The Monetary Financing of a Large Fiscal Shock*

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Abstract

Motivated by the surge in debt levels through the pandemic crisis, we revisit the issue of the optimal financing of public debt. In contrast with the existing literature, we find that the optimal response of inflation to a large increase in debt levels, such as the recent one, is a gradual but significant and long-lasting rise in inflation. While the literature has focused on sticky prices, of either the Calvo or Rotemberg type, we consider sticky plans as in the sticky information set up of Mankiw and Reis (2002). A crucial feature of our results is that a significant inflation response is desirable only if the maturity of debt is (realistically) long. In a calibrated example, we show that QE policies, by reducing the maturity of the debt held by the private sector, may lead to an optimally higher response of inflation.

Key words: pandemic; fiscal shocks; inflation; monetary and fiscal policy

1 Introduction

The COVID-19 pandemic has caused a surge of debts levels in all advanced economies. The prolonged economic lockdown led to a sharp increase in transfers and public consumption and, at the same time, a fall in tax revenues. This led to a sharp increase in public debt. In the euro area, starting from an average level of 85.9% at the end of 2019, public debt is expected

*The opinions expressed are personal and do no necessarily represent those of the European Central Bank, the Bank of Portugal, or the Eurosystem.

to exceed 102% by the end of 2021.[1] While starting from different initial points in terms of debt levels, most euro area countries were expected to experience broadly similar increases in debt levels relative to GDP.

Motivated by the surge in debt levels, we revisit the issue of the optimal financing of debt including monetary financing. The exercise is the standard Ramsey optimal fiscal and monetary policy exercise with noncontingent debt, in the tradition of Benigno and Woodford (2003), Schmitt-Grohé and Uribe (2004) and Siu (2004). Crucially we allow for long maturity debt in line with Lustig, Sleet and Yeltekin (2008) and Faraglia, Marcet, Oikonomou and Scott (2013, 2019a, 2019b).[2] While this literature has considered sticky prices of the Calvo (1983) or Rotemberg (1982) type, we allow for both Calvo (1983) firms and Mankiw and Reis (2002) firms and compare optimal policy in the two extreme cases where one of the two firm types is dominant.

The main policy question is whether the increase in debt levels should be financed with higher taxes or, instead, the higher nominal debt levels should be depleted with higher inflation. We study this question through the lens of a relatively standard model of optimal monetary and fiscal policy, with a single labor income tax acting on the intratemporal consumption-leisure margin.[3]

As is well known (see Chari, Christiano and Kehoe, 1991), absent costs of price adjustment, inflation can be used to replicate state-contingent public debt, so that taxes do not need to be adjusted. If the shocks to public debt are very large, optimal inflation will be very volatile. The literature on optimal fiscal and monetary policy with sticky prices has reversed this result and concluded that using price level surprises to make the nominal public debt state-contingent is too costly, since it inevitably generates very large price dispersion. This is intuitively clear when the debt has short maturity, because sudden and very large inflation surprises are necessary to change its real value. However the result also holds when debt is long-term and the required inflationary changes are smaller, smoother and more persistent (see Faraglia et al., 2013). This is striking, since a smooth and persistent change in inflation is akin to a change in the inflation

[1] See European Commission (2020). The effect of the pandemic crisis on debt levels are substantially higher than these forecasts if the public guarantees on private loans are also included.

[2] See also Leeper and Zhou (2013).

[3] Gali (2020) compares the effects of public spending under an alternative form of monetary financing involving the issuance of money with those under debt financing, showing that the effects on output are larger under monetary financing.

target. The finding that, for example, even a one percentage point change in the inflation target would be prohibitively costly in terms of price dispersion is not an intuitively appealing feature of the baseline sticky price model. It is also not supported by the evidence in Nakamura, Steinsson, Sun and Villar (2018) that show that price dispersion was not affected by the level of inflation during the US great inflation.

We believe that this feature has to do with the assumption that the restrictions on the setting of prices are not affected by policy. This is an important limitation of the analysis, that is a general feature of this literature. It is reasonable to expect that a temporary, but persistent change in the inflation target would be reflected in the price-setting decisions of firms in ways that sticky prices of the Calvo type cannot take into account. Firms under Calvo price setting adjust to an increase in the target by increasing current prices, not future prices, therefore creating additional price dispersion. The assumption of sticky information as in Mankiw and Reis (2002) is one way to, at least partially, overcome the limitation. The timing of price setting decisions is still exogenous,[4] but firms are able to revise price plans, not just current prices. They are therefore able to adjust to inflation trends even if in a sluggish, and staggered manner.

For this reason we rely on the assumption of sticky information proposed in Mankiw and Reis (2002). While we also solve the optimal fiscal and monetary policy exercises under the assumption that this information restriction is policy invariant, we argue that it is less of a limitation under sticky information. The reason is that sticky information does allow firms to take into account temporary revisions in the inflation target when setting their prices. For example, if the central bank credibly announced an increase in the target by one percentage point for two years, sticky information firms, when they have the chance, would all set higher prices over the two-year period and lower prices again thereafter.

Mankiw and Reis (2002) argue that sticky information has additional advantages. It induces inflation inertia without the need for additional ad hoc ingredients, such as inflation indexation. More specifically, sticky information appears to be an appropriate assumption to characterize the sluggish reaction of individual firms' prices to aggregate macroeconomic shocks, such as

[4] See Burstein (2006) for a model where firms are able to choose price plans by paying a menu cost.

the monetary policy changes that we are interested in here (see Boivin, Giannoni and Mihov, 2009).[5]

In sharp contrast with the results in the previous literature, we find that the optimal response to a large increase in debt levels, such as the recent one, includes a gradual, large, and long-lasting rise in inflation (by up to 10%). Both sticky information and long-term maturity of debt are crucial assumptions to obtain this result. Sticky information is important because it makes inflationary episodes less costly, the further in advance they are anticipated. The reason is that many firms will be able to incorporate inflation in their pricing decisions, if it is pre-announced. However, the credible promise of inflation far in the future would be irrelevant in determining the real value of the public debt, if debt was of short maturity. The maturity of debt must be (realistically) long for the real value of debt to be affected by surprise changes in future inflation.

The response of inflation under sticky information is comparable to the one under flexible prices with a delay. Under flexible prices, the response is a large immediate rise in inflation followed by a gradual return to target.[6] Under sticky information, the response of inflation is very slow initially, before it rises fast, to a level that is close to the one under flexible prices, followed by a similar gradual return to target.

