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Abstract

This paper revisits the equilibrium and welfare effects of long-run inflation in the presence of distortionary taxes and financial constraints. Expected inflation interacts with corporate taxation through the deductibility of i) capital expenditures at historical value 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 negatively, relaxes firms' financial constraints and stimulates investment. We show that, in the presence of collateralized debt, the second effect dominates. Therefore, in contrast to earlier literature, we find that when the tax code creates an advantage of debt financing, a positive rate of long-run inflation is beneficial in terms of welfare as it mitigates the financial distortion and spurs capital accumulation.

JEL Classification: E31, E43, E44, E52 and G32
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"The explicit recognition of corporate taxation substantially changes the relation between the rates of inflation and of interest that is implied by equilibrium theory. The Fisherian conclusion that the nominal rate of interest rises by the expected rate of inflation, leaving the real rate of interest unchanged, is no longer valid when borrowers treat interest payments as a deductible expense and pay tax on profits net of accounting depreciation" (Feldstein and Summers, 1978)

1 Introduction

A large body of literature maintains that long-run inflation reduces welfare (e.g. Cooley and Hansen, 1991; Lucas, 2000; Lagos and Wright, 2005; Schmitt-Grohe and Uribe, 2010). In particular, it has been argued that in the presence of corporate taxation, inflation exacerbates the distortionary effects of this tax, thereby providing a further argument in favor of low (if not negative) rates of inflation.[1] 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 typically distorts firms' investment choices. Tax deductions are generally designed to mitigate these distortions, absent more granular tax systems. As tax deductions refer to nominal values, the rate of inflation can affect the effective tax burden, thus creating a source of monetary non-neutrality. This is, for example, 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. Inflation acts as a subsidy to borrowers and generates two counteracting effects on welfare. On the one hand, inflation induces firms to resort more heavily to external finance: which in turn drives a larger wedge between the effective cost of capital and its efficient level, reinforcing the case for low inflation. On the other hand, in the presence of collateralized debt, inflation mitigates the effective cost of external finance reducing the bite of borrowing constraints and their social inefficiency. Thus, building a countervailing case for *high* inflation. This last channel, absent from previous literature, turns out to be dominant. By mitigating financial distortions, infla-

[1] 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.

tion ultimately stimulates capital accumulation and brings the return to capital closer to the first best. The overall effects of inflation on the equilibrium welfare are thus reversed compared to the frictionless model.

We make these points in a simple equilibrium model featuring corporate taxes and a collateral constraint à la Kiyotaki and Moore (1997). Our stylized tax code 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. We proceed in two steps. First, we consider the simple benchmark case of perfect competition. Second, we examine the effects of monopolistic competition and costly price adjustment. Our results can be summarized as follows. In a world with perfectly competitive markets and flexible prices, we show that, for a given tax structure, positive and relatively large deterministic long-run inflation is a non-trivial source of welfare gains. Furthermore, we establish that the inflation rate which brings about the frictionless equilibrium is identical to the one that would be chosen, for a given set of taxes, by a Ramsey policymaker — a "divine coincidence" of sorts. For standard parameter values, the Ramsey-optimal inflation rate is indeed positive. The Friedman rule (i.e., deflation at the real rate of interest) is optimal only in the limit case of full deductibility of investment.

With monopolistic distortions, we prove that the Ramsey policy ceases to reproduce the efficient allocation. We show numerically that 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). Introducing price stickiness only affects our results quantitatively: as price adjustments are costly also in the long run, the optimal inflation rate is smaller under a larger degree of price stickiness. However, even with a large degree of nominal rigidity, the optimal rate of inflation remains relatively large. We also document that uncertainty, to second order of approximation, only marginally affects the optimal long-run inflation rate. For empirically plausible magnitudes of the underlying innovations, the deterministic results are a good measure of the trade-offs faced by the Ramsey policymaker.

In this paper, we take the tax system as exogenously determined. 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, this ideal configuration might differ, for reasons that are beyond the scope of this paper, from the *observed* constellation of taxes.[2] Our paper should thus be taken as providing

[2] 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

counterarguments to the received wisdom on the effects of inflation in the presence of exogenous given corporate taxation. Our findings contribute to the literature on the welfare costs of expected inflation (cited above) by focusing on the interaction between inflation, corporate taxes and the firms' financing conditions. Schmitt-Grohe and Uribe (2010) survey the literature on the optimal rate of inflation. A consistent finding is that the optimal rate of long-run inflation should range between the Friedman Rule and numbers close to zero. In this paper we show that, under plausible conditions, the interplay between borrowing constraints and distortionary taxes justifies a positive long-run target inflation.[3]

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 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.

The paper is organized as follows. Section 2 describes the baseline model. Section 3 explores the equilibrium impact of the corporate tax and of the two types of deductibility. Section 4 presents analytical results concerning the optimal, deterministic, long-run level of inflation. Section 5 introduces price rigidity and monopolistic competition. Section 6 studies the optimal response of the economy to productivity and cost-push shocks and characterizes the optimal degree of inflation volatility and how

interest deductions to their non-inflationary component. However, no changes to the tax code have been implemented up to current date.

[3] Schmitt-Grohe and Uribe (2010) show that positive inflation could be justified 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.

uncertainty affects average inflation. Section 7 examines the robustness of preceding results to the introduction of extra frictions such as monetary transaction costs or of additional taxes. Section 8 concludes. Most proofs and model details are gathered in the Appendix.

2 Baseline 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 non-contingent 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 deductible interest payments and capital expenditures. The output of production is sold in competitive markets.

2.1 Households

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

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln c_t + \eta \ln(1 - l_t)\right] \tag{1}$$

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

$$b_t = \frac{1 + r_{t-1}}{\pi_t} b_{t-1} + w_t l_t + T_t + d_t - c_t \tag{2}$$

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

Optimal leisure-consumption choice requires

$$\frac{w_t}{c_t} = \eta \frac{1}{1 - l_t}. \tag{3}$$

The intertemporal condition for a utility maximum is

$$E_t \left(\Lambda_{t,t+1} \frac{1 + r_t}{\pi_{t+1}} \right) = 1, \tag{4}$$

where, using the utility function (1), the pricing kernel of the consumers equals $\Lambda_{t,t+1} = \beta c_t / c_{t+1}$. It follows that, in a deterministic steady state with constant consumption, the pricing kernel is $\Lambda_{t,t+1} = \beta$ so that the gross nominal interest rate is simply

$$1 + r = \pi / \beta, \tag{5}$$

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 that $\pi > \beta$.

2.2 Firms

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

$$Y_t = z_t k_{t-1}^{\alpha} l_t^{1-\alpha} \tag{6}$$

where $\alpha \in (0,1)$ denotes the share of capital and z_t is a productivity shock. It maximizes the expected present discounted value of its future dividends

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} d_t, \tag{7}$$

using the pricing kernel of the consumers.

Firms distribute dividends equal to their output net of inputs costs and depreciation, plus net debt issues, minus corporate tax payments

$$\begin{aligned} d_t = {} & Y_t - w_t l_t - [k_t - (1-\delta) k_{t-1}] \\ & + b_t - (1 + r_{t-1}) \frac{b_{t-1}}{\pi_t} \\ & - \tau \Psi_t, \end{aligned} \tag{8}$$

where $\delta \in [0,1]$ is the physical rate of depreciation of capital, τ is the proportional corporate tax rate and Ψ_t denotes taxable profits.

