominal cash flow discounted at the nominal rate of interest:

$$V_b = \tau \varkappa_r \frac{r}{1 + r} > 0. \tag{4}$$

Absent a financial constraint limiting borrowing, the firm would issue infinite debt to turn the tax shield provided by the deductibility of interest payments into a money machine.

2.3 Corporate taxation, nominal interest deductibility, and financial constraints

Now assume borrowing is limited by a collateral constraint that can be loosened by extra capital:

$$b \leq B(k), \tag{5}$$

with $B_k \in (0, 1)$ and $B_{kk} \leq 0$. If $B(k)$ is proportional to k, the collateral constraint simply imposes an upper bound the leverage ratio b/k. Otherwise, any extra capital is assumed to relax the collateral constraint less than one-to-one, and more when capital is scarce than when it is abundant.

An extra unit of capital loosens the collateral constraint by B_k and thus enhances the marginal value of the firm by μB_k where μ denotes the shadow value of the collateral constraint. As a result, optimal investment now satisfies

$$V_k = -1 + \frac{1 + (1-\tau)Y_k}{1+\rho} + \mu B_k = 0. \tag{6}$$

This implies, quite naturally, that the tighter the collateral constraint, the larger the capital stock since more capital slackens the constraint.[5]

Issuing extra debt affords the firm the benefit of the tax shield provided by the deductibility of nominal interest but this marginal benefit is reduced, in the presence of a collateral constraint, by the marginal cost μ of tightening the constraint. At the borrowing optimum, therefore, the firm chooses debt to set

$$V_b = \tau \varkappa_r \frac{r}{1+r} - \mu = 0, \tag{7}$$

so that the collateral constraint binds ($\mu > 0$) as soon as debt provides an effective tax shield (τ, $\varkappa_r$ and r positive). Moreover, the higher the inflation and the nominal interest rate, the more valuable the tax shield and the tighter the bite of the collateral constraint.[6]

Expressions (7) and (6) capture in a nutshell the central mechanism of this paper. Given the real interest rate, inflation raises the value of the corporate tax shield afforded by the deductibility of nominal interest payments. By equation (7), it therefore induces the firm to take on more debt and raises the shadow price of the collateral constraint. By equation (6), the increase in the shadow price of the collateral constraint spurs capital accumulation. Thus, while corporate taxation distorts and reduces the capital stock of the firm, inflation spurs capital accumulation due to the interaction of the collateral constraint with the nominal interest deduction.

2.4 Optimal inflation

We now show that the mechanism highlighted above can be exploited by the monetary authority to mitigate or even eliminate the investment distortion created by corporate taxation:

Proposition 1 *(Optimal inflation) There is a unique positive net inflation rate, equivalently a gross inflation rate $\pi > 1$, that eliminates the effect of the corporate tax on capital accumulation.*

Proof. The proof is an implication of the first-order condition (6). To eliminate the detrimental effect of the corporate tax on capital, the inflation rate must be chosen

[5] This follows from our assumptions $Y_{kk} < 0$ and $B_{kk} < 0$ since, by differentiation of equation (6), $\partial k/\partial\mu = -(1+\rho)B_k/[(1-\tau)Y_{kk} + \mu(1+\rho)B_{kk}] > 0$.

[6] The first-order condition (7) implies that $\partial\mu/\partial r > 0$.

to increase the capital stock up to the point where the marginal product of capital reaches its undistorted level $Y_k = \rho$, i.e., $k = \tilde{k}$. Imposing this equality into the first-order condition (6), this requires that μ satisfies $(1-\tau)\rho = \rho + \mu(1+\rho)B_k(\tilde{k})$— that the negative effect of corporate taxation on the after-tax marginal product of capital is counterbalanced by the positive effect of the borrowing constraint. By equation (7), the nominal interest rate must be set to ensure that

$$\frac{\rho}{1+\rho} = \frac{r}{1+r}\varkappa_r B_k(\tilde{k}). \tag{8}$$

Since $\varkappa_r$ and $B_k(\cdot)$ are both between 0 and 1, the nominal interest rate that solves this equation is larger than the real rate ($r > \rho$), so that the optimal net inflation rate is positive, as claimed. ■

At the optimal inflation rate, the distortion imposed by the collateral constraint offsets the distortion stemming from the corporate tax. Two observations are in order. First, the optimal inflation rate is independent of the level of the corporate tax. This is because the marginal impact of the corporate tax rate on gross tax revenues cancels its marginal impact on the deductions. Second, whether these countervailing marginal effects translate into average effects on tax revenues depends on the proportionality of the collateral constraint:

Proposition 2 *(Tax revenue) If the collateral constraint is proportional to the capital stock, the revenue from the corporate tax is zero at the optimal inflation, and declines locally with the inflation rate. These results do not generally hold otherwise.*

Proof. Tax revenue equals the tax rate times taxable profits (output net of labor costs and of the real value of the nominal interest deduction):

$$\Psi = \tau \left[Y(k,l) - wl - \frac{\varkappa_r r b}{\pi} \right], \tag{9}$$

where w denotes the wage rate. Since the collateral constraint (5) binds and the first-order condition for optimal debt (7) holds, using the fact that under constant returns to scale $Y - wl = Y_k k$, this can be rewritten as $\Psi = \tau Y_k k - \mu(1+\rho)B(k)$. Using the first-order condition for optimal capital (6), tax revenue when the firm optimizes is thus given by

$$\Psi = (Y_k - \rho)k - \mu(1+\rho)[B(k) - kB_k(k)]. \tag{10}$$

i) Suppose first that the collateral constraint is proportional to k so that $B(k) - kB_k(k)$ is identically zero regardless of the value of μ and tax revenue is $(Y_k - \rho)k$. Now note that, in this case tax, revenue is zero at a zero capital stock,[7] zero at the first-best capital stock (i.e., at first-best inflation or zero corporate tax) where $Y_k - \rho$, and positive in between. This induces a Laffer curve in policy instruments (corporate tax rate, nominal interest deduction, inflation) that affect the capital stock, with revenue

[7] This is true if $\lim_{k\to 0}(Y_k k) = 0$ as in the Cobb-Douglas case.

necessarily falling locally at the first best when the capital stock rises.[8] Since inflation spurs capital accumulation, it decreases tax revenue at or near optimal inflation.

ii) The above results need not hold when the collateral constraint is not proportional as the following example suffices to demonstrate. Imagine that creditors can only recoup, in case of bankruptcy, a fraction $\gamma \in (0,1)$ of the capital stock *net of fixed liquidation costs* $\underline{\mathrm{k}} > 0$, so that the collateral constraint is linear in, not proportional to, the capital stock: $B(k) = \gamma(k - \underline{\mathrm{k}})$.[9] Then, tax revenue becomes $\Psi = (Y_k - \rho)k + \mu(1+\rho)\gamma\underline{\mathrm{k}}$. It is positive at the first best and thus at optimal inflation. As for the derivative $\partial\Psi/\partial\mu$ evaluated at the first best, it rises by $(1+\rho)\gamma\underline{\mathrm{k}} > 0$ relative to its negative level when $\underline{\mathrm{k}} = 0$ and there is no presumption anymore it is negative in total. Thus, any parallel, linear translation of a given proportional collateral constraint leaves optimal inflation unchanged but alters tax revenue at the optimum inflation rate. ■

This proposition establishes that, in general, optimal inflation does not eliminate the distortion of the corporate tax by increasing the value of the nominal interest rate deduction up to the point where taxable corporate income equals zero. To reiterate, the economic mechanism at work here is a marginal one, not a level one, as it rests on two distortions (the corporate tax and the financial constraint) canceling each other out when inflation is chosen optimally by the central bank. How this translates into tax revenue depends on the shape of the collateral constraint.

3 First best and optimal long-run inflation

The foregoing results are now extended to an infinite-horizon dynamic general equilibrium framework. This section first describes the model economy. Then, it defines the first best and the constrained optimal inflation problem.

3.1 Baseline general equilibrium model

Consider a discrete time infinite horizon economy populated by firms and households. Households consume the final good, provide labor to the production sector, hold bonds issued by firms and receive dividend payments from firms. Firms face borrowing constraints à la Kiyotaki and Moore (1997) and are subject to corporate taxation with two nominal deductions i) for interest payments and ii) investment expenditures. Output is sold in competitive markets.

[8] With a Cobb-Douglas production function with a share of capital α, the tax revenue $(Y_k - \rho)k$ is maximized when the marginal product of capital equals ρ/α. When the borrowing constraint is not binding ($\mu = 0$), this occurs with a corporate tax rate $\tau = 1 - \alpha$. Below that critical level, tax revenue rises with a higher tax rate and the implied lower capital stock.

[9] Assume that $\underline{\mathrm{k}} < \tilde{k}$ to ensure that the firm can borrow and the collateral constraints binds when inflation is at its optimal level and the capital stock is at the first best level.

3.1.1 Households

Households choose consumption c and labor supply l to maximize lifetime utility

$$\sum_{t=0}^{\infty} \beta^t \left[\ln c_t + \eta \ln (1 - l_t)\right] \tag{11}$$

with $\beta \in (0, 1)$ and $\eta > 0$, subject to the budget constraint

$$b_t = \frac{1 + r_{t-1}}{\pi_t} b_{t-1} + w_t l_t - T_t + d_t - c_t \tag{12}$$

and a no-Ponzi game condition. The variable b_t denotes the real value of the end-of-period holdings of firm-issued nominal debt, r_{t-1} is the nominal interest rate, $\pi_t = P_t/P_{t-1}$ the (gross) inflation rate between $t-1$ and t, w_t the real wage rate, T_t lump-sum taxes (or transfers) and d_t dividends received from firms.

In the deterministic steady state with constant consumption the gross nominal interest rate is

$$1 + r = \pi/\beta, \tag{13}$$

i.e. the product of the gross real interest rate (equal to the gross rate of time preference $1/\beta$) and of the gross inflation rate (π). Being away from the zero lower-bound on the net nominal interest rate obviously requires $\pi > \beta$.

