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The cost of disinflation in a small open economy vis-à-vis a closed economy*

Oleksandr Faryna[a], Magnus Jonsson[b] and Nadiia Shapovalenko[c]

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Abstract

We use a standard new Keynesian model to evaluate the cost of disinflation – measured by the sacrifice ratio, the central bank's loss function, and the welfare cost – in a small open economy vis-à-vis a closed economy. Disinflation is either more costly or less beneficial in the small open economy, but the results vary quantitatively depending on the measure and the economic environment. Optimised simple monetary policy rules imply that the relative weight on inflation stabilisation should be lower in the small open economy if the central bank minimises the loss function, but higher if it maximises welfare.

Keywords: Disinflation, sacrifice ratio, central bank's loss function, welfare cost, small open economy, new Keynesian model, optimised rules, imperfect credibility.

JEL classification: E31, E5, F41.

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Introduction

Studies of the cost of disinflation have a long history in monetary economics. In particular, there is a large empirical literature that estimates the so-called sacrifice ratio, which measures the percentage of output the economy has to give up for each percentage point reduction in long-run inflation. Recently, a number of theoretical papers have examined the sacrifice ratio in a new Keynesian framework, see Ascari and Ropele (2012a, 2012b, and 2013). They find, among other things, that the sacrifice ratio in this framework is in line with many of the empirical estimates. Hence, the new Keynesian model should be a useful framework for evaluating the cost of disinflation.

The studies by Ascari and Ropele examine the cost of disinflation in a closed economy. We extend the analysis to a small open economy. This is of theoretical interest, but also of interest from a policy perspective. Over the last 30 years, inflation has been decreasing in many emerging market economies to the point where it is only about 2–3 percentage points higher than in developed economies.[1] Many of these emerging markets are small open economies. To evaluate the cost of reducing inflation by a few percentage points is thus of real interest. Furthermore, to evaluate how monetary policy should be conducted in a small open economy vis-à-vis a closed economy is therefore also of interest.

We consider three different measures of the cost of disinflation. The first measure is the sacrifice ratio. The second measure is based on a central bank loss function with equal weights on inflation and output stabilisation. This measure complements the sacrifice ratio since it in addition to the output cost also accounts for the cost of deviating from the new inflation target. The central bank's loss function may, however, differ from the society´s objective. We therefore consider a third measure, the welfare of the representative household. We compute both the welfare cost of the transition to the new inflation target, the long-run welfare cost, and the aggregated total welfare cost. In the long-run, there is not a welfare cost of disinflation, but a benefit due to less price dispersion in steady state.

Our modelling framework is the standard new Keynesian model of Galí (2008) and Woodford (2003) with two additions: The small open economy framework of Adolfson et al. (2007) and Galí and Monacelli (2005) and the imperfect central bank credibility framework of Ascari and Ropele (2013). The main frictions that affect the cost of disinflation in this framework are price stickiness and imperfect central bank credibility. In the small open economy, there is also price stickiness in the import sector, which implies imperfect exchange rate pass-through. The uncovered interest rate parity condition is a specific channel through which disinflation can be affected in the small open economy that is not present in the closed economy.

[1] See Daly and O'Doherty (2019) and Box 1.1. in World Bank (2019).

To calibrate the model, we use standard parameters values from the literature and assume a disinflation episode of three percentage points, i.e., a lowering of the inflation target from five to two per cent. In the benchmark calibration, we assume that monetary policy follows a standard Taylor rule, see Taylor (1993).

We carry out sensitivity analysis with respect to the level of openness and central bank credibility. We also consider so-called optimised simple monetary rules in the sensitivity analysis. From a policy perspective, simple rules are attractive since they are easy to understand for policy makers, and can easily be compared to the Taylor rule, which is often used as a benchmark case for evaluating policy. We consider two types of optimised simple rules. In the first type, the central bank minimises a loss function. This rule is called an optimised *loss* rule. In the second type, the central bank maximises welfare, this rule is accordingly called an optimised *welfare* rule.

Finally, a potential way to reduce the cost of disinflation is to pre-announce an implementation path of the new inflation target. We carry out sensitivity analysis with respect to pre-announcement by computing how accelerating and decelerating disinflation paths, with implementation horizons up to eight quarters, affect the cost of disinflation in both economies.

Benchmark results. We first illustrate the basic economic mechanisms in the disinflation episode. Disinflation is associated with an initial increase of the real interest rate. This implies a short-term fall of output, which is amplified in the small open economy due to an appreciation of the real exchange rate. The appreciation shifts consumption from domestic to imported goods, which has a negative effect on net exports and domestic output, but it also lowers import prices and potentially makes the disinflation period shorter.

Quantitatively, the sacrifice ratio is about 0.29 percentage points higher in the small open economy. The central bank's loss is also higher, but only by about 1 per cent. The transition welfare cost is from a policy perspective very small in both economies, although marginally less in the small open economy, about 0.0004 per cent of extra initial steady state consumption each period (per each percentage point of reduced inflation).

The long-run (steady state) welfare benefit of disinflation is substantially larger than the cost of the transition. The total welfare effect of disinflation is therefore positive in both economies, but the benefit is about 0.004 percentage points lower in the small open economy.

Sensitivity analysis. The benchmark result that disinflation is either more costly or less beneficial in the small economy holds irrespective of the level of openness. We show that as openness increases, the sacrifice ratio and the central bank's loss increase and the total welfare benefit decreases in the small open economy.

The accelerating implementation paths reduce the sacrifice ratio in both economies, but to a larger extent in the small open economy. However, the accelerating paths lead to a slower transition of inflation to the new target, and this increases the central bank's loss relatively more in the small open economy. For example, if the implementation horizon is 8 quarters the loss becomes about 6 per cent higher in the small open economy, compared to about 1 per cent with immediate implementation. The decelerating paths are shown to have small effects on the measures of the cost of disinflation.

The optimised loss rules also strengthen the benchmark result that disinflation is more costly in the small open economy when the cost of disinflation is measured by the central bank's loss. The loss becomes about 21 per cent higher with the optimised loss rules, compared to about 1 per cent higher with the Taylor rule.

The extent to which monetary policy should be conducted differently in the small open economy vis-à-vis the closed economy depends on the central bank's objective. If the objective is to minimise the loss function, the relative weight on inflation stabilisation should be lower in the small open economy, but higher if the objective is to maximise welfare. In terms of policy implications, the policy rate should be smoothly reduced towards the long-run value in the small open economy, but increased by about two percentage points in the closed economy when the objective is to minimise the loss function. When the objective is to maximise welfare, the policy rate should be raised by approximately two percentage points in both economies.

The sacrifice ratio is an increasing and convex functions of imperfect credibility in both economies irrespective of the monetary policy rules. The Taylor rule is better in mitigating the sacrifice ratio than both of the optimised rules, in particular when credibility is low. The optimised welfare rule is particularly costly in the small open economy, since it puts a high weight on inflation stabilisation.

When the cost of disinflation is measured by the central bank's loss, lack of credibility is relatively more costly in the small open economy. The optimised loss rules – compared to the Taylor rule – mitigate the loss to a larger extent in the closed economy the lower is the central bank's credibility.

Finally, the sensitivity analysis does not change the benchmark result that the transition welfare cost is very small from a policy perspective and that the total welfare benefit of disinflation is lower in the small open economy.

Related literature. The literature on the cost of disinflation is vast. Limiting ourselves to the theoretical literature, Ball (1994) pointed out that in a version of the new Keynesian model where inflation is a purely forward-looking variable there is no cost of disinflation. This is due to a specific assumption on how firms that are not able to re-optimise prices set their prices in the Calvo (1983) sticky price model, i.e., prices that are not re-optimised remain constant between re-optimisation periods. However, a common assumption in more recent work is that prices that are not re-optimised are indexed to past inflation rates or the inflation target, see Christiano et al. (2005) and Smets and Wouters (2007). This generates a backward looking inflation component in the Phillips curve and output losses of disinflation. Imperfect central bank credibility also produces a backward looking component and output losses of disinflation, see Ball (1995).

This paper is closely related to the work of Ascari and Ropele (2012a, 2012b, and 2013) who study the cost of disinflation in a closed economy framework. One of the main contributions of their work is to show that the new Keynesian model is in line with empirical estimates of the sacrifice ratio. Among other things, they also show that a gradual implementation of the target implies lower sacrifice ratios than with an immediate implementation. From a welfare perspective, they show that the long-run benefit of lower inflation outweighs the short run transition cost of disinflation.

There are few theoretical papers that study the cost of disinflation in small open economies. The paper by Restrepo-Echavarria (2005) computes the welfare effect of achieving the long-run inflation target in Colombia in a model calibrated to fit the Colombian economy. In line with the results of Ascari and Ropele (2012a, 2013) the paper finds long-run welfare benefits of disinflation. The paper by Sunel (2018) computes the welfare consequences of the gradual but large disinflation in emerging economies that we have observed. In a small open economy model with uninsurable idiosyncratic risk, a gradual decline of 12 per cent in the quarterly inflation rate leads to an aggregate welfare benefit of 0.40 per cent in consumption equivalent terms.

The paper is organised as follows. In the next section, we present the economic environment and the calibration of the model. We then illustrate and discuss the economic mechanisms of disinflation in the small open economy and the closed economy. The next two sections report the cost of disinflation in the benchmark calibration and the results from the sensitivity analysis. The final section conclude with some suggestions for future research.

The economic environment

We assume a world economy that is made up of a small open economy and a foreign economy, i.e., the rest of the world. The closed economy is a special case of the world economy where the level of openness is zero.

Households

Intertemporal decision problem

A representative household has preferences $\mathcal{U}$ over an aggregate consumption index C and hours worked N according to,

$$\mathcal{U} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \tag{1}$$

where $\mathbb{E}$ is the expectation operator, $U(\cdot)$ is the period utility function, and the parameter $\beta < 1$ is the subjective discount factor. The per-period utility function takes the following functional form,

$$U(C_t, N_t) = \ln C_t - \frac{N_t^{(1+1/\varphi)}}{1 + 1/\varphi}, \tag{2}$$

where the parameter φ is the compensated elasticity of labor supply, i.e., the Frisch intertemporal elasticity of substitution.