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 $\delta \frac{k_{t-1}}{\pi_t}$,[4] and ii) a fraction $\varkappa_r \in [0,1]$ of interest payments on debt $r_{t-1} \frac{b_{t-1}}{\pi_t}$. As a result, taxable profits are

$$\Psi_t = Y_t - w_t l_t - \varkappa_\delta \delta \frac{k_{t-1}}{\pi_t} - \varkappa_r r_{t-1} \frac{b_{t-1}}{\pi_t}. \tag{9}$$

Note that the only reason for a firm to issue debt in this environment is to take advantage of the tax deductibility of interest payments (the last term in equation (9)). We introduce financial frictions by assuming that loans must be collateralized. More precisely, we assume that only a fraction γ of the

[4] 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.

expected value of next-period capital stock, k_t, can serve as collateral to debt and that this collateral is, in addition, subject to an exogenous shock ζ_t. The borrowing constraint can therefore be expressed (in real terms) as[5]

$$(1+r_t)\, b_t \leq \gamma \zeta_t k_t E_t \pi_{t+1}. \tag{10}$$

We will prove below that as long as there is an actual tax advantage of debt (which requires, of course, that there be a positive nominal net interest rate r_t, a positive corporate tax rate τ_t and a positive exemption $\varkappa_t$ for interest payments), this collateral constraint is binding in every date and state.[6]

Using equations (8), (9) and (6), maximization of the firm's market value (7) with respect to capital and debt subject to the borrowing constraint (10) yields the following two first-order conditions together with a complementary slackness condition

$$-1 + E_t \Lambda_{t,t+1} \left((1-\tau)\, \alpha k_t^{\alpha-1} l_{t+1}^{1-\alpha} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right) + \mu_t \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1+r_t)} = 0, \tag{11}$$

$$1 - E_t \left(\Lambda_{t,t+1} \frac{R_t}{\pi_{t+1}} \right) - \mu_t = 0, \tag{12}$$

$$\mu_t \left(\gamma \zeta_t k_t \frac{E_t \pi_{t+1}}{(1+r_t)} - b_t \right) = 0, \tag{13}$$

where

$$R_t = 1 + (1 - \varkappa_r \tau) r_t, \tag{14}$$

is the effective, after-tax, gross interest rate paid by the firm on its debt and $\mu_t \geq 0$ is the Lagrange multiplier of the time-t borrowing constraint. The multiplier is larger the tighter the financial constraint, thus making external finance more costly for the firm.

Note that by substituting (4) into (12) we get, using (14), an expression for the shadow price of the collateral constraint:

$$\mu_t = E_t \left(\Lambda_{t,t+1} \tau \varkappa_r \frac{r_t}{\pi_{t+1}} \right). \tag{15}$$

This equation establishes the claim we made above that the collateral constraint always binds ($\mu_t > 0$ for all t) if the nominal interest rate r_t is positive and there is a deduction for nominal interest payments ($\tau > 0$ and $\varkappa_r > 0$). In a deterministic steady state with constant consumption and nominal interest rate, the Lagrange multiplier of the collateral constraint is thus

$$\mu = \beta \tau \varkappa_r \frac{r}{\pi}. \tag{16}$$

[5] We assume, for simplicity, that the collateral constraint is imposed on average, and not state by state. Note that, in the case of borrowing limits set to a fixed level $\bar{B}$, the optimal debt would simply be a constant $\bar{B}/(1+r)$ whose value would affect the value of the firm through a wealth effect but not its marginal choices, as we will discuss further below.

[6] We abstract from other factors bearing on the cost of funds that could keep the debt of the firm below the maximum allowed by the collateral constraint. See, for instance, Jermann and Quadrini (2012) and Gale and Gottardi (2013). Note also 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 expected inflation in equation (10)

Financial frictions generate a wedge between the lending rate and the return on capital (an implicit credit spread). In our model it is not possible to disentangle the tax advantage from the credit spread: if $\tau = 0$, then $\mu = 0$. It should, however, be noted that our analysis would carry over to a version of the model that ensures borrowing constraint to be relevant in the long run by assuming different discounting, rather than tax benefits of debt (e.g. Kiyotaki and Moore, 1997).[7] In this latter case, it would be clear that the financial friction (a positive credit spread) discourages investment and, by equation (11), the more so the lower the value of γ. The tax advantage, on the contrary, encourages borrowing and thus investment. Hence, the financial friction mitigates the incentive coming from the tax deductibility of interest payments.

Combining equation (5) and (16) 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.[8] However, the presence of other distortions makes this policy sub-optimal.

2.3 Monetary and fiscal authority

The monetary authority optimally chooses the inflation rate π_t by taking as given the constant corporate tax rate τ and the exemptions $\varkappa_r$ and $\varkappa_\delta$. Tax revenues are rebated lump-sum to households, thus the government budget constraint reads

$$T_t = \tau \Psi_t \tag{17}$$

where Ψ_t denotes firms' taxable profits, defined as

$$\Psi_t = Y_t - w_t l_t - \varkappa_\delta \delta \frac{k_t}{\pi_t} - \varkappa_r r_t \frac{b_t}{\pi_t} \tag{18}$$

2.4 Competitive equilibrium

We now define a competitive equilibrium:

Definition 1 *A competitive equilibrium is a sequence of interest rates, wage rates and price levels* $\{r_t, w_t, P_t\}_{t=0}^{\infty}$*, a tax system summarized by the corporate tax rate, tax deductions and transfers to households* $\{\tau, \varkappa_\delta, \varkappa_r, T_t\}_{t=0}^{\infty}$ *and an allocation* $\{c_t, l_t, b_t, d_t, k_t\}_{t=0}^{\infty}$ *such that: i) given the price sequence and initial values of* k_0 *and* b_0*, the allocation solves the optimum problem of households and firms; ii) the government's budget constraint is satisfied for all* $t \geq 0$*; and iii) goods, factors and financial markets clear.*

[7] This can be gauged by replacing β with $\beta^e < \beta$ in the first-order conditions of the firm and evaluating the result in the steady state. We don't pursue that modelling strategy for the sake of simplicity.

[8] In a setting with different discounting, firms would be financially constrained even without interest deductibility. Introducing interest deductibility would lead firms to take up even more debt, making the constraint even tighter. Thus, setting $\pi = \beta$ would reduce rather than eliminate the financial friction. Calculations are available upon request.

3 Inflation and Corporate Taxes: Inspecting the mechanism

This section shows how corporate taxes and inflation affect the steady-state allocation.

In the absence of financial frictions, distortionary taxes and uncertainty, 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 but without uncertainty. The allocation Ω can be compactly represented by its marginal product of capital, Y_K which satisfies, using the first-order condition (11), the following condition

$$(1-\tau)(Y_K - Y_{K,FB}) = \tau \left[Y_{K,FB} - \frac{\delta \varkappa_\delta}{\pi} - \frac{\gamma(\pi - \beta)\varkappa_r}{\pi} \right]. \tag{19}$$

Clearly, a social planner who is optimally manipulating taxes could achieve the first best by setting the corporate tax rate τ to zero.[9] 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 engendered by corporate taxation leads to capital under-accumulation in the absence of corporate tax deductions since $Y_K = Y_{K,FB}/(1-\tau) > Y_{K,FB}$ if $\varkappa_r = \varkappa_\delta = 0$. When the nominal interest rate is positive (i.e., when inflation π is above the Friedman rule β), the deductibility of interest expenses is usually designed to mitigate this under-accumulation of capital and reduce the gap between Y_K and $Y_{K,FB}$. The deductibility of depreciated capital expenses from taxable profits achieves the same objective. The real effect of both deductions depends, as expression (19) shows, on the magnitude on the inflation rate. 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 (but absent, here, uncertainty or monopolistic distortions)? The answer is found in equation (19): to achieve the first best and thus achieve a capital stock such that $Y_K = Y_{K,FB}$ when $\tau > 0$, we need an inflation rate, which we will call π^{FB}, that sets to zero the term in square brackets on the right-hand side of equation (19). Since π is the gross inflation rate, thus strictly positive, π^{FB} is the unique root to the linear equation in π

$$S(\pi) \equiv \pi Y_{K,FB} - \delta \varkappa_\delta - \gamma(\pi - \beta)\varkappa_r = 0, \tag{20}$$

namely

$$\pi^{FB} = \beta + \frac{\beta Y_{K,FB} - \delta \varkappa_\delta}{\gamma \varkappa_r - Y_{K,FB}} \tag{21}$$

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

where $S(\pi)$, the *modified tax base*, denotes a function proportional to taxable profits as further explained below. In other words, π^{FB} satisfies the following definition

Definition 2

$$\pi^{FB} = \left\{\pi : \Omega = \Omega^{FB}\right\}.$$

To understand the economics of equation (20) or of its solution (21), observe from definition (9) that, in a deterministic steady state, taxable profits are

$$\Psi = Y - wl - \varkappa_{\delta}\delta\frac{k}{\pi} - \varkappa_{r} r\frac{b}{\pi} \tag{22}$$

while, from inequality (10), the collateral constraint imposes that

$$\frac{1+r}{\pi}b = \gamma k \tag{23}$$

with

$$\beta\frac{1+r}{\pi} = 1. \tag{24}$$

Combining these three equations, while noting that $Y - wl = Y_K k$ under constant returns to scale and perfect competition, yields the following equation for steady-state taxable profits:

$$\Psi = \left[Y_K\pi - \varkappa_{\delta}\delta - \varkappa_{r}(\pi - \beta)\gamma\right]\frac{k}{\pi} = S(\pi)\frac{k}{\pi} \tag{25}$$

In combination with equation (20), this expression shows that taxable corporate profits are zero when $\pi = \pi^{FB}$ and $Y_K = Y_{K,FB}$, i.e. when the modified tax base $S(\pi)$ is zero. In other words, *to reach the first best* (absent monopolistic or other distortions) *despite a positive corporate tax rate, taxable corporate profits must be brought to zero* via the impact of inflation on tax deductions. The gross inflation rate π^{FB} achieves this objective. 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 two propositions provide the answers to these queries.