3.1.2 Firms

The representative firm, which is owned by consumers, produces final consumption using capital and labor according to a Cobb-Douglas technology

$$Y_t = k_{t-1}^{\alpha} l_t^{1-\alpha} \tag{14}$$

where $\alpha \in (0, 1)$ denotes the share of capital. The firm maximizes the present discounted value of its future dividends net of taxes

$$\sum_{t=0}^{\infty} \Lambda_{0,t} d_t, \tag{15}$$

where $\Lambda_{t,t+1} = \beta \frac{U_{c_{t+1}}}{U_{c_t}}$ is the pricing kernel of the consumers. For tax purposes, firms can make two adjustments to output net of wages: they can deduct i) a fraction $\varkappa_\delta \in [0, 1]$ of capital depreciation at historical value $\delta \frac{k_{t-1}}{\pi_t}$,[10] and ii) a fraction $\varkappa_r \in [0, 1]$ of interest payments on debt $r_{t-1} \frac{b_{t-1}}{\pi_t}$. Thus, taxable profits are:

$$\Psi_t = Y_t - w_t l_t - \varkappa_\delta \delta \frac{k_{t-1}}{\pi_t} - \varkappa_r r_{t-1} \frac{b_{t-1}}{\pi_t}. \tag{16}$$

[10] To evaluate at historical values, we would need in principle to keep track of capital vintages. For simplicity, we assume that the "book value" of capital lags market value by one period.

As in the partial equilibrium model, the only reason for a firm to issue debt in this environment is to take advantage of the tax deductibility of interest payments. The effective, after-tax, gross interest rate paid by the firm on its debt is $R_t = 1 + (1 - \varkappa_r \tau) r_t$. We assume that loans must be collateralized and only a fraction γ of the value of next-period capital stock, k_t, can serve as collateral to debt. The borrowing constraint can be expressed (in real terms) as[11]

$$(1 + r_t)\, b_t \leq \gamma k_t \pi_{t+1}. \tag{17}$$

The firm's first-order condition for optimal debt

$$\mu_t = \Lambda_{t,t+1} \tau \varkappa_r \frac{r_t}{\pi_{t+1}} \tag{18}$$

implies that the collateral constraint binds ($\mu > 0$) when the nominal interest rate r is positive and there is a deduction for nominal interest payments ($\tau > 0$ and $\varkappa_r > 0$). Combining equation (13) and (18) it follows that by setting the net interest rate to zero, i.e. $\pi = \beta$, the social planner could completely offset the financial friction since firms would have no incentive to borrow. However, we will show below that the presence of other distortions makes this policy sub-optimal.

3.1.3 Fiscal authority

The government can levy both distortionary taxes (τ) and lump-sum taxes (T_t) to finance an exogenous stream of public consumption

$$\tau \Psi_t + T_t = G_t. \tag{19}$$

3.2 First best

In the absence of financial frictions and distortionary taxes, the economy converges towards the first-best (FB) steady state, Ω^{FB}, which is invariant in real terms to inflation and features a marginal product of capital at its modified golden rule level $Y_{K,FB} = (\beta^{-1} - 1) + \delta$.

Now let Ω represent the steady-state allocation conditional on a particular inflation rate in the presence of financial frictions and corporate taxation with deductions. The allocation Ω can be compactly represented by its marginal product of capital, Y_K, which satisfies the following condition[12]

$$Y_k = Y_{FB} + \Phi(\pi) \tag{20}$$

where $\Phi(\pi) = \frac{\tau}{(1-\tau)\pi} \Delta(\pi)$ and $\Delta(\pi)$, the *modified distortion*, denotes a function proportional to inflation measuring how far capital is from the first best allocation, as further explained below. Clearly, a social planner who is optimally manipulating

[11]Note that, in the absence of adjustment costs, in our framework the price of capital equals the price of the final good of production. This justifies the presence of inflation in equation (5)

[12]Equation (20) can be easily derived rearranging the optimality condition with respect to capital.

taxes could achieve the first best by setting the corporate tax rate τ to zero.[13] This would trivially equate the long-run marginal product of capital to its first-best level, i.e. $Y_K = Y_{K,FB}$. In general, however, and for reasons that are beyond the scope of this paper, the corporate tax rate τ is positive in actual economies. The investment distortion leads to capital under-accumulation in the absence of corporate tax deductions: $Y_K = Y_{K,FB}/(1-\tau) > Y_{K,FB}$. Tax deductions are usually designed to mitigate this under-accumulation of capital and reduce the gap between Y_K and $Y_{K,FB}$. This naturally leads to the question at the heart of this paper: in the presence of a corporate tax, is there an inflation rate which enables the economy to reach the first best in spite of the corporate tax and of financial frictions? Achieving the first best and thus reaching a capital stock such that $Y_K = Y_{K,FB}$ when $\tau > 0$ requires an inflation rate π^{FB} that sets to zero the term $\Phi(\pi)$ on the right-hand side of equation (20), i.e. π^{FB} is the unique root to the linear equation in π

$$\Delta(\pi) \equiv (\pi Y_{FB} - \gamma(\pi - \beta)\varkappa_r - \delta\varkappa_\delta) = 0, \tag{21}$$

namely

$$\pi^{FB} = \beta + \frac{\beta Y_{K,FB} - \delta\varkappa_\delta}{\gamma\varkappa_r - Y_{K,FB}}. \tag{22}$$

To confirm that π^{FB} actually leads to the first best, we must verify that it corresponds to a feasible equilibrium, i.e., that it does not result in a nominal interest rate that violates the zero lower bound. We also need to inquire whether it leads to inflation or deflation, i.e., whether the gross inflation rate π^{FB} is above or below 1. The next proposition provides the answers to these queries.

Proposition 3 *Assume that corporate taxes are positive. Then, the necessary and sufficient condition for the existence of a feasible inflation rate that brings about the first best allocation, is that the modified distortion is continuous and decreasing in inflation, i.e.*

$$\Delta'(\pi) = Y_{K,FB} - \gamma\varkappa_r < 0. \tag{23}$$

If $\pi^{FB}$is feasible, net inflation is positive at the first best ($\pi^{FB} > 1$) if and only if the modified distortion is positive in the absence of inflation (i.e., in a de facto *real economy).*

Proof. As a preliminary, note from equation (21) that the modified distortion at the Friedman rule (when $\pi = \beta$) is positive since $\Delta(\beta) = \beta\left(\beta^{-1} - (1-\delta)\right) - \delta\varkappa_\delta = (1-\beta)(1-\delta) + \gamma(1-\varkappa_\delta) > 0$. The proof of the proposition follows immediately: since $\Delta(\beta)$ is positive at the Friedman rule, a necessary and sufficient condition for it to be zero at an inflation rate π^{FB} *above* the Friedman rule (i.e., for $\pi^{FB} > \beta$) is that the function $\Delta(\cdot)$ is continuous and decreasing in inflation. This establishes the necessary and sufficient condition of the proposition. The condition of Proposition 3 is likely to be satisfied empirically (unless firms cannot borrow or deduct any interest

[13] Note that this result does *not* hold in the presence of monopolistic competition and sticky prices. See section 5

expense at all) as the steady state marginal product of capital at the first best, which is the sum of the subjective rate of time preference and of the rate of depreciation, is a very small number. Feasibility amounts to $\Delta'(\cdot) < 0$. Since $\Delta(1) > 0$ it must be that $\Delta(\pi^{FB}) = 0$ for some $\pi^{FB} > 1$. ■

Equation (22) also shows that if debt is low either because only a small fraction of capital can be collateralized (low γ) or because the tax advantage of debt is low (low $\varkappa_r$), the subsidy to borrowers brought about by inflation bears on a small base so that more of the inflation subsidy is required to restore the first best.

3.3 Monetary policy and optimal inflation

The monetary authority optimally chooses the inflation rate π_t by taking as given the constant corporate tax rate τ and the deductions $\varkappa_r$ and $\varkappa_\delta$. The optimal inflation problem consists of finding the competitive equilibrium that maximizes households' welfare w.r.t. $\{Y_t, c_t, l_t, \pi_t, k_t, r_t, \mu_t\}$ and subject to the optimal choices by private agents and the resource constraint as reported in Appendix B.[14] It is possible to show analytically that the inflation rate that brings about the efficient allocation, π^{FB}, coincides with the inflation rate that would be chosen by the monetary authority, π^*.

Proposition 4 *Given an economy with flexible prices and perfectly competitive markets, π^{FB} satisfies the first-order conditions of the optimal monetary problem, i.e. $\pi^* = \pi^{FB}$.*

Proof. See Appendix B. ■

The result in proposition 4 relies on two crucial assumptions: i) the government can balance his budget with lump-sum taxes ii) the two distortions, i.e. fiscal and financial, affect the same margin, Y_K. In Sections 5 and 7, we relax these two assumptions and show that even in a second-best world, optimal policy deviates from price stability.

4 Quantitative Results

We now assess the quantitative relevance of the foregoing qualitative results by deriving the optimal rate of inflation in a calibrated version of our baseline model. The model is calibrated at a quarterly frequency using US data for the period 1980:1-2016:4. Table 1 reports the calibration targets.[15]

Table 1 about here

We assume separable log-utility and calibrate the utility weight on leisure, η, by fixing steady-state hours worked at around 0.33. The credit limit parameter, γ, is set to 0.41

[14] In our set-up, the monetary authority maximizes the welfare of a representative agent, *given* frictions in the economic environment (see Khan et al., 2003)

[15] See Appendix A for the data definitions and sources.

to match the average leverage for the non financial business sector. The steady state inflation rate matches the average inflation rate over the period. The discount factor, β, equals 0.99617 implying an annual real rate of 1.54 percent. The capital share in the production for intermediate goods, α, is set to 0.3. Government spending amounts to about 20 percent of steady state output. The corporate tax rate is set at 35 percent, consistent with the US average corporate tax rate over the sample.

The depreciation rate of capital and the degrees of capital expenses and interest rate deductibility are chosen simultaneously to target: i) corporate income revenues to GDP; ii) the sensitivity of tax revenues to changes in the corporate tax; iii) business investment to GDP.[16] Table 2 (column A) reports the parameter values resulting from the calibration of our baseline model. As shown in Table 1 (column A), the model matches the data reasonably well and produces results for the corporate tax that are in line with the data.

