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the Role of Input-Output Interactions

Ivan Petrella, Raffaele Rossi and Emiliano Santoro

Øster Farimagsgade 5, Building 26, DK-1353 Copenhagen K., Denmark

Tel.: +45 35 32 30 01 – Fax: +45 35 32 30 00

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Discretion vs. Timeless Perspective Policy-Making: the Role of Input-Output Interactions

Ivan Petrella* Raffaele Rossi†
Birkbeck, University of London Lancaster University

Emiliano Santoro‡
Catholic University of Milan
University of Copenhagen

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Abstract

This paper contributes to a recent debate about the structural and institutional conditions under which discretionary monetary policy-making may be superior to timeless perspective. To this end, we formulate an input-output economy in which firms' technology employs both labor and intermediate goods produced by all firms in the economy. Unlike price stickiness, input materials reduce the slope of the New Keynesian Phillips curve, while leaving the policy maker's preference for consumption stabilization unaffected. Strategic complementarities stemming from realistic degrees of input-output interactions greatly amplify the loss of social welfare under timeless perspective, even for small departures of the economy from its steady state. By contrast, price rigidity proves to be ineffective at improving the performance of discretion relative to timeless perspective.

JEL classification: E23; E32; E52

Keywords: Input-Output Economy, Monetary Policy, Discretion, Timeless Perspective

*Department of Economics, Mathematics and Statistics, Birkbeck, University of London. *Address:* Malet St, London WC1E 7HX, UK. *E-mail:* i.petrella@bbk.ac.uk.

†Department of Economics, Lancaster Management School, Lancaster University. *Address:* Lancaster LA1 4YX, UK. *E-mail:* r.rossi@lancaster.ac.uk.

‡ITEMQ, Catholic University of Milan and Department of Economics, University of Copenhagen. *Address:* Via Necchi 5, 20123 Milan, Italy. *E-mail:* emiliano.santoro@unicatt.it.

1 Introduction

Woodford (1999, 2003) has influentially argued that monetary policy should be conducted from a timeless perspective, a policy that helps overcoming both the traditional inflation bias (Barro and Gordon, 1983) and the stabilization bias, a dynamic loss that stems from the presence of cost shifters in the New Keynesian model (Clarida et al., 1999). Despite the direct advantages of such a commitment technology, Dennis (2010) and Sauer (2010a, 2010b) report situations in which, depending on the initial conditions of the economy, timeless perspective may be inferior to discretion. Their result hinges on the role of elements that reduce the slope of the New Keynesian Phillips curve (NKPC), such as nominal price rigidities, firm-specific labor/capital, and Kimball (1995) aggregation, as well as on the policy maker's preference for output stabilization. The common trait of these factors is to raise the conditional volatility of the auxiliary state variables that track the value of commitments under timeless perspective, so that discretion becomes the superior policy. Given the prominence of timeless perspective in the normative literature, it is essential to identify practical situations in which discretion may be preferred. This paper focuses on both nominal and real rigidities that reduce the sensitivity of prices to the real marginal cost. In doing so, it takes a structural approach, accounting for the influence of these factors on both the slope of the NKPC and the policy maker's preferences.

As a matter of fact, intermediate goods correspond to the largest determinant of the total cost of production in modern production technologies.¹ As such, they represent a major source of strategic complementarity among firms in the economy and exert strong influence on the slope of the aggregate supply schedule (Basu, 1995). We show that realistic degrees of input-output interactions greatly enlarge the set equilibrium outcomes in which discretion is superior to timeless perspective. Moreover, unlike nominal rigidities, a greater income share of input materials lowers the slope of the NKPC, while not affecting the policy maker's preferences for consumption stabilization. This aspect has not been

¹Dale Jorgenson's data on input expenditures by US industries show that materials (including energy) account for roughly 50% of outlays, while labor and capital account for 34% and 16%, respectively.

considered by previous studies, which have typically assumed exogenously postulated welfare criteria. Price rigidities, instead, reduce both the slope of the NKPC and the relative importance of consumption gap stabilization in the welfare criterion. These forces tend to offset each other, resulting into optimal policies that are insulated from variations in nominal rigidity.

The remainder of the paper is laid out as follows: Section 2 presents the model; Section 2 compares the relative performance of discretionary policy-making and timeless perspective policy-making in the presence of both input-output interactions and varying degrees of price stickiness; Section 3 concludes.

