Modelling the transmission mechanism of monetary policy in the Czech Republic

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1 Introduction

In December 1997, the Czech Republic became the first transitional economy to adopt an inflation-targeting (IT) framework for its monetary policy. This was an important change in monetary policy procedure. The IT framework requires that many types of information be analysed and explained to the public.[2] The central bank must communicate both the weights attached to each macroeconomic indicator and explain how these weights evolve as the economy develops.

This paper attempts to develop a general picture of the monetary transmission mechanism, following the move to an IT framework, and examines what this mechanism means for the Czech IT framework. More specifically, we address two questions about the design of the Czech IT framework:

i What is the optimal inflation-targeting horizon for forward-looking policy?
ii How steep should be the disinflating path for the targeted rate of inflation?

The first question is familiar to other inflation targeting countries. Batini and Haldane (1999(a))[3] found that policy rules with a forecast horizon for quarterly inflation of about three to six quarters appeared to minimise output and inflation volatility in the United Kingdom. When translated into annual inflation rates, this time period is similar to the one- to two-year targeting horizon[4] that is often referred to in the United Kingdom (see Budd, 1998). Batini and Haldane's findings provide a useful benchmark for comparison of results from the Czech Republic; the two countries have different economic structures but similar monetary policy frameworks.

The approach taken in this paper is to calibrate and estimate a small, aggregate, forward-looking model of the Czech monetary policy transmission mechanism. We answered the first question above by comparing the consequences of different forecast horizons for setting interest rates when this model was hit by shocks.

For much of its recent history the Czech Republic has not targeted a constant rate of inflation: inflation has been converging towards EU rates. It is natural then to ask the second question: what is the optimal rate of disinflation to be targeted? Our results can be interpreted as telling us about targeting too rapid and too slow disinflations; we estimate what different rates of disinflation imply for output and trade balances.

Several empirical problems relate to model-based analysis of the Czech economy. Few findings have been established from past research, and the short samples of available data are plagued by structural breaks. One particular example of a coefficient for which no consensus estimate exists is the effect of the output gap on inflation in the Phillips curve. This coefficient is very important because different estimates, all equally justifiable empirically, could significantly affect the estimated short-run output costs of lowering inflation. In order to provide some guidance as to what the inherent uncertainty in Phillips curve estimates could mean for monetary policy, this paper reports on various simulations using different values for this important but unknown coefficient.

Section 2 describes how we constructed our experiments with a model, a policy rule and a set of structural shocks. Sections 3 and 4 present our results on the forecast horizon and timing of disinflation, respectively. Section 5 presents some concluding remarks.

2 Method

This paper aims to explore, first, the consequences of targeting inflation at different horizons and, second, the effect of disinflating at different speeds. The analytical tools to conduct these 'what-if' experiments on monetary policy are presented in this section. We describe how the transmission mechanism, the monetary policy reaction, and the structural shocks faced by the economy were modelled for this paper.

2.1 The model of the Czech transmission mechanism

Batini and Haldane (1999(a)) and Svensson (1999) contain references to the predecessors and theoretical foundations of the small, open economy monetary policy model that we construct. But it is worth reminding ourselves of one reason why this class of models is suitable when working with Czech data.

It is important that the model is semi-structural, particularly in the sense that the transmission mechanism is written independently of the policy regime. Using a structural model partially protects from the Lucas critique. A reduced-form model – unrestricted VARs for example – would be more open to the risk of reflecting the influence of previous Czech monetary policy regimes (see Šmídková and Hrnčíř in this volume), which are of no interest in this paper. Also, in the rapidly changing environment of the Czech economy in transition, untreated estimates on past data can be a poor guide to the present and future. A more structural approach allows priors about economic theory to be imposed on the calibrations to reflect transition. The price to pay is that the paper's results are conditional on these assumptions. The small model comprises the following equations and base-line parameter values:

$$y_t = \ln(\exp dd_t + \exp x_t - \exp m_t) \tag{1}$$

$$dd_t = dd_t^s + c_{10} + c_{11}(i_t - \exp \text{inf}_t) + c_{12}(dd_{t-1} - dd_{t-1}^s) + \epsilon_{1t} \tag{2}$$
with $c_{10} = 0.03$, $c_{11} = -0.37$ and $c_{12} = 0.51$.