Table 2 about here

The optimal long-run inflation in the calibrated model is 5.67 percent. As explained in Section 2, the optimal inflation level does not depend on the tax rate. Nevertheless, equation (22) shows that the results are not invariant to the degree of interest and capital deductibility levels. Specifically, the higher the degree of deductibility, the lower the resulting optimal inflation. Table 3 reports sensitivity of the optimal inflation to alternative deductibility values.

Table 3 about here

For a given investment deductibility, a lower interest rate deductibility reduces the effectiveness of inflation in mitigating the distortionary effect of the corporate tax. Thus, ceteris paribus, a higher level of inflation is needed to reach the first best. For a given interest deductibility, a lower investment deductibility implies larger distortionary effects of the corporate income tax. Ceteris paribus, a higher level of inflation is needed to bring the economy to the first best. Interestingly, the optimal inflation level is positive and sizable (2.37%) even in the case of full deductibility of interest payment and capital expenditures.

5 Costly Price Adjustment

Our baseline model assumes perfect competition and flexible prices. In the New Keynesian literature, sticky prices are invoked as the primary rationale for the optimality of zero inflation. Thus, one could argue that the optimality of positive inflation stems, in our set-up, from this omission. To prove the quantitative relevance of our results, we now extend our model to monopolistic competition and costly price adjustment.

As standard in the literature, we distinguish between intermediate- and final-good producers: intermediate-good producers use labor and capital as input of production and face credit constraints as in equation (17), whereas final-good producers buy

[16] We target a long-run sensitivity of tax revenues to changes in the corporate tax of about 0.049 in line with the estimates for big close economies countries in Clausing (2007).

intermediate inputs of production in a competitive market and face a cost of changing prices as in Rotemberg (1982).[17]

In the presence of both monopolistic competition and sticky prices, the difference between the efficient allocation and the distorted one cannot be simply summarized by the return on capital. Deriving analytical results under price stickiness is, thus, too cumbersome, and we turn to numerical results.

In order to provide quantitative results, we calibrate the model as reported in column B of Table 1 and 2. In addition to the moments targeted with the baseline model, in the sticky price model: i) we set the elasticity of substitution across intermediate good varieties, ε, equal to 11, implying a steady state markup of 10%; ii) and calibrate the price adjustment costs to match a frequency of price adjustment of about 3 quarters as in the range of values reported by Nakamura and Steinsson (2008) for non-sale prices.

The resulting optimal inflation rate is significantly lower compared to the flexible price case but still positive and sizable, i.e. 2.7%. To quantify the welfare benefits of the proposed optimal policy with positive inflation we compare agents conditional welfare under the optimal inflation rate and under zero inflation, i.e. assuming that the central bank pursues a policy of strict inflation stabilization (i.e. $\pi_t = 0, \forall t$). The resulting consumption equivalent welfare gains of adopting the optimal policy are about 2.3%.[18] Although these gains are admittedly high, their order of magnitude is in line with the results in Burstein and Hellwig (2008) who measure the welfare costs of inflation in a menu costs model. Similar to their paper, we also find that the contribution of price rigidities to the steady state welfare effects of inflation does not offset the effects of other first-order distortions.

In order to explore the role of the taxes, monopolistic competition and price rigidities, we run some comparative statics. Table 4 shows how the optimal long-run rate of inflation varies with the degree of monopolistic distortion for different degrees of price stickiness, when the corporate tax is set at the baseline value, i.e. $\tau = 0.35$.[19] In the table, each column corresponds to values obtained under different frequencies of price-adjustments (in months).

Table 4 about here

Our results show that, in the presence of corporate taxation, the optimal long-run inflation is an increasing function of the degree of monopolistic distortion. The long-run equilibrium level of capital return highlights the contribution of different market

[17] See Appendix C for a detailed description of the final- and intermediate-good sectors of production.

[18] The gains are computed as discussed in Benigno and Woodford (2012) taking into account the supplemental constraint imposed by the "timeless" perspective. We condition both policies to start from the unconditional mean of the state variables under the optimal monetary policy. See the Appendix E for further details.

[19] Throughout the analysis, the mark-up in the model is kept to 10%, as in the baseline calibration. In order to vary the incidence of the monopolistic distortion we introduce a partly/fully offsetting subsidy. Monopolistic distortion equal zero reproduces the perfect competition case, whereas one indicates the same degree of monopolistic competition as in the calibrated model.

failures in distorting the steady-state capital accumulation:

$$Y_k = Y_{K,FB} + \frac{1}{(1-\tau)\chi}\left((1-(1-\tau)\chi)\, Y_{K,FB} - \mu\gamma - \frac{\tau \varkappa_\delta \delta}{\pi}\right), \tag{24}$$

where χ is the inverse of the markup of final over intermediate good price. Through an increase in profits, a higher degree of monopolistic competition amplifies the distortionary effect of the corporate tax and, thus, requires a higher level of inflation to minimize the distortion on the accumulation of capital.[20] Thus, introducing monopolistic distortion into our model generates a further reason to inflate.[21]Increasing the degree of price stickiness instead reduces the optimal rate of inflation, as the policymaker needs to take into account the resource cost entailed by higher inflation. For plausible degrees of price stickiness, the optimal inflation remains well above the Friedman rule.[22]

Table 5 about here

Finally, as shown in Table 5, differently from our baseline results with perfectly competitive markets, in the presence of monopolistic competition and nominal rigidities, the optimal inflation rate decreases as the corporate tax rate increases.[23] The table displays the optimal long-run annualized inflation rate for alternative degrees of costly price adjustment and different corporate tax rates, while keeping the degree of monopolistic competition as in the calibrated model. Adopting the Friedman rule would eliminate the financial friction and at the same time reduce the costs of price adjustment. Yet, as shown in equation (24), in the presence of corporate income tax and credit frictions, the monetary authority needs to engineer positive inflation in order to partially subsidize borrowing and mitigate the distortionary effect of the corporate tax.

6 Financial frictions and the optimal long-run inflation rate

The mechanism suggested in this paper can be generalized to other frictional economies where inflation can mitigate the distortions via its effect on nominal deductions. In

[20] In the special case of an economy with monopolistic competition and flexible prices it is possible to derive some analytical results and show that $\Omega = \Omega^{FB}$ does not satisfy the first-order conditions of the optimal monetary problem: i.e. $\pi^* \neq \pi^{FB}$. The proof is in Appendix D.

[21] In a static economy, and in the presence of monopolistic distortion, a non-vertical Phillips curve implies that welfare can be increased by positive inflation. In contrast to this static result, a number of papers have emphasized that in the standard dynamic New-Keynesian model, with sticky prices and monopolistic competition, the Ramsey-optimal long-run inflation (in the absence of risk) is zero independently of the degree of monopolistic competition (Benigno and Woodford, 2005; King and Wolman, 1999).

[22] The Appendix reports the optimal long-run annualized inflation rate for alternative degrees of costly price adjustment and different corporate tax rates, while keeping the degree of monopolistic competition as in the calibrated model.

[23] The relation with the tax rate is non-monotonic, althought it is so for empirically plausible ranges.

our set up, inflation has a dampening effect on the investment inefficiency, $\Phi(\pi, ...)$, since it induces firms to take on more debt and thereby accumulate more collateral. Four assumptions are at the heart of our analysis: i) the use of debt only for its tax advantages, ii) the presence of endogenous borrowing limits, iii) the use of capital as collateral, iv) absence of default.

With regards to the first assumption, the nominal deductibility of interest rates is indeed a crucial element. Although in reality firms may issue debt for reasons behind its tax shield (see Myers and Majluf, 1984), dynamic trade-off theories of debt account for a number of empirical regularities in corporate finance decisions of large firms (see Hennessy and Whited, 2005). In this respect, our work is more suitable to capture the behavior of the latter. In what follows, we discuss more thoroughly the role of the other three assumptions. In the interest of space, all detailed derivations are reported in the appendices.

6.1 Exogenous Borrowing Limit

Notably, it is not the presence of borrowing limits per se that justifies the beneficial effect of inflation, but rather the fact that borrowers are allowed to use capital (an endogenous variable) as collateral, as shown in the following proposition.

Proposition 5 *If the borrowing limit is exogenous, $\pi^{FB} < \beta$.*

Proof. Under exogenous debt limits, i.e. $\gamma = 0$ (or $b \leq \bar{b}$), equation (23) simplifies to

$$\Delta'(\pi) = Y_{K,FB} > 0. \tag{25}$$

Then, as established by Proposition 3, there is no admissible inflation rate, $\pi \geq \beta$, that can produce the first best allocation. ■

6.2 A model with land

So far we have assumed that firms can invest only in one asset, i.e. capital. Our mechanism can be generalized to environment where borrowing is collateralized by other means, such as land. More specifically, consider the simplified environment presented in section 2 and assume that firms can invest in two assets, capital and land, L. Land can be used as collateral instead of capital, $b \leq B(L; ...)$ and it is a factor of production, $Y = f(k, L)$. In this set-up, inflation i) induces firms to invest more in land to take advantage of the tax shield, $\frac{dL}{d\pi} > 0$ ii) has a positive impact on steady state capital accumulation *as long as* investments in land boost capital productivity, i.e. capital and land are two complementary factors of productions $Y_{KL} > 0$

$$\frac{dk}{d\pi} = -\frac{Y_{kL}}{Y_{kk}}\frac{dL}{d\pi} > 0 \tag{26}$$

Trivially, it follows that in a world where land has collateral value but it is not a productive asset, i.e. $Y_L = 0$, a higher rate of steady state inflation would not impact on capital accumulation, thereby hampering the mechanism proposed in our paper. On the other hand, a model with unproductive land but were also capital enters the collateral constraint in a complementary fashion could boost the channel.