Utility maximisation is subject to an intertemporal budget constraint,

$$\begin{gathered} P_t C_t + B_t + S_t B_t^W = \\ B_{t-1}(1 + R_{t-1}) + S_t B_{t-1}^W (1 + R_{t-1}^w) \Psi_{t-1} + \\ W_t N_t + D_{D,t} + D_{F,t} - T_t, \end{gathered} \tag{3}$$

where B is the stock of nominal bonds denominated in the domestic currency, B^W the stock of foreign nominal bonds denominated in the foreign currency, S the nominal exchange rate defined as the price of foreign currency in terms of domestic currency, W the nominal wage rate, R and R^W are the nominal interest rates on domestic and foreign bonds, respectively, Ψ is a risk premium, D_D and D_F are profits from owning the equity of domestic and importing firms, respectively, and T represents lump-sum transfers.

The risk premium depends negatively on the stock of net foreign assets measured in domestic consumption units A, i.e., SB^W/P, according to the following functional form,

$$\Psi_t = \exp\{-\psi(A_t - \bar{A})\}, \tag{4}$$

where ψ is a risk premium parameter and a bar above a variable denotes a steady state value. The risk premium adds realism and induces stationarity in the net foreign asset position.

The first order conditions of the households' intertemporal maximisation problem can be summarised by the following conditions,

$$\frac{W_t}{P_t} = -\frac{U_{N,t}}{U_{C,t}}, \tag{5}$$

$$1 + R_t = (1 + r_t)\mathbb{E}_t \pi_{t+1}, \tag{6}$$

$$1 + R_t = (1 + R_t^W)\mathbb{E}_t\left(\frac{S_{t+1}}{S_t}\right)\Phi_t, \tag{7}$$

where $\pi_{t+1} = P_{t+1}/P_t$ is gross inflation in period $t+1$, and r the real interest rate given by the following condition,

$$1 + r_t = \frac{1}{\beta}\mathbb{E}_t\left(\frac{U_{C,t}}{U_{C,t+1}}\right). \tag{8}$$

The first condition (5) gives the familiar result that the real wage is the negative of the marginal rate of substitution between labor supply and consumption. The next condition (6) is the Fisher equation, which says that the nominal interest rate equals the real interest rate times expected inflation. Condition (7) is the uncovered interest rate parity condition, according to which the domestic nominal interest rate equals the foreign interest rate times the expected depreciation of the exchange rate and a risk premium. The final condition (8) is the standard Euler equation, which shows that the gross return to saving is equal to the household's intertemporal marginal rate of substitution between present consumption for future consumption.

Intratemporal decision problem

The aggregate consumption index is given by,

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}}\left(C_{D,t}\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}}\left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{9}$$

where C_D is an index of consumption goods produced domestically, C_F an index of foreign (imported) consumption goods. The parameter $\alpha \in [0,1]$ is the level of trade openness ($1-\alpha$ is often interpreted as a measure of home bias in preferences) and the parameter $\eta > 1$ measures the elasticity of substitution between domestic and foreign (imported) consumption goods. The indices of domestic and foreign (imported) consumption goods are given by,

$$C_{D,t} = \left(\int_0^1 C_{D,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{10}$$

$$C_{F,t} = \left(\int_0^1 C_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{11}$$

where the parameter $\epsilon > 1$ is the elasticity of substitution between domestic and foreign (imported) consumption goods.

Formally, households first minimise the total expenditure required to purchase a given amount of total consumption $\tilde{C}$,

$$\min_{C_{D,t}, C_{F,t}} P_{D,t} C_{D,t} + P_{F,t} C_{F,t}, \qquad s.t. C_t = \tilde{C}, \tag{12}$$

where P_D is the price of one unit of the domestic consumption good index and P_F is the price of one unit of the foreign (imported) consumption good index measured in the domestic currency. The first order conditions yield the following demand functions,

$$C_{D,t} = (1-\alpha)\left(\frac{P_{D,t}}{P_t}\right)^{-\eta} C_t, \tag{13}$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t, \tag{14}$$

where P is the price of a consumption basket, i.e., the consumer price index expressed in units of domestic currency and is given by,

$$P_t = \left[(1-\alpha)\left(P_{D,t}\right)^{1-\eta} + \alpha\left(P_{F,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{15}$$

Second, households minimise the total expenditure required to purchase a given amount of total domestically produced consumption $\tilde{C}_D$ and a given amount of total foreign (imported) consumption, $\tilde{C}_F$. This yields the following demand functions for the individual goods,

$$C_{D,t}(i) = (1-\alpha)\left(\frac{P_{D,t}(i)}{P_{D,t}}\right)^{-\epsilon}\left(\frac{P_{D,t}}{P_t}\right)^{-\eta} C_t, \tag{16}$$

$$C_{F,t}(i) = \alpha\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon}\left(\frac{P_{F,t}}{F_t}\right)^{-\eta} C_t. \tag{17}$$

By analogy, we assume that the foreign (export) demand for the domestically produced consumption good is given by,

$$C_{D,t}^W(i) = \alpha\left(\frac{P_{D,t}^W(i)}{P_{D,t}^W}\right)^{-\epsilon}\left(\frac{P_{D,t}^W}{S_t P_t^W}\right)^{-\eta} Y_t^W, \tag{18}$$

where P_D^W is the price of one unit of the export consumption good index, P^W the foreign consumer price index and Y^W foreign real output. We assume that the law of one price holds. This means that when measured in the same currency, the price of consumption goods domestically produced and consumed is the same as the price of consumption goods domestically produced and exported,

$$P_{D,t}^{W}(i) = \frac{P_{D,t}(i)}{S_t}, \tag{19}$$

$$P_{D,t}^{W} = \frac{P_{D,t}}{S_t}. \tag{20}$$

Firms

There is a continuum of firms indexed by $i \in [0,1]$. Each firm produces a differentiated good, using a constant returns to scale production function with labor (hours worked) as the only input factor,

$$Y_t(i) = N_t(i), \tag{21}$$

where Y is output. The technology level, which is equal to all firms, is normalised to one. Firms sell their goods in domestic and foreign markets under so-called producer currency pricing, i.e., firms set a single price in domestic currency.

Following Calvo (1983), each firm can re-optimise its price in a given period with a constant probability $1-\theta_D$. These firms choose the optimal price, $P_D^*(i)$, to maximise profits while the prices remain effective,

$$\begin{aligned} \max_{P_{D,t}^*(i)} \mathbb{E}_t \sum_{k=0}^{\infty} \theta_D^k \Lambda_{\mathrm{t,t+k}} \Bigg[\left(\frac{P_{D,t+k-1}}{P_{D,t-1}} \right)^{\omega_D} P_{D,t}^*(i) \\ - (1+\tau) W_{t+k}(i) \Bigg] Y_{t+k}(i)\,, \end{aligned} \tag{22}$$

where Λ is the nominal one-period stochastic discount factor and the parameter τ a subsidy set to eliminate the steady state distortion implied by imperfect competition. The maximisation is subject to the following demand constraint,

$$Y_t(i) = C_{D,t}(i) + C_{D,t}^{W}(i), \tag{23}$$

where $C_D(i)$, and $C_D^W(i)$ are defined by equations (16) and (18), respectively. The first order condition is given by,

$$\begin{aligned} \mathbb{E}_t \sum_{k=0}^{\infty} \theta_D^k \Lambda_{\mathrm{t,t+k}} Y_{t+k}(i) \left(\frac{P_{D,t+k-1}}{P_{D,t-1}} \right)^{\omega_D} P_{D,t}^* = \\ = \mathbb{E}_t \sum_{k=0}^{\infty} \theta_D^k \Lambda_{\mathrm{t,t+k}} Y_{t+k}(i) \frac{\varepsilon}{\varepsilon - 1} (1+\tau) W_{t+k}\,. \end{aligned} \tag{24}$$

Firms that do not re-optimise set prices according to the following rule,

$$P_{D,t}(i) = P_{D,t-1}(i)\left(\frac{P_{D,t-1}}{P_{D,t-2}}\right)^{\omega_D}, \tag{25}$$

where $\omega_D \in [0,1]$ is a parameter that measures the level of price indexation to previous period's inflation.

An aggregate domestic price can be derived as a weighted average of prices set by firms that re-optimise and by those that do not re-optimise,

$$\left(P_{D,t}\right)^{1-\epsilon} = (1-\theta_D)\left(P_{D,t}^{*}\right)^{1-\epsilon} + \theta_D\left(P_{D,t-1}\left(\frac{P_{D,t-1}}{P_{D,t-2}}\right)^{\omega_D}\right)^{1-\epsilon}. \tag{26}$$

Import sector

There is a continuum of importing firms that acquire a homogeneous foreign consumption good on the international market. The price of this good in domestic currency is SP^{W}. The importing firms rebrand the good and sell it to domestic households under monopolistic competition.

Imperfect exchange rate pass-through is an important empirical feature, which means that changes in the nominal exchange rate affect import prices gradually. In the long-run pass-through is complete, though. A possible explanation for this behavior is sticky import prices. Importing firms can only optimally revise their price in any given period with a constant probability, $1-\theta_F$, and solve the following profit maximisation problem,

$$\begin{aligned}\max_{P_{F,t}^{*}(i)} \mathbb{E}_t \sum_{k=0}^{\infty} \theta_F^k \Lambda_{\mathrm{t+k}} \Bigg[\left(\frac{P_{F,t+k-1}}{P_{F,t-1}}\right)^{\omega_F} P_{F,t}^{*}(i) \\ - (1+\tau)S_{t+k}P_{t+k}^{W}\Bigg] C_{F,t+k}(i),\end{aligned} \tag{27}$$

subject to the foreign demand function $C_F(i)$ defined in equation (11). The first order condition is given by,

$$\begin{aligned}\mathbb{E}_t \sum_{k=0}^{\infty} \theta_H^k \Lambda_{\mathrm{t,t+k}} C_{F,t+k}(i)\left(\frac{P_{F,t+k-1}}{P_{F,t-1}}\right)^{\omega_F} P_{F,t}^{*} = \\ = \mathbb{E}_t \sum_{k=0}^{\infty} \theta_H^k \Lambda_{\mathrm{t,t+k}} C_{F,t+k}(i) \frac{\varepsilon}{\varepsilon-1}(1+\tau)S_{t+k}P_{t+k}^{W}.\end{aligned} \tag{28}$$

Importing firms that cannot re-optimise in a given period, update their prices according to the following rule,

$$P_{F,t}(i) = P_{F,t-1}(i)\left(\frac{P_{F,t-1}}{P_{F,t-2}}\right)^{\omega_F}, \tag{29}$$

where $\omega_F \in [0,1]$ measures the level of price indexation to previous period's foreign (import) inflation.