$$m_t = c_{20} + c_{21}dd_{t-1} + c_{22}(pf_{t-1} + e_{t-1} - p_{t-1}) + c_{23}\Delta dd_t + \epsilon_{2t} \tag{3}$$
with $c_{20} = 2.82$, $c_{21} = 0.93$, $c_{22} = -0.82$ and $c_{23} = 0.51$.

$$x_t = c_{30} + c_{31}yf_t + c_{32}(pf_t + e_t - p_t) + c_{33}x_{t-1} + \epsilon_{3t} \tag{4}$$
with $c_{30} = -55.17$, $c_{31} = 1.95$, $c_{32} = 0.27$ and $c_{33} = 0.60$.

$$\Delta e_t = c_{40}\left(E_{t-1}\Delta e_t^e - \frac{i_{t-1} - if_{t-1}}{4} + c_{41}\right) + \epsilon_{4t} \tag{5}$$
with $c_{40} = -0.80$ and $c_{41} = -0.02$.

$$e_T = e_{T-1} \tag{6}$$

$$\Delta_4 p_t = \exp \text{inf}_t + c_{50}(\Delta_4 p_{t-1} + c_{51}(\Delta_4 pf_{t-1} + \Delta_4 e_{t-1})) + c_{52}(y_{t-1} - y_{t-1}^s) + \epsilon_{5t} \tag{7}$$
where $c_{50} = -0.47$, $c_{51} = 0.3$ and $c_{52} = 0.5$ or 0.15.

$$\Delta_4 p_T = c_{31}(\Delta_4 pf_T + \Delta_4 e_T) \tag{8}$$

$$\exp \text{inf}_t = c_{70} E_t \Delta_4 p_{t+1}^e + (1 - c_{70})\Delta_4 p_{t-1} \tag{9}$$
where $c_{70} = 0.2$.

The operator Δ_4 indicates the difference between the present value and the value of four quarters ago, and Δ indicates the difference with last quarter's value. The variable $E_t z_{t+s}^e$ refers to the rational expectation of the variable z at time t+s, calculated at time t. The parameters were either calibrated or estimated using data from 1994Q1–1997Q4. Our calibrations are described in the text below. The details of the estimations are in an appendix to this paper.

Since the model is highly aggregated, the simultaneous system can be described as a GDP block, an exchange-rate block, a domestic-price block, and an inflation-expectations block. The model contains two terminal conditions that relate expectations to long-run assumptions on exchange rate and inflation. The model is then closed with a policy rule to be discussed at the end of this section.

Equation (1) in the GDP block is the familiar identity that links real private-sector GDP to the aggregate of real domestic demand, imports, and exports. For simplicity, we excluded government expenditure from demand and output variables. In what follows, we are therefore assuming that the government's behaviour is exogenous.

Equation (2) is the IS curve. Aggregate private-sector domestic demand (dd_t) depends on the cost of borrowing, which depends on a measure of the short-term *extante* real rate of interest ($i_t - \exp \inf_t$) and its lagged value. Domestic demand is affected relative to its steady-state level (dd_t^s) where that steady state is estimated by a simple time trend.

The Czech economy is very open – exports plus imports have steadily increased to reach about 130% of GDP in 1997 – and it is interesting to include an indicator that shows whether inappropriate monetary policy destabilises trade as well as inflation or growth. The import and export equations, numbered (3) and (4), respectively, summarise how trade is linked to growth and inflation through income and price effects. In equation (3), the level of imports (m_t) depends on domestic demand, with the real exchange rate ($e_t + pf_t - p_t$) also being influential.[5] Similarly, the demand for Czech exports (x_t) is both price- and income-elastic, with world demand (yf_t) being especially important. The relatively short dynamics in both equations reflects a quick pass-through of exchange-rate changes onto volumes.

Two important compromises were made in modelling the trade sector. First, imports (and exports) of goods and services were not treated separately. Second, as there is no adequate Czech export price data, only export volume adjustments are explicitly incorporated.