6.3 A trade-off theory of debt with defaults

Consider an alternative set-up where firms face a trade-off between the tax advantage of debt and bankruptcy costs. More precisely, suppose that every period firms incur a positive probability of defaulting, $\Gamma(\cdot)$ satisfying the following properties

$$\Gamma_b > 0,\ \Gamma_k < 0,\ 0 \leq \Gamma(\cdot) \leq 1 \wedge -\frac{\Gamma_k}{\Gamma_b} = \frac{b}{k} \equiv \gamma \tag{27}$$

That is, the probability of default is a function of leverage and highly leveraged firms are more likely to default (see Campbell et al., 2008).[24] It is further assumed that defaulting firms are not excluded from the market but bear a pecuniary cost Ξ. Firms borrow up to the point where the value of the tax shield equals the marginal expected bankruptcy cost. In the deterministic steady state, the optimality conditions for debt reads

$$\frac{\pi - \beta\left(1 - \Gamma\left(\frac{b}{k}\right)\right)}{\pi}\varkappa_r \tau = \beta\Gamma_b\left(\Xi - R\frac{b}{\pi}\right) \tag{28}$$

The left hand side is the marginal benefit of debt measured by its tax shield value. The right hand side is the marginal expected bankruptcy cost which takes into account the positive contribution of debt on the probability of default (Γ_b) and the spared interest rate costs in case of default $\left(R\frac{b}{\pi}\right)$. As in our baseline model, the tax code is a source of monetary non-neutrality and inflation has a positive impact on the tax-shield of debt. However, debt as an impact on the default probability. For high steady state probability of defaults, the second effect can dominate. The shape of the investment distortion provides some insights

$$\Phi(\pi) \equiv \frac{\tau}{1-\tau}\left[Y_{FB} - \gamma\frac{\pi - \beta\left(1 - \Gamma\left(\frac{b}{k}\right)\right)}{\beta\pi}\varkappa_r\right]. \tag{29}$$

As in our baseline model, higher taxes disincentive capital investment and inflation impacts on capital accumulation via its effect on debt. Here, debt and capital are linked by their impact on default probabilities rather than a collateral constraint. To gauge the relative magnitude of these effects, we derive an expression for π^{FB}

$$\pi^{FB} = \frac{\beta\gamma\varkappa_r\left(1 - \Gamma\left(\frac{b}{k}\right)\right)}{\gamma\varkappa_r - \beta Y_{FB}}. \tag{30}$$

[24] An example of probability function that satisfies these properties is $\Gamma\left(\frac{b}{k}\right) = \frac{\alpha\exp\left(\frac{b}{k}\right)}{1+\alpha\exp\left(\frac{b}{k}\right)}$.

It follows that positive inflation is optimal as long as $\left(1 - \Gamma\left(\frac{b}{k}\right)\right) > \frac{\gamma \varkappa_r - \beta Y_{FB}}{\beta \gamma \varkappa_r}$. This is because in economies characterized by high default probabilities and too high leverage, inflation decreases the marginal benefit of debt, thereby curbing capital accumulation. For steady state figures that resembles the U.S economy, such as a quarterly default frequency of 6.4%[25] and all other parameters at our baseline calibration, the optimal annual inflation rate is approximately 4.6%.

7 Dissecting our fiscal policy assumptions

In what follows, we evaluate the importance of our characterization of fiscal policy. We first show the robustness of our results in absence of lump-sum taxes. We then document that the Friedman rule would restore the first best if firms were allowed to fully deduct their investment at market value. Finally, we characterize fiscal policy in terms of the optimal choice of deductions ($\varkappa_\delta$ and $\varkappa_r$) for a given tax rate, τ, and rate of inflation. The purpose of this last experiment is to evaluate the extent to which inflation is the right tool to undo the investment inefficiency.

7.1 Absence of lump-sum taxes

So far we have assumed that the government balances its budget period by period through lump-sum taxes. Qualitatively similar results can be obtained if we assume that the government can finance its expenditures only with two distortionary taxes: a corporate and a labor income tax.[26] Trivially, in the absence of lump-sum taxes, a higher rate of inflation indirectly increases the distortion from the labor tax by reducing revenues from the capital tax. As a result, the optimal inflation rate is somewhat reduced. More precisely, in the flexible price model, for a corporate tax rate equal to $\tau = .35$ and a labor tax equal to $\tau^w = .27$, the optimal annualized inflation rate reads 5.63%, only slightly below the optimum in the lump-sum taxes case (5.67%). With sticky prices, the labor tax required to balance the budget is $\tau^w = .33$ and the optimal annualized inflation rate is 2.16%, somewhat lower than the optimum we found in the lump-sum taxes case (2.7%).

Table 6 shows that these results are robust to different levels of the corporate tax rate. The table displays the optimal annualized inflation rate for different values of the corporate tax rate and the implied values of the labor tax that ensures a balanced budget period by period in the model with nominal rigidities.

Table 6 about here

Two observations are in order. First, for the empirically relevant range of the corporate tax rate, the optimal long-run inflation rate increases. Second, as the corporate tax increases, the distortionary labor tax necessary to finance public expenditures

[25] Source: Moodys KMV. NFCs' expected default probability all debt 1990/1-2016/4 EDF cross-sectional average unweighted.

[26] Throughout these experiments, we keep government expenditures at the values calibrated in Section 4.

falls, despite a higher rate of inflation, and thus a higher implicit subsidy to borrowers.

7.2 Full Deductibility of Investment

If the fiscal code allows for both investment and interest rate deductions, optimal policy requires a positive inflation rate. Here we show that if *all* investment expenses were deductible at market values, the Friedman rule would be optimal.

Proposition 6 *In the baseline model with flexible prices, under full deductibility of investments, $\pi^{FB} = \beta$.*

Proof. If, rather than depreciated capital at book value $\frac{\varkappa_\delta \delta}{\pi_t} k_{t-1}$, firms could fully deduct investments at market value $k_t - (1-\delta) k_{t-1}$, then the marginal product of capital would read

$$Y_K = Y_{K,FB} - \frac{(\pi - \beta)}{\pi} \frac{\tau \varkappa_r \gamma}{(1-\tau)}. \tag{31}$$

In this case, fully offsetting the financial friction by following the Friedman rule ($\pi = \beta$), would indeed restore the first best. This is because at the same time this policy eliminates the fiscal inefficiency. ■

7.3 Optimal degree of fiscal deductions

We can now turn to the question of what is the optimal degree of fiscal deductions for a given level of inflation. Recall equation (20), i.e. the distorted marginal product of capital in our simple flexible prices model, with interest and investment deductions. In order to insulate the effects of the tax deduction from monetary policy, let's consider a *de facto* real economy, i.e. $\pi = 1$. As a primer, let's assume that only interest rate expenses can be deducted, $\varkappa_\delta = 0$. It can be shown that in this case achieving the first best would require a degree of interest-rate deductibility greater than 100%.

Proposition 7 *In absence of inflation, the first best allocation could be achieved only if interest rate expenses were more than 100% deductible, i.e*

$$\varkappa_r^{FB} > 1$$

Proof. By simple algebra, we can compute the optimal degree of deduction as $\varkappa_r^{FB} = \frac{Y_{FB}}{\gamma(1-\beta)}$. Then $Y_{FB} - \gamma(1-\beta) > \beta Y_{FB} - \gamma(1-\beta) > (1-\beta)(1-\gamma) > 0$, as long as $\beta, \gamma < 1$. It follows that $\varkappa_r^{FB} > 1$. ■

Finally, if the tax code prescribes *both* interest and investment deductions, $\varkappa_r, \varkappa_\delta > 0$, any combination of $\varkappa_r, \varkappa_\delta$ that solves the linear equation $\Phi(\varkappa_r, \varkappa_\delta) = 0$ could potentially restore the first-best. However, also in this case, under standard assumptions about β, δ and γ, the first best cannot be achieved for a degree of deductibility lower than 100%. This is shown in Figure 1 which plots the optimal degree of deductions under our baseline calibration and no inflation. We interpret these findings as suggesting that, for a given tax rate, inflation is a more efficient tool to tackle our investment distortion.

Figure 1 about here

8 Conclusions

The central contribution of our work is to revisit the debate on the effects of inflation in the presence of corporate taxation initiated by Feldstein and Summers (1978). Previous literature emphasized the distortionary effects of positive inflation in the presence of corporate taxes when interest payments are deductible and investment expenditures are (partially) deductible at historical values. However, it had abstracted from the financing decisions of firms. In this paper, we allow the level of debt to be endogenously determined as the optimal response to costs and incentives. On the one hand, firms want to raise debt to take advantage of the deductibility of interest payments. On the other hand, lenders impose limits to the amount of funds that can be borrowed. We prove analytically that, under interest debt deductibility, for given positive tax rates, the first best efficient allocation can be restored by an appropriate choice of inflation. Optimal inflation also results to be positive in the presence of costly price adjustments and when labor taxes are used to balance the government budget constraint. We also show in a stylized model that our results could carry over to an environment where firms trade-off the tax benefit of debt with the cost of default.

Admittedly, investments and interest rate deductions are not the only two nominal features of the tax code. The deductibility of nominal inventory profits, tax credits or the effective progressivity of the tax, with different rates applying to positive and negative profits, are all important aspects of corporate taxation that interact with inflation which deserve further investigation and are left out from our analysis.