An aggregate import price can be derived as a weighted average of prices set by importing firms that re-optimise and by those that do not re-optimise,

$$\left(P_{F,t}\right)^{1-\epsilon} = (1-\theta_F)\left(P_{F,t}^{*}\right)^{1-\epsilon} + \theta_F\left(P_{F,t-1}\left(\frac{P_{F,t-1}}{P_{F,t-2}}\right)^{\omega_F}\right)^{1-\epsilon}. \tag{30}$$

Imperfect central bank credibility

Imperfect central bank credibility is an important factor of the cost of disinflation according to many papers, see for example Goodfriend and King (2005), Erceg and Levin (2003), Gibbs and Kulish (2015). When credibility is imperfect, households revise their expectations of the new inflation target gradually. Over time – as new information becomes available – they put greater weight on the new inflation target.[2]

To model imperfect central bank credibility, we follow the approach by Ascari and Ropele (2013) and Goodfriend and King (2005). In this framework is expected inflation $\widetilde{\mathbb{E}}_t(\pi_{t+1})$ a weighted average of the rational expected value of inflation and the old (higher) inflation target,

$$\widetilde{\mathbb{E}}_t(\pi_{t+1}) = (1-\omega_t)\mathbb{E}_t(\pi_{t+1}) + \omega_t\,\bar{\pi}^{high}, \tag{31}$$

where $\omega \in [0,1]$ is a measure of central bank credibility. When $\omega = 0$ there is full credibility and when $\omega = 1$ there is zero credibility. In the long-run, expectations converge to the rational expected value, i.e, $\widetilde{\mathbb{E}}_\infty(\pi_{t+1}) = \mathbb{E}_\infty(\pi_{t+1})$. Initially, households and firms are not convinced of the central bank's commitment to the new target, i.e., $\omega = 1$. Over time, the central bank's credibility improves, which is modelled by an AR(1)-process,

$$\omega_t = \rho_C\,\omega_{t-1}, \tag{32}$$

where the parameter ρ_C measures the rate at which credibility converges to full credibility. The formation of inflation expectations affects the Phillips curve, the Fisher equation, and the uncovered interest rate parity condition. Hence, the uncovered interest rate parity condition provides an

[2] Price indexation to previous inflation, as in the Calvo price-setting framework, can to a certain extent be viewed as a reduced-form substitute for imperfect credibility, since it adds a backward-looking component to the Phillips curve, see Ascari and Ropele (2013).

additional channel through which credibility can affect the cost of disinflation in the small open economy.

Monetary Policy

Monetary policy follows the standard Taylor rule, see Taylor (1993). According to this rule, the policy rate R depends on deviations of inflation from its target – the inflation gap – and deviations of output from its long-run value – the output gap – and the long-run interest rate,

$$\frac{1+R_t}{1+\bar{R}} = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\rho_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\rho_Y}, \tag{33}$$

where the parameters ρ_π and ρ_Y show the strength by which the policy rate reacts on the inflation gap and the output gap, respectively.

Market clearing conditions and trade

There are five markets that require market clearing: the labor market, the markets for domestically produced and imported goods and the domestic and foreign bond markets.

Labor market clearing requires that,

$$N_t^S = \int_0^1 N_t^D(i)di = N_t^D. \tag{34}$$

Domestic bonds cannot be traded in the international financial market and their net supply is zero, i.e., $B_t = 0 \; \forall \; t$. The supply of foreign bonds is assumed to be perfectly elastic at the foreign nominal interest rate.

Domestically and imported goods market clearing requires that for any firm the production is either consumed domestically or exported,

$$Y_t(i) = C_{D,t}(i) + C_{D,t}^W(i) \implies \tag{35}$$

$$\int_0^1 Y_t(i)di = \int_0^1 C_{D,t}(i)di + \int_0^1 C_{D,t}^W(i)di. \tag{36}$$

An economy-wide goods-market clearing condition, including imported goods, is achieved by integrating over the continuum of goods and plugging in demand and production functions for individual goods,

$$\int_0^1 N_t(i)di = \int_0^1 \left(C_{D,t}(i) + C_{D,t}^W(i)\right) di \qquad \Leftrightarrow$$
$$N_t = \left[(1-\alpha)C_t + \alpha Q_t^\eta Y_t^W\right]\Delta_{D,t}, \tag{37}$$

where $\Delta_{D,t} = \int_0^1 \left(\frac{P_{D,t}(i)}{P_{D,t}}\right)^{-\epsilon} \left(\frac{P_{D,t}}{P_t}\right)^{-\eta} di$ denotes price dispersion across firms.

Nominal domestic output $P_D Y$ equals nominal income consisting of labor income and profits from firms D_D and imported goods firms D_F, which equals nominal sales, i.e., nominal consumption plus nominal exports minus nominal imports,

$$P_{D,t}Y_t = W_t N_t + D_{D,t} + D_{F,t} = P_t(C_t + X_t - M_t). \tag{38}$$

The real exchange rate Q is defined as,

$$Q_t = S_t \frac{P_t^W}{P_t}. \tag{39}$$

Real exports X and real imports M are then given by,

$$X_t = \alpha \left(\frac{P_{H,t}}{P_t}\right)^{1-\eta} Q_t^\eta Y_t^W, \tag{40}$$

$$M_t = \alpha Q_t C_t \Delta_{F,t}, \tag{41}$$

where $\Delta_{F,t} = \int_0^1 \left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\epsilon} \left(\frac{P_{F,t}}{P_t}\right)^{-\eta} di$ is a measure of price dispersion across importing firms.

Stationarity and equilibrium

To make the model stationary, we divide the nominal variables P_H, P_F, W, and SB^W by the consumer price index P. In addition, domestic and foreign consumer price indices are replaced with the corresponding stationary inflation rates $\pi_t = P_t/P_{t-1}$ and $\pi_t^W = P_t^W/P_{t-1}^W$. Lastly, we replace the nominal exchange rate S with the stationary real exchange rate Q.

Calibration

We use standard values from the literature to parameterise the benchmark model, see Table 1. The length of a time period is one quarter. The discount factor β is set to 0.9951, which implies an annual long-run real interest rate of two per cent. The Frisch elasticity ϕ is generally between two and four in macroeconomic models, see Peterman (2016). We set ϕ to 2. Evidence from Nakamura and Steinsson (2008) suggests that the median duration between price changes is about 3–4 quarters. Hence, we set the Calvo parameters θ_D to 0.75 and θ_F to 0.5, implying an average duration between price changes of 4 and 2 quarters, respectively. The price indexation parameters ω_D and ω_F are set to 0.6 in line with estimates in Smets and Wouters (2003). Price markups are set to 20 per cent for both firms and importing firms, see Bayoumi, Laxton and Pesenti (2004). Estimates of the elasticity of substitution between domestic and foreign (imported) goods are around 5–20 in micro data (see references in Obstfeld and Rogoff (2000) and others). Estimates using macro data are, however, lower, see Collard and Dellas (2002). We therefore set the elasticity of substitution parameter η at the lower range of the estimates from the micro data, i.e., to 10. The openness parameter α is set at 0.4, in line with the value suggested by Adolfson et al. (2007). The central bank credibility parameter ρ_C is set to 0.7 as in Ascari and Ropele (2013). Finally, the weight on the inflation gap ρ_π is set to 1.5 and the weight on the output gap ρ_Y is set to 0.125, following Taylor (1993).

Table 1. Benchmark parameter values

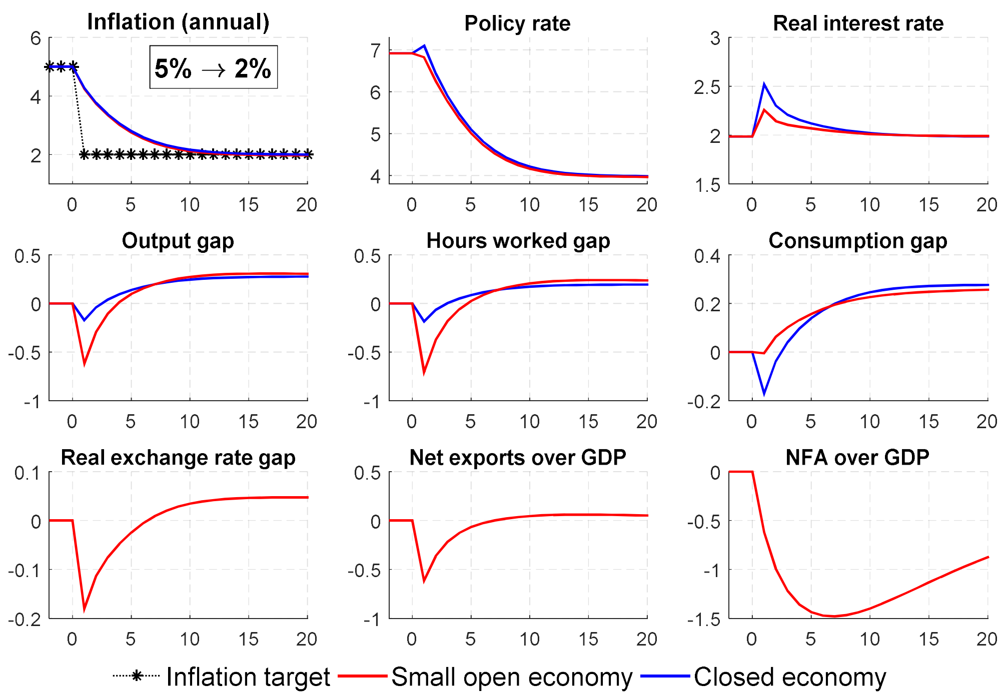
Parameter	Description	Value
α	Openness	0.4
η	Substitution elasticity between domestic and imported goods	10
β	Discount factor	1.02^(−0.25)
ϕ	Frisch elasticity	2
θ_D	Price stickiness (firms)	0.75
θ_F	Price stickiness (importers)	0.5
ω_D	Price indexation (firms)	0.6
ω_F	Price indexation (importers)	0.6
$1/\epsilon + 1$	Price markup (firms and importers)	20 per cent
ψ	Risk premium	0.0015
ρ_C	Central bank credibility parameter	0.7
ρ_π	Weight on the inflation gap	1.5
ρ_Y	Weight on the output gap	0.5/4

To solve for the transition paths between the initial steady state and the new steady state, we stack the model's equilibrium conditions and solve the system of equations numerically with the non-linear solver in Dynare.[3]

Illustrating the mechanisms

Figure 1 illustrates the economic mechanisms of the disinflation episode. The central banks announce a reduction of the inflation target from five to two per cent with immediate implementation.[4] As soon as the new target is announced, households and firms revise their inflation expectations downwards and inflation starts to fall. In the long-run, the lower inflation target must be accompanied by a lower policy rate. However, there is a small initial increase of the policy rate in the closed economy to ensure that inflation expectations are adjusted downwards.[5] In both economies, the policy rate decreases at a slower rate than inflation, which leads to a rise of the real interest rate. This gives households an incentive to substitute current consumption for future consumption, and consequently they also work less in the current period. Output – being a linear function of hours worked – also falls.