In the exchange-rate block, the dynamic adjustment equation (5) is used to forecast the nominal exchange rate (e_t). The long run is based on the uncovered interest-parity relationship, which equates the expected exchange-rate change to the nominal interest rates at home and abroad (i_t and if_t, respectively) and a constant risk premium, (c_{41}). The parameters of this exchange rate equation are calibrated rather than estimated because the Czech exchange rate data was fixed for much of the estimation period. The risk premium is equal to the average interest rate differential from 1995 to 1997. The value of the other parameter, (c_{40}), determines the extent to which the exchange rate is a random walk as opposed to being given by the interest parity condition. Our base-line calibration implies that any deviation of the exchange rate from uncovered interest parity is temporary – 80% of the short-run disequilibrium disappears by the following quarter. Our checks on this calibration indicated that our results were not affected seriously by using any value where between 30% to 90% of the disequilibrium was eliminated in the first quarter.[6]

The real exchange rate in the Czech Republic has been appreciating at about 5% per year since 1993. This partly reflects the combination of different rates of productivity growth and the equalising of nominal wages between the traded and non-traded goods sectors. Appreciation could also be due to a gradual lowering of the risk premium on koruna-denominated assets. To incorporate this trend and to acknowledge that it is likely to persist, we introduce a constant nominal exchange rate as a terminal condition in equation (6). This would imply that the foreign-exchange market expects the upward trend in real exchange rates to persist as long as inflation in the Czech Republic is higher than that of its trading partners.

The main characteristics of consumer prices (p_t) in a very open transitional economy should be incorporated in the price block. For example, our intuition was that Czech prices are very sensitive to the domestic price of imports,[7] and the exchange-rate effect via import prices would be a major channel of monetary policy transmission in our model. To support our crucial calibrations, we used monthly data to test how consumer prices are determined by foreign prices and with what lags. The details are in the appendix, but the main findings can be summarised as follows:

1 A first step was to estimate how domestic and foreign prices are cointegrated. The bulk of results indicate that in the long run, about one third of any increase in annual import price inflation was passed on to annual Czech consumer price inflation. This was used as a terminal condition for inflation expectations in equation (8).
2 Our estimates also confirm that this import price pass-through is quick. This long-run effect of about a third is reached after about three to six months.
3 The autoregressive lag structure of domestic consumer prices is also important for our results. We estimated this lag length in a VAR using monthly data on domestic consumer prices, disaggregated into its economically interesting components – net inflation and regulated price inflation – with import price inflation as an exogenous variable. The statistical tests on lag length indicate that only recent (at most one quarter ago) past inflation affects current inflation.

Turning to other influences on prices, the GDP output gap measures the extent to which real private sector GDP (y_t) is over the full-capacity level (y_t^s), at which there is pressure on wages and prices. A researcher of western industrialised economies could calculate full-capacity output by using capital stock and employment data to fit a production function. But for the Czech economy, we do not have the luxury of reliable data on the factors that contribute to the non-standard pricing and production decisions over transition. We have instead chosen to approximate the

GDP output gap by fitting a simple log-linear trend to GDP from 1994 to 1997.

In the event, a significant statistical estimate of the influence of this GDP output gap on inflation could not be obtained. Several explanations for this failure are plausible. First, the output gap could be seriously mismeasured. But the measure used, although imperfect, is correlated with other measures of demand pressure, such as the balance of payments–GDP ratio. A second view is that the output-gap effect is simply dormant. In our small sample of past data, the inflation profile could have been dominated by measurement error and transitional shocks. And the type of excess domestic-demand pressures that emerged could have dissipated mostly into trade deficits rather than manifesting as a GDP gap. If these influences were to die away, the output gap effect *would* become more prominent in the future, and imposing a zero coefficient could then prove misleading.[8]

In the face of this uncertainty about the coefficient on the output gap in a Phillips curve equation, this paper allows for a broad range of possibilities by presenting the results from two very different calibrations. In our baseline scenario, the initial effect of a 1% increase in the output gap is to raise inflation by 0.5%, *ceteris paribus*. This value is comparable to an upper bound reported for other countries.[9] We re-ran our simulations with an alternative value for this parameter that approximates the lowest value reported for other countries. For this alternative scenario, a 1% increase in the output gap causes inflation to rise by only 0.15%.