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9 Tables and figures

Description	Data	A) Flex P. Model	B) Sticky P. Model
Real Interest Rate	1.54	1.54	1.54
Average working time	0.33	0.33	0.33
Business Investment to GDP	0.17	0.24	0.23
Leverage	0.41	0.41	0.41
Corporate Tax Revenues to GDP	0.020	0.016	0.017
Corporate Tax Revenues Sensitivity	0.049	0.065	0.058
Inflation	2.14	2.14	2.14
Frequency of Price Adj. (quarters)	3	–	3
Markup	0.10	–	0.10

Table 1: Calibration Targets

Description	Parameter	A) Flex P. Model	B) Sticky P. Model
Discount factor	β	0.99617	0.99617
Leisure preference par.	η	1.886	2.27
Share of capital in production	α	0.3	0.3
Depreciation rate	δ	0.025	0.025
LTV	γ	0.41	0.41
Government expenditures	g_y	0.20	0.20
Corporate tax rate	τ	0.35	0.35
Interest rate deductibility	$\varkappa_r$	0.8904	0.8643
Investment deductibility	$\varkappa_\delta$	0.9062	0.9692
Price adjustment cost	ϕ	-	59.54
Elasticity of substitution	ε	-	11

Table 2: Parameters' Values

Table 3: Optimal annual inflation (annualized percent)

$\varkappa_\delta \backslash \varkappa_r$	0.8	0.85	0.9	0.95	1
0.8	10.10	9.35	8.70	8.12	7.60
0.85	8.43	7.79	7.23	6.73	6.29
0.9	6.77	6.24	5.77	5.35	4.98
0.95	5.10	4.68	4.30	3.97	3.68
1	3.44	3.12	2.84	2.59	2.37

Table 4: Optimal annual inflation (annualized percent)

$mark-up \backslash months$	3	4.5	6	7.5	9
0	3.98	2.75	1.8	1.21	0.85
0.2	5.59	3.88	2.55	1.71	1.20
0.4	7.20	5.04	3.31	2.23	1.56
0.6	8.81	6.22	4.1	2.75	1.93
0.8	10.42	7.41	4.90	3.29	2.31
1	12.04	8.63	5.72	3.85	2.70

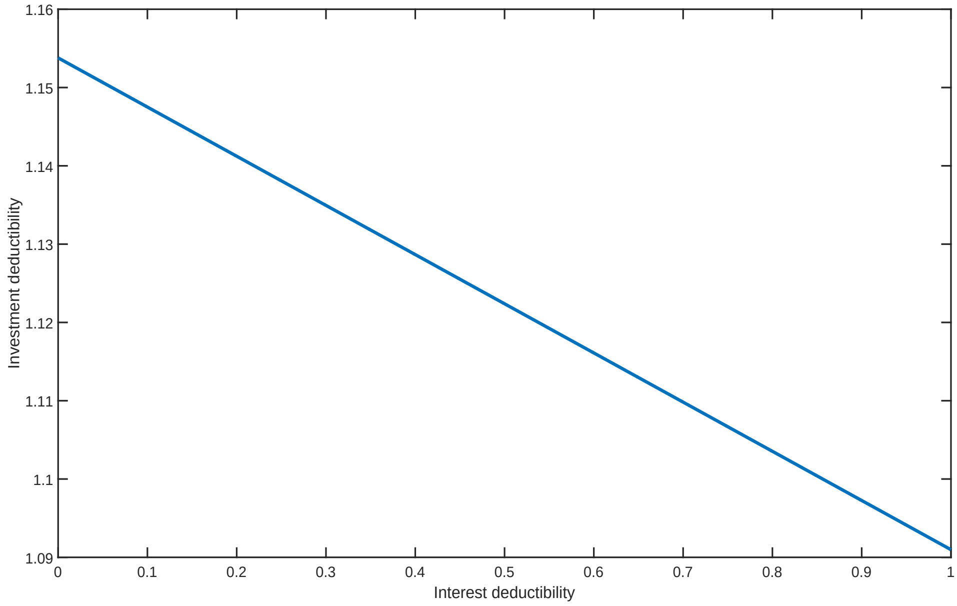
Table 5: Optimal annual inflation (percent): Mark-up=100%

$\tau \backslash months$	3	4.5	6	7.5	9
0.15	29.61	5.87	2.52	1.40	0.89
0.25	17.16	8.26	4.34	2.60	1.72
0.35	12.04	8.63	5.72	3.85	2.70
0.45	9.25	7.93	6.31	4.85	3.70

Table 6: Optimal annual inflation and implied labor tax for various corporate taxes (percent)

τ	τ_w	π_Y
0.10	0.39	0.41
0.15	0.38	0.69
0.20	0.37	1.01
0.25	0.35	1.36
0.30	0.34	1.75
0.35	0.33	2.16
0.40	0.32	2.59
0.45	0.31	3.01

Figure 1: Optimal deductions



Optimal Inflation with Corporate Taxation and Financial Constraints

Technical Appendix

A Data sources

The corporate tax rate of 35% is from the OECD Tax Database and corresponds to the federal government corporate income tax rate since 1993. All other data sources are from the FRED for the sample period 1980Q1-2016Q4. The investment to GDP ratio comes is the share of gross private domestic investment in domestic product. The tax revenue over GDP is computed as the Federal government current tax receipts on corporate income over nominal Gross Domestic Product. The inflation rate in the growth rate of the Implicit GDP deflator in annualized percentage points. The real rate is built as the Effective Fed fund rate minus the inflation rate.

	Description	Source
I	Gross private domestic investment	FRED
GDP	Gross Domestic Product (nominal)	FRED
FFR	Effective Federal Funds Rate	FRED
Inflation	Growth rate of the Implicit GDP deflator in annualized p.p.	FRED
Revenues	Federal government current tax receipts on corporate income	FRED
Corporate tax rate	Federal government corporate income tax rate	OECD Tax Database

B Monetary authority problem

The monetary authority solves

$$\max_{\{Y_t,c_t,l_t,\pi_t,k_t,r_t,\mu_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln c_t + \eta \ln\left(1 - l_t\right)\right) \tag{32}$$

subject to the optimal choices by private agents and the resource constraint, i.e.

$$\lambda_1 : \beta E_t \frac{(1+r_t)}{\pi_{t+1}} \frac{c_t}{c_{t+1}} - 1 = 0 \tag{33}$$

$$\lambda_2 : \eta \frac{c_t}{1-l_t} - (1-\alpha) l_t^{-\alpha} k_{t-1}^{\alpha} = 0 \tag{34}$$

$$\lambda_3 : -1 + \mu_t \gamma \frac{\pi_{t+1}}{(1+r_t)} + \beta \frac{c_t}{c_{t+1}} \left[(1-\tau)\, \alpha l_{t+1}^{1-\alpha} k_t^{\alpha-1} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right] = 0 \tag{35}$$

$$\lambda_4 : -b_t + \gamma \frac{k_t}{(1+r_t)} \pi_{t+1} \leq 0 \tag{36}$$

$$-\mu_t + 1 - \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \left[1 + r_t \left(1 - \tau \varkappa_r \right) \right] = 0 \tag{37}$$

$$\lambda_5 : Y_t - c_t - k_t + (1-\delta) k_{t-1} - G_t = 0. \tag{38}$$

B.1 First order conditions

The following system of dynamic equations characterizes the first-order conditions of the Optimal policy problem, where λ_i is the Lagrange multiplier associated to the i^{th} constraint. :

$$r_t : \beta \frac{\lambda_{1t}}{\pi_{t+1}} \frac{c_t}{c_{t+1}} - \lambda_{3t} \left(\begin{array}{c} \gamma \frac{\pi_{t+1}}{(1+r_t)^2} \left(1 - \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \left(1 + r_t \left(1 - \tau \varkappa_r \right) \right) \right) \\ + \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \gamma \frac{\pi_{t+1}}{(1+r_t)} \left(1 - \tau \varkappa_r \right) \end{array} \right) \tag{39}$$
$$+ \gamma \lambda_{4t} \frac{k_t \pi_{t+1}}{(1+r_t)^2} = 0$$

$$c_t : \frac{1}{c_t} + \beta \lambda_{1t} \frac{(1+r_t)}{\pi_{t+1}} \frac{1}{c_{t+1}} - \beta \frac{\lambda_{1t-1}}{\beta} \frac{(1+r_{t-1})}{\pi_t} \frac{c_{t-1}}{c_t^2} + \tag{40}$$
$$+ \lambda_{2t} \eta \frac{1}{1-l_t} + \lambda_{3t} \left(\begin{array}{c} \beta \frac{1}{c_{t+1}} \left[(1-\tau)\, Y_{k,t+1} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right] \\ - \beta \frac{1}{c_{t+1}} \frac{1}{\pi_{t+1}} R_t \gamma \frac{\pi_{t+1}}{(1+r_t)} \end{array} \right)$$
$$- \frac{\lambda_{3t-1}}{\beta} \left[\begin{array}{c} \beta \frac{c_{t-1}}{c_t^2} \left[(1-\tau)\, Y_{k,t} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_t} \right] \\ - \beta \frac{c_{t-1}}{c_t^2} \frac{1}{\pi_t} R_{t-1} \gamma \frac{\pi_t}{(1+r_{t-1})} \end{array} \right]$$
$$- \lambda_{5t} = 0$$

$$l_t : -\eta \frac{1}{(1-l_t)} + \lambda_{2t} \left(\eta \frac{c_t}{(1-l_t)^2} - Y_{ll,t} \right) \tag{41}$$
$$+\lambda_{3t-1} \frac{1}{\beta} \beta \frac{c_{t-1}}{c_t} (1-\tau) Y_{kl,t}$$
$$+\lambda_{5t} Y_{l,t} = 0$$

$$k_t : -\beta \lambda_{2t+1} Y_{lk,t+1} \tag{42}$$
$$+\lambda_{3t} \beta \frac{c_t}{c_{t+1}} [(1-\tau) Y_{kk,t}]$$
$$-\lambda_{4t} \gamma \frac{1}{(1+r_t)} \pi_{t+1}$$
$$+\beta \lambda_{5t+1} ((1-\delta) + Y_{k,t+1}) - \lambda_{5t} = 0$$

$$\pi_t : -\lambda_{1t-1} \beta \frac{(1+r_{t-1})}{\pi_t^2} \frac{c_{t-1}}{c_t} + \tag{43}$$
$$+\lambda_{3t-1} \left[\begin{array}{c} \left(1 - \beta \frac{c_{t-1}}{c_t} \frac{1}{\pi_t} R_{t-1}\right) \gamma \frac{1}{(1+r_{t-1})} \\ +\beta \frac{c_{t-1}}{c_t} \frac{1}{\pi_t^2} R_{t-1} \gamma \frac{\pi_t}{(1+r_{t-1})} \\ -\beta \frac{c_{t-1}}{c_t} \tau \frac{\varkappa_\delta \delta}{\pi_t^2} \end{array} \right]$$
$$-\lambda_{4t-1} \gamma \frac{k_{t-1}}{(1+r_{t-1})} = 0$$
$$b_t : \lambda_{4t} = 0 \tag{44}$$