3.1 First-best inflation and the Friedman rule

We now establish the condition under which the first-best inflation rate is feasible, in the sense that π^{FB} is above the level prescribed by the Friedman rule and the nominal steady state rate of interest is positive.

Proposition 1 *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 tax base is continuous and decreasing in inflation, i.e.*

$$S'(\pi) = Y_{K,FB} - \gamma \varkappa_r < 0. \tag{26}$$

Proof: *As a preliminary, note from equation* (25) *that taxable corporate profits at the Friedman rule (when $\pi = \beta$) are positive since $S(\beta) = \beta Y_{K,FB} - \delta \varkappa_\delta = \beta[\beta^{-1} - 1 + \delta] - \delta \varkappa_\delta = (1-\beta)(1-\delta) + \delta(1-\varkappa_\delta) > 0$ under standard assumptions about β, δ and $\varkappa_\delta$ being between* 0 *and* 1*. In other words, at the Friedman rule where inflation equals the rate of time preference and the nominal interest rate is zero (so that the interest expense deduction is irrelevant), the deduction for depreciation never results in the corporate tax becoming a subsidy.*

The proof of the proposition follows immediately: since taxable profits are positive at the Friedman rule, a necessary and sufficient condition for them to be zero at an inflation rate π^{FB} above *the Friedman rule (i.e., for $\pi^{FB} > \beta$) is that the function $S(\cdot)$ is continuous and decreasing in inflation. This establishes the necessary and sufficient condition of the proposition.* •

The condition of Proposition 1 is likely to be satisfied empirically (unless firms cannot borrow or deduct any interest 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 at an annual frequency.

Note also from equation (21) that the smaller $\gamma \varkappa_r$, the higher above the Friedman rule the inflation rate which eliminates the distortion stemming from the corporate tax. If debt is low either because 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.

3.2 Positive net inflation at the first best

The next Proposition establishes that net inflation is positive at the first best under a very plausible restriction on the parameters of the tax code:

Proposition 2 *Under the condition of Proposition 1, net inflation is positive at the first best ($\pi^{FB} > 1$) if and only if the tax code is such that firms would face a tax liability in the absence of inflation (i.e., in a* de facto *real economy).*

Proof: *From Proposition 1, feasibility amounts to* $S'(\cdot) < 0$*. Since* $S(1) > 0$ *(tax revenue is positive with zero net inflation) it must be that* $S(\pi^{FB}) = 0$ *for some* $\pi^{FB} > 1$*.* •

The condition of Proposition 2 is a natural restriction to impose on the tax code. It just ensures that, in the absence of inflation, the combination of corporate tax rate τ and deductions $(\varkappa_\delta, \varkappa_r)$ leave firms facing an actual corporate tax liability and not a subsidy.

3.3 Inflation, corporate taxes and capital accumulation

Further light on the preceding results can be shed by determining the condition under which inflation, and a positive nominal interest rate, can eliminate the underinvestment otherwise stemming from the taxation of corporate profits.

To that effect, compute the semi-elasticity of the steady-state marginal product of capital with respect to inflation as follow:

$$\frac{\partial Y_K}{\partial \pi / \pi} = \frac{\tau}{(1-\tau)\pi}\left[\varkappa_\delta \delta - \varkappa_r \beta \gamma\right], \tag{27}$$

where π is the *gross* inflation rate, therefore always positive.

The term in square brackets on the right hand-side captures the *positive* contribution of the deduction for depreciation on the impact of inflation on the marginal product of capital: the real " book-value" of depreciated capital decreases with inflation. Therefore higher inflation reduces this tax deduction. Paying higher taxes, firms reduce investment and the return on capital increases. This channel has been thoroughly studied by previous literature and is key in motivating the existence of benefits of low inflation under distortionary corporate taxes.

By contrast, inflation acts as a subsidy to borrowers through nominal-interest deductibility. This subsidy generates two counteracting effects. On the one hand, under interest deductibility, inflation decreases the effective real interest rate faced by the borrower and firms can retain part of the compensation. In other words, the subsidy induces firms to resort more heavily to external finance, generating a larger wedge between the efficient rate and the effective cost of capital (note that $\partial\mu/\partial\pi > 0$). On the other hand, through deductibility of interest expenses, inflation acts as a subsidy to constrained borrowers, thus reducing the social inefficiency of the borrowing constraint. The second term in square brackets shows that the combined contribution of inflation to the marginal product of capital (the stock of capital) via interest deductibility is always *negative* (positive).

Overall, under empirically plausible parameter values, the negative effect of interest rate deductibility always dominates the positive contribution of the deduction for depreciation:

Corollary 1 *If the condition of Proposition 1 is satisfied, then* $\partial Y_K / \partial \pi < 0$.

Proof: *The condition of Proposition 1 requires* $\varkappa_r \gamma > Y_{K,FB}$ *while its proof establishes that* $\beta Y_{K,FB} > \varkappa_\delta \delta$*. It immediately follows that* $\varkappa_r \gamma \beta > \beta Y_{K,FB} > \varkappa_\delta \delta$*.* •

Under the condition of Proposition 1, the monetary authority can always use inflation to reduce the effect of distortionary taxation and eliminate the under-accumulation of capital that stems from the corporate tax.

4 The divine coincidence

Under the particular assumptions entertained so far, the efficient allocation can be achieved by an appropriate choice of inflation. In this section we show analytically that the inflation rate that brings about the efficient allocation coincides with the inflation rate that would be chosen by the Ramsey social planner.

The Ramsey problem

The Ramsey optimal policy problem consists of finding the competitive equilibrium that maximizes households' welfare. In particular, the Ramsey policy solves

$$\max_{\{Y_t, c_t, l_t, \pi_t, k_t, r_t, \mu_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln c_t + \eta \ln (1 - l_t) \right) \tag{28}$$

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

$$\beta E_t \frac{(1 + r_t)}{\pi_{t+1}} \frac{c_t}{c_{t+1}} - 1 = 0 \tag{29}$$

$$\eta \frac{c_t}{1 - l_t} - (1 - \alpha) l_t^{-\alpha} k_{t-1}^{\alpha} = 0 \tag{30}$$

$$-1 + \mu_t \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1 + r_t)} + E_t \beta \frac{c_t}{c_{t+1}} \left[(1 - \tau) \alpha l_{t+1}^{1-\alpha} k_t^{\alpha - 1} + (1 - \delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right] = 0 \tag{31}$$

$$-b_t + \gamma \zeta_t E_t \frac{k_t}{(1 + r_t)} \pi_{t+1} \leq 0 \tag{32}$$

$$-\mu_t + 1 - E_t \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \left[1 + r_t (1 - \tau \varkappa_r) \right] = 0 \tag{33}$$

$$Y_t - c_t - k_t + (1 - \delta) k_{t-1} = 0. \tag{34}$$

4.0.1 The deterministic long-run rate of inflation

The first order derivatives of the Lagrangian associated to the policy problem evaluated at the (deterministic) steady-state, for an arbitrary rate of long-run inflation, can be written as

$$\mathscr{R}_\pi \equiv A_\pi \lambda - \eta_\pi \tag{35}$$

where A_π is a 7×6 matrix of derivatives of the 6 equations describing the economy (29-34) relative to the 7 endogenous variables $\{Y_t, c_t, l_t, \pi_t, k_t, r_t, \mu_t\}$, η_π is a 7×1 vector of derivatives of the objective function (28) relative to the 7 endogenous variables. Both of these objects are functions of deep parameters and inflation. Finally λ is the 6×1 vector of Lagrange multipliers.