We also show that the interaction of price adjustment costs and financing benefits is non monotonic in the maturity of debt. In a calibrated example to the euro area, we show that quantitative easing (QE) policies, by reducing the maturity of the debt held in private hands, may lead to an optimally higher response of inflation to a large fiscal shock.

We consider bonds of longer maturities summarized by a single average maturity. Allowing for multiple maturities helps complete markets, but it can require the government to take extreme asset/liability positions over different maturities. The literature, as in Lustig et al. (2008) and Faraglia et al. (2013, 2019a, 2019b) has imposed restrictions on the tradeability of bonds of different maturities to obtain more reasonable results. Our assumption of a single average maturity is an extreme version of such tradeability restrictions.

In line with the previous literature, fiscal policy in the model is kept relatively simple. It is summarized by a single labor income tax acting on the intratemporal margin. As highlighted by

[5] Sticky information appears instead to impose too much sluggishness in the response of prices to technology and other firm level shocks (Boivin, Giannoni and Mihov, 2009; Coibion, 2010).

[6] The return to target is the result of our assumption that there is a share of Calvo-type firms. With only Mankiw-Reis type firms, the asymptotic paths would not be determined.

the finance literature, a richer menu of taxes would alter policy conclusions. More specifically, a combination of labor and consumption taxes would have the same effects in the model as unanticipated inflation, possibly without the costs associated with sticky prices.

2 The model

The model we consider is similar to the one in Benigno and Woodford (2003), except that firms set prices as in Mankiw and Reis (2002). The model is also similar to the one in Schmitt-Grohe and Uribe (2004) and Siu (2004), again with sticky information.

As is well known, with sticky information, because firms can adjust price plans, optimal policy does not pin down a single deterministic path for the price level. For this reason, we consider that there is a small number of Calvo-type firms. This allows to pin down a single deterministic price path in the set of optimal ones.

While the Calvo framework is standard in this literature, it has limitations as a model of price determination in particular for the kinds of questions we ask in this paper. Using BLS micro-data on U.S. consumer prices dating back to 1977, Nakamura et al. (2018) argue that the Calvo set-up overstates the costs of inflation. It implies that the absolute size of individual firms' price changes, and thus price dispersion, should increase rapidly with inflation. However, no such increase can be detected from the micro-data during the high-inflation episode of the 1970s.

The alternative framework we consider in this paper, sticky information, also has limitations. Coibion (2010) finds that the sticky information Phillips curve leads to excessively persistent and insufficiently volatile inflation. However, much of the actual volatility in inflation comes from technology and other firm-level shocks. Firms react quickly to such shocks – see Boivin et al. (2009) – hence in a manner which is not consistent with sticky information.[7] In reaction to macroeconomic and monetary shocks, however, the response of inflation tends to be delayed and the sticky information model can reproduce it well.

Kiley (2007) also argues that information imperfections, such as those captured by the sticky information model, may explain the need for a "hybrid" new Keynesian Phillips curve

[7] Calvo firms that are able to adjust prices react strongly to those shocks, since they may not be able to revise prices for long. This generates volatility in inflation and price dispersion.

(i.e. with features such as inflation indexation) to match the data. The sticky information model is therefore useful for the policy analysis that we are interested in.

Households A representative household derives utility from the consumption of a composite good C_t and disutility from hours worked H_t. The household works in all intermediate firms (as in Woodford, 2003). The utility function is

$$\max_{C_t, H_{k,t}} \mathrm{E}_0 \sum_{t=0}^{\infty} U_t \left(C_t, H_{k,t} \right)$$

where $H_{k,t}$ are hours worked in each of the k monopolistic competitive firms in the economy, for $k \in [0,1]$. Temporary utility is

$$U_t = \frac{1}{1+\sigma} C_t^{1+\sigma} - \frac{\gamma}{1+v} \int_0^1 H_{k,t}^{1+v} \mathrm{d}k$$

The period-by-period budget constraint is

$$Q_t^B B_t = \left(1 + \rho Q_t^B\right) B_{t-1} + \left(1 - \tau_t^W\right) \int_0^1 W_{k,t} H_{k,t} \mathrm{d}k + \left(1 - \tau_t^\Pi\right) \int_0^1 \Pi_{k,t} \mathrm{d}k + T_t - P_t C_t,$$

where B_t are non-state contingent, nominal consol bonds issued by the government, Q_t^B is their price, T_t are exogenous taxes/transfers, P_t is the price level, $W_{k,t}$ is the wage rate in sector k, $\Pi_{k,t}$ are profits from firms in sector k, and τ_t^W and τ_t^Π are possibly different income taxes levied on salaries and profits.

A consol bond issued at t has a geometrically declining coupon ρ^{s-t}, for $s \geq t$. In steady state, the Macauley duration of the bond, i.e. the weighted average maturity of its cash flows, can be expressed as

$$\mathrm{MacD} = \frac{1}{1 - \beta\rho}$$

Consol bonds with a geometrically declining coupon are often used to approximate the average distribution of a portfolio of long-term bonds in a parsimonious way (see e.g. Woodford, 2001). As we illustrate below, the average duration of government bonds is of the order of many years, hence the frequent assumption of short-term (i.e. 1-quarter) bonds is clearly unrealistic. Nevertheless, the literature on optimal fiscal and monetary policy with sticky prices has shown that, while affecting the shape and the duration of the inflation response to shocks, long-term bonds do not significantly alter the conclusions of analyses based on short-term bonds. Even if the optimal inflation response tends to be smaller, smoother and more persistent with long-term bonds, inflation remains extremely costly and it is therefore as undesirable for a Ramsey planner as in the case of short-term bonds (see Faraglia et al., 2013). We will show that this conclusion is starkly different when firms have sticky information.

Firms There is a continuum of firms indexed by $k \in [0,1]$ producing intermediate goods under monopolistic competition. The intermediate goods are bundled into a final good by a competitive industry.