Figure 1. Disinflation in the small open economy and the closed economy



The uncovered interest rate parity condition provides an additional channel through which the small open economy is affected by disinflation. The increase of the real interest rate leads to an appreciation

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[3] Ascari (2004) shows that it is important to account for the non-linear effects for values of the long-run inflation rate that we evaluate.
[4] For larger reductions of the inflation target other price-setting schemes are more appropriate than the Calvo price-setting scheme, e.g., state-dependent pricing schemes. See also Ascari and Ropele (2013) for an analysis of how the size of the reduction affects the cost of disinflation.
[5] The small increase is due to the assumption of imperfect central bank credibility.

of the real exchange rate (the foreign real interest rate is constant in all simulations). This has two main implications: First, it lowers import prices, which makes the transition of inflation to the new target potentially faster. Second, lower import prices gives households an incentive to substitute domestic goods for imported goods, which has a negative effect on net exports and output. This leads to a larger fall in output in the small open economy, despite having a lower real interest rate than the closed economy.

The appreciation of the real exchange rate puts a stronger downward pressure on inflation in the small open economy, which rather than a faster transition of inflation to the new target leads to a lower policy rate and a lower real interest rate. In the sensitivity analysis, where we study the implications of optimsed policy rules, the inflation paths will differ between the two economies. Note also that in the closed economy consumption initially falls, while it increases continuously to the new steady state in the small open economy, despite a larger drop in output. This is due to increased consumption of cheaper imported goods from a stronger real exchange rate.

The cost of disinflation – benchmark results

The sacrifice ratio is a common measure of the cost of disinflation. It shows the percentage of output the economy has to give up for each percentage point reduction of inflation. We formally define the sacrifice ratio $\mathcal{S}$ in the following way,

$$\mathcal{S} = -\frac{1}{\bar{\pi}^{high} - \pi_T} \sum_{t=0}^{T} \frac{Y_t - \bar{Y}^{low}}{\bar{Y}^{low}}, \tag{42}$$

where $\bar{\pi}^{high}$ is the high (initial) inflation target, π_T inflation at period T, and $\bar{Y}^{low}$ the steady state level of output in the new and low inflation target regime. We follow Ascari and Ropele (2013) and set T to the number of periods it takes for inflation to fall below 2.1 per cent. In the benchmark case this implies 12 periods.

The disinflation episode leads to an initial increase of the real interest rate and a short-term loss of output. In the small open economy, there is an additional effect from the appreciation of the real exchange rate, leading to a larger output loss. Quantitatively, the sacrifice ratio is 0.97 per cent in the small open economy and 0.68 per cent in the closed economy, i.e., the sacrifice ratio is 0.29 percentage points (or 43 per cent) higher in the small open economy, see Table 2.

The central bank's loss. The sacrifice ratio does not account for the cost of deviating from the new inflation target. To account for the potential trade-off between inflation and output stabilisation, we also compute the cost of disinflation from the central bank's loss function. We assume a loss function with equal weights on inflation deviations from the new target (the inflation gap) and output deviations from the steady state (the output gap). Formally, the loss function $\mathcal{L}$ has the following functional form,

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \left[\left(\pi_t - \bar{\pi}^{low} \right)^2 + \left(\frac{Y_t - \bar{Y}^{low}}{\bar{Y}^{low}} \right)^2 \right]. \tag{43}$$

The loss is 2.228 in the small open economy and 2.209 in the closed economy (we scale the loss by 1000 for easier comparison), see Table 2. Hence, the loss is slightly higher in the small open economy, i.e., about 1 per cent higher.

The welfare cost. The sacrifice ratio and the central bank's loss do not measure the actual welfare cost of disinflation, which should be computed from the households' utility function. We follow Ascari and Ropele (2012) and compute a so-called welfare-based sacrifice ratio, i.e., we compute the percentage increase in consumption that a household would need to be as well off under the high inflation target as under the low inflation target. This value is then normalised by the reduction of the inflation target, i.e., three percentage points in our case. The welfare-based sacrifice ratio tells us how much extra initial steady state consumption a household would have to give up each period to reduce the inflation target by one percentage point. To formally compute this number, we first find the number Δ by solving this equation,

$$\sum_{t=0}^{\infty} \beta^t U\left(C_t^{high} (1 + \Delta), N_t^{high} \right) = \sum_{t=0}^{\infty} \beta^t U\left(C_t^{low}, N_t^{low} \right), \tag{44}$$

where C_t^{high} and N_t^{hig} denote consumption and hours worked, respectively, under the high inflation target and including the transition to the low inflation target, C_t^{low} and N_t^{low} denote consumption and hours worked, respectively, under the low inflation target. The welfare-based sacrifice ratio or for short the welfare cost $\mathcal{W}$ is then computed as follows,

$$\mathcal{W} = \frac{\Delta}{\bar{\pi}^{high} - \bar{\pi}^{low}}. \tag{45}$$

The welfare measure can be divided into of two parts: a transition part and a long-run part. To get the total welfare cost, the transition and long-run parts are summarised. Moreover, the long-run part is negative in the model, since there is a long-run welfare benefit of a lower inflation target from less price dispersion.

To evaluate the welfare cost based on a representative household can be criticised on different grounds, for example, the welfare measure do not take into account that some households become unemployed during recessions and may suffer disproportionally big drops in welfare. Ascari and Ropele

(2012) discuss this and other issues related to measuring welfare. We agree with their conclusion that not only is this welfare measure common in the literature, but it also provides a valuable model consistent measure of the cost of disinflation.

The transition welfare cost. The disinflation episode leads to a recession where both consumption and hours worked remain below their long-run values during the transition to the new inflation target. Less consumption has a negative effect on welfare, while fewer hours worked has a positive effect since it implies more leisure. These two opposing effects more or less cancel each other and the transition welfare cost is very small in both economies. The cost is about 0.0002 per cent of extra initial steady state consumption each period (per each percentage point of reduced inflation) in the small open economy compared to about 0.0006 per cent in the closed economy, see Table 2. The cost is smaller in the small open economy for two reasons. The fall in total consumption is mitigated due to cheaper imported goods and the larger fall in output implies less work and more leisure.

The transition welfare cost in our closed economy model is smaller than in Ascari and Ropele (2012), where the cost is about 0.008 per cent of extra initial steady state consumption each period (per each percentage point of reduced inflation). The model by Ascari and Ropele includes more frictions than our model, for example wage stickiness, which potentially increases the welfare cost.

The long-run and total welfare cost. A lower inflation target is beneficial in the long-run due to less price dispersion in steady state. The long-run benefit is substantially larger than the transition cost. In the small open economy, the long-run benefit is about 0.024 per cent of extra initial steady state consumption each period (per each percentage point of reduced inflation) compared to 0.028 per cent in the closed economy, see Table 2. The long-run and the total welfare benefit of disinflation is thus about 0.004 percentage points (or 14 per cent) lower in the small open economy.

Table 2. The cost of disinflation – benchmark calibration

	Sacrifice ratio	Central bank's loss	Welfare cost (transition)	Welfare cost (long-run)	Welfare cost (total)
Small open economy	0.97	2.228	0.0002	−0.024	−0.0238
Closed economy	0.68	2.209	0.0006	−0.028	−0.0274
Difference (PP)	0.29	1*	−0.0004	0.004	0.0036

Note. PP is an abbreviation of percentage points and the central bank's loss is in per cent, as indicated by the star. A negative welfare cost implies a welfare benefit.

In the model by Ascari and Ropele (2012) there is full price indexation and no price dispersion in the steady state of their model. There is still a long-run benefit of disinflation from a so-called cash-in-advance constraint on firms wage payments. The long-run welfare benefit of disinflation is about 0.07 per cent of extra initial steady state consumption each period (per each percentage point of reduced inflation) in their model, which suggests that the cash-in-advance constraint on firms wage payments is more costly than price dispersion in the long-run.

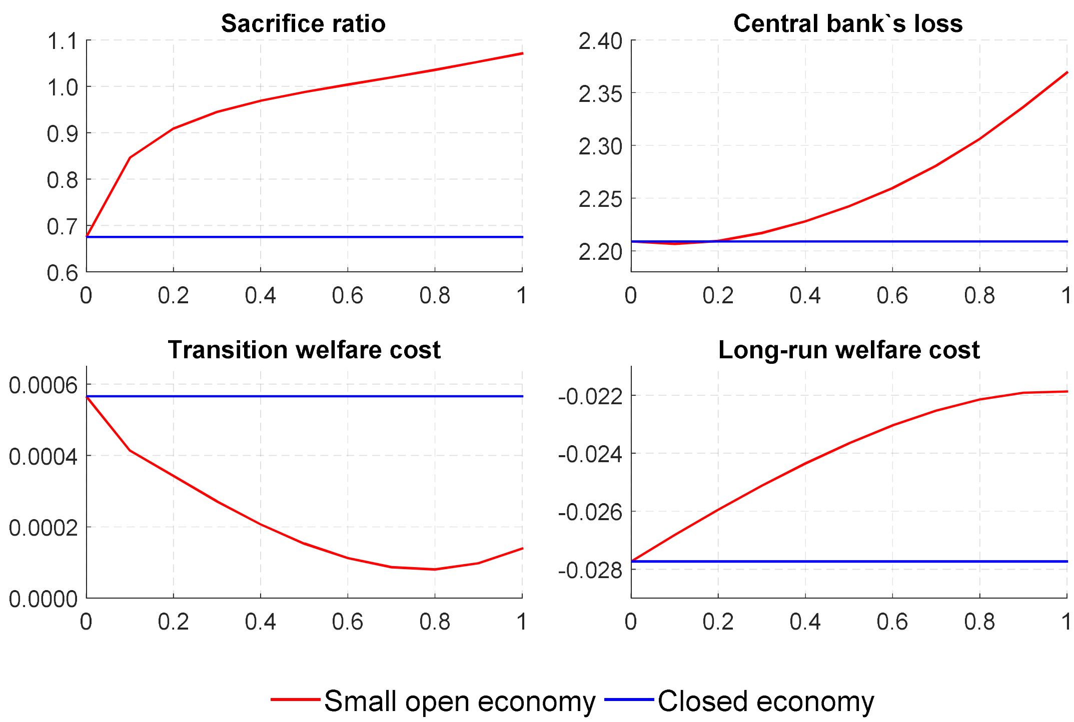
Sensitivity analysis

Sensitivity analysis is carried out with respect to openness, pre-announcement of the inflation target, optimised monetary policy rules and central bank credibility.