Definition 3

$$\pi^{Ramsey} = \{\pi : \mathscr{R}_\pi = 0\}.$$

Proposition 3 *Given an economy with flexible prices and perfectly competitive markets, $\Omega = \Omega^{FB}$ satisfies the FOCs of the Ramsey problem, i.e. $\pi^{Ramsey} = \pi^{FB}$.*

Proof: *See Appendix A.*[10] •

To summarize, under the simplifying assumptions maintained so far, the Ramsey allocation coincides with the first best allocation. Furthermore, as shown in the previous section, for a wide range of parameter values, optimal policy requires a positive inflation rate. The next two subsections show that our results crucially depend on capital having a collateral value and on the presence of a fiscal distortion which leads to under-investment.

4.1 Borrowing Constraint

The analysis presented above documents that in the presence of borrowing constraints and a tax advantage of debt, inflation stimulates capital accumulation. Notably, it is not the presence of borrowing limits *per se* (nor whether the interest rate appears in the constraint or not) that justifies this beneficial effect of inflation, but rather the fact that borrowers are allowed to use capital (an endogenous variable) as collateral.

Proposition 4 *If the borrowing limit is exogenous, $\pi^{FB} < \beta$.*

[10] A general result in this class of models is $\pi^{Ramsey} \neq \pi^{FB}$. For example, in the standard New Keynesian model, $\pi^{FB} > 1 = \pi^{Ramsey}$ (see e.g. Benigno and Woodford, 2005 and Woodford, 2003).

Proof: *Under exogenous debt limits, i.e.* $\gamma = 0$ *(or* $b \leq \bar{b}$*), equation* (26) *simplifies to*

$$S'(\pi) = Y_{K,FB} > 0. \tag{36}$$

Then, as established by Proposition 1, there is no admissible inflation rate, $\pi \geq \beta$*, that can produce the FB allocation.* •

4.2 Full Deductibility of Investment

In the analysis above we document that under both types of 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.[11]

Proposition 5 *Under full deductibility of investments,* $\pi^{Ramsey} = \pi^{FB} = \beta$*.*

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*

$$Y_K = Y_{K,FB} - \frac{(\pi - \beta)}{\pi} \frac{\tau \varkappa_r \gamma}{(1-\tau)}. \tag{37}$$

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 would also eliminate the fiscal distortion.* •

5 Monopolistic competition and sticky prices

So far we have studied an economy featuring perfectly competitive markets for goods and flexible prices. However, in the new Keynesian literature, price stickiness is the primary rationale for the optimality of zero inflation. One could argue that in our set-up, the optimality of positive inflation is justified by this omission. We assess the robustness of our results in a model where the production sector is modified to introduce monopolistic competition and costly price adjustment. More specifically, we distinguish

[11] If investment expenses were deducted at historical value, the Friedman rule would cease to replicate the first best. This last proof is available upon request.

between intermediate- and final-good producers. Intermediate-good producers use labor and capital as input of production and sell their output to final goods producers in competitive markets. These firms face borrowing constraints à la Kiyotaki and Moore (1997). Final-good producers transform intermediate goods into final goods, and sell them in imperfectly competitive markets. Final-good producing firms face a cost of changing prices as in Rotemberg (1982). Appendix B describes in detail both final- and intermediate-good sectors. In this version of the model, we also introduce government expenditure, G, in order to assess the sensitivity of our results to alternative sources of government revenues. More specifically, we assume that the government can levy both distortionary and lump-sum taxes, T_t^G, to finance an exogenous stream of public consumption[12]

$$\tau \Psi_t + T_t^G = G_t \tag{38}$$

5.1 Monopolistic competition and flexible prices

We first consider an economy with monopolistic competition and flexible prices. In this special case, it is still possible to derive some analytical results.

Proposition 6 *Given an economy characterized by monopolistic competition, then $\Omega = \Omega^{FB}$ does not satisfy the FOCs of the Ramsey problem: i.e. $\pi^{Ramsey} \neq \pi^{FB}$.*

Proof: *See Appendix C.* •

The introduction of monopolistic competition breaks the "divine coincidence" and generates a further reason to inflate. Deriving more analytical results under this extended set of frictions is too cumbersome, and would not add further intuition relative to the case discussed above. We thus turn to numerical results. The baseline parametrization of the model is reported in Table 1.[13]

[12] In the robustness section, we introduce an additional distortionary labor tax used by the government to balance its budget in absence of lump-sum taxes.

[13] We assume separable log-utility and calibrate the utility weight on leisure, η, by fixing steady-state hours worked at 0.33. The discount factor, β, is equal to 0.995, implying an annual real rate of 2 percent. Capital share in the production for intermediate goods, α, is set to 0.36 and the depreciation rate of capital, δ, equals 0.025. The elasticity of substitution across intermediate good varieties, ε, is 6 and price adjustment costs are calibrated in order to match a frequency of price adjustment of about 3 quarters, a value in the range reported by Nakamura and Steinsson (2008) for non-sale prices. The credit limit parameter, γ, is set to 0.40 to match the average leverage for the non financial business sector as reported in the Flow of Funds. The corporate tax rate is set at 25 percent, corresponding to the average corporate tax rate for OECD countries (Source OECD, http://www.oecd.org/ctp/tax-policy/). Government spending amounts to about 20 percent of long-run output. As for the shock processes, we assume an autocorrelation parameter set to 0.75 and normalize the standard deviation of the shocks to one. Note that the parametrization of the shocks has no effects for the long-run optimal inflation results. Regarding the dynamic implications of optimal policy, we discuss the results in terms of the two shocks separately.

5.2 Price stickiness and long-run inflation

In this section, we explore the implications of monopolistic distortions and price stickiness for the optimal long-run rate of inflation. In the presence of monopolistic competition and sticky prices, the long-run equilibrium level of capital return is such that

$$\beta(1-\tau)\,\chi Y_k = Y_{K,FB} - \mu\gamma\frac{\pi}{(1+r)} - \beta\tau\varkappa_\delta\delta\pi. \tag{39}$$

where χ is the inverse of the markup of final over intermediate good price.[14] The expression above highlights the contribution of different market failures in distorting the steady-state capital accumulation. Table 2 displays the optimal long-run annualized inflation rate for alternative degrees of price stickiness and different corporate tax rates when the degree of monopolistic distortion is zero (by appropriately setting a subsidy on sales). The first column of Table 2 illustrates the results for the case of flexible prices. Our numerical results show that the long-run inflation is positive and relatively large, for all tax-rate values considered.[15] As we have argued above, adopting the Friedman rule would eliminate the financial friction. Yet, in a second-best world, this policy in general would be inappropriate to tackle the other distortions emerging from the combination of corporate taxation and partial amortization of investment costs. Therefore, the Ramsey policymaker need to engineer positive inflation in order to partially subsidize borrowing and, at the same time, mitigate the distortionary effect of the corporate tax. Increasing the degree of price stickiness, while maintaining zero monopolistic distortion reduces the optimal rate of inflation, as the policymaker now also takes the resource cost entailed by inflation into account.

Introducing monopolistic distortion into our model generates a further reason to inflate. Table 3 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. τ equals 0.25. In the table each column corresponds to values obtained under different frequencies of price-adjustments (in quarters). A higher degree of monopolistic distortion calls for larger rates of long-run inflation as this allows the policymaker to bring the economy closer to the first best, while mitigating the ensuing costs of financial frictions.

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

[14] In the presence of monopolistic competition and sticky prices, the difference between the efficient allocation and the distorted one cannot be simply summarized by the return on capital. Nevertheless, here we report the marginal product of capital for the sake of comparison with the previous section.

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

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). In contrast, 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.

It is important to highlight that the large positive long-run inflation prescribed by the Ramsey policy generates large welfare gains relative to full-price stability in the long run. The welfare comparison under the optimal inflation rate and under zero inflation gives a consumption equivalent welfare gains of 1.6 percent.[16]

6 Optimal Inflation volatility

So far we have discussed the optimal long-run inflation rate and we have argued that expected inflation positively affects the real allocation through the tax-advantage channel. The policy maker could also optimally use this channel in the short run to affect the response of the economy to shocks. In this section we discuss the extent to which the presence of corporate taxation and financial distortions affect inflation volatility.