2 The Model

We embed an input-output production structure into a dynamic general equilibrium New Keynesian model. Firms operate within a monopolistically competitive setting. Their production technology embodies both labor and intermediate goods, so that the gross product of each firm in the economy is both consumed and used in the production of all other goods in the economy.

2.1 Consumers

Households derive income from working in firms, investing in bonds, and from the stream of profits generated by firms in the economy. They have preferences defined over a composite of goods (C_t) and labor (L_t). They maximize the expected present discounted value of their utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \varrho \frac{L_t^{1+\nu}}{1+\nu} \right], \quad \varrho > 0 \tag{1}$$

where β is the discount factor, σ is the inverse of the intertemporal elasticity of substitution, ν is the inverse of the Frisch elasticity of labor supply.

The following sequence of (nominal) budget constraints applies:

$$P_t C_t + B_t = R_{t-1} B_{t-1} + P_t W_t L_t - T_t + \Psi_t, \quad (2)$$

where P_t is the price of the composite good, B_t denotes a one-period risk-free nominal bond remunerated at the gross risk-free rate $R_t \equiv 1 + i_t$, W_t is the real wage rate, T_t is a lump-sum tax paid to the government and Ψ_t is the aggregate nominal flow of firm dividends.

2.2 Producers

The production side of the economy consists of one sector producing a continuum of differentiated goods $i \in [0, 1]$. We assume that the consumption composite takes the form of a Dixit-Stiglitz aggregator:

$$C_t = \left[\int_0^1 (Y_{it})^{\frac{\varepsilon_t - 1}{\varepsilon_t}} di \right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}}, \quad (3)$$

where ε_t denotes the time-varying elasticity of substitution between differentiated goods in the consumption composite. It is possible to show that a generic firm i faces the following demand schedule:

$$C_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\varepsilon_t} C_t, \quad (4)$$

where P_{it} is the price of the generic good i .

As in Basu (1995), Bergin and Feenstra (2000) and Moro (2009) we assume a Cobb-Douglas production technology for a generic firm i :²

²The key insights reported in the remainder of this paper are valid under more general production technologies, such as the CES specification of Dotsey and King (2006).

$$Y_{it} = Z_t M_{it}^\alpha L_{it}^{1-\alpha}, \quad (5)$$

where Z_t is a productivity shifter, L_{it} denotes the number of hours worked in the i^{th} firm and M_{it} denotes the amount of material inputs employed by firm i . Material inputs are combined according to a CES aggregator:

$$M_{it} = \left[\int_0^1 (M_{kit})^{(\varepsilon_t-1)/\varepsilon_t} dk \right]^{\varepsilon_t/(\varepsilon_t-1)}, \quad (6)$$

where M_{kit} is the intermediate input produced by firm k and employed in the production process of firm i . This specification implies the following demand function for the k^{th} intermediate good:

$$M_{kit} = \left(\frac{P_{kt}}{P_t} \right)^{-\varepsilon_t} M_{it}. \quad (7)$$

The gross product of the i^{th} firm may be sold on the market for final consumption goods or used as an intermediate good by all firms in the economy, so that $Y_{it} = C_{it} + M_{it}$.

Firms are assumed to adjust their price with probability $1 - \theta$ in each period. When they are able to do so, they set the price that maximizes expected profits:

$$\max_{P_{it}} E_t \sum_{n=0}^{\infty} (\beta\theta)^n \Omega_{t+n} [(1 + \tau) P_{it} - MC_{it+n}] \frac{Y_{it+n}}{P_t} \quad (8)$$

where Ω_t is the stochastic discount factor consistent with households' maximizing behavior, τ is a steady state subsidy to producers and MC_{it} denotes firm's i nominal marginal cost of production. In every period each firm solves a cost minimization problem to meet demand at its stated price, so that

$$MC_{it} = \frac{P_t W_t L_{it}}{(1 - \alpha) Y_{it}} = \frac{P_{it} M_{it}}{\alpha Y_{it}}. \quad (9)$$

2.3 The Government and the Monetary Authority

The government serves two purposes in the economy. First, it delegates monetary policy to an independent Central Bank. The second task of the government consists of taxing households and providing subsidies to firms to eliminate distortions arising from monopolistic competition in the markets for both classes of consumption goods. This task is pursued via lump-sum taxes that maintain a balanced fiscal budget.