A representative final goods firm produces good Y_t which is the aggregate of intermediate goods $Y_{k,t}$ according to the aggregator

$$Y_t = \left\{ \int_0^1 Y_{k,t}^{\frac{\theta-1}{\theta}} \mathrm{d}k \right\}^{\frac{\theta}{\theta-1}} .$$

We assume that a mass $0 < \delta < 1$ of firms is subject to sticky prices à la Calvo and the remaining mass $1-\delta$ to sticky information. Accordingly, we can split the composite good into two sub-bundles

$$Y_t = \left\{ \delta^{\frac{1}{\theta}} Y_{C,t}^{\frac{\theta-1}{\theta}} + (1-\delta)^{\frac{1}{\theta}} Y_{S,t}^{\frac{\theta-1}{\theta}} \right\}^{\frac{\theta}{\theta-1}} ,$$

where

$$Y_{C,t} = \left\{ \int_0^\delta \frac{Y_{k,t}^{\frac{\theta-1}{\theta}}}{\delta^{\frac{1}{\theta}}} \mathrm{d}k \right\}^{\frac{\theta}{\theta-1}} \qquad \text{and} \qquad Y_{S,t} = \left\{ \int_\delta^1 \frac{Y_{k,t}^{\frac{\theta-1}{\theta}}}{(1-\delta)^{\frac{1}{\theta}}} \mathrm{d}k \right\}^{\frac{\theta}{\theta-1}} .$$

We can then define intermediate price indices $P_{C,t}$ and $P_{S,t}$ as the minimum cost of a unit of the composite sub-aggregates $Y_{C,t}$ and $Y_{S,t}$, respectively. The two price indices will be

$$P_{C,t} = \left\{ \frac{\int_0^\delta P_{k,t}^{1-\theta} \mathrm{d}k}{\delta} \right\}^{\frac{1}{1-\theta}} \qquad \text{and} \qquad P_{S,t} = \left\{ \frac{\int_\delta^1 P_{k,t}^{1-\theta} \mathrm{d}k}{1-\delta} \right\}^{\frac{1}{1-\theta}} .$$

and the overall price index can be written as

$$P_t = \left(\delta P_{C,t}^{1-\theta} + (1-\delta) P_{S,t}^{1-\theta} \right)^{\frac{1}{1-\theta}} .$$

Intermediate goods are produced according to

$$Y_{k,t} = A_t \left(H_{k,t} \right)^{\frac{1}{\phi}} .$$

The assumed Dixit-Stiglitz preferences imply that the demand for the intermediate good is $Y_{k,t} = \left(\frac{p_{k,t}}{P_t} \right)^{-\theta} Y_t$, so that the amount of hours needed to produce output is

$$H_{k,t} = \left(\frac{Y_{k,t}}{A_t} \right)^{\phi} .$$

Profits in sector k are therefore

$$\Pi_{k,t} = p_{k,t}\left(\frac{p_{k,t}}{P_t}\right)^{-\theta} Y_t - W_{k,t}\left(\frac{1}{A_t}\left(\frac{p_{k,t}}{P_t}\right)^{-\theta} Y_t\right)^{\phi}.$$

When they have the chance, sticky price firms will set a constant price p_t^* so as to maximise expected discounted future profits. When they update their information, sticky information firms will select a sequence of (possibly different) prices for the current period and all future periods, again with the objective of maximizing expected discounted future profits.

Government In every period the real government surplus, s_t, is equal to the revenues from labor and profit taxes minus government expenditure, G_t, and transfers $t_t = T_t/P_t$:

$$s_t = \gamma C_t^{\sigma}\frac{\tau_t^W - \tau_t^{\Pi}}{1-\tau_t^W}\left(\frac{Y_t}{A_t}\right)^{1+\omega} d_t + \tau_t^{\Pi} Y_t - G_t - t_t,$$

where d_t indicates price dispersion, which is defined as the combination of price dispersion for sticky-price ($d_{C,t}$) and sticky-information ($d_{S,t}$) firms,

$$d_t = \delta d_{C,t} + (1-\delta)\, d_{S,t},$$

and government expenditure and transfers are exogenously given by

$$G_t = \left(1-\rho_g\right) G + \rho_g G_{t-1} + \sigma_g \varepsilon_t^g$$

and

$$t_t = \rho_t t_{t-1} + \sigma_t \varepsilon_t^t.$$

Given that bonds are long-term, the period-by-period government budget constraint is

$$Q_t^B B_t = \left(1+\rho Q_t^B\right) B_{t-1} - P_t s_t.$$

As in Benigno and Woodford (2003), the intertemporal budget constraint can be written as

$$C_t^{-\sigma}\left(1+\rho Q_t^B\right)\frac{b_{t-1}}{\Pi_t} = \mathrm{E}_t \sum_{T=t}^{\infty} \beta^{T-t} C_T^{-\sigma} s_T$$

where $b_t \equiv B_t/P_t$ or, in recursive terms,

$$C_t^{-\sigma}\left(1+\rho Q_t^B\right)\frac{b_{t-1}}{\Pi_t} = C_t^{-\sigma} s_t + \beta \mathrm{E}_t C_{t+1}^{-\sigma}\left(1+\rho Q_{t+1}^B\right)\frac{b_t}{\Pi_{t+1}}$$

In our numerical simulations we concentrate on the problem of financing government expenditures/transfers.[8]

Resource constraint The aggregate resource constraint in this economy can be written as

$$Y_t = C_t + G_t$$

for each period t.

Ramsey policy We solve the model for optimal policy. This implies choosing state-contingent paths for inflation Π_t, the tax rate τ_t^W and the other endogenous variables so as to maximise intertemporal household utility, given initial government debt b_{-1} and price dispersion d_{-1}. We assume the timeless perspective, hence we look for the optimal time-invariant rule that a policy maker who solves a traditional Ramsey problem would be willing to commit to follow eventually (Woodford, 2003).

As in Benigno and Woodford (2003) and Schmitt-Grohé and Uribe (2004), we analyse the response to shocks around a non-stochastic steady state in which the outstanding level of government debt is constant and inflation is equal to zero. By construction, therefore, we ignore any stochastic, nonlinear effects which may be produced in equilibrium in our model economy. Siu (2004) demonstrates that such effects can be sizable if the variance of government spending shocks is large, i.e. as large as in war-time periods. However, we think this is not particularly relevant for a pandemic shock that we treat as a very rare even, a black swan. The assumption is that the overall variance of government spending will return to relatively low, post-WWII levels. Our question is how to respond to exceptionally large shocks in an environment where such shocks are very unlikely to occur again going forward.

[8] We abstract from the problem of correcting the monopoly distortion by assuming a profit tax rate equal to 100%, i.e. $\tau_t^{\Pi} = 1$ (see also Schmitt-Grohé and Uribe, 2004).

3 Sticky prices vs. sticky information

3.1 Calibration

In our numerical exercises, we abstract from the underlying reasons for the increase in government deficit. We simply assume an exogenous increase in government spending and focus on its financing. The results would be largely unchanged if we assumed instead an increase in government transfers.