All the price-setting influences are combined in a Phillips curve – equation (7). The functional form that seems best to capture the lag structure assumes that the difference between annual inflation and next-period expected inflation is a function of the lagged private-sector GDP gap and the last-period's deviation of inflation from its long-run relationship with import price inflation. If private-sector domestic demand is in equilibrium, expectations are consistent with actual inflation, and annual inflation is constant, the annual CPI inflation rate will then be described by the long-run relationship with import price inflation.

Due to the absence of adequate labour market data for the Czech economy, we chose not to incorporate wages and employment into the model explicitly. The inflation-expectation block reflects our attempt to model wage-setting behaviour implicitly. Czech wages, particularly in the public sector, have traditionally been set to adjust for future inflation (OECD, 1998). So equation (9) assumes that expectations of annual inflation are a weighted average of forward-looking, model-consistent expectations and adaptive expectations.[10]

The weight on forward-looking as opposed to backward-looking expectations (parameter c_{70}) was calibrated at 0.2. That does seem to be a robust approximation of Czech inflation expectations. Simulations with different values in the plausible range from 0 to 0.5 did little to change the results of the paper. When agents were assumed to have predominantly forward-looking expectations of annual inflation in forming their view on the real interest rate and current inflation, the inflation profile became implausibly unstable.

A cursory summary of the model would describe it as emphasising that the transmission of monetary policy occurs through the exchange rate in the Czech Republic. That seems to be true of the direct effect of the exchange rate on inflation (via import prices). But the indirect effect of policy-induced exchange-rate changes (on the trade balance, and so on output) will only feed through onto prices if the Phillips-curve relationship is significant.

Monetary policy in the model also works through the inflation-expectations and real-interest-rate channels. When are these last two domestic channels important monetary policy transmitters? As inflation is sticky and slow to adjust, inflation expectations are not likely to shift much in response to temporary monetary policy movements. It will be persistent, long-run monetary policy changes that can affect inflation through altering long-run expectations. The real-interest-rate channel describes how nominal interest changes affect the real *exante* interest rate, and subsequently consumption and investment. But the extent to which lower domestic demand affects GDP depends on any offsetting trade imbalances. Whether lower GDP then goes on to reduce inflation further depends on the Phillips-curve link.

A simulation from the model may serve as a guide to the importance of these channels, to the role played by the output gap coefficient in the Phillips curve, and to the model's properties. In this simple experiment, we temporarily raised interest rates by one percentage point for 1995 above its historical values. Chart 1 compares simulations in which the coefficient on the output gap in the Phillips curve is 0.5 to simulations in which the coefficient is zero.

In the experiment with a zero coefficient on the Phillips curve, the only channels through which monetary policy can affect *inflation* are the direct effect of the exchange rate on import prices and inflation expectations. In this zero-coefficient simulation, the import-price and inflation-expectation channels' contribution together is to lower inflation by about 0.45% after a 1% interest-rate rise. That is about half of the 1% maximum fall in inflation when the output gap coefficient is at its largest value. A rough indication of how important these channels are in our simulations is that at their maximum strength, the real interest rate and trade channels together achieve about as much inflation reduction as the import price effect and inflation expectations. Since the interest rate move is temporary, inflation expectations are not likely to be much altered; the largest part of the 0.45% fall in inflation will be due to the import-price effect.