2.4 Solution and Calibration

The rational expectations equilibrium is defined by the behavior of households, firms and the government, along with the transversality and the no-Ponzi scheme conditions. Prior to pursuing our normative analysis, we log-linearize structural equations and resource constraints around the non-stochastic steady state and then take the deviation from their counterparts in the efficient equilibrium. The difference between the logarithm of a generic variable X_t under sticky prices and its counterpart in the efficient equilibrium, X_t^* , is denoted by x_t . The rate of inflation, π_t , evolves in accordance with the following NKPC:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa (\sigma + \nu) (1 - \alpha) c_t + \eta_t, \quad (10)$$

where $\kappa = (1 - \beta\theta)(1 - \theta)\theta^{-1}$ and η_t is a reduced-form expression for the time-varying cost-shifter in the NKPC. We should note that the income share of input materials (α) is a key determinant of the slope of the supply schedule. In a hypothetical situation with intermediate goods as the only production input, current inflation would be insensitive to movements in the real wage. In the limit, strategic complementarities stemming in the

market for intermediate goods may render the NKPC completely flat.

The model is calibrated at a quarterly frequency. In line with standard parameterizations employed in the New Keynesian literature, we set $\beta = 0.9913$, $\sigma = 1$ and $\nu = 0.2$. As to the production technology, our numerical exercises will rely on different values of α , though Bouakez, Cardia, and Ruge-Murcia (2009) point to an average income share of input materials of about 0.65.³ We will also consider alternative values of the probability of not being able to adjust prices, though in the baseline parameterization $\theta = 0.75$, implying that on average firms reset prices once a year. As to the elasticity of substitution, $\varepsilon = 6$ in the non-stochastic steady state. Finally, we assume a purely transitory cost-push shock.

3 Monetary Policy

To evaluate social welfare we take a second-order Taylor approximation to the representative household's lifetime utility (see Rotemberg and Woodford, 1998).⁴ Following the analysis of Petrella and Santoro (2011) we obtain the following intertemporal social loss function:

$$\mathcal{W}_0 \approx -\frac{U_C C}{2} E_0 \sum_{t=0}^{\infty} \beta^t [(\sigma + \nu) c_t^2 + \omega \pi_t^2] + t.i.p. + O(\|\xi\|^3), \quad (11)$$

where C denotes the steady state level of consumption, U_C is the (steady state) marginal utility with respect to C_t , t.i.p. collects the terms independent of policy stabilization and $O(\|\xi\|^3)$ summarizes all terms of third order or higher. A peculiarity of (11) is that the preference for inflation stabilization, $\omega \equiv \varepsilon \kappa^{-1}$, does not depend on α . This is an inherent property of expressing the welfare criterion in terms of consumption gap

³Note this is a rather conservative choice. Basu (1995) argues that the income share of intermediate goods can lie between 0.8 and 0.9 if fixed costs of production are taken into account (see also Bergin and Feenstra, 2000 and Huang and Liu, 2004).

⁴We assume that shocks that hit the economy are not big enough to lead to paths of the endogenous variables distant from their steady state levels. This means that shocks do not drive the economy too far from its approximation point and, therefore, a linear quadratic approximation to the policy problem leads to reasonably accurate solutions.

variability. In the present context C_t can *de facto* be interpreted as a measure of value added (see Petrella and Santoro, 2011).

Under discretionary policy-making the policy maker can ignore the impact of her policies on inflation expectations and reoptimize in each period. This policy, together with the occurrence of cost-push shocks, gives rise to the stabilization bias pointed out in Clarida et al. (1999). Minimizing (11) subject to (10) and to given inflation expectations $E_t\pi_{t+1}$ results into the following optimality condition:

$$\pi_t = -\frac{1}{\varepsilon(1-\alpha)}c_t. \quad (12)$$

If, however, the policy maker is able to credibly commit herself to some future policy, she can minimize (11) by taking the impact of her actions on expectations into account. The optimality conditions in this case are (12), for $t = 0$, together with

$$\pi_t = -\frac{1}{\varepsilon(1-\alpha)}\Delta c_t, \quad t = 1, 2, \dots \quad (13)$$

Discretion and commitment are identical in the initial period, though (13) optimally accounts for the possibility to spread the effects of shocks over several periods. Yet, commitment is time inconsistent in two ways: first, the policy maker can switch from (13) to (12) in any period $t \geq 1$ and exploit given inflation expectations. Second, as argued by McCallum (2003) the policy maker is aware that applying the same optimization procedure again in the future implies a departure from today's optimal plan, a feature he refers to as "strategic incoherence".