For most parameters, we rely on the calibration by Benigno and Woodford (2004). The parameters are standard and they facilitate the comparison to the previous analyses in the literature with sticky prices. The main exception is the rate of time preference β. Standard calibrations in the literature are consistent with a steady state real interest rate of 4%. This value was reasonable in the 80s and 90s, but real interest rates on public debt have been much lower than that for a long time. Recent estimates of the natural rate of interest find that it is equal to or even lower than 1%.[9] We therefore set $\beta = 0.9975$, corresponding to a steady state interest rate of 1%. With such low real real interest rates the financing of debt is particularly inexpensive, so that the case for inflation as a shock absorber is harder.

The level and maturity of the initial nominal liabilities of the government are estimated using euro area data, taking into account the impact of QE-type programmes.

More precisely, we start again from European Commission (2020), where it is reported that the debt-to-GDP ratio in the euro area at the end of 2019 was 85.9%. The average maturity of debt across euro area countries is obtained from the ECB's Centralised Securities Database (CSDB), which holds information on all individual securities relevant for the statistical purposes of the European System of Central Banks. The data we use are taken from ECB (2020).[10]

We start from country-level data on the average residual maturity of the outstanding debt and obtain the euro area average residual maturity as a weighted average across countries, with weights given by the value of each country's debt as a fraction of total euro area debt. This yields an average residual maturity of 7.4 years.

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[9] See for example Holston, Laubach and Williams (2017).

[10] The information from this source may be different from the government finance statistics, partly because it is not consolidated within the general government sector, partly due to discrepancies in valuation, scope (e.g. bonds without an ISIN are not included in ECB, 2020), sectoral classification and time of recording.

We then consolidate the liabilities of the public sector (governments and central bank), i.e. take into account the impact of ECB bond purchases. Central bank purchases determine a shortening of the maturity of the total public liabilities held by the private sector, since they are a swap of short-term reserves against long-term debt. [11]

The result is an average maturity of total public liabilities in the euro area of 5.8 years.

Finally, we need to calibrate the degree of information stickiness α. Many different values can be found in the literature. Many estimates for the U.S. are consistent with relatively high values of α.[12] In an estimated model, however, Reis (2009) finds values of 0.48 for the U.S. and 0.42 for the euro area. Since the application is to the euro area, in the paper we report results for two values of α: 0.42, taken from Reis' estimates, and 0.635, which is the value used by Benigno and Woodford (2004). The latter has the advantages of being both closer to other estimates for the U.S. and of facilitating the comparison with sticky price results.

3.2 Short-term vs. long-term bonds

As is well known that, under flexible prices, inflation can be used, in response to shocks, to adjust the real value of government debt, replicating state-contingent real debt and avoiding changes in taxes – see Chari, Christiano and Kehoe (1991). If bonds have short maturity, the required price increase in response to adverse public finance shocks tends to be large. When prices are sticky, large changes in prices are costly. Schmitt-Grohé and Uribe (2004), Siu

[11] We use information on quantities and average maturity of ECB government bond holdings from the ECB (https://www.ecb.europa.eu/mopo/implement/app/html/index.en.html). We estimate for each country i the average maturity of the remaining government debt in private hands m_i^P (in years) as

$$m_i^P = \frac{B_i m_i^B - B_i^C m_i^C}{B_i - B_i^C}$$

where B is the total stock of government debt, m_i^B is its average maturity, B_i^C is the government debt purchased by the ECB, and m_i^C its average maturity. We then impute to central bank reserves a maturity equal to 1 time period in the model, i.e. 1 quarter or 0.25 years. Since the amount of ECB reserves held by the private sector is equal to B_i^C, the average maturity of the total public liabilities in private hands, m_i^T, can be estimated as

$$m_i^T = \frac{B_i^C}{B_i}\,0.25 + \frac{B_i - B_i^C}{B_i}\,m_i^P$$

We find that m_i^T ranges across countries between approximately 4 and 9 years. Finally, we obtain euro area data as a weighted average of the national maturities, with weights given by national public debts as a fraction of the total.

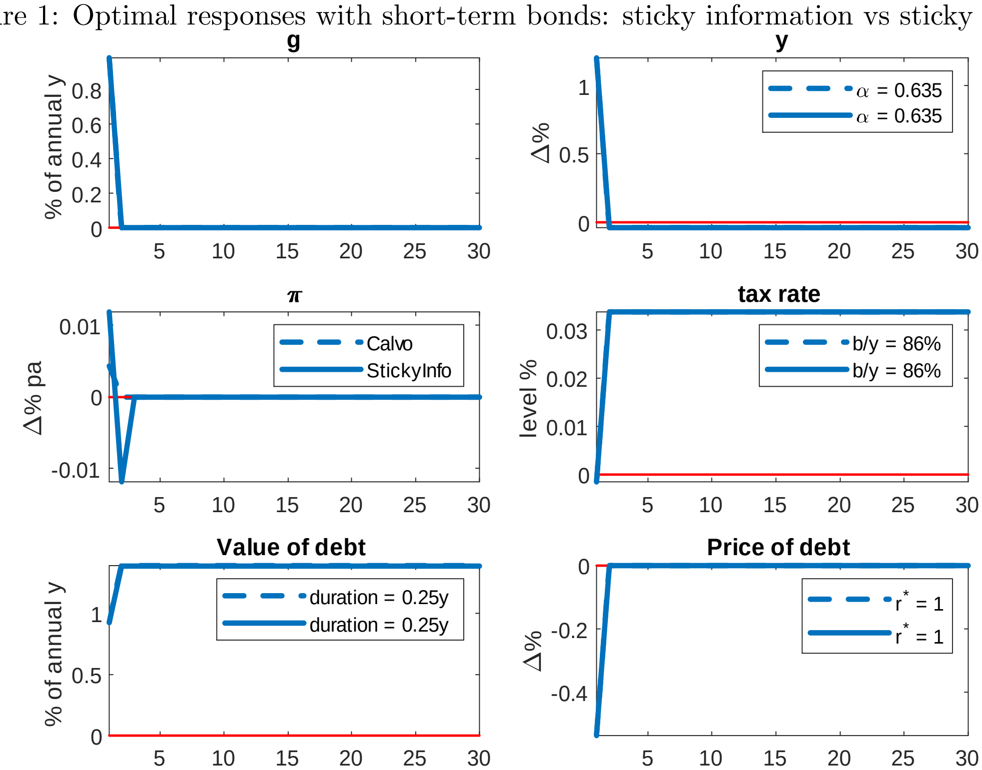
[12] Khan and Zhu (2006) obtain an average estimate of 0.24. Similar values are found in Mankiw and Reis (2003) and Carroll (2002).