The simulation also shows how the effect of monetary policy in output

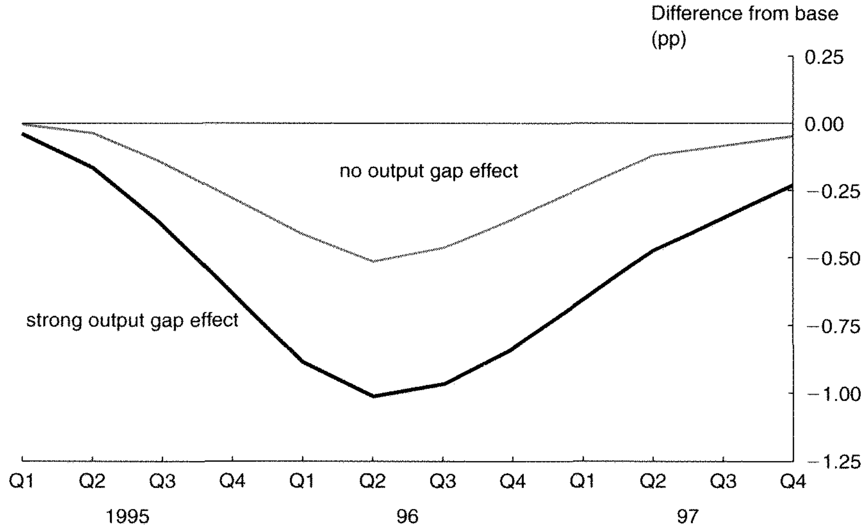

Chart 1a Annual inflation after a 1% interest rate rise for 1995Q1–95Q4

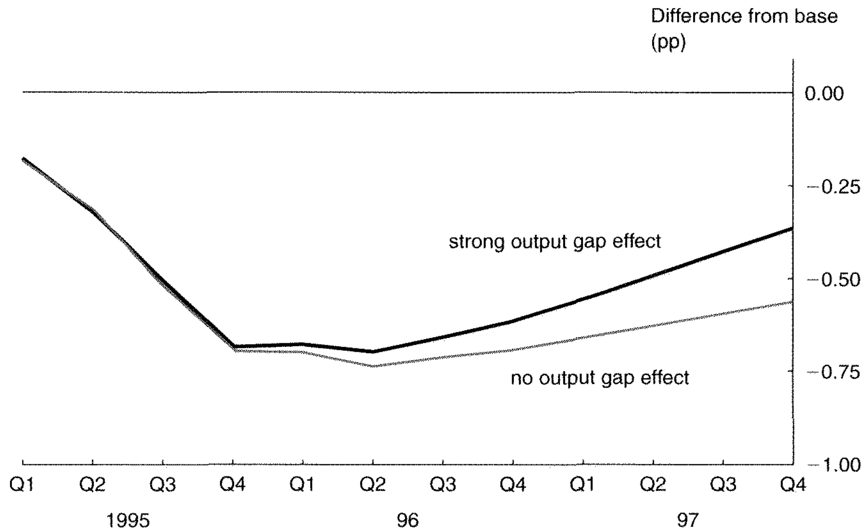

Chart 1b The private-sector GDP gap after a 1% interest rate rise for 1995Q1–95Q4

depends on the output gap coefficient. Lower values of the coefficient reduce the interest rate's influence on inflation and heighten the output costs of the policy tightening; i.e. the trade-off between inflation and output is unequivocally worse with lower coefficient values.[11] Output instability may be as extensive as it is with a weaker Phillips curve may be because the policy rule is switched off in this illustrative experiment. But it could also demonstrate that when the interest-rate rise and consequent exchange-rate appreciation are not matched by an adequate fall in prices, the real exchange rate and the real interest rate both rise. That affects both trade and domestic demand. This sensitivity to the output gap coefficient can thus be expected to feature in the results.

Chart 1 also gives us some idea of the speed of monetary policy transmission. It takes interest rates about one-and-a-half years to exercise their full effect on inflation, irrespective of the output gap coefficient. This transmission is quicker than what we can judge from comparative illustrative simulations for the United Kingdom (Bank of England, 1999). Section 3 explores what this could mean for the forecast horizon.

2.2 The policy rule

A second stage in setting up our experiment is to develop a hypothetical rule for setting interest rates that can be incorporated into the model. This rule is a stylised description of our counterfactual Czech monetary policy. We use it as a yardstick – comparing across different rules approximates a comparison across the monetary policies that they represent.

Our rule can then be written as

$$i_t = c_{80} i_{t-1} + (1 - c_{80})(\text{target}_t + if_t - \Delta_4 pcf_t + \gamma(\Delta_4 p_{t+j} - \text{target}_{t+j})) \tag{10}$$

with base-line parameter values $c_{80} = 0.2$, $j = 4$, and $\gamma = 3$, and the target reflecting a linear rate of disinflation from 9% in 1994 to 2% in 2008.