Openness

Figure 2 shows how the sacrifice ratio, the central bank's loss, the transition and long-run welfare cost are affected by increased openness (the parameter α is increased from zero to one, i.e., from no openness to full openness). The sacrifice ratio and the central bank's loss are both increasing functions of openness. An increased appreciation of the real exchange rate makes the output gap more negative, which affects both the sacrifice ratio and the central bank's loss negatively. In addition, the effect on the inflation gap is in comparison small, which is shown in Figure 1 for $\alpha = 0.4$.

Figure 2. The cost of disinflation for different levels of openness



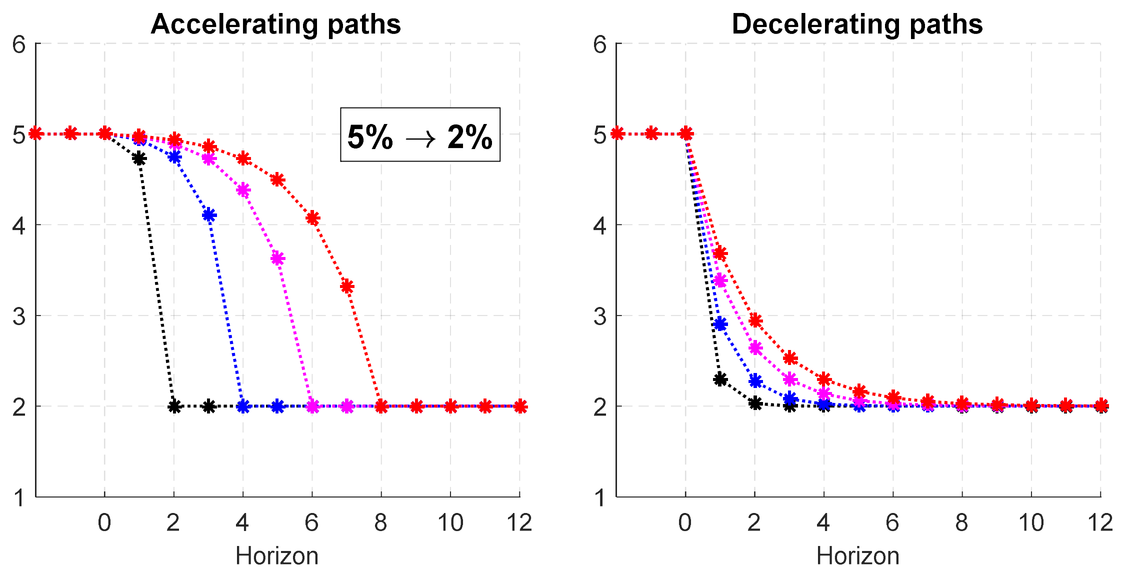
The transition welfare cost is a decreasing function of openness, except when openness is very high. An increased fall of output as openness increases, diminishes the consumption possibilities of domestic goods but this can to some extent be compensated by cheaper imported goods. There is also more leisure available when output falls, and more leisure outweighs less total consumption in terms of welfare.

The long-run welfare cost is an increasing function of openness, or put differently, the long-run benefit decreases as openness increases. The lower inflation target leads to less price dispersion in steady state and as a consequence higher output and imports. However, since we assume that net exports are zero in the long-run, the real exchange rate must depreciate in steady state to ensure that exports and imports are equal. The depreciation stimulates production and domestic consumption, but more domestic consumption is outweighed by less leisure and more expensive imports in terms of welfare. The long-run benefit of the lower inflation target is therefore smaller, the more open the economy is.

Pre-announcement of the inflation target

A potential way to reduce the cost of disinflation is to pre-announce the inflation target, i.e., to announce an implementation path for the new inflation target in advance. We evaluate two pre-announced paths: an accelerating path and a decelerating path, see Wieland (2009). The accelerating path reduces the target slowly initially and then more quickly, while the decelerating path reduces the target quickly initially and then more slowly. The implementation horizons are up to eight quarters for both paths, see Figure 3 for an illustration.[6] The advantage of one path over another generally depends on the frictions in the economy, see Giamattei (2015).

Figure 3. Accelerating and decelerating implementation paths for different time horizons (quarters)

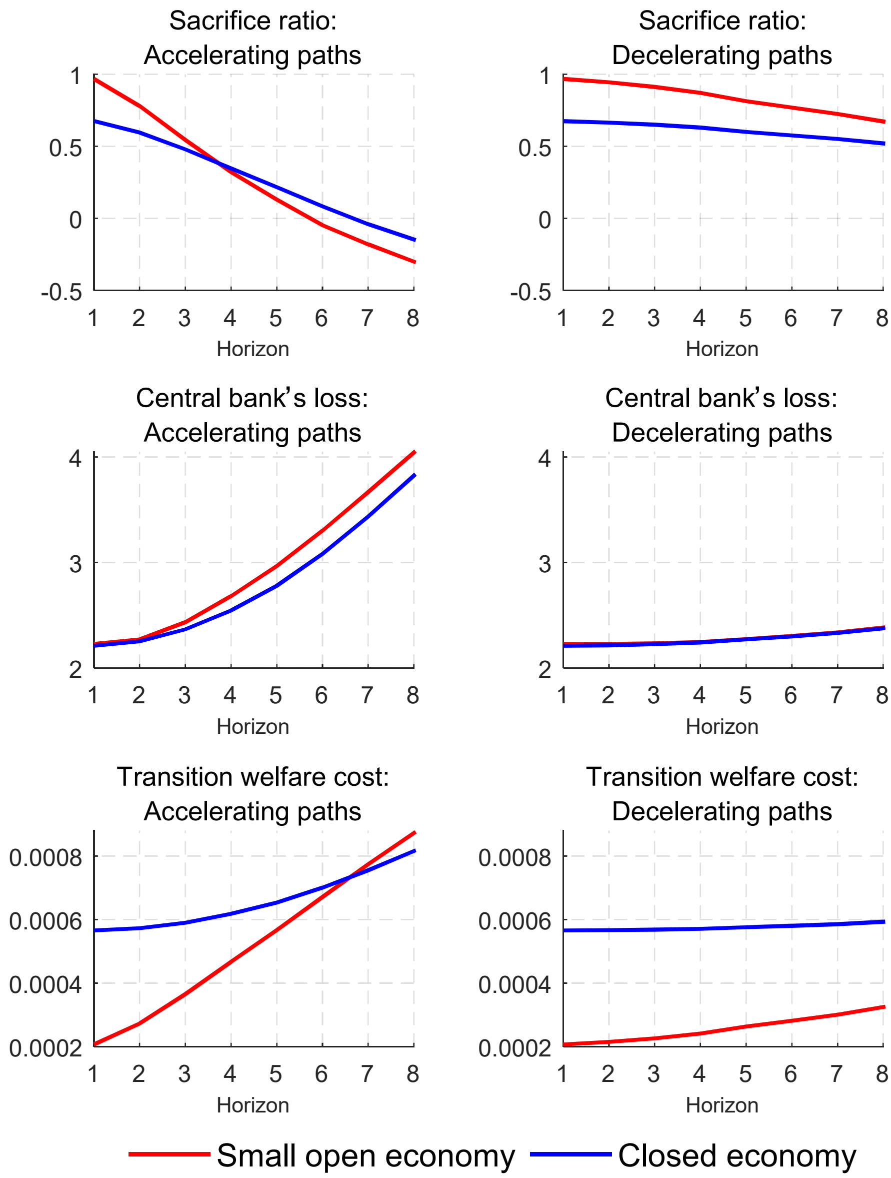


The accelerating paths lead to a reduction of the speed at which inflation reaches the new target. This

[6] For example, the National Bank of Ukraine followed this latter path when introducing an inflation target, see the National Bank of Ukraine's inflation report from July 2019.

in turn mitigates the initial rise of the real interest rate and the initial fall of output. It also mitigates the appreciation of the real exchange rate, which further mitigates the fall in output in the small open economy. Hence, the accelerating paths reduce the sacrifice ratio in both economies, but to a larger extent in the small open economy, see Figure 4. Note also that for longer implementation horizons, exceeding 8 quarters, the sacrifice ratio becomes negative in both economies, implying a benefit of disinflation.

Figure 4. The cost of disinflation when pre-announcing the inflation target and implementation horizons between 1 and 8 quarters



The central bank's loss is in contrast increased by pre-announcing accelerating paths. The prolonged transition of inflation to the new target outweighs the benefit of a smaller decrease in output. The accelerating paths are particularly costly for long implementation horizons in the small open economy, due to an increased mitigation of the downward pressure on inflation from the mitigation of the appreciation of the real exchange rate. For example, if the implementation horizon is 8 quarters, the loss is about 6 per cent higher in the small open economy, compared to about 1 per cent with immediate implementation.

The accelerating paths increase the transition welfare cost in both economies, but to a larger extent in the small open economy. The mitigation of the appreciation of the real exchange rate makes imported goods relatively more costly and increases the welfare cost. For implementation horizons that are longer than 6 quarters, the transition welfare cost becomes higher in the small open economy.

Pre-announcing accelerating paths can have substantial effects on the cost of disinflation, but if the paths increase or decrease the cost depend on the measure. Both the central bank's loss and the transition welfare cost increase and it is generally more costly to pre-announce in the small open economy. Although, the sacrifice ratio can be substantially mitigated, in particular in the small open economy.

The decelerating paths lead to transition paths for inflation that are qualitatively and quantitatively similar to the immediate implementation path. The measures of the cost of disinflation are therefore approximately unaffected by the decelerating paths, see Figure 4.