(2004), and Benigno and Woodford (2003), show that the optimal combination of fiscal and monetary policy is to keep prices almost unchanged in response to shocks.

Figure 1 confirms these results for the sticky-price case (with a very small share of sticky information firms).[13] A one quarter increase in government spending equal to 1% of GDP is reflected in a permanent increase in public debt of a comparable size (in percent of GDP). Inflation increases for one quarter, but the increase is quantitatively very small. The tax rate must therefore increase to finance the larger debt.

Figure 1 also compares these results to the sticky information case (very small share of sticky price firms) and shows that the results are almost identical to the sticky price case. The only qualitative difference is that the price level returns to the original value under sticky information. Inflation must therefore fall below zero after the shock, before returning back to zero. This ensures that firms which could not adjust prices one or two quarters after the shock automatically charge the optimal price. As in the sticky price case, however, the tax rate must increase to finance the higher public debt.

Figure 1: Optimal responses with short-term bonds: sticky information vs sticky prices



[13] In all the figures, government debt is reported as a ratio of annual GDP.

Figure 2 makes the same comparison in the case of long-term bonds. In this case, the bond maturity is chosen to match the maturity of euro area government debt in the hands of the private sector, which was 5.8 years on average at the end of 2019. Under sticky prices, the results on inflation are essentially unchanged. Once again the tax rate must rise to finance the larger stock of private debt, but the rise can be smaller, because the bond price, and therefore the value of government debt, falls after the shock.

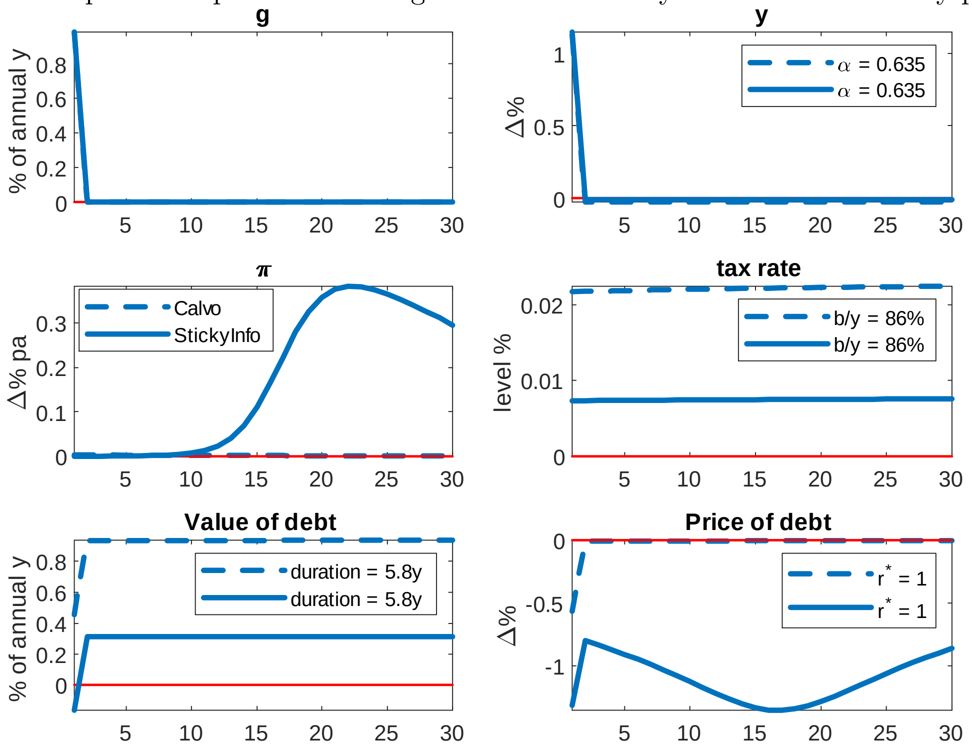
Results are quite different with sticky information. Inflation kept constant on quite a while (10 quarters), before it slowly and progressively increases to reach a peak of 40 basis points after approximately 6 years. The inflation increase is not too costly in terms of price dispersion. Firms that do not adjust their information in the first three years after the shock will nevertheless have a near-optimal price, given that the price level remains roughly unchanged. Thereafter most firms will have the chance to revise the information, hence price dispersion will be small.

Of course these considerations are also valid when bonds are short term, but an inflation increase after many years would not change the real value of short-term debt. By contrast, the inflation increase is effective in making the real value of public debt be state contingent when bonds have long maturities. The benefits of this policy coupled with its limited cost in terms of price dispersion explain why it is optimal to let inflation increase. The key benefit is that inflation reduces the price of public debt. As a result, the real value of public debt, whose quantity must increase to finance the larger government spending, increases by only half as much as in the Calvo case. Consequently, the tax rate must also increase by much less than in the case with sticky prices.

Figure 3 provides intuition as to why sticky information generates different results from sticky prices. It displays the overall price level together with the individual prices set by firms that have the opportunity to revise them 0, 4 and 8 quarters after the shock.

Under sticky information, price dispersion emerges once some firms have the opportunity to reoptimize their prices. These firms (e.g. those that do so on impact after the shock) behave differently from those whose price is set based on old information. More specifically, adjusting firms will fully take into account the expected dynamics of the economy's price level in their future pricing. This implies that all adjusting firms will choose similar prices. As more and more firms update their information over time, all individual prices will become consistent

Figure 2: Optimal responses with long-term bonds: sticky information vs sticky prices



with the evolution of the price level. Consequently, price dispersion will quickly be reabsorbed and the inflationary episode will not produce large inefficiencies.

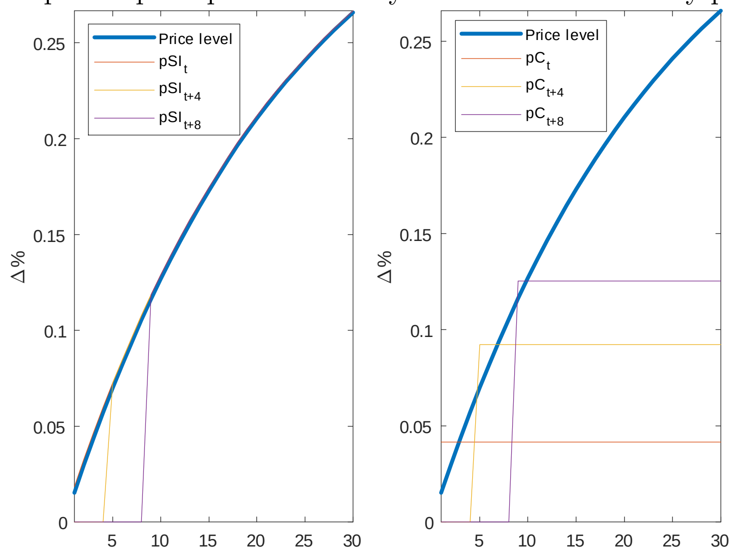
In the Calvo case, price dispersion emerges again once some firms have the opportunity to re-set their prices. Even if they know that the price level will continue increasing in the future, however, these firms must set a constant price until they have another chance to reoptimize it. As a result, firms that have the opportunity to adjust their prices at different points in time will choose different re-set prices. Consequently, price dispersion will be much more persistent and the inflationary episode will be highly costly.