In our model, due to nominal debt contracts and corporate taxation, inflation has two effects on the external cost of finance. First, even in the absence of corporate taxation, unexpected inflation affects the real value of debt, generating a redistribution between borrowers and lenders. Since the distortion generated by financial frictions can be mitigated by subsidies paid to constrained borrowers, the central bank can improve welfare by increasing the inflation "subsidy" when unexpected shocks exacerbate the financial distortion. This channel has been studied by a number of papers which concluded that financial frictions do not generate a sufficiently strong reason to deviate from price stability.[17] Second, in the presence of corporate taxation, the entire path of the response of inflation to shocks affects the real cost of loans. This strengthens the ability of the monetary authority to mitigate inefficient fluctuations.

Tables 4 and 5 compare the unconditional mean and standard deviation of key variables under the Ramsey policy (column A) and full price stability, $\pi_t = \bar{\pi}$, (column B). First moments are in deviation from the non-stochastic steady state. We consider productivity and mark-up shocks separately and report the moments divided by the variance of the shocks.[18]

This exercise provides several insightful results. First, the two policies generate very similar moments,

[16]The period utility under the optimal inflation is -0.2455, while under zero inflation falls to -0.2609. So in order to be indifferent between regimes, under zero inflation the consumer should be given an extra 1.6% of consumption goods per period. Calculations are based on our benchmark parametrization. See Table 1.

[17]See, among others, Carlstrom et al., 2010; Kolasa and Lombardo, 2014.

[18]The stochastic mean is computed solving a second-order approximation of the model. Thus, the stochastic mean is proportional to the variance of the shocks. See, for example, Lombardo and Sutherland (2007).

except for inflation. Second, for empirically plausible magnitudes of the underlying innovations, the role of uncertainty in our model is rather limited. Under the Ramsey policy, the average optimal inflation falls if the source of uncertainty is a markup shock; on the contrary it increases under a productivity shock. In order to appreciate the magnitude of the contribution of uncertainty we need to multiply the values in the tables by reasonable estimates of the volatility of the underlying shocks. Consider, for example, a standard-deviation of the innovation process of the mark-up shock of 1.8%, as estimated by Jermann and Quadrini (2012) using a model with credit frictions and tax benefits of debt.[19] This implies, for example, that the quarterly inflation rate under the Ramsey policy and mark-up shocks (Table 5) is $\pi^{Ramsey} = 0.0145 - 0.08733 \cdot 0.019^2 \approx 0.0145$. Similar results hold for productivity shocks.[20]

We now shed light on the role of corporate taxation for the short-run optimal response by the monetary authority. Note that in our model, in the absence of corporate taxes the capital structure of the firm is indeterminate, i.e. the lagrange multiplier of the borrowing constraint is zero, corresponding to a non-binding constraint. In this latter case, the policy maker only faces price distortions. Column C of Tables 4 and 5 reports the unconditional moments under a productivity and mark-up shock, respectively, in the absence of both corporate tax and financial distortions.[21] As expected, under both shocks and in the presence of only price distortions, the case for full price stability is almost re-established. When the only distortions is due to costly price adjustment, under the Ramsey policy, the average inflation rate displays a less sizeable deviation from the steady state than in the fully distorted economy.[22]

Finally, in the analysis above we have only considered mark-up shocks as sources of cost-push disturbances. As pointed out by Carlstrom et al. (2010), in the presence of financial frictions, financial shocks play a similar role as mark-up shocks, in many respects. In the following, we also consider financial shocks, as denoted by ζ_t in (10). Table 6 confirms that most of the results obtained under mark-up and productivity shocks carry over to the case of financial shocks.[23] A notable exception is the effect of financial shocks on hours worked. While mark-up and productivity shocks imply that on average hours worked are less than in the non-stochastic steady state, the opposite is true under financial shocks both under the Ramsey policy and under price stability. Also in this case, uncertainty affects our results only marginally, for reasonable estimates of the volatility of the underlying shocks.

[19] Jermann and Quadrini (2012) estimate a value of the persistence parameter of the mark-up shock that is higher than that used in our simulations. The quantitative implications of the larger persistence are negligible.

[20] Jermann and Quadrini (2012) report a standard deviation of the productivity shock of 0.005.

[21] Since, in the latter case, the capital structure of the firm is indeterminate, for simplicity, the model is solved under the no firms' debt assumption.

[22] Robustness checks show that the optimal degree of inflation volatility increases in the degree of monopolistic distortion and falls in the degree of price rigidity, paralleling the results for the optimal long-run inflation rate discussed above.

[23] We abstract from the comparison with the zero-tax case, since it coincides with the absence of financial frictions.

7 Robustness

7.1 Monetary frictions and the optimal rate of inflation

The first robustness analysis that we consider consists of the introduction of monetary transaction costs à la Schmitt-Grohe and Uribe (2010). This friction can capture the inefficiency cost of positive nominal interest rates in the spirit of Friedman (1969). Under the Friedman rule, both the transaction cost and the financial friction would be eliminated. One might argue that under our baseline specification, i.e. without transaction costs, the incentive to follow the Friedman rule might be milder than in the presence of transaction costs. This section shows that introducing monetary-transaction costs affects our results only modestly. The introduction of real balances in the model only affects the specification of the households' problem and the Government budget constraint, which we describe below.

7.1.1 Households

Households choose consumption (c) and labor (l) in order to maximize their lifetime utility

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \tag{40}$$

with

$$U(c_t, l_t) = \ln c_t + \eta \ln(1 - l_t)$$

subject to a budget constraint:

$$w_t l_t + \frac{b_{t-1}}{\pi_t}(1 + r_{t-1}) + \frac{m_{t-1}}{\pi_t} = b_t + c_t(1 + s(v_t)) + m_t - T_t - d_t + T_t^G, \tag{41}$$

where w_t is real wages, b_t are loanable bonds issued by firms, T_t and d_t represent lump-sum transfers from intermediate and final-good producers, respectively, T_t^G lump-sum taxes and $s(v_t)$ is a function measuring the extent to which real balances reduce the transaction cost of procuring the consumption good, where $v_t = \frac{c_t}{m_t}$. A demand for money is motivated by the assumption that consumption purchases are subject to a transaction cost, $s(v_t)$, increasing in v_t with the following properties:

1. $s(v) \geq 0$ and twice continuously differentiable.

2. $\exists \underline{v} > 0 : s(\underline{v}) = s'(\underline{v}) = 0$.

3. $(v - \underline{v})\, s'(v) > 0$ for $v \neq \underline{v}$

4. $2s\prime(v) + v s''(v) > 0$ for all $v \geq \underline{v}$.

In particular we follow Schmitt-Grohe and Uribe (2010) by assuming that

$$s(v_t) \equiv A_s v_t + \frac{B_s}{v_t} - 2\sqrt{(A_s B_s)}$$

7.1.2 Government

The Government prints money, M, and levies both distortionary and lump-sum taxes, T^G, to finance an exogenous stream of public consumption:

$$m_t + \tau_t \Psi_t + T_t^G = \frac{m_{t-1}}{\pi_t} + G_t \tag{42}$$

7.1.3 Numerical results

For the numerical results, we use the same parameter values reported in Table 1. In addition, we calibrate the transaction cost following Schmitt-Grohe and Uribe (2010), i.e. $A_s = 0.0111$ and $B_s = 0.07524$.

By introducing monetary frictions à la Schmitt-Grohe and Uribe (2010) the incentive to generate positive long-run inflation is mitigated. Table 7 reproduces the results shown in Table 2 when a transaction cost is included in the model. The Table shows that our main results are unchanged. Under our baseline calibration and for most of the parameters under consideration, positive long-run inflation is beneficial in terms of welfare.

The presence of transaction costs also produces an effect on the dynamic properties of optimal policy (not shown). Nevertheless, for plausible degrees of uncertainty, the deterministic results are a good approximation of the welfare gains from a positive long-run inflation rate.

7.2 Absence of lump-sum taxes

So far we have assumed that the government can balance its budget period by period through lump-sum subsidies. In this section we show that qualitatively similar results concerning the optimal long-run inflation rate can be obtained in the absence of lump-sum taxes, with exogenous government spending and in the presence of an additional distortionary labor tax.