Monetary policy rules

The Taylor rule is often used to evaluate monetary policy. However, under certain conditions this rule can be a poor guidance for monetary policy. A typical example is a financial crisis, but other events that occurs on irregular bases may also call for a different policy rule. To evaluate this possibility in a disinflation episode, we compute so-called optimised simple disinflation rules. These rules are designed to perform well during a disinflation episode, given a central bank objective. The following general functional form is assumed for the optimised rules,

$$\frac{1+R_t}{1+\bar{R}} = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\rho_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\rho_Y} \left(\frac{Q_t}{\bar{Q}}\right)^{\rho_Q}, \tag{46}$$

where ρ_Q denotes the reaction coefficient on the real exchange rate gap. We consider two common central bank objectives that are frequently studied in the literature: Minimising a loss function and maximising welfare, i.e., maximising the utility function of the representative household. For each of these two objectives, we compute the optimised rules, i.e., optimised loss rules if the objective is to minimise the loss function and optimised welfare rules if the objective is to maximise welfare.

Optimised loss rules

To compute the optimised loss rules, we choose the reaction coefficients in the policy rule that minimise the central bank's loss function during the transition to the new inflation target. Formally, we search for the parameter vector $\rho^{\mathcal{L}} = [\rho_{\pi}, \rho_{Y}, \rho_{Q}]$ of reaction coefficients that solves,

$$\tilde{\rho}^{\mathcal{L}} = \arg\left\{\min_{\rho^{\mathcal{L}}} \mathcal{L}\right\}, \tag{47}$$

where $\mathcal{L}$ denotes the central bank's loss function defined in (43).[7]

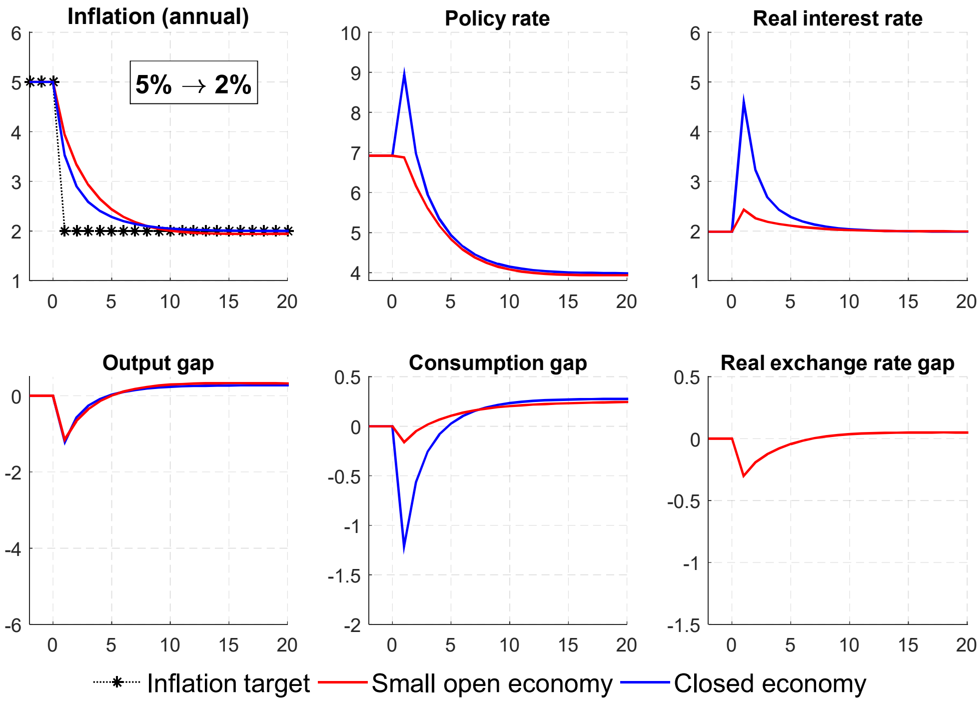
The optimised reaction coefficients in the small open economy are 4.1 on the inflation gap, 0.85 on the output gap, and zero on the real exchange rate gap. In the closed economy, the coefficients are 4.5 and 0.325, on the inflation gap and the output gap, respectively, see Table 3. This implies that the relative weight on inflation stabilisation is substantially lower in the small open economy. The weight is 4.7 in the small open economy, compared to 14.2 in the closed economy.[8] The appreciation of the real exchange rate has two counteracting effects on the central bank's loss: On one hand, it makes the transition of inflation to the new target potentially faster, on the other hand, it increases the output gap. On balance, it is optimal to put a relatively low weight on the inflation gap to mitigate the loss from the output gap, which is more costly on the margin.

Figure 5 shows the impulse responses of the disinflation episode for the optimised loss rules. The policy rate should be reduced smoothly towards the long-run value in the small open economy, due to a relatively low weight on inflation stabilisation. In the closed economy, the relative weight is substantially higher and the policy rate should be raised by about two percentage points. Inflation reaches the new target faster in the closed economy, while the output loss is nearly identical in both economies.

[7] Technically, we simulate the model for different values of $\rho_{\pi}, \rho_{Y}, \rho_{Q}$. For each set-up of parameter values, we compute the central bank's loss and the transition welfare cost. Specifically, $\rho_{\pi} = [1.1{:}\,0.1{:}\,4]$, and for values between 4 and 150 the steps are exponentially increasing, $\rho_{Y} = [0{:}\,0.05{:}\,2]$, and $\rho_{Q} = [0{:}\,0.05{:}\,1]$. We get 8100 simulations for the closed economy and 170100 for the small open economy. In order to avoid corner solutions and extreme parameter values, we define a sub-optimal range covering five per cent of all simulations with the lowest loss and welfare cost values. This is the green area in the diagrams. From this sub-optimal range we select the simulation with the lowest parameter values of ρ_{π}, ρ_{Y}, and ρ_{Y} as the optimised rule.

[8] The relative weight on inflation stabilisation is 4.1/0.85≈4.8 in the small open economy and 4.6/0.325≈14.2 in the closed economy.

Figure 5. Disinflation when monetary policies follow optimised loss rules



If we compare the losses between the two economies from the optimised loss rules with the Taylor rule, the optimised loss rules mitigate the central bank's loss relatively more in the closed economy. The loss is 1.9774 in the small open economy and 1.6310 in the closed economy when the central banks follow the optimised loss rules, see Table 3. The loss is thus about 21 per cent higher in the small open economy, compared to about 1 per cent higher with the Taylor rule.

Table 3. The optimised loss rules and the corresponding central bank loss

	ρ_π	ρ_Y	ρ_Q	Central bank loss
Small open economy	4.1	0.850	0.0	1.9774
Closed economy	4.6	0.325	—	1.6310
Difference in loss (per cent)				21.2

Optimised welfare rules

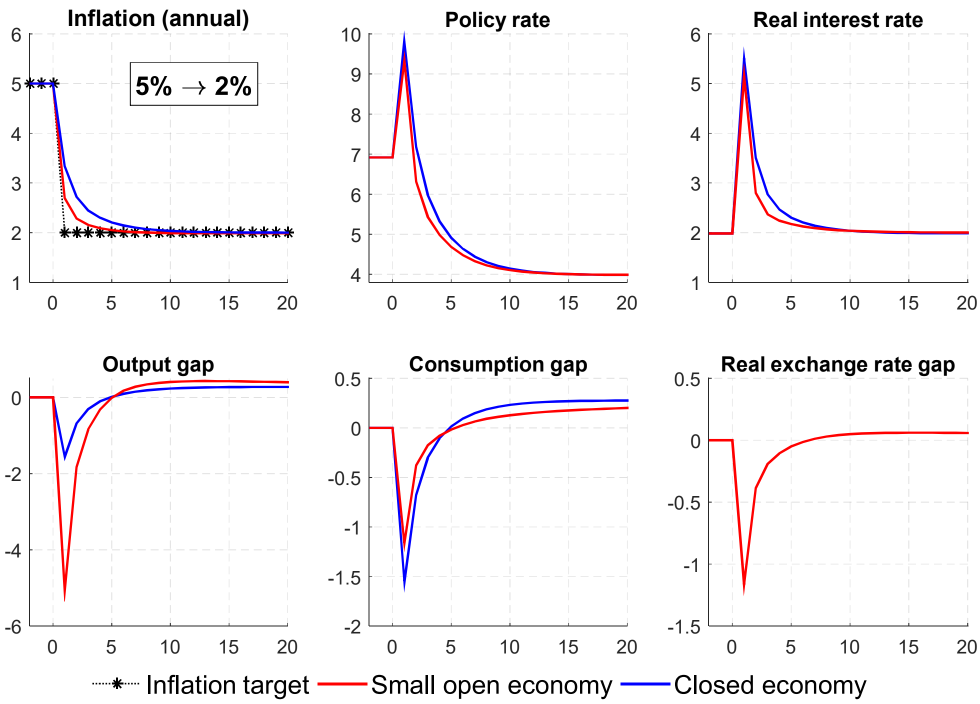
To compute the optimised welfare rules, we search for the parameter vector $\rho^{\mathcal{U}} = [\rho_\pi, \rho_Y, \rho_Q]$ of reaction coefficients that maximise the household's utility function during the transition to the new inflation target,

$$\tilde{\rho}^{\mathcal{U}} = \arg\left\{\max_{\rho^{\mathcal{U}}} \mathcal{U}\right\}. \tag{48}$$

The optimised reaction coefficients in the small open economy are 29.6 and 0.7, on the inflation gap and the output gap, respectively, and zero on the real exchange rate gap, see Table 4. In the closed economy, the coefficients are 6.1 on the inflation gap and 0.3 on the output gap. The relative weight on inflation stabilisation is thus high in both economies, but higher in the small open economy, i.e., 42.3 compared to 20.3.[9] The additional effect of the appreciating real exchange rate in the small open economy makes imported goods cheaper and reduces the fall in total consumption. By putting a relatively high weight on inflation stabilisation this effect becomes stronger, which improves welfare. In sticky price models, optimal policy should typically stabilise inflation fluctuations. These results indicate that this should also be the case in a pure disinflation episode.

Figure 6 shows the impulse responses of the disinflation episode for the optimised welfare rules. The policy rate is raised by near three percentage points in both economies and there is a similar increase in the real interest rate. In the small open economy, the real exchange rate appreciates, which leads to a faster transition of inflation, as well as a larger fall in output. Although, total consumption falls by similar magnitudes in both economies, due increased consumption of cheaper imported goods in the small open economy.

Figure 6. Disinflation when monetary policies follow optimised welfare rules



In terms of welfare, there is a welfare benefit of disinflation in the small open economy, since more leisure outweighs less consumption. The benefit is very small though, 0.00035 per cent of extra initial steady state consumption each period (per each percentage point of reduced inflation), see Table 4. This can be compared to a cost of 0.00021 per cent when the central bank follows the Taylor rule.