3.3 The role of information stickiness and bond maturity

Figure 2 is derived under a benchmark calibration of the probability to change prices. Under sticky prices, this parameter is of little importance in determining optimal policy. As highlighted by Schmitt-Grohé and Uribe (2004), even a small probability that firms will be unable to change prices is sufficient to make price stability desirable at all times.

With sticky information, inflation rises earlier, the higher the frequency at which firms update their information. Figure 4 shows results for three values of the probability not to

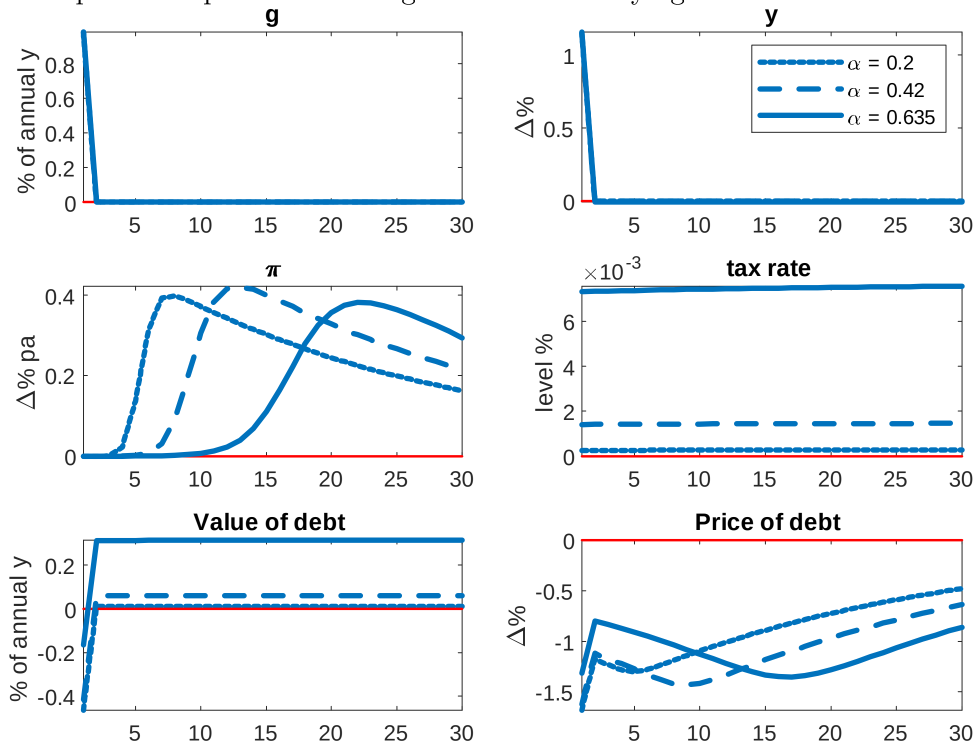
Figure 3: Optimal price paths for sticky-information and sticky-price firms



adjust information, α: the benchmark value taken from the Calvo literature (0.635), the value estimated by Reis (2009) for the euro area (0.42), and a much lower value (0.2). When information is updated almost every quarter ($\alpha = 0.2$), the increase in government spending can be financed without any increase in the tax rate. However an early increase in inflation is costlier when information is stickier, because it generates larger price dispersion. It becomes desirable to delay the inflationary episode (so as to reduce price dispersion) while keeping its peak largely unchanged (to maximise the impact on the real value of debt). The inflation peak is in fact almost identical for low and moderate levels of stickiness (between $\alpha = 0.2$ and $\alpha = 0.42$), but it falls if the firms adjust their prices very infrequently. This result is affected by the maturity of the public debt. The announced inflation increase can only affect the real value of the outstanding debt if the maturity is long enough. If it is expected to occur only *after* all the outstanding debt has been retired, it will be ineffective. In other words, the stickier information is, the longer the required maturity of public debt to make a delayed inflationary episode desirable.

The link between optimal policy and the maturity of outstanding debt is explored in Figure 5. We report results in three cases: the benchmark corresponding to the average duration of euro area government bonds held by the private sector (5.8 years); a higher average duration, which would be observed in the absence of central bank purchases of sovereign bonds (7.4 years); and an arbitrarily lower value (2 years). The figure shows that optimal fiscal and monetary policy responses to the shock are not monotonic in the maturity of debt.

Figure 4: Optimal responses with long-term bonds: varying the stickiness of information