Table 8 shows the optimal inflation rate (under the baseline parametrization) for different values of the corporate tax rate and the implied values of the labor tax that ensures a balanced budget period by period. Two observations are in order. First, for the empirically relevant range of the corporate tax rate, the optimal long-run inflation rate increases.[24] Second, as the corporate tax increases, the distortionary labor tax necessary to finance public expenditures falls, despite a higher rate of inflation, and thus a higher implicit subsidy to borrowers.

[24]Table 8 also shows that the relationship between inflation and the corporate tax is non-monotonic (see last two rows).

8 Conclusion and extensions

This paper revisits 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 abstracted from the microeconomic determinants of firms' debt. By contrast, we derive the level of debt endogenously as an 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. These limits generate an inefficiently low level of capital accumulation as financing costs exceed the frictionless interest rate — a case for corrective subsidies. In the presence of deductible interest payments, inflation can generate an implicit subsidy to borrowers. In this way inflation stimulates capital accumulation while mitigating the distortionary effect of the corporate tax and of the financial friction. We prove analytically that, under interest debt deductibility and for given positive tax rates, the efficient allocation can be restored by an appropriate choice of inflation. The Ramsey optimal inflation also turns out to be positive in the presence of costly price adjustments, and is increasing in the degree of monopolistic distortion.

In our model, the capital structure of the firm is determined by two opposing forces. On the one hand interest deductibility incentivizes firms to raise external funds. On the other hand a collateral constraint forces firms to resort to some equity issuance to finance their expenditures. We conjecture that our results would carry over to an environment in which the upper bound on borrowing is motivated by different assumptions: e.g. by the cost of fire-sales as in Gale and Gottardi (2013).

Finally, leverage is exogenously determined in our model. The interaction between monetary policy and financial decisions has been a recurrent topic in the literature, with an evident revival due to the recent financial crisis (e.g. Modigliani, 1982 and Borio and Zhu, 2012). To the extent that higher leverage amplifies business cycle fluctuations (e.g. Bernanke et al., 1999), the optimal choice of long-run inflation will have to trade off the benefits of increased capital accumulation (discussed here) with the costs of larger macroeconomic volatility, an aspect that deserves further investigation.

References

Benigno, P. and Woodford, M. (2005). Inflation stabilization and welfare: The case of a distorted steady state. *Journal of the European Economic Association*, 3(6):1185–1236.

Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In Taylor, J. B. and Woodford, M., editors, *Handbook of Macroeconomics*, volume 1 of *Handbook of Macroeconomics*, chapter 21, pages 1341–1393. Elsevier.

Borio, C. and Zhu, H. (2012). Capital regulation, risk-taking and monetary policy: a missing link in the transmission mechanism? *Journal of Financial Stability*, 8(4):236–251.

Carlstrom, C. T., Fuerst, T. S., and Paustian, M. (2010). Optimal monetary policy in a model with agency costs. *Journal of Money, Credit and Banking*, 42(s1):37–70.

Coibion, O., Gorodnichenko, Y., and Wieland, J. (2012). The Optimal Inflation Rate in New Keynesian Models: Should Central Banks Raise Their Inflation Targets in Light of the Zero Lower Bound? *Review of Economic Studies*, 79(4):1371–1406.

Cooley, T. F. and Hansen, G. D. (1991). The Welfare Costs of Moderate Inflations. *Journal of Money, Credit and Banking*, 23(3):483–503.

Feldstein, M. (1983). *Inflation, Tax Rules, and Capital Formation.* National Bureau of Economic Research, Inc.

Feldstein, M. (1999). *The Costs and Benefits of Price Stability.* University of Chicago Press.

Feldstein, M. and Summers, L. (1978). Inflation, Tax Rules, and the Long Term-Interest Rate. *Brookings Papers on Economic Activity*, 9(1):61–110.

Fischer, S. (1999). Comment on "Capital Income taxes and the benefits of price stability". In Feldstein, M., editor, *The cost and benefits of price stability*, NBER Conference Report. The University of Chicago Press.

Friedman, M. (1969). *The optimum quantity of money, and other essays.* Chicago:. Aldine Publishing Company.

Gale, D. and Gottardi, P. (2013). Capital structure and investment dynamics with fire sales. LSE,SRC Discussion Paper No 7.

Jermann, U. and Quadrini, V. (2012). Macroeconomic effects of financial shocks. *American Economic Review*, 102(1):238–71.

Kim, J. and Ruge-Murcia, F. J. (2009). How much inflation is necessary to grease the wheels? *Journal of Monetary Economics*, 56(3):365–377.

King, R. and Wolman, A. L. (1999). *What Should the Monetary Authority Do When Prices Are Sticky?*, pages 349–404. University of Chicago Press.

Kiyotaki, N. and Moore, J. (1997). Credit cycles. *Journal of Political Economy*, 105(2):211–247.

Kolasa, M. and Lombardo, G. (2014). Financial Frictions and Optimal Monetary Policy in an Open Economy. *International Journal of Central Banking*, 10(1):43–94.

Lagos, R. and Wright, R. (2005). A unified framework for monetary theory and policy analysis. *Journal of Political Economy*, 113(3).

Lombardo, G. and Sutherland, A. J. (2007). Computing Second-Order-Accurate Solutions for Rational Expectation Models using Linear Solution Methods. *Journal of Economic Dynamics and Control*, 31(2):515–530.

Lucas, R. E. (2000). Inflation and Welfare. *Econometrica*, 68(2):247–274.

Modigliani, F. (1982). Debt, dividend policy, taxes, inflation and market valuation. *The Journal of Finance*, 37(2):255–273.

Nakamura, E. and Steinsson, J. (2008). Five facts about prices: A reevaluation of menu cost models. *The Quarterly Journal of Economics*, 123(4):1415–1464.

Rotemberg, J. (1982). Monopolistic price adjustement and aggregate output. *The Review of Economic Studies*, 49(4):517–531.

Schmitt-Grohe, S. and Uribe, M. (2010). The Optimal Rate of Inflation. NBER Working Papers 16054, National Bureau of Economic Research, Inc.

Venkateswaran, V. and Wright, R. (2013). *Pledgability and Liquidity: A New Monetarist Model of Financial and Macroeconomic Activity*, pages 227–270. University of Chicago Press.

Woodford, M. (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton U.P., Princeton, NJ.

Table 1: Parameters' Values

α	Share of capital in production	0.36
β	Discount factor	0.995
η	Leasure preference parameter	0.4974
δ	Depreciation rate	0.025
τ	Corporate tax	0.25
ϕ	Price adjustment costs	29.70
ε	Elasticity of substitution	6
γ	LTV	0.40

Table 2: Optimal annualized inflation: Price stickiness vs. tax rate†

	Frequency of Price Adjustments (quarters)					
τ	1	1.5	2	2.5	3	4
0.1	63.54	14.07	6.233	3.511	2.252	1.155
0.2	28.93	17.97	10.78	6.871	4.684	2.537
0.25	22.35	16.89	11.72	8.115	5.792	3.28
0.3	18.03	15.18	11.82	8.896	6.703	4.019
0.4	12.69	11.82	10.54	9.08	7.646	5.297

†Other parameters at their baseline values.

Table 3: Optimal annualized inflation: Price stickiness vs. monopolistic distortion

	Frequency of Price Adjustments					
Monop. dist.†	1	1.5	2	2.5	3	4
0	3.249	2.347	1.601	1.108	0.7939	0.453
0.2	7.028	5.12	3.504	2.424	1.736	0.989
0.4	10.83	7.957	5.463	3.78	2.705	1.539
0.6	14.65	10.86	7.483	5.179	3.702	2.103
0.8	18.49	13.84	9.568	6.623	4.731	2.683
1	22.35	16.89	11.72	8.115	5.792	3.28

†Monopolistic distortion denotes degree of steady state distortion: 0=min; 1=100% mark-up distortion.