In the closed economy, the optimised rule reduces the transition welfare cost to 0.00043 per cent from 0.00057 per cent with the Taylor rule. Compared to the small open economy, the transition welfare

[9] The relative weight on inflation stabilisation is 29.6/0.7≈42.3 in the small open economy and 6.1/0.3≈20.3 in the closed economy.

cost is about 0.00078 percentage points higher in the closed economy, which is a very small number from a policy perspective.

Table 4. The optimised welfare rules and the corresponding transition welfare cost

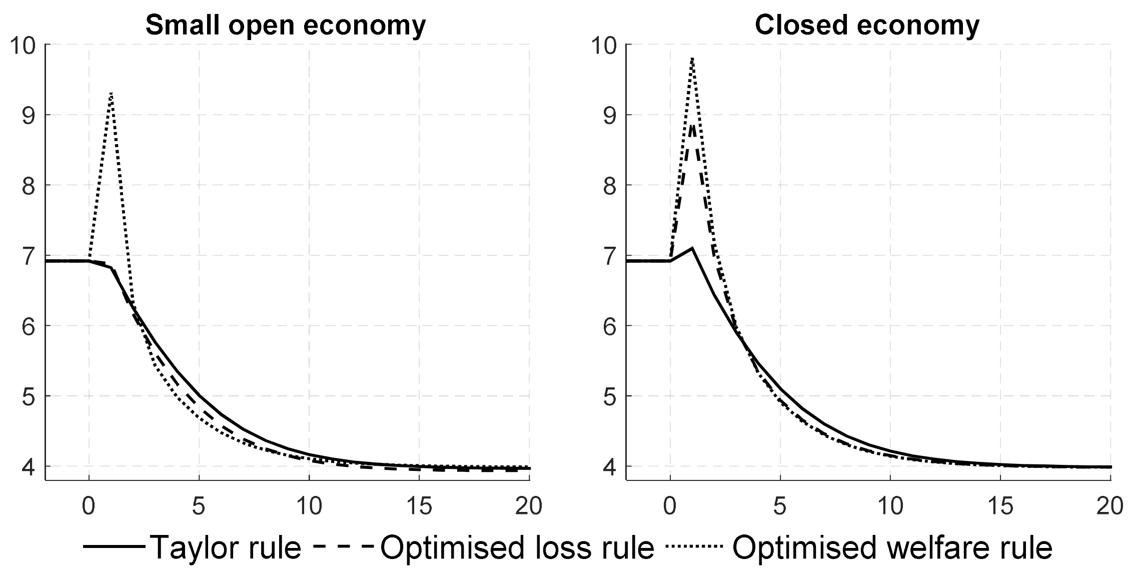
	ρ_π	ρ_Y	ρ_Q	Welfare cost (transition)
Small open Economy	29.6	0.700	0.0	−0.00035
Closed Economy	6.1	0.300	—	0.00043
Difference in loss (PP)				−0.00078

Note. PP is an abbreviation for percentage points. A negative welfare cost implies a welfare benefit.

Policy implications of the different monetary policy rules

Figure 7 shows the policy rate for the three different monetary policy rules during the disinflation episode. According to the optimised loss rule and the Taylor rule, the policy rate should be smoothly reduced towards the long-run value in the small open economy. However, according to the the optimised welfare rule – which puts a high relative weight on inflation stabilisation – the policy rate should be raised by well above two percentage points.

Figure 7. The policy rate for different monetary policy rules



In the closed economy, both the optimised loss rule and the optimised welfare rule put relatively high weights on inflation stabilisation, and the policy rate should be raised by about 2–3 percentage points. This is a substantially higher compared to the relatively marginal increase with the Taylor rule.

To the extent that monetary policy should be conducted differently in the small open economy vis-à-vis the closed economy during a disinflation episode depends on the central bank's objective. If the objective is to minimise the loss function, the policy implications are substantially different. However, if the objective is to maximise welfare, the policy implications are similar. They are also approximately similar for the Taylor rule.

Central bank credibility

The credibility of the central bank influences the inflation expectations of households and firms and, therefore, the cost of disinflation. When the central bank's credibility is high, inflation expectations are shifted down towards the new and lower inflation target relatively quickly, which contributes to a faster and less costly disinflation episode. In contrast, when credibility is low, inflation expectations are to a larger extent based on past outcomes and respond only gradually to the lower inflation target. This mitigates the initial increase of the real interest rate, but the real rate remains above its long-run value for longer. Output falls less initially, but remains low for longer. In the small open economy, the appreciation of the real exchange rate is also mitigated, dampening the initial fall of output further.

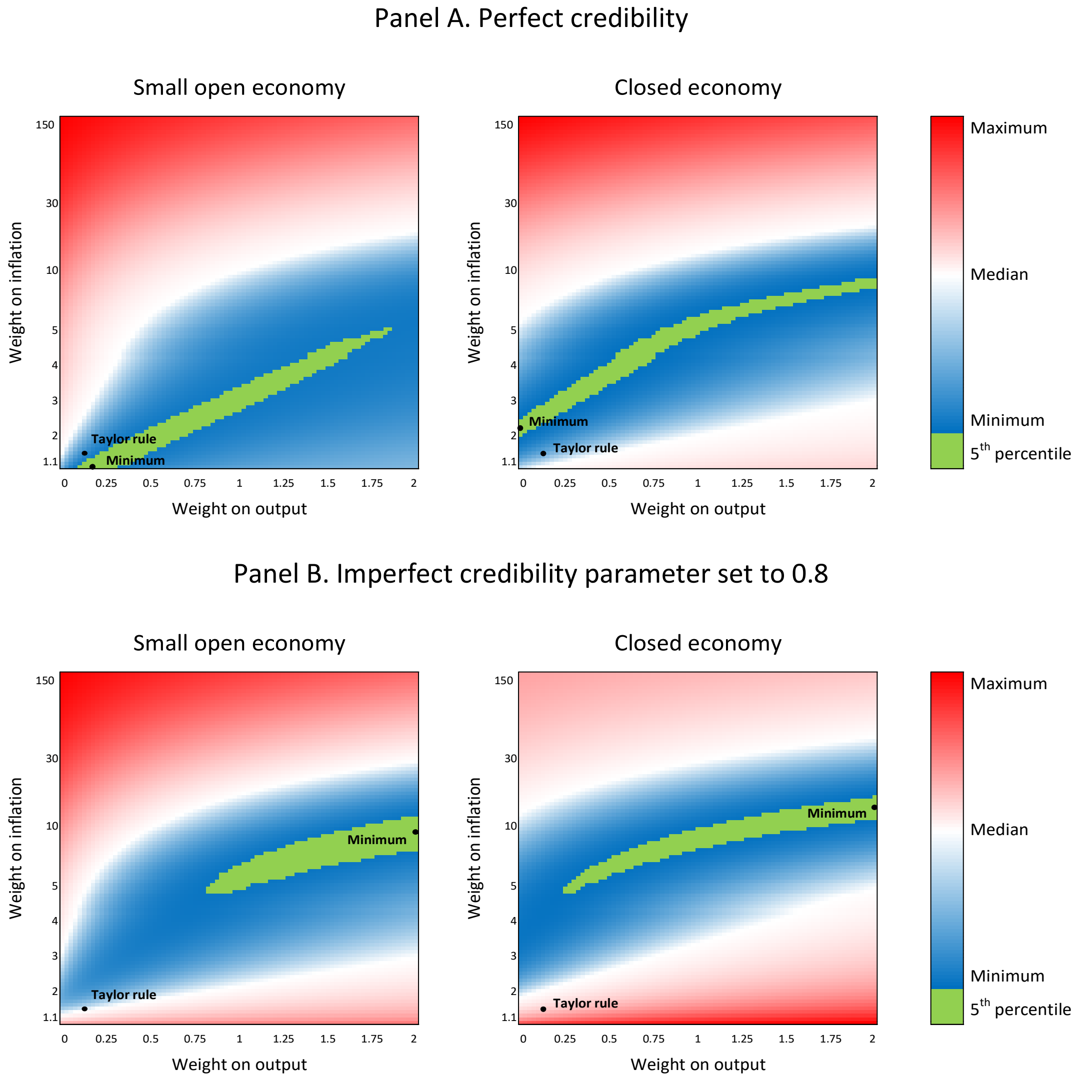
Central bank credibility and optimised rules

We illustrate the impact of imperfect central bank credibility on the optimised monetary policy rules by showing so-called heat maps. These maps show the central bank's loss and transition welfare cost for a given level of central bank credibility, respectively, for different weights on the inflation and output gaps in the policy rule.

The heat maps in Figure 8 show the impact of central bank credibility on the central bank's loss. Panel A shows the case of perfect credibility, while in Panel B credibility is assumed to be imperfect and very low (the credibility parameter is 0.8). The red area shows different combinations of weights on the inflation and output gaps that give rise to high losses. The blue area shows combinations where the loss is lower, and in the green area the loss is within a five per cent margin from the minimum loss. Policy rules within the green area are considered optimised rules according to our metric. The black dots show the overall minimum loss and the loss from the Taylor rule, as indicated.

Panel A shows that for perfect credibility, the green area in the small open economy is below the green area in the closed economy for each weight on the output gap. Hence, the benchmark result that the weight on the inflation gap should be lower in the small open economy also holds for perfect credibility. The Taylor rule in the small open economy is close to the border of the green area and is thus nearly an optimised loss rule according to our metric. However, in the closed economy, the Taylor rule is clearly outside the green area.