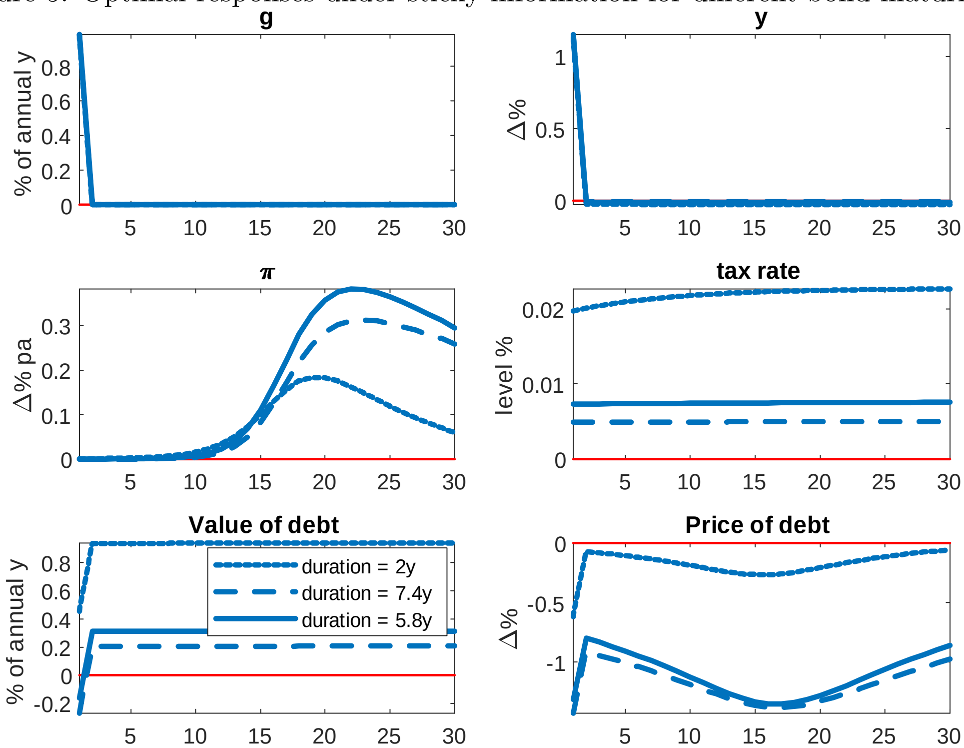


The reason for the non-monotonicity is that a higher debt duration makes inflation both more effective and less costly (because it can be smoother) in reducing the real value of debt. Since it is more effective, it doesn't have to be used as much. Because it is less costly, there is more of a reason to use it. For very low duration, inflation is low both because it is not effective and because it is costly. For very high duration, inflation is so effective that it is not much used, even if it is not very costly. In between, for debt durations close to the ones in the data, inflation can be sizable. The highest inflation peak happens for debt duration slightly lower than in our benchmark.

4 Optimal fiscal and monetary policy after a pandemic-size shock

This section provides illustrative results on the combination of fiscal and monetary policy which, according to our model, would be desirable in the euro area after the large increase in debt levels caused by the pandemic shock. We rely on European Commission estimates of the effects of the shock. The Autumn 2020 European Economic Forecast predicted an increase

Figure 5: Optimal responses under sticky information for different bond maturities



in government deficits approximately equal to 20% of GDP over the 2020-2022 period. These forecasts lead us to focus on a persistent increase in government spending in our model.[14] All other parameters are kept at the benchmark levels discussed above. Given the uncertainty in estimates of the degree of informational stickiness, we rely on the value of α typically used in sticky price models to maximise comparability with the results from those models. The results are displayed in figure 5 together with the flex-price and the Calvo cases.[15] The appendix shows that using the less sticky estimate of α for the euro area in Reis (2009) would not substantially alter our conclusions.

The flexible price case is presented as a useful benchmark for comparison. An inflation surprise occurs in reaction to the government spending shock to ensure that taxes remain constant. This is consistent with the analysis in Chari and Kehoe (1999), but the inflation surprise is smaller and much more persistent due to our assumption of long-term government debt. Inflation increases on impact by about 7% and remains at elevated levels for many years. This increase in non-negligible, but much smaller than what would be necessary if all

[14] More specifically, we assume that the initial shock is 5 times as large as in previous figures and it has a persistence of 0.76.

[15] In the sticky-price case, we also use the standard value of α.

bonds were short-term. Again consistently with Chari and Kehoe (1999), unexpected inflation variations implement the same allocation as under fully state-contingent government debt.[16]

Under nominal rigidities of the Calvo type, the price level, government debt and the tax rate all have unit roots, consistently with the results of the models with short-term government debt in Benigno and Woodford (2003) and Schmitt-Grohé and Uribe (2001). Nevertheless, inflation is so costly that it is kept almost unchanged (and the price level, though permanently, moves very little). Consequently, the increase in government deficits is reflected in an essentially one-to-one increase in government debt, which also increases by 20 percentage points as a share of GDP. To service the cost of the debt, tax rates must increase permanently. In spite of the low level of real rates, they go up by almost 0.5 percentage points. This is reflected in a permanent output loss of about 0.5% in steady state.

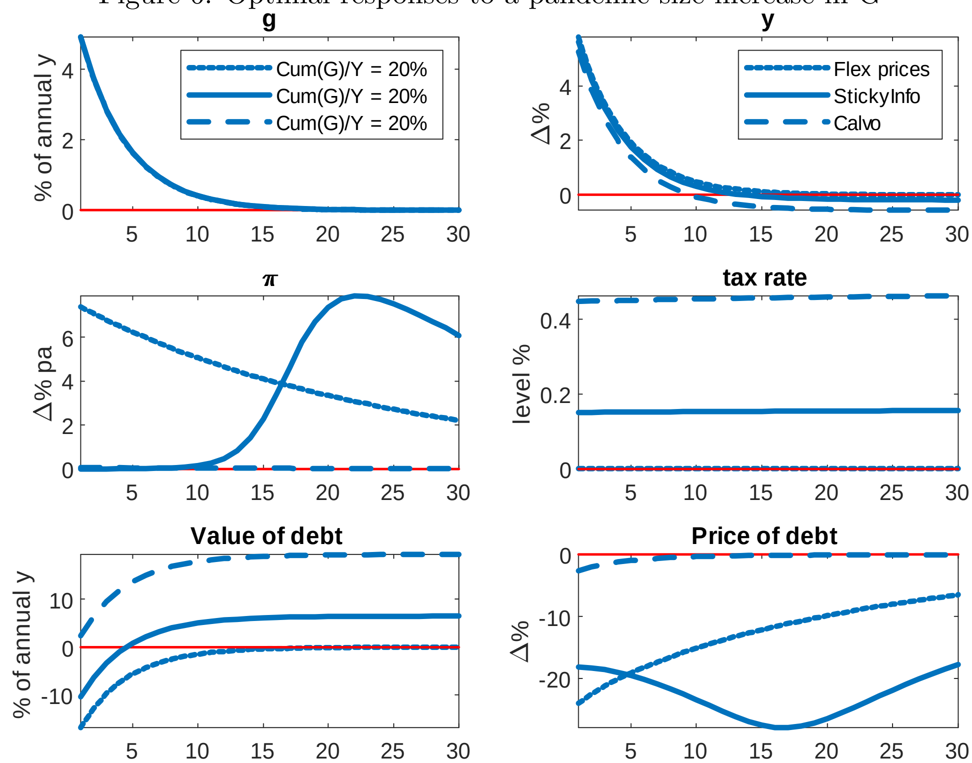
Sticky information produces intermediate results between the two cases above. Inflation is initially kept unchanged as in the sticky price case, but it increases quite substantially roughly two years after the shock up to a peak comparable to the flexible-price case. The inflation increase is temporary, but persistent, and it is sufficient to reduce the increase in the real value of debt by an order of magnitude, compared to the sticky price case. The debt to GDP ratio increases by 6 percentage points in steady state. Consequently, the permanent increase in the tax rate can also be much smaller, i.e. equal to 0.15%. The permanent output loss is also an order of magnitude smaller.