Table 4: Ramsey vs. price stab. vs. no-tax case: Productivity shocks††

Variable	(A) Ramsey		(B) Price Stability		(C) $\tau = 0$	
	Mean♭	Stdev.♭♭	Mean♭	Stdev♭♭	Mean♭	Stdev♭♭.
Inflation†	0.003784	0.03007	0	0	0.0001423	0.004551
Consumption	2.09	1.163	2.077	1.211	1.999	1.191
GDP	0.5853	2.047	0.5557	2.061	0.4372	2.031
Policy rate	-0.009404	0.02933	-0.01776	0.03958	-0.0158	0.04346
Lagrange mult.	-0.002464	0.007052	-0.004781	0.009797	0	0
Hours	-0.7532	0.5078	-0.7789	0.5184	-0.774	0.5094
Debt	46.17	18.08	42.36	16.84	0	0
Investment	-17.08	6.577	-19.34	6.922	-18.11	6.651

† Underlying quarterly steady-state inflation of 1.45% under the Ramsey policy and zero in the other two cases.

♭ Values divided by the *variance* of the productivity-shock innovation.

♭♭ Values divided by the *standard deviation* of the productivity-shock innovation.

†† Values not in percentages.

Table 5: Ramsey vs. price stab. vs. no-tax case: Mark-up shocks††

Variable	(A) Ramsey		(B) Price Stability		(C) $\tau = 0$	
	Mean$^\flat$	Stdev.$^{\flat\flat}$	Mean$^\flat$	Stdev.$^{\flat\flat}$	Mean$^\flat$	Stdev.$^{\flat\flat}$.
Inflation†	-0.08733	0.05076		0	-0.0006872	0.05207
Consumption	0.3243	0.2611	0.3183	0.2872	0.4736	0.2696
GDP	0.6221	0.4275	0.7124	0.4906	0.9092	0.4344
Policy rate	-0.09105	0.04076	0.0003714	0.03553	-0.003198	0.05309
Lagrange mult.	-0.02229	0.009802	-0.0002189	0.008793	0	0
Hours	-0.1124	0.5751	-0.2908	0.6649	-0.06006	0.5832
Debt	20.27	4.222	23.74	4.419	0	0
Investment	0.8056	1.557	0.9063	1.849	1.417	1.618

†Underlying steady-state inflation 1.45% under the Ramsey policy and zero in the other two cases.

$^\flat$Values are divided by the *variance* of the mark-up-shock innovation.

$^{\flat\flat}$Values are divided by the *standard deviation* of the mark-up-shock innovation.

††Values are not in percentages.

Table 6: Ramsey vs. price stab.: Financial shocks††

Variable	(A) Ramsey		(B) Price Stability	
	Mean$^\flat$	Stdev.$^{\flat\flat}$	Mean$^\flat$	Stdev.$^{\flat\flat}$
Inflation†	0.001143	0.02308	0	0
Consumption	0.111	0.02401	0.01278	0.002807
GDP	0.1998	0.01936	0.01894	0.001211
Policy rate	0.001525	0.02988	-1.366e-06	0.0008369
Lagrange mult.	0.0001561	0.007185	-5.106e-07	0.0002072
Hours	0.02814	0.02883	0.002103	0.00118
Debt	16.47	15.12	10.82	13.73
Investment	0.5037	0.05414	0.04883	0.009562

† Underlying quarterly steady-state inflation 1.45% under the Ramsey policy and zero under price stability.

$^\flat$ Values are divided by the *variance* of the financial-shock innovation.

$^{\flat\flat}$ Values are divided by the *standard deviation* of the financial-shock innovation.

††Values are not in percentages.

Table 7: Optimal annualized inflation with transaction costs[†]: Price stickiness vs. tax rate

τ	1	1.5	2	2.5	3	4
0.1	51.55	10.6	4.803	2.749	1.78	0.9212
0.2	27.15	16.47	9.779	6.226	4.249	2.308
0.25	21.46	16.02	11.01	7.589	5.409	3.063
0.3	17.54	14.68	11.35	8.503	6.388	3.821
0.4	12.53	11.65	10.36	8.903	7.476	5.159

[†] Other parameters at their baseline values.

Table 8: Optimal annualized inflation, under a range of corporate taxes and endogenously determined labor tax.[†]

τ	τ_w	π
0.1	0.4089	1.7874
0.15	0.3883	2.7573
0.2	0.3698	3.7046
0.25	0.3534	4.5718
0.3	0.339	5.3014
0.35	0.3262	5.8462
0.4	0.3144	6.1817
0.45	0.3032	6.3133
0.5	0.2918	6.2709

[†] Under baseline parametrization.

Optimal Inflation with Corporate Taxation and Financial Constraints

Technical Appendix

A Ramsey problem in the baseline model

Consider an economy with perfect competition and flexible prices. The Ramsey policymaker maximizes households' welfare taking into account the equilibrium reactions of consumers and firms. Specifically, she solves the following problem under timeless perspective commitment:

$$\max_{r_t, c_t, l_t, k_t, \pi_t, b_t, \mu_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[\log(c_t) + \eta \log(1 - l_t)\right]$$

subject to:

$$\lambda_{1t} : \beta E_t \frac{(1 + r_t)}{\pi_{t+1}} \frac{c_t}{c_{t+1}} - 1 = 0 \tag{43}$$

$$\lambda_{2t} : \eta \frac{c_t}{1 - l_t} - Y_{l,t} = 0 \tag{44}$$

$$\lambda_{3t} : -1 + \left(1 - E_t \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} (1 + r_t (1 - \tau \varkappa_r))\right) \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1 + r_t)} \tag{45}$$

$$+ E_t \beta \frac{c_t}{c_{t+1}} \left[(1 - \tau) Y_{k,t+1} + (1 - \delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}}\right] = 0$$

$$\lambda_{4t} : 0 \leq b_t - \gamma \zeta_t E_t \frac{k_t}{(1 + r_t)} \pi_{t+1} \tag{46}$$

$$\lambda_{5t} : Y_t - c_t - k_t + (1 - \delta) k_{t-1} = 0 \tag{47}$$

where λ_i is the Lagrange multiplier associated to the i^{th} constraint.

A.1 First order conditions

The following system of dynamic equations characterizes the first-order conditions of the Ramsey problem :

r_t :

$$\beta E_t \frac{\lambda_{1t}}{\pi_{t+1}} \frac{c_t}{c_{t+1}} - \lambda_{3t} \left(\begin{array}{c} \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1+r_t)^2} \left(1 - E_t \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} (1 + r_t (1 - \tau \varkappa_r))\right) \\ + E_t \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1+r_t)} (1 - \tau \varkappa_r) \end{array} \right)$$

$$+ \gamma \zeta_t \lambda_{4t} E_t \frac{k_t \pi_{t+1}}{(1 + r_t)^2} = 0$$

c_t :

$$\frac{1}{c_t}+\beta\lambda_{1t}E_t\frac{(1+r_t)}{\pi_{t+1}}\frac{1}{c_{t+1}}-\beta\frac{\lambda_{1t-1}}{\beta}E_{t-1}\frac{(1+r_{t-1})}{\pi_t}\frac{c_{t-1}}{c_t^2}+$$

$$+\lambda_{2t}\eta\frac{1}{1-l_t}+\lambda_{3t}E_t\left(\begin{array}{c}\beta\frac{1}{c_{t+1}}\left[(1-\tau)Y_{k,t+1}+(1-\delta)+\tau\frac{\varkappa_\delta\delta}{\pi_{t+1}}\right]\\-\beta\frac{1}{c_{t+1}}\frac{1}{\pi_{t+1}}R_t\gamma\zeta_t\frac{\pi_{t+1}}{(1+r_t)}\end{array}\right)$$

$$-\frac{\lambda_{3t-1}}{\beta}E_{t-1}\left[\begin{array}{c}\beta\frac{c_{t-1}}{c_t^2}\left[(1-\tau)Y_{k,t}+(1-\delta)+\tau\frac{\varkappa_\delta\delta}{\pi_t}\right]\\-\beta\frac{c_{t-1}}{c_t^2}\frac{1}{\pi_t}R_{t-1}\gamma\zeta_{t-1}\frac{\pi_t}{(1+r_{t-1})}\end{array}\right]$$

$$-\lambda_{5t}=0$$

l_t :

$$-\eta\frac{1}{(1-l_t)}+\lambda_{2t}\left(\eta\frac{c_t}{(1-l_t)^2}-Y_{ll,t}\right)$$

$$+\lambda_{3t-1}\frac{1}{\beta}E_{t-1}\beta\frac{c_{t-1}}{c_t}(1-\tau)Y_{kl,t}$$

$$+\lambda_{5t}Y_{l,t}=0$$

k_t :