B.2 Steady state

In a deterministic steady state, the system above reads as follows:

$$b : \lambda_4 = 0 \tag{45}$$
$$r : \lambda_1 = \lambda_3 \frac{\pi}{\beta} \left[\begin{array}{c} \gamma \zeta \frac{\pi}{(1+r)^2} \left(1 - \beta \frac{1}{\pi} R\right) \\ +\beta \frac{1}{\pi} (1 - \tau \varkappa_r) \gamma \zeta \frac{\pi}{(1+r)} \end{array} \right] \tag{46}$$
$$c : \lambda_5 = \frac{1}{c} + \lambda_2 \eta \frac{1}{1-l} - (1-\beta) \left(\Xi \lambda_3 + \frac{(1+r)}{\pi} \frac{1}{c} \lambda_1 \right) \tag{47}$$

where $\Xi = \frac{1}{c} \left((1-\tau) Y_k + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi} - \gamma \zeta \frac{(1+r(1-\tau\varkappa_r))}{(1+r)} \right)$

$$l : \eta \frac{1}{(1-l)} - \lambda_2 \left(\eta \frac{c}{(1-l)^2} - Y_{ll} \right) =$$
$$\lambda_3 (1-\tau) Y_{kl} + \lambda_5 Y_l \tag{48}$$

$$k : \lambda_5 \left(Y_k + 1 - \delta - \frac{1}{\beta} \right) = \lambda_2 Y_{lk} - \lambda_3 \left[(1-\tau) \, Y_{kk} \right] \tag{49}$$

$$\pi : \lambda_1 = \lambda_3 \pi \left(\frac{\gamma\zeta}{(1+r)} - \beta\tau \frac{\varkappa_\delta \delta}{\pi^2} \right) \tag{50}$$

B.3 Proof

We are now ready to prove proposition 4. We guess that the Lagrange multiplier on the first constraint equals zero, i.e. $\lambda_1 = 0$. From equation 50 it follows $\lambda_3 = 0$. This simplifies considerably the original system. By plugging Eq. 47 into equation 48, we obtain:

$$\lambda_2 \left(\eta \frac{c}{(1-l)^2} - Y_{ll} + \eta \frac{1}{1-l} Y_l \right) = 0 \tag{51}$$

The term in parenthesis is positive since $Y_{ll} < 0$, then:

$$\lambda_2 = 0 \tag{52}$$

and, from equation 47:

$$\lambda_5 = \frac{1}{c} \tag{53}$$

The first-order condition with respect to capital further simplifies to:

$$\lambda_5 \left(Y_k + 1 - \delta - \frac{1}{\beta} \right) = 0, \tag{54}$$

from which it follows:

$$Y_k = \frac{1 - (1-\delta)\,\beta}{\beta} = Y_{K,FB}. \tag{55}$$

This last equality proves proposition 4.

C Model with Monopolistic Competition and Price Stickiness

In an economy with sticky prices and imperfect competition, the household problem is unchanged while the firm conditions are distorted by the presence of monopolistic competition. For analytical simplicity, we distinguish between an intermediate and a final good sector.

C.1 Intermediate Goods Producers

The intermediate goods sector is perfectly competitive. The representative firm produces intermediate goods, Y, using capital, k, and labor, l, according to a constant returns-to-scale technology:

$$Y_t = k_{t-1}^{\alpha} l_t^{1-\alpha},$$

where z_t is an aggregate productivity shock. Each firm maximizes its market value for the shareholders:

$$\max \sum_{t=0}^{\infty} \Lambda_{0,t} d_t \tag{56}$$

subject to the budget constraint:

$$d_t = b_t - (1 + r_{t-1}) \frac{b_{t-1}}{\pi_t} + (\chi_t Y_t - w_t l_t) + k_t - (1 - \delta) k_{t-1} + \tag{57}$$

$$- \tau \left(\chi_t Y_t - \varkappa_r r_{t-1} \frac{b_{t-1}}{\pi_t} - \frac{\varkappa_\delta \delta}{\pi_t} k_{t-1} - w_t l_t \right), \tag{58}$$

and the following collateral constraint:

$$b_t \leq \gamma \frac{k_t}{(1 + r_t)} \pi_{t+1}, \tag{59}$$

where $\chi = \frac{\tilde{P}}{P}$ is the inverse of the markup of final (P) over intermediate good price $\left(\tilde{P}\right)$. The first order conditions with respect to labor, l, debt, b, and capital, k, are as follows:

$$\chi_t Y_{l_t} = w_t, \tag{60a}$$

$$\mu_t = 1 - \frac{R_t}{\pi_{t+1}}, \tag{60b}$$

$$1 = \mu_t \gamma \frac{\pi_{t+1}}{(1 + r_t)} + \Lambda_{t,t+1} \left[(1 - \tau) \chi_{t+1} Y_{k,t+1} + (1 - \delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right], \tag{60c}$$

where μ is the Kuhn-Tucker multiplier on the borrowing constraint.

C.2 Final goods producers

Final good producers choose the optimal price P_i by solving the following profit maximization problem:

$$\max \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(\frac{P_{i,t}}{P_t} - \chi_t \right) Y_{i,t} - \frac{\varphi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - 1 \right)^2 Y_t \right] \tag{61}$$

Subject to the demand function:

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon} Y_t. \tag{62}$$

The first-order condition of this optimization problem is:

$$(1-\varepsilon)\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}+\varepsilon\chi_t\left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon-1}-\varphi\left(\frac{P_{i,t}}{P_{i,t-1}}-1\right)\frac{P_t}{P_{i,t-1}} \tag{63}$$
$$+\Lambda_{t,t+1}\varphi\left(\frac{P_{i,t+1}}{P_{i,t}}-1\right)\frac{Y_{t+1}}{Y_t}\frac{P_{i,t+1}}{P_{i,t}^2}P_t=0-$$

In a symmetric equilibrium, the equation above simplifies to:

$$\varphi\,(\pi_t-1)\pi_t=(1-\varepsilon)+\varepsilon\chi_t+\Lambda_{t,t+1}\varphi\frac{Y_{t+1}}{Y_t}(\pi_{t+1}-1)\pi_{t+1}. \tag{64}$$

where $\pi_t=\frac{P_t}{P_{t-1}}$ denotes gross inflation.

C.3 All equations

We can now list the full set of dynamic equations which characterizes the equilibrium:

$$\beta E_t\frac{(1+r_t)}{\pi_{t+1}}\frac{c_t}{c_{t+1}}-1=0 \tag{65}$$

$$\eta\frac{c_t}{1-l_t}-Y_{l,t}\chi_t=0 \tag{66}$$

$$-1+\mu_t\gamma\frac{\pi_{t+1}}{(1+r_t)}+\beta\frac{c_t}{c_{t+1}}\left[(1-\tau)\,\chi_{t+1}Y_{k,t+1}+(1-\delta)+\tau\frac{\varkappa_\delta\delta}{\pi_{t+1}}\right]=0 \tag{67}$$

$$-b_t+\gamma\frac{k_t}{(1+r_t)}\pi_{t+1}\leq 0 \tag{68}$$

$$-\mu_t+1-\beta\frac{c_t}{c_{t+1}}\frac{1}{\pi_{t+1}}\left(1+r_t\left(1-\tau\varkappa_r\right)\right)=0 \tag{69}$$

$$-\varphi\,(\pi_t-1)\pi_t+(1-\varepsilon)+\varepsilon\chi_t+\beta\frac{c_t}{c_{t+1}}\varphi\frac{Y_{t+1}}{Y_t}(\pi_{t+1}-1)\pi_{t+1}=0 \tag{70}$$

$$Y_t-c_t-k_t+(1-\delta)k_{t-1}-G_t=0 \tag{71}$$

C.4 Steady State

The steady state of this economy is described by the following system of equations:

$$(1+r) = \frac{\pi}{\beta} \tag{72}$$

$$-\frac{U_l}{U_c} = w \tag{73}$$

$$Y_l \chi = w \tag{74}$$

$$\mu = \frac{(\pi - \beta)}{\pi} \tau \varkappa_r \tag{75}$$

$$Y_k = \frac{1 - \mu\gamma \frac{\pi}{(1+r)} - \beta \left[(1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi}\right]}{\beta (1-\tau) \chi} \tag{76}$$

$$\chi {=} \frac{\varphi}{\varepsilon}(\pi - 1)\pi (1-\beta) - \frac{(1-\varepsilon)}{\varepsilon} = \frac{\tilde{P}}{P} \tag{77}$$

D Model with flexible prices and monopolistic competition

To derive the equilibrium conditions for the model with flexible prices and monopolistic competition, is sufficient to set the Rotemberg adjustment costs parameter to zero, $\varphi = 0$.

D.1 Optimal Policy

Imperfect competition only affects the following two constraints in the Optimal policy problem:

$$\lambda_2 : \eta \frac{c_t}{1 - l_t} - \chi Y_{l,t} = 0 \tag{78}$$

$$\begin{aligned} \lambda_3 : -1 + \left(1 - \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \left(1 + r_t \left(1 - \tau \varkappa_r\right)\right)\right) \gamma \frac{\pi_{t+1}}{(1+r_t)} \\ + \beta \frac{c_t}{c_{t+1}} \left[(1-\tau) \chi Y_{k,t+1} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}}\right] = 0 \end{aligned} \tag{79}$$

The following two first-order conditions of the optimal policy problem are modified accordingly:

$$\begin{aligned} l_t : -\eta \frac{1}{(1-l_t)} + \lambda_{2t} \left(\eta \frac{c_t}{(1-l_t)^2} - \frac{\varepsilon - 1}{\varepsilon} Y_{ll,t}\right) \\ + \lambda_{3t-1} \frac{1}{\beta} \beta \frac{c_{t-1}}{c_t} (1-\tau) \frac{\varepsilon - 1}{\varepsilon} Y_{kl,t} \\ + \lambda_{5t} Y_{l,t} = 0 \end{aligned} \tag{80}$$

$$
\begin{aligned}
k_t : -\beta\lambda_{2t+1}\frac{\varepsilon-1}{\varepsilon}Y_{lk,t+1} \\
+\lambda_{3t}\beta\frac{c_t}{c_{t+1}}\left[(1-\tau)\frac{\varepsilon-1}{\varepsilon}Y_{kk,t+1}\right] \\
-\lambda_{4t}\gamma\frac{1}{(1+r_t)}\pi_{t+1} \\
+\beta\lambda_{5t+1}\left((1-\delta)+Y_{k,t+1}\right)-\lambda_{5t}=0.
\end{aligned}
\tag{81}
$$