Woodford (1999, 2003) has proposed to follow a "timeless perspective" approach so as to overcome the second form of time inconsistency and strengthen credibility. This involves ignoring the conditions that prevail at the regime's inception, thus imagining that the commitment to apply the rules deriving from the optimization problem had been made in the distant past. Under timeless perspective the policy maker applies (13)

already from $t = 0$. In this case, there is no dynamic inconsistency in terms of the Central Bank's own decision-making process.

3.1 Policy Evaluation

To compare the relative loss induced by alternative policies we follow Sauer (2010a, 2010b) and compute the following statistics:

$$RL = \left(\frac{\mathcal{W}_0^{tp}}{\mathcal{W}_0^d} - 1 \right) \times 100, \quad (14)$$

where \mathcal{W}_0^{tp} is the conditional loss under timeless perspective and \mathcal{W}_0^d represents the conditional loss under discretion. Specifically, RL measures the percentage gain from implementing discretion over timeless perspective.

As discussed in the introduction, the short run costs from adhering to the timeless perspective policy are generally amplified in the presence of elements that reduce the slope of the NKPC, or when the monetary authority poses increasing emphasis on consumption stabilization. Under these circumstances the Central Bank must generate greater volatility in the real marginal costs, so as to stabilize inflation. According to Dennis (2010) and Sauer (2010a, 2010b), to the extent that real marginal costs are correlated with the Central Bank's other policy objectives, higher volatility in real marginal costs raises the volatility of the commitments that characterize timeless perspective, so that discretion may become the superior policy.

Figure 1 portrays the relative loss conditional on different values of c_{-1} . We perform the exercise for different (empirically plausible) values of the Calvo parameter, θ . To abstract from the contribution of input-output interactions, we set $\alpha = 0$, so that we effectively focus on the baseline NK model where consumption and gross output are equivalent. In the left-hand panel we set the preference for consumption stabilization to $1/16$ and normalize the weight on inflation stabilization to one.⁵ By contrast, the right-

⁵This implies an equal weight on the quarterly variances of annualized inflation and the consumption gap. Our qualitative insight is not affected by the choice of a different preference for consumption

hand panel accounts for the dependence of ω on the degree of price stickiness, so that we can evaluate the extent to which lower responsiveness of inflation induced by greater price rigidity is counteracted by the stronger focus required on inflation stabilization. Timeless perspective maximizes its performance at $c_{-1} = 0$, where it is analogous to the optimal policy under commitment. However, the gain from committing to the timeless perspective policy decreases symmetrically for deviations of c_{-1} from zero. The greater the percentage deviation of the initial lagged consumption from the steady state, the greater the short run costs from following timeless perspective, so that there are states for which discretion is superior.⁶

Insert Figure 1 here

While the dynamic properties described so far are shared by both panels of Figure 1, a crucial difference can be traced from their comparison. As remarked at different stages of the analysis, price rigidity reduces the slope of the NKPC, helping discretion to improve its relative performance. In fact, the left-hand panel of Figure 1 shows that increasing price stickiness enlarges the set of equilibrium outcomes in which $RL > 0$.⁷ Under the baseline calibration for price stickiness ($\theta = 0.75$) and $|c_{-1}| > 1.3\%$ the discretionary regime dominates timeless perspective, with the gains increasing rapidly for larger values of $|c_{-1}|$. Larger stickiness reduces the situations in which timeless perspective dominates, but most importantly it implies considerable gains from discretion, even at small absolute values of c_{-1} . Accounting for the structural factors behind the weight on output stabilization in (11) presents us with a very different picture though. In fact, the right-hand panel of Figure 1 shows that increasing the degree of nominal rigidity restricts the set of outcomes in which discretion prevails over timeless perspective. Under the baseline calibration discretion only prevails for $|c_{-1}|$ greater than about 3%. To explain the difference between the two panels of Figure 1, we need to consider that increasing θ has

stabilization.

⁶This fact reflects that timeless perspective assumes that it is the stationary asymptotic equilibrium that governs outcomes, and not the initial conditions and the associated transition dynamics.