$$-\beta\lambda_{2t+1}Y_{lk,t+1}$$

$$+\lambda_{3t}E_t\beta\frac{c_t}{c_{t+1}}\left[(1-\tau)Y_{kk,t}\right]$$

$$-\lambda_{4t}\gamma\zeta_tE_t\frac{1}{(1+r_t)}\pi_{t+1}$$

$$+\beta\lambda_{5t+1}\left((1-\delta)+Y_{k,t+1}\right)-\lambda_{5t}=0$$

π_t :

$$-\lambda_{1t-1}\beta E_{t-1}\frac{(1+r_{t-1})}{\pi_t^2}\frac{c_{t-1}}{c_t}+$$

$$+\lambda_{3t-1}\left[\begin{array}{c}\left(1-E_{t-1}\beta\frac{c_{t-1}}{c_t}\frac{1}{\pi_t}R_{t-1}\right)\gamma\zeta_{t-1}E_{t-1}\frac{1}{(1+r_{t-1})}\\+E_{t-1}\beta\frac{c_{t-1}}{c_t}\frac{1}{\pi_t^2}R_{t-1}\gamma\zeta_{t-1}E_{t-1}\frac{\pi_t}{(1+r_{t-1})}\\-E_{t-1}\beta\frac{c_{t-1}}{c_t}\tau\frac{\varkappa_\delta\delta}{\pi_t^2}\end{array}\right]$$

$$-\lambda_{4t-1}\gamma\zeta_{t-1}E_{t-1}\frac{k_{t-1}}{(1+r_{t-1})}=0$$

b_t :

$$\lambda_{4t}=0$$

A.2 Steady state

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

b:

$$\lambda_4 = 0 \tag{48}$$

r:

$$\lambda_1 = \lambda_3 \frac{\pi}{\beta} \left[\begin{array}{c} \gamma\zeta \frac{\pi}{(1+r)^2} \left(1 - \beta \frac{1}{\pi} R\right) \\ +\beta \frac{1}{\pi} \left(1 - \tau \varkappa_r\right) \gamma\zeta \frac{\pi}{(1+r)} \end{array} \right] \tag{49}$$

c:

$$\lambda_5 = \frac{1}{c} + \lambda_2 \eta \frac{1}{1-l} - \left(1-\beta\right) \left(\Xi \lambda_3 + \frac{(1+r)}{\pi} \frac{1}{c} \lambda_1\right) \tag{50}$$

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:

$$\eta \frac{1}{(1-l)} - \lambda_2 \left(\eta \frac{c}{(1-l)^2} - Y_{ll}\right) = \lambda_3 (1-\tau) Y_{kl} + \lambda_5 Y_l \tag{51}$$

k:

$$\lambda_5 \left(Y_k + 1 - \delta - \frac{1}{\beta}\right) = \lambda_2 Y_{lk} - \lambda_3 \left[(1-\tau) Y_{kk}\right] \tag{52}$$

π:

$$\lambda_1 = \lambda_3 \pi \left(\frac{\gamma\zeta}{(1+r)} - \beta\tau \frac{\varkappa_\delta \delta}{\pi^2}\right) \tag{53}$$

A.3 Proof

We are now ready to prove proposition 3. We guess that the Lagrange multiplier on the first constraint equals zero, i.e. $\lambda_1 = 0$. From Eq. 53 it follows $\lambda_3 = 0$. This simplifies considerably the original system. By plugging Eq. 50 into Eq. 51, we obtain:

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

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

$$\lambda_2 = 0$$

and, from Eq. 50:

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

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

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

from which it follows:

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

This last equality proves proposition 3.

B Model with Monopolistic Competition and Price Stickiness

Consider now 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.

B.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:

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

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

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{t,t+1} d_t$$

subject to the budget constraint:

$$d_t = b_t - (1 + r_{t-1}) \frac{b_{t-1}}{\pi_t} + \left(\chi_t Y_t - w_t l_t\right) + k_t - (1-\delta)\, k_{t-1} + \tag{54}$$

$$-\tau \left(\chi_t Y_t - \varkappa_r r_{t-1} \frac{b_{t-1}}{\pi_t} - \frac{\varkappa_\delta \delta}{\pi_t} k_{t-1} - w_t l_t \right), \tag{55}$$

and the following collateral constraint:

$$b_t \le \gamma \zeta_t E_t \frac{k_t}{(1+r_t)} \pi_{t+1}, \tag{56}$$

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:

$$\chi_t Y_{l_t} = w_t,$$

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

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

B.2 Final goods producers

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

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_t \left[\left(\frac{P_{i,t}}{P_t} - \chi_t \right) Y_{i,t} - \frac{\varphi}{2} \left(\frac{P_{i,t}}{P_{i,t-1}} - 1 \right)^2 Y_t \right]$$

Subject to the demand function:

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

The first-order condition of this optimization problem is:

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

In a symmetric equilibrium, the equation above simplifies to:

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

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

B.3 All equations

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

$$\beta E_t \frac{(1+r_t)}{\pi_{t+1}} \frac{c_t}{c_{t+1}} - 1 = 0 \tag{57}$$

$$\eta \frac{c_t}{1-l_t} - Y_{l,t}\chi_t = 0 \tag{58}$$

$$-1 + \mu_t \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1+r_t)} + E_t \beta \frac{c_t}{c_{t+1}} \left[(1-\tau)\chi_{t+1} Y_{k,t+1} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right] = 0 \tag{59}$$

$$-b_t + \gamma \zeta_t E_t \frac{k_t}{(1+r_t)} \pi_{t+1} \leq 0 \tag{60}$$

$$-\mu_t + 1 - E_t \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} (1 + r_t (1 - \tau \varkappa_r)) = 0 \tag{61}$$

$$-\varphi(\pi_t - 1)\pi_t + (1-\varepsilon) + \varepsilon \chi_t + E_t \beta \frac{c_t}{c_{t+1}} \varphi \frac{Y_{t+1}}{Y_t} (\pi_{t+1} - 1)\pi_{t+1} = 0 \tag{62}$$

$$Y_t - c_t - k_t + (1-\delta) k_{t-1} - G_t = 0 \tag{63}$$

B.4 Steady State

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

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

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

$$Y_l \chi = w$$

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

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

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

C 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, $\varphi = 0$, in the system in appendix

B.3.[25]

C.1 Ramsey

Imperfect competition only affects the following two constraints in the Ramsey problem reported in appendix A:

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

$$\lambda_3 : -1 + \left(1 - E_t \beta \frac{c_t}{c_{t+1}} \frac{1}{\pi_{t+1}} \left(1 + r_t \left(1 - \tau \varkappa_r\right)\right)\right) \gamma \zeta_t E_t \frac{\pi_{t+1}}{(1+r_t)} + E_t \beta \frac{c_t}{c_{t+1}} \left[(1-\tau) \chi Y_{k,t+1} + (1-\delta) + \tau \frac{\varkappa_\delta \delta}{\pi_{t+1}} \right] = 0 \tag{64}$$

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

l_t :

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

k_t :

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

Which in steady state read as follows:

l :

$$-\eta \frac{1}{(1-l)} + \lambda_2 \left(\eta \frac{c}{(1-l)^2} - \frac{\varepsilon - 1}{\varepsilon} Y_{ll} \right) - \lambda_3 (1-\tau) \frac{\varepsilon - 1}{\varepsilon} Y_{kl} + \lambda_5 Y_l = 0 \tag{65}$$

[25] Here we consider an economy with no government spending, i.e. $G_t = 0$.

$k:$

$$\lambda_5 \left(Y_k + 1 - \delta - \frac{1}{\beta} \right) = \lambda_{2t} Y_{lk} \frac{\varepsilon - 1}{\varepsilon} - \lambda_3 \left[(1-\tau) Y_{kk} \right] \tag{66}$$

C.2 Proof

We can now prove Proposition 6. The proof closely follows the one for the perfect competition case. We guess $\lambda_1 = 0$ and simplify accordingly the original system :

$$\lambda_5 = \frac{1}{c} + \lambda_2 \eta \frac{1}{1-l} \tag{67}$$

By substituting the first order condition with respect to consumption into Eq. 65, it follows:

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

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:

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

from which we can deduct $\left(Y_k + 1 - \delta - \frac{1}{\beta} \right) \neq 0$ and $\pi^{Ramsey} \neq \pi^{FB}$. This proves our Proposition 6.