Which in steady state read as follows:

$$
\begin{aligned}
l : -\eta\frac{1}{(1-l)}+\lambda_2\left(\eta\frac{c}{(1-l)^2}-\frac{\varepsilon-1}{\varepsilon}Y_{ll}\right) \\
-\lambda_3(1-\tau)\frac{\varepsilon-1}{\varepsilon}Y_{kl} \\
+\lambda_5 Y_l = 0
\end{aligned}
\tag{82}
$$

$$
k : \lambda_5\left(Y_k+1-\delta-\frac{1}{\beta}\right)=\lambda_{2t}Y_{lk}\frac{\varepsilon-1}{\varepsilon}-\lambda_3\left[(1-\tau)Y_{kk}\right] \tag{83}
$$

D.2 Proof

We can now prove that under monopolistic competition, the first best cannot be achieved. The proof closely follows the one for the perfect competition case. We guess $\lambda_1 = 0$ and simplify accordingly the original system :

$$
\lambda_5=\frac{1}{c}+\lambda_2\eta\frac{1}{1-l} \tag{84}
$$

By substituting the first order condition with respect to consumption into equation 82, it follows:

$$
\lambda_2=\frac{-\frac{\eta}{(1-l)(\varepsilon-1)}}{\left(\eta\frac{c}{(1-l)^2}-\frac{\varepsilon-1}{\varepsilon}Y_{ll}+\eta\frac{1}{1-l}Y_l\right)}<0. \tag{85}
$$

where the last inequality follows from $\frac{Y_l}{c}=\eta\frac{\varepsilon}{(1-l)(\varepsilon-1)}$ and $Y_{ll}<0$.The first order condition with respect to capital reads as follows:

$$
\lambda_5\left(Y_k+1-\delta-\frac{1}{\beta}\right)=\lambda_2 Y_{lk}\frac{\varepsilon-1}{\varepsilon}<0 \tag{86}
$$

from which we can deduct $\left(Y_k+1-\delta-\frac{1}{\beta}\right)\neq 0$ and $\pi^*\neq\pi^{FB}$.

E Welfare

Welfare is reported in permanent units of steady consumption that are necessary to compensate the households for moving from an equilibrium under the optimal policy to an equilibrium under the suboptimal policy.

In order to take account of all the dimensions of the policy problem (including the "timeless" perspective), and the fact that the initial conditions matter for policy evaluation, it is convenient to measure the welfare gain in the following way. Consider an economy that has been under the optimal policy between time T_0 and time $T_1 \gg T_0$, i.e. for a very long time. Under this economy households would have reached the level of welfare (per period) $\mathcal{W}_{T_1|T_0}^{Ramsey}$ defined as

$$\mathcal{W}_{T_1|T_0}^{Ramsey} \equiv E_{T_0}(1-\beta)\sum_{t=T_0}^{T_1}\beta^{t-T_0}\left(\log\left(C_t^{Ramsey}\right)-\eta log\left(1-L_t^{Ramsey}\right)\right)+\mathcal{P}_{T_0}$$

where $\mathcal{P}_{T_0}$ is the term related to the "timeless" constraint, as discussed by Benigno and Woodford (2012).[27] Since the economy is stationary, we can choose a value for T_1 such that $\mathcal{W}_{T_1|T_0}^{Ramsey} \approx \mathcal{W}_{\infty|T_0}^{Ramsey} \equiv \mathcal{W}_{T_0}^{Ramsey}$.

Moving (unexpectedly) from the optimal policy to a suboptimal policy at time $T_2 \equiv T_1+1$ would produce the welfare level defined as $\mathcal{W}_{T_2}^{suboptimal}$, i.e.

$$\mathcal{W}_{T_2}^{suboptimal} \equiv E_{T_2}(1-\beta)\sum_{t=T_2}^{\infty}\beta^{t-T_2}\left(\log\left(C_t^{suboptimal}\right)-\eta log\left(1-L_t^{suboptimal}\right)\right)+\mathcal{P}_{T_2}. \tag{87}$$

We compute these two measures taking time T_0 and T_1 to be the unconditional mean of the variables under the optimal policy. After having computed these measures we define the welfare compensation (per period) $\omega_{\mathcal{W}}$ as the parameter that solves

$$\begin{aligned}\Omega &\equiv \mathcal{W}_{T_0}^{Ramsey}-\mathcal{W}_{T_2}^{suboptimal}\\ &=(1-\beta)\sum_{t=T_2}^{\infty}\beta^{t-T_2}\left(\log\left((1-\omega_{\mathcal{W}})\,C_t^{suboptimal}\right)-\eta log\left(1-L_t^{suboptimal}\right)\right)+\\ &-(1-\beta)\sum_{t=T_2}^{\infty}\beta^{t-T_2}\left(\log\left(C_t^{suboptimal}\right)-\eta log\left(1-L_t^{suboptimal}\right)\right)\\ &\approx \omega_{\mathcal{W}}.\end{aligned} \tag{88}$$

Hence, $\omega_{\mathcal{W}}\%$ is the percentage welfare gain in following the optimal policy expressed in units of steady state consumption. We evaluate $\omega_{\mathcal{W}}$ to second order of accuracy.

[27] This term is the product of the $t=T_j-1$ vector of Lagrange multipliers of the Ramsey policy problem and the T_j vector of variables appearing in the forward-looking equations of the model – with $j=\{1,2\}$ depending on which economy is evaluated – scaled by the Jacobian of this block of equations with respect to the forward-looking equations of the model.

F Model with land as collateral

The marginal value of land is given by:

$$V_L = \frac{(1-\tau)\,Y_L + 1}{1+\rho} - 1 + \mu B_L \tag{89}$$

where and δ^L is the rate of depreciation of land. The marginal value of debt is, as before:

$$V_b = \tau \varkappa_r \tau \frac{r}{1+r} - \mu \tag{90}$$

The optimality conditions can be simplified as:

$$\begin{aligned} (1-\tau)\,Y_K - \rho &= 0 \\ (1-\tau)\,Y_L - \rho + \mu\,(1+\rho)\,B_L &= 0 \end{aligned} \tag{91}$$

By totally differentiating the equations above:

$$Y_{kk} dk = -Y_{kl} dL \tag{92}$$

$$(1-\tau)\,Y_{LL} dL + (1-\tau)\,Y_{Lk} dk + (1+\rho)\,B_L d\mu + \mu\,(1+\rho)\,B_{LL} dL = 0 \tag{93}$$

Rearranging them:

$$\frac{dL}{d\mu} = -\frac{(1+\rho)\,B_L}{\left[(1-\tau)\,Y_{LL} + (1-\tau)\,Y_{Lk}\left(\frac{Y_{k_L}}{Y_{kk}}\right) + (1+\rho)\,\mu B_{LL}\right]} > 0 \tag{94}$$

$$\frac{dk}{d\mu} = -\frac{Y_{kL}}{Y_{kk}}\frac{dL}{d\mu} > 0 \tag{95}$$

Then

$$\frac{dL}{d\pi} = \frac{dL}{d\mu}\frac{d\mu}{d\pi} > 0 \tag{96}$$

$$\frac{dk}{d\pi} = \frac{dK}{d\mu}\frac{d\mu}{d\pi} > 0 \tag{97}$$

since

$$\frac{d\mu}{d\pi} = \frac{1}{(1+\rho)\,\pi^2} \tag{98}$$

G Model with defaults

Suppose that every period firms incur a positive probability of defaulting, $\Gamma(\cdot)$ satisfying the following properties:

$$\begin{aligned} &\Gamma_b > 0,\ \Gamma_k < 0,\ 0 \leq \Gamma(\cdot) \leq 1 \\ &-\frac{\Gamma_k}{\Gamma_b} = \frac{b}{k} \equiv \gamma \end{aligned} \tag{99}$$

In this set-up, firms distribute dividends to shareholders equal to:

$$d_t = (1-\tau)\left(Y_t - w_t l_t\right) - \left[k_t - (1-\delta)k_{t-1}\right] \tag{100}$$
$$+b_t - \left(1 + r_{t-1}\left(1 - \varkappa_r \tau\right)\right)\left(1 - \Gamma\left(\frac{b_{t-1}}{k_{t-1}}\right)\right)\frac{b_{t-1}}{\pi_t} - \Gamma\left(\frac{b_{t-1}}{k_{t-1}}\right)\Xi$$

where Ξ represent a pecuniary cost associated to default. Firms maximize their market value by solving to the following problem:

$$\max \sum_{t=0}^{\infty} \Lambda_{0,t} d_t \tag{101}$$
$$st: d_t = (1-\tau)\left(Y_t - w_t l_t\right) - \left[k_t - (1-\delta)k_{t-1}\right]$$
$$+b_t - \left(1 + r_{t-1}\left(1 - \varkappa_r \tau\right)\right)\left(1 - \Gamma\left(\frac{b_{t-1}}{k_{t-1}}\right)\right)\frac{b_{t-1}}{\pi_t} - \Gamma\left(\frac{b_{t-1}}{k_{t-1}}\right)\Xi$$

where

$$\Lambda_{t,t+1} \equiv \beta\frac{U_{c,t+1}}{U_{c,t}} = \frac{\pi_{t+1}}{(1+r_t)}\left(1 - \Gamma\left(\frac{b_{t-1}}{k_{t-1}}\right)\right) \tag{102}$$

The problem yields the following first-order conditions for debt and capital:

$$b: 1 - \Lambda_{t,t+1}\left(1 - \Gamma\left(\frac{b_t}{k_t}\right)\right)\left(R_t\frac{1}{\pi_{t+1}}\right) - \Lambda_{t,t+1}\Gamma_{b_t}\left(\Xi - R_t\frac{b_t}{\pi_{t+1}}\right) = 0 \tag{103}$$

$$k: -1 + \Lambda_{t,t+1}\left((1-\tau)Y_{k_t} + (1-\delta)\right) - \Lambda_{t,t+1}\Gamma_{k_t}\left(\Xi - R_t\frac{b_t}{\pi_{t+1}}\right) = 0 \tag{104}$$

In steady state:

$$b: 1 - \beta\left(1 - \Gamma\left(\frac{b}{k}\right)\right)\left(\frac{R}{\pi}\right) - \beta\Gamma_b\left(\Xi - R\frac{b}{\pi}\right) = 0 \tag{105}$$

$$k: -1 + \beta\left((1-\tau)Y_k + (1-\delta) + \tau\frac{\varkappa_\delta \delta}{\pi}\right) - \beta\Gamma_k\left(\Xi - R\frac{b}{\pi}\right) = 0 \tag{106}$$

We can then rewrite the first order condition with respect to capital as

$$Y_k = Y_{FB} + \Phi(\pi) \tag{107}$$

where

$$\Phi(\pi) \equiv \frac{\tau}{1-\tau}\left[Y_{FB} + \frac{\Gamma_k}{\Gamma_b}\frac{\pi - \beta\left(1 - \Gamma\left(\frac{b}{k}\right)\right)}{\beta\pi}\varkappa_r\right] \tag{108}$$

It follows

$$\pi^{FB} = \frac{\beta\gamma\varkappa_r\left(1 - \Gamma\left(\frac{b}{k}\right)\right)}{\gamma\varkappa_r - \beta Y_{FB}}. \tag{109}$$

where we substituted for $-\frac{\Gamma_k}{\Gamma_b} = \gamma$.