⁷In this case the optimal policy under discretion is $\pi_t = -\frac{1/16}{\kappa(\sigma+\nu)}c_t$ for $(t = 0, 1, 2, \dots)$, while the optimality condition under timeless perspective is $\pi_t = -\frac{1/16}{\kappa(\sigma+\nu)}\Delta c_t$ (for $t = 0, 1, 2, \dots$).

three main effects on the economic system: first, firms attach greater weight to future profits, given that they have fewer chances to adjust their prices. This incentive favors timeless perspective over discretion, as the former policy regime optimally incorporates forward-looking expectations. Second, more rigid prices reduce the pass-through from the real marginal cost to the rate of inflation, so that timeless perspective entails higher costs of being tough on inflation already in the initial period. The last effect – which has not been explored by the literature available to date – is that increasing θ lowers the relative weight attached to consumption gap variability in (11), so that the short run cost of being tough on inflation in the initial period decreases. As a matter of fact, the last two effects perfectly offset each other when monetary policy relies on a welfare criterion derived from a second-order approximation of households' utility. To see this, consider that the optimal policy rules (12) and (13) are insulated from changes in θ . Therefore, the dominant effect in the right-hand panel is the first one, which generally makes timeless-perspective prevail over discretion, even for high values of $|c_{-1}|$.

The analysis so far has shown that price rigidity may have poor influence on RL , at least when the policy maker relies on a welfare criterion that approximates households' utility. This is not the case for strategic complementarities stemming from input-output interactions. When input materials are part of the production technology and prices are sticky, firms face constant costs for their inputs, so that the sensitivity of the real marginal cost to variations in aggregate demand are rather small. In turn, firm-level incentives to cut prices and increase output are reduced (Basu, 1995). Therefore, input-output interactions have the potential to turn small price-setting frictions into considerable degrees of real rigidity. In addition, α has no impact on the welfare function, as discussed in Section 3. Figure 2 evaluates the effect of increasing α on the relative performance of timeless perspective. Input-output interactions restrict the set of outcomes in which timeless perspective dominates discretion, even for small departures of the initial state from its long run equilibrium.

Insert Figure 2 here

Inspecting the optimality conditions (12) and (13) clarifies further why input-output

interactions improve the relative performance of discretion. As discussed by Sauer (2010a), the history dependence implied by (13) improves the short run consumption/inflation trade-off in each period, as it makes today's consumption gap enter tomorrow's optimal policy with the opposite sign, but with the same weight in both periods. This way, timeless perspective eliminates the stabilization bias and reduces the relative variance of inflation and the consumption gap. However, along with these long run gains timeless perspective entails a short run cost that increases in $[\varepsilon(1 - \alpha)]^{-1}$ (and thus α). In fact, a higher income share of input materials imposes a softer attitude on inflation stabilization today, while requiring a tougher policy tomorrow. The resulting effect is to raise the short run costs from timeless perspective, while decreasing its long run gains.

4 Conclusions

Recent contributions have reported situations in which the short run costs associated with timeless perspective policy-making dominate the long run gains with respect to discretion, so that the latter may become the superior policy (Dennis, 2010; Sauer, 2010a, 2010b). This result hinges on the influence of factors that reduce the slope of the NKPC or increase the policy maker's preference for consumption stabilization on the volatility of the auxiliary state variables that track the value of commitments under timeless perspective.

This paper confirms the importance of assessing the performance of timeless perspective policies alongside that of discretion. However, it shows that nominal rigidity in price-setting has limited capability to improve the relative performance of discretionary policy-making when the policy maker accounts for a welfare criterion obtained through a second-order approximation of households' utility (Rotemberg and Woodford, 1998). Under these circumstances an increase in the degree of nominal rigidity has the joint effect of reducing both the slope of the NKPC and the policy maker's preference for consumption stabilization. These forces tend to offset each other, resulting into optimal policies that are insulated from movements in the degree of nominal rigidity. As a result, increasing price stickiness only results into firms attaching greater weight to future

profits, an effect that favors timeless perspective over discretion, given that the former regime optimally incorporates forward-looking expectations. A key contribution of this paper is to show that strategic complementarities arising in input-output economies may greatly enhance the chances that discretion performs better than timeless perspective. In fact, the short run costs associated with timeless perspective increase in the importance of input-output interactions, while not affecting the policy maker's preference for consumption stabilization.

On a more general note, we should stress that the framework employed in our normative analysis is necessarily stylized. Considering more realistic multi-sector frameworks embedding intersectoral trade of input materials would reinforce our conclusions. Factor demand linkages would in fact amplify the influence of input materials on the slope of the sector-specific supply schedules, inducing non-negligible sectoral complementarities.