As a stylised representation of inflation targeting, our interest rate setting rule combines three elements. First, it depends on policy-makers' expectations of the deviation of future inflation ($\Delta_4 p_{t+j}$) from the target rate (target_{t+j}). The choice of horizon (j) at which this is done and the way to set a falling target rate are the subjects of this paper. The expectation of future inflation is calculated as the rational expectation that is consistent with this model. Although shocks remain unanticipated, the incorporation of model-consistent expectations confers some advantage on policy-makers over the public-sector price-setters, whose expectations are largely backward-looking; less advantage is gained over foreign-exchange market participants, whose expectations are more forward-looking.

Another factor in the rule is the equilibrium anchor for interest rates. The assumption adopted was that the Czech real interest rate ($i_t - t\arg et_t$)

would be equal to the world real interest rate ($if_t - \Delta_4 pcf_t$) when the final objective, inflation, is at its target. For consistency, both foreign and domestic real rates in this rule are assumed to be *expost* and in terms of consumer prices.

A low weight on the third component, past interest rates, reflects the assumption that it is less costly to alter nominal interest rates in transitional economies. Czech inflation is expected to trend downward over time and, given the extra difficulties of managing disinflation, Czech policymakers are allowed more leeway in changing nominal interest rates. In our stylised rule, the weight on last quarter's rate, (c_{80}), is 0.2. That is less than the value of 0.5 typically in use in Taylor rule for the United Kingdom and the United States. Furthermore, different values in the range of 0 to 0.5 do not change the qualitative rankings that comprise the results.

2.3 The shocks

The final elements in our experiments are the shocks that hit the economy. The mix should resemble the disturbances that the Czech economy plausibly could face in the future. Many sources of volatility could be unique to transitional economies. For example, the economy could be shocked by repeated corrections in relative prices towards their free-market proportions.[12] But the Czech economy also experiences shocks more typical of other economies: changes in the world demand for Czech goods, falls in commodity and oil prices, and variations in the foreign exchange market perception of the risk in holding koruna-denominated assets.[13]

Given these considerations, we decided to allow for shocks to the following five endogenous variables: domestic demand, imports, exports, the nominal exchange rate, and inflation. These shocks are represented by ϵ_{1t}, ϵ_{2t}, ϵ_{3t}, ϵ_{4t}, and ϵ_{5t}, in equations 2, 3, 4, 5, and 7, respectively. But we wanted to add an extra emphasis to price disturbances arising from abroad, as world prices have been a major source of exogenous external supply-side shocks for the Czech economy; an additional shock from foreign import prices is also included.

In the absence of alternatives, the statistical standard errors of the residuals in our estimated equations were used to scale the variances of the shocks to the endogenous variables. The import price shock was scaled by the variance of foreign import prices, adjusted for trends and structural breaks. Table 1 reports these calibrations.

The simulations were carried out on Winsolve software[14] for the period 1994 to 1997. The rational (or model-consistent) expectations were calculated by a Stacked Newton numerical algorithm. The non-linear parts of the model were also solved numerically by the Newton–Raphson method. The simulations were repeated using 100 draws of antithetic, unanticipated shocks with the predetermined variances above and zero covariances.

Table 1 Scaling of the shocks

Sources of uncertainty	*Standard errors (percentage points)*
	Equation uncertainty
Inflation	0.7
IS curve	3.8
Imports	5.2
Exports	8.2
Exchange rate	2.0
	Exogenous variable uncertainty
Foreign price of imports	6.0

2.4 Caveats

Although the simulations seem to be a reasonable depiction of the Czech transmission mechanism, many limitations remain in the aggregate structure of the model and its calibrations. One important omission is that we have not incorporated credit, money, or wealth effects. Their potential influence cannot be quantified and incorporated easily in this type of model. In particular, it is difficult to find an adequate aggregate measure of credit and money over this period of intense financial innovation.