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Bayesian Inference of General Linear Restrictions on the Cointegration Space *by Mattias Villani*	2005:189
Forecasting Performance of an Open Economy Dynamic Stochastic General Equilibrium Model *by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani*	2005:190
Forecast Combination and Model Averaging using Predictive Measures *by Jana Eklund and Sune Karlsson*	2005:191
Swedish Intervention and the Krona Float, 1993-2002 *by Owen F. Humpage and Javiera Ragnartz*	2006:192
A Simultaneous Model of the Swedish Krona, the US Dollar and the Euro *by Hans Lindblad and Peter Sellin*	2006:193
Testing Theories of Job Creation: Does Supply Create Its Own Demand? *by Mikael Carlsson, Stefan Eriksson and Nils Gottfries*	2006:194
Down or Out: Assessing The Welfare Costs of Household Investment Mistakes *by Laurent E. Calvet, John Y. Campbell and Paolo Sodini*	2006:195
Efficient Bayesian Inference for Multiple Change-Point and Mixture Innovation Models *by Paolo Giordani and Robert Kohn*	2006:196
Derivation and Estimation of a New Keynesian Phillips Curve in a Small Open Economy *by Karolina Holmberg*	2006:197
Technology Shocks and the Labour-Input Response: Evidence from Firm-Level Data *by Mikael Carlsson and Jon Smedsaas*	2006:198
Monetary Policy and Staggered Wage Bargaining when Prices are Sticky *by Mikael Carlsson and Andreas Westermark*	2006:199
The Swedish External Position and the Krona *by Philip R. Lane*	2006:200

Price Setting Transactions and the Role of Denominating Currency in FX Markets 2007:201
by Richard Friberg and Fredrik Wilander

The geography of asset holdings: Evidence from Sweden 2007:202
by Nicolas Coeurdacier and Philippe Martin

Evaluating An Estimated New Keynesian Small Open Economy Model 2007:203
by Malin Adolfson, Stefan Laséen, Jesper Lindé and Mattias Villani

The Use of Cash and the Size of the Shadow Economy in Sweden 2007:204
by Gabriela Guibourg and Björn Segendorf

Bank supervision Russian style: Evidence of conflicts between micro- and macro-prudential concerns 2007:205
by Sophie Claeys and Koen Schoors

Optimal Monetary Policy under Downward Nominal Wage Rigidity 2007:206
by Mikael Carlsson and Andreas Westermark

Financial Structure, Managerial Compensation and Monitoring 2007:207
by Vittoria Cerasi and Sonja Daltung

Financial Frictions, Investment and Tobin's q 2007:208
by Guido Lorenzoni and Karl Walentin

Sticky Information vs Sticky Prices: A Horse Race in a DSGE Framework 2007:209
by Mathias Trabandt

Acquisition versus greenfield: The impact of the mode of foreign bank entry on information and bank lending rates 2007:210
by Sophie Claeys and Christa Hainz

Nonparametric Regression Density Estimation Using Smoothly Varying Normal Mixtures 2007:211
by Mattias Villani, Robert Kohn and Paolo Giordani

The Costs of Paying – Private and Social Costs of Cash and Card 2007:212
by Mats Bergman, Gabriella Guibourg and Björn Segendorf

Using a New Open Economy Macroeconomics model to make real nominal exchange rate forecasts 2007:213
by Peter Sellin

Introducing Financial Frictions and Unemployment into a Small Open Economy Model 2007:214
by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin

Earnings Inequality and the Equity Premium 2007:215
by Karl Walentin

Bayesian forecast combination for VAR models 2007:216
by Michael K. Andersson and Sune Karlsson

Do Central Banks React to House Prices? 2007:217
by Daria Finocchiaro and Virginia Queijo von Heideken

The Riksbank's Forecasting Performance 2007:218
by Michael K. Andersson, Gustav Karlsson and Josef Svensson

Macroeconomic Impact on Expected Default Freqency 2008:219
by Per Åsberg and Hovick Shahnazarian

Monetary Policy Regimes and the Volatility of Long-Term Interest Rates 2008:220
by Virginia Queijo von Heideken

Governing the Governors: A Clinical Study of Central Banks 2008:221
by Lars Frisell, Kasper Roszbach and Giancarlo Spagnolo

The Monetary Policy Decision-Making Process and the Term Structure of Interest Rates 2008:222
by Hans Dillén

How Important are Financial Frictions in the U S and the Euro Area 2008:223
by Virginia Queijo von Heideken

Block Kalman filtering for large-scale DSGE models 2008:224
by Ingvar Strid and Karl Walentin

Optimal Monetary Policy in an Operational Medium-Sized DSGE Model 2008:225
by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson

Firm Default and Aggregate Fluctuations 2008:226
by Tor Jacobson, Rikard Kindell, Jesper Lindé and Kasper Roszbach

Re-Evaluating Swedish Membership in EMU: Evidence from an Estimated Model 2008:227
by Ulf Söderström

The Effect of Cash Flow on Investment: An Empirical Test of the Balance Sheet Channel 2009:228
by Ola Melander

Expectation Driven Business Cycles with Limited Enforcement 2009:229
by Karl Walentin

Effects of Organizational Change on Firm Productivity 2009:230
by Christina Håkanson

Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost 2009:231
by Mikael Carlsson and Oskar Nordström Skans

Monetary Policy Trade-Offs in an Estimated Open-Economy DSGE Model 2009:232
by Malin Adolfson, Stefan Laséen, Jesper Lindé and Lars E. O. Svensson

Flexible Modeling of Conditional Distributions Using Smooth Mixtures of Asymmetric Student T Densities 2009:233
by Feng Li, Mattias Villani and Robert Kohn

Forecasting Macroeconomic Time Series with Locally Adaptive Signal Extraction 2009:234
by Paolo Giordani and Mattias Villani

Evaluating Monetary Policy 2009:235
by Lars E. O. Svensson

Risk Premiums and Macroeconomic Dynamics in a Heterogeneous Agent Model 2010:236
by Ferre De Graeve, Maarten Dossche, Marina Emiris, Henri Sneessens and Raf Wouters

Picking the Brains of MPC Members 2010:237
by Mikael Apel, Carl Andreas Claussen and Petra Lennartsdotter

Involuntary Unemployment and the Business Cycle 2010:238
by Lawrence J. Christiano, Mathias Trabandt and Karl Walentin

Housing collateral and the monetary transmission mechanism 2010:239
by Karl Walentin and Peter Sellin

The Discursive Dilemma in Monetary Policy 2010:240
by Carl Andreas Claussen and Øistein Røisland

Monetary Regime Change and Business Cycles 2010:241
by Vasco Cúrdia and Daria Finocchiaro

Bayesian Inference in Structural Second-Price common Value Auctions 2010:242
by Bertil Wegmann and Mattias Villani

Equilibrium asset prices and the wealth distribution with inattentive consumers 2010:243
by Daria Finocchiaro

Identifying VARs through Heterogeneity: An Application to Bank Runs 2010:244
by Ferre De Graeve and Alexei Karas

Modeling Conditional Densities Using Finite Smooth Mixtures 2010:245
by Feng Li, Mattias Villani and Robert Kohn

The Output Gap, the Labor Wedge, and the Dynamic Behavior of Hours 2010:246
by Luca Sala, Ulf Söderström and Antonella Trigari

Density-Conditional Forecasts in Dynamic Multivariate Models 2010:247
by Michael K. Andersson, Stefan Palmqvist and Daniel F. Waggoner

Anticipated Alternative Policy-Rate Paths in Policy Simulations 2010:248
by Stefan Laséen and Lars E. O. Svensson

MOSES: Model of Swedish Economic Studies 2011:249
by Gunnar Bårdsen, Ard den Reijer, Patrik Jonasson and Ragnar Nymoen

The Effects of Endogenuos Firm Exit on Business Cycle Dynamics and Optimal Fiscal Policy 2011:250
by Lauri Vilmi

Parameter Identification in a Estimated New Keynesian Open Economy Model 2011:251
by Malin Adolfson and Jesper Lindé

Up for count? Central bank words and financial stress 2011:252
by Marianna Blix Grimaldi

SCALABLE MCMC FOR LARGE DATA PROBLEMS USING DATA SUBSAMPLING AND THE DIFFERENCE ESTIMATOR *by MATIAS QUIROZ, MATTIAS VILLANI AND ROBERT KOHN*	2015:306
SPEEDING UP MCMC BY DELAYED ACCEPTANCE AND DATA SUBSAMPLING *by MATIAS QUIROZ*	2015:307
Modeling financial sector joint tail risk in the euro area *by André Lucas, Bernd Schwaab and Xin Zhang*	2015:308
Score Driven Exponentially Weighted Moving Averages and Value-at-Risk Forecasting *by André Lucas and Xin Zhang*	2015:309
On the Theoretical Efficacy of Quantitative Easing at the Zero Lower Bound *by Paola Boel and Christopher J. Waller*	2015:310

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