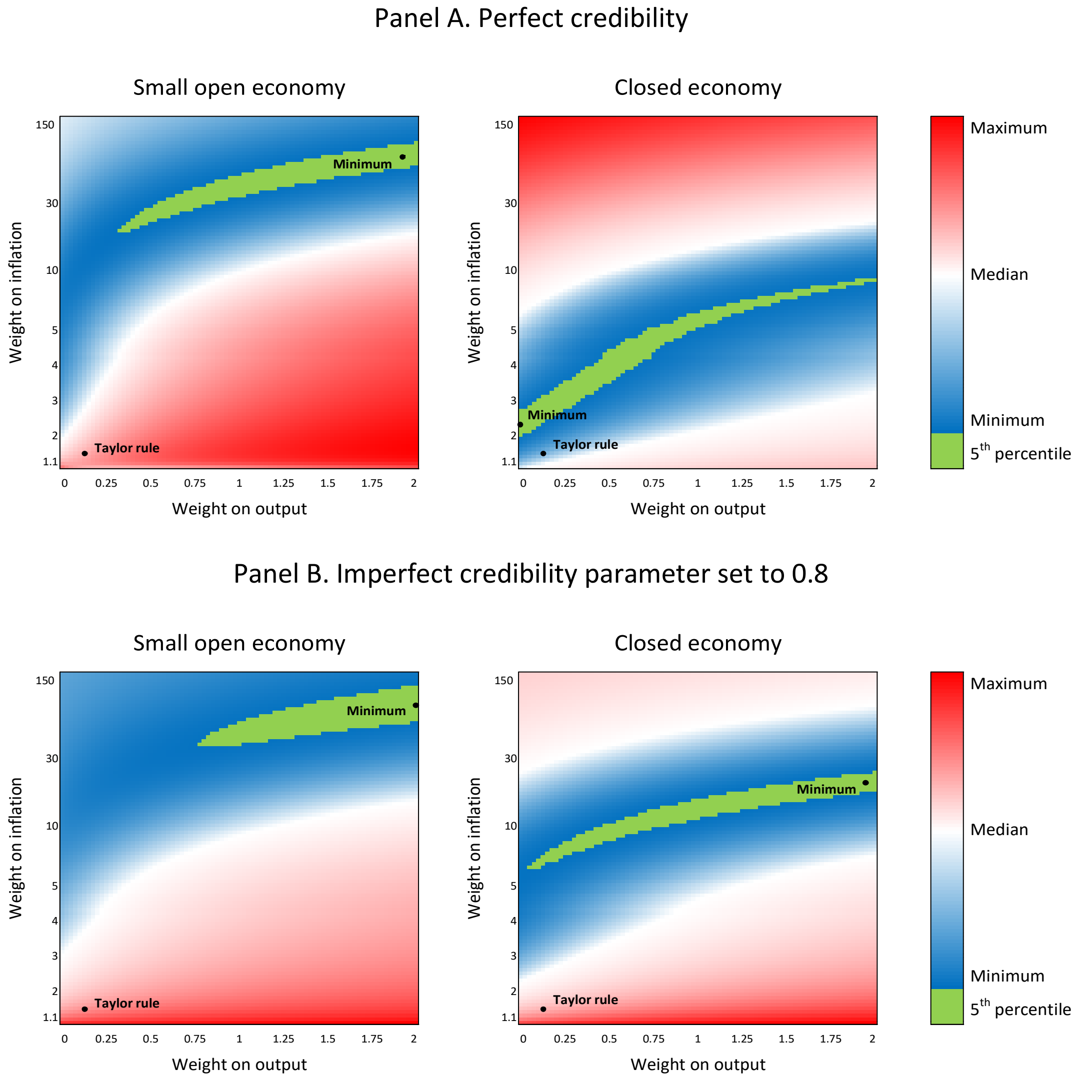
Figure 8. The central bank's loss for different weights on the inflation and output gaps, the Taylor rule and the minimum loss are indicated by black dots.



For the low credibility case in panel B, the relative weight on inflation stabilisation should generally be higher than in the perfect credibility case. At the same time, the weight on the output gap should be increased, but not by as much as the weight on the inflation gap. Moreover, the Taylor rule is clearly outside the green area in both economies, illustrating that the Taylor rule can be a poor guidance for monetary policy when credibility is imperfect.

Figure 9 shows the heat maps for the transition welfare cost. In general, optimal policy should typically stabilise inflation in sticky price models. The heat maps indicate that this is also the case in a disinflation episode both for high and low central bank credibility. Although, the relative weight on inflation stabilisation should be higher in the small open economy, both for high and low credibility disinflation episodes.

Figure 9. The transition welfare cost for different weights on the inflation and output gaps, the Taylor rule and the minimum cost are indicated by black dots.



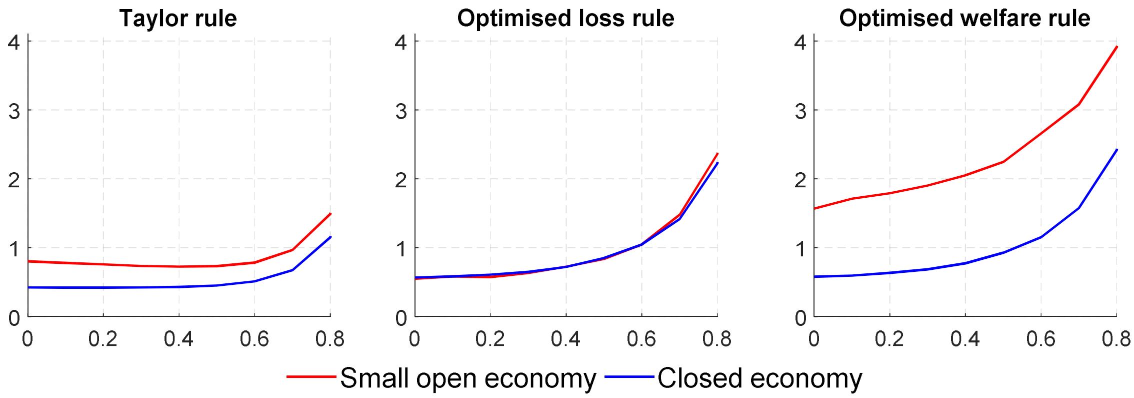
The sacrifice ratio

Imperfect or low credibility has two counteracting effects on the sacrifice ratio. On one hand, the mitigation of the initial fall in output makes the sacrifice ratio lower, but on the other hand, a more persistent fall in output increases the sacrifice ratio. This latter effect is particularly important for low levels of credibility, i.e., for values of the credibility parameter above about 0.5 in the model. This implies a non-linear relationship between imperfect credibility and the sacrifice ratio, see Figure 10.

Neither the Taylor rule nor the optimised rules are designed to minimise the sacrifice ratio. To minimise the sacrifice ratio, the relative weight on output stabilization should, in principle, be as high as possible. This weight is generally higher in the Taylor rule than in the optimised rules, which is why the Taylor rule performs better in terms of minimising the sacrifice ratio.

The sacrifice ratio is higher in the small open economy for both high and low levels of credibility for the Taylor rule. For the optimised loss rules, the sacrifice ratio is only marginally higher in the small open economy, due to the relatively low weight on inflation stabilisation. The opposite is, however, the case for the optimised welfare rules, where the relatively high weight on inflation stabilisation leads to high sacrifice ratios compared to the closed economy.

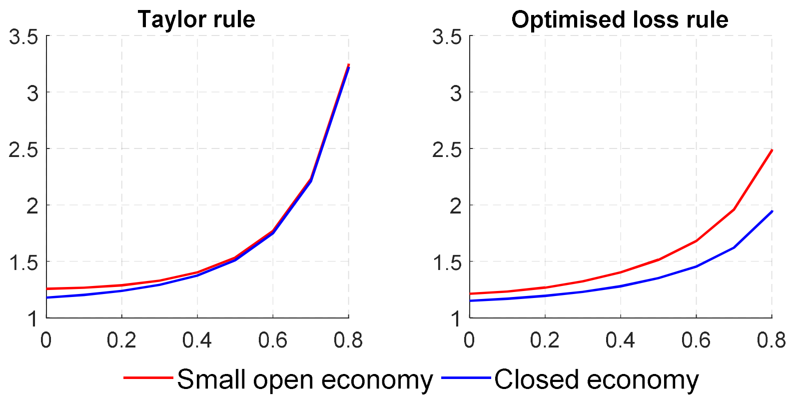
Figure 10. The sacrifice ratio for different levels of central bank credibility



The central bank's loss

The central bank's loss is a convex function of imperfect credibility in both economies, see Figure 11. For the Taylor rule, the loss in the small open economy is a bit higher when credibility is perfect, but as credibility worsens the losgs becomes almost indistinguishable in the two economies.

Figure 11. The central bank's loss for different levels of central bank credibility

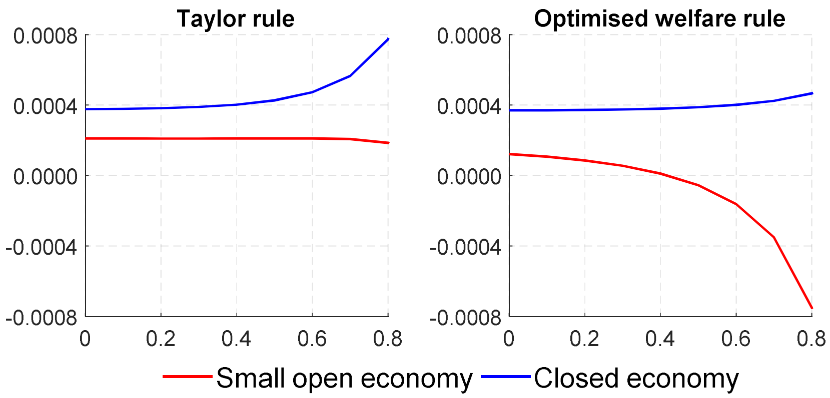


The optimised loss rules mitigate as expected the loss compared to the Taylor rule in both economies, but relatively more in the closed economy as credibility becomes lower. The optimised loss rule in the small open economy puts a relatively low weight on inflation stabilisation, which is particularly costly when credibility is low.

The transition welfare cost

The transition welfare cost is an increasing function of imperfect credibility in the closed economy for the Taylor rule, while the cost is almost unaffected in the small open economy, see Figure 12. In contrast, for the optimised welfare rules the effect of imperfect credibility is negligible in the closed economy, while in the small open economy the cost is a decreasing function of imperfect credibility. The high weight on inflation stabilisation appreciates the real exchange rate further as credibility becomes lower, which increases welfare due to cheaper imported goods. From a policy perspective, the transition welfare cost is very small in both economies and this is the case irrespective of the level of credibility.

Figure 12. The transition welfare cost for different levels of central bank credibility



Concluding remarks

We have quantified the cost of disinflation in a small open economy vis-à-vis a closed economy in a standard new Keynesian model and shown that the cost of disinflation is generally higher in the small open economy. This work can be extended in many different directions. To give a few examples. It would be interesting to consider more frictions. We have limited ourselves to price stickiness and central bank credibility. These two frictions are often considered key for the cost of disinflation, but other frictions such as wage stickiness, search and matching frictions, financial frictions or heterogeneous agents are also of interest to evaluate. We have modelled central bank credibility as an exogenous process. Given that credibility is often a major concern in a disinflation episode, evaluating the effect of endogenous credibility is an interesting extension. Finally, optimal monetary policy – and not just optimised simple disinflation rules – is another interesting area for future research.

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