As shown in the appendix, results are quantitatively different in the case with lower information stickiness, but inflation plays a comparable role in the optimal fiscal and monetary policy response to the shock. The inflation peak is a bit higher (8% compared to 7%) and less delayed (3 years compared to almost 6 years) if firms adjusted their information more frequently. This would be accompanied by a much smaller, permanent increase in the debt-to-GDP ratio (little over 1%) and, consequently, in the tax rate.

Figure 6 focuses on the response of inflation to the shock of figure 5, to clarify its level and persistence. Impulse responses are displayed over a periods of 20 years, rather than the 30 quarters shown in the previous figures. The most striking feature emerging from this figure is that the increase in inflation must be extremely persistent. In the sticky information case, ten years after the initial shock inflation is at 4%, and even twenty years after the shock it

[16] The fact that there is a small share of Calvo-type firms plays an important role. Otherwise there would be multiple inflation outcomes.

Figure 6: Optimal responses to a pandemic-size increase in G



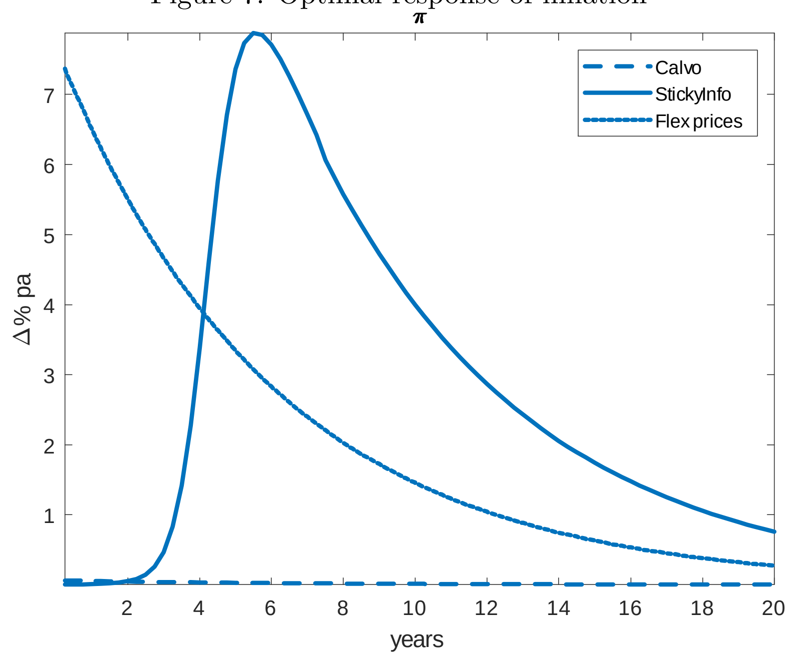
is only slightly below 1%. This very persistent response ensures a smooth return to price stability. A pre-announced period of inflation has a low cost in the model, because, being known in advance, it can be reflected in the price plans of most firms. Consequently, not only the inflation peak, but also the persistence of the inflationary episode is comparable to the flexible-price case.

4.1 Discussion

We have shown that, in a model where firms are restricted in setting price plans as in the sticky information model of Mankiw and Reis (2002), a pandemic-size increase in government debt ought to be financed in part by a large and highly-persistent increase in inflation. Such an increase would be costly, but less so than the other form of financing of the government debt available in the model, i.e. a permanent increase in taxes. The fact that the maturity of debt is relatively long plays an important role.

Our results are for a model with sticky-information. We have argued that this is an appropriate assumption for the questions we ask in this paper. But at the bear minimum, our results support the view that the conclusions in the literature, based on a model with sticky

Figure 7: Optimal response of inflation



prices of the Calvo or Rotemberg type, are extreme and very fragile. A different, but plausible, model of nominal rigidity alters them dramatically in response to infrequent, aggregate shocks such as the recent crisis. In reality, a combination of sticky price and sticky information may be more realistic and the optimal inflation rate may lay in between the prescriptions of these two models.

We also emphasise that the optimal policy results that we have illustrated in the paper are symmetric. The same policy responses would be applied in reverse, should there be a large positive shock to government revenues.

5 Concluding remarks

The COVID-19 pandemic has caused a surge in public debts levels. In the absence of a growth spurt, higher public debt levels would require a permanent increase in taxes. Given the nominal denomination of public debts, it is useful to consider whether a temporary inflation increase may be desirable instead.

So far, the research in this field has captured the costs of inflation through the assumption of sticky prices. It has concluded that even mild inflation episodes are extremely costly, because they force many firms to persistently sell their products at either too low, or too high, prices.

We have instead adopted the assumption of sticky information, which is arguably better suited to capture firms' responses to infrequent, aggregate shocks (as opposed to firm-specific shocks). In sharp contrast with the results in the previous literature, we find that the optimal response to a large increase in debt levels, such as the recent one, includes a gradual, long-lasting and large (of the order of several percentage points) rise in inflation.

This result is robust to small changes in the degree of information stickiness. The lower the stickiness, the faster is the increase in inflation, but its peak remains largely unchanged. The maturity of the debt plays a crucial role. If the maturity is very short, inflation would have to go up very fast to have an effect on the value of debt and that would be too costly. If the maturity is very large, a very small and persistent increase in inflation can have the desired effect on the value of debt. For relatively long maturities, close to the ones in the data, a relatively little costly increase in inflation can be very effective in reducing the real value of debt.

We compute the optimal response of both fiscal and monetary policy for the euro area as a whole, but different countries within the area have different debt levels and different maturities. For example, Austria, has an average debt maturity of 10.5, while the maturity in the area is 7.4 years. This means that these policies would have distributional implications, that we abstract from.

In line with the past literature on optimal fiscal and monetary policy, we have also abstracted from the broader distributional effects of these policies across households. These effects are however relevant when assessing how such policies should contribute to social welfare. For example, our conclusions may be reinforced if we took into account that surprise inflation may be not just less costly, but even beneficial for certain households – e.g. mortgage borrowers. Distributional considerations would also require taking a stance on the appropriate welfare criterion and may justify considering additional, household-type specific subsidies and taxes. We leave these questions to future research.

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6 Appendix

Figure 8: Optimal responses to a pandemic-size increase in G: lower information stickiness