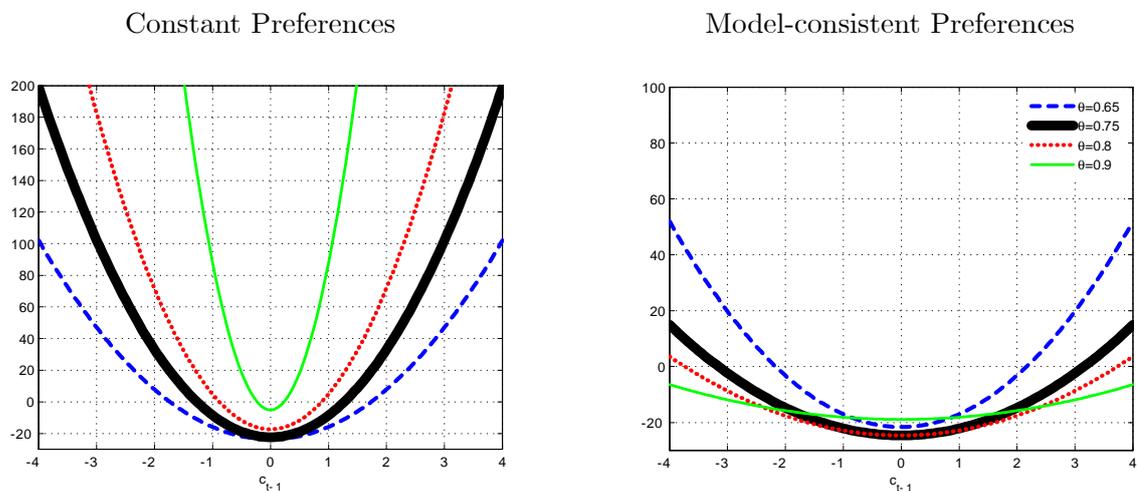
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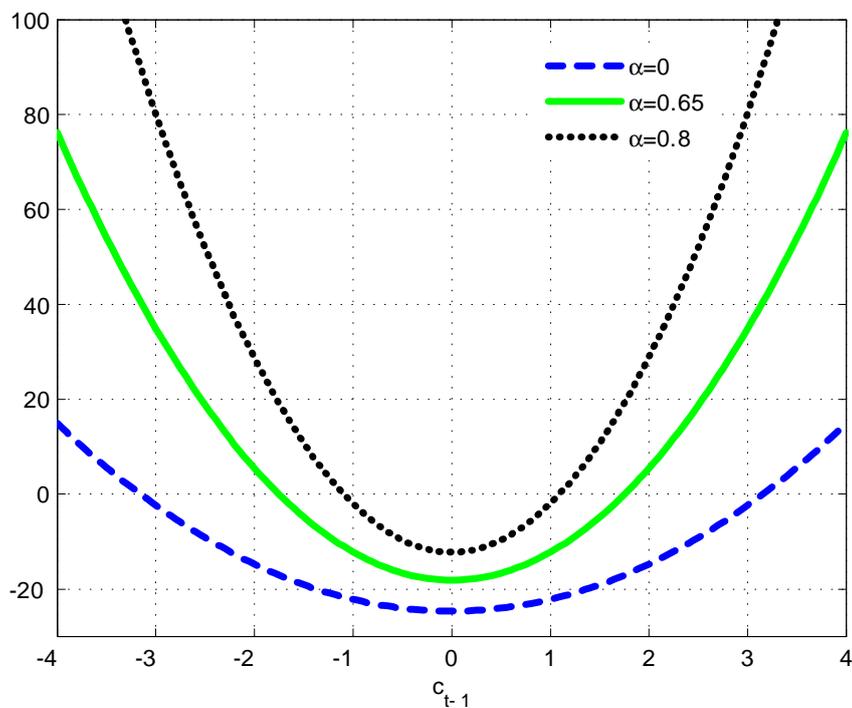
Figures

FIGURE 1: RELATIVE LOSS UNDER VARYING DEGREES OF PRICE STICKINESS



Notes. Figure 1 portrays the relative loss (RL) conditional on different values of c_{-1} and for varying degrees of price stickiness. In the left-hand panel we set the policy maker's preferences on consumption stabilization to $1/16$ and normalize the weight on inflation stabilization to one. By contrast, the right-hand panel considers $\omega \equiv \varepsilon\kappa^{-1}$. In both cases $\alpha = 0$. Negative (positive) values of RL imply that timeless perspective is superior (inferior) to discretion.

FIGURE 2: RELATIVE LOSS UNDER VARYING DEGREES OF INPUT-OUTPUT INTERACTIONS



Notes. Figure 2 portrays the relative loss (RL) conditional on different values of c_{-1} and for varying degrees of input-output interactions. Negative (positive) values of RL imply that timeless perspective is superior (inferior) to discretion.