Nor have we considered how the central bank's instrument, the policy interest rate, transmits to market interest rates, especially on instruments of longer maturities. Instead, this structure is collapsed into one interest rate: the three-month maturity interbank rate. If there were a slow and imperfect transmission to market interest rates, and especially if this were to depend on the policy rule in place, our results would certainly be affected.[15]

More generally, we are not confident that there is an adequate role for expectations in our model. Future research could improve on our findings by incorporating data on published inflation forecasts and also by looking for a forward-looking element in the nominal wage-setting behaviour. A more disaggregated consideration of expectations of price shocks could also be important. Some transitional shocks could be anticipated by agents (e.g. tax reforms) and others not (e.g. the timing of regulated price adjustments).

As far as possible, the robustness of results for different calibrations is mentioned in the paper. But this study does not address the monetary policy implications of model uncertainty in sufficient depth. That would require asking how policy should be altered to cope with stochastic parameters as well as (additive) stochastic shocks as recent articles by Sack (1998) and Martin and Salmon (1999) discuss for the United States and the United Kingdom respectively.

Finally, there are no covariances in the shocks. Allowing for covariance could alter the weights of the different sources of inflation and output volatility and affect the relative performance of rules. The zero-covariance assumption was made in the absence of alternatives. The statistical residuals from our equations did not indicate a significant covariance, although that could easily arise from the poor quality of Czech data. The short data sample does not permit VAR estimates, the other popular way to obtain these estimates.

The results of the simulations could be sensitive to these considerations to a lesser or greater degree. Nevertheless, this paper should be taken as a first step toward addressing inflation-targeting issues for the Czech Republic. Further research could return to improve upon its preliminary conclusions.

3 The search for the optimum forecasting horizon

In principle, targeting inflation at either too short or too long a horizon can be destabilising for both output and inflation.[16] Targeting too short a horizon – reacting to current or even past inflation – runs the risk of using large interest-rate changes to react unnecessarily to temporary movements in inflation. Targeting inflation too far forward in the future runs the risk of allowing damaging inflationary (or deflationary) pressure to build up. The horizons that lie between these extremes are then all possible optima where lower inflation volatility can be procured only with more output volatility.[17] But this theoretical discussion begs the question, how long is too long? And how short is too short? In this section, a first answer is provided for the Czech Republic.

A stochastic simulation is first performed on the model using a policy rule that reacts to current inflation, setting $j = 0$ in equation (10). The experiment is then repeated with ever longer horizons, estimating the unconditional means and variances of output and inflation at each stage.[18] In this initial set of experiments, all the parameters were set at their baseline values. The output gap coefficient in the Phillips curve was set at its maximum value of 0.5. Table 2 reports the outcomes of our experiments over the period 1994Q1–1996Q4 for horizons of up to six quarters ahead. As shall be discussed, the consequences of longer forecasting horizons did not need to be reported in the Czech case.

Arguably, the costs and benefits of different horizons are better understood in terms of inflation and output volatilities than by their mean values. Chart 2 plots the locus that joins the inflation and output volatility pairs from using each forecast horizon. The arrow directs the eye toward longer horizons.

The chart illustrates that the optimal forecast horizon for the Czech economy should be around a year. The inflation and output volatilities for horizons of one to five quarters ahead are bunched together and closest to

Table 2 Inflation and output outcomes with different forecast horizons and a strong output-gap effect*

	Inflation		*GDP output gap*	
Horizon (in quarters)	*Mean*	*Std deviation*	*Mean*	*Std deviation*
0	8.24	6.52	0.64	5.39
1	8.32	4.19	0.78	4.10
2	8.44	3.79	0.88	4.50
3	8.58	3.87	0.99	4.74
4	8.78	4.09	1.40	5.04
5	9.17	4.58	1.50	5.62
6	10.28	7.61	1.45	7.54

* Inflation volatility is measured in terms of the standard deviation of the annual inflation rate from its target path because that is what is relevant for welfare costs. Output volatility is measured in terms of the standard deviation of an output gap for similar reasons. It is the volatility of overall consumer price inflation that is reported, although the Czech National Bank target an inflation rate that is net of the first-round effect of regulated price changes. As regulated price inflation is exogenous in the model, conclusions based on comparisons across simulations should be equally valid for net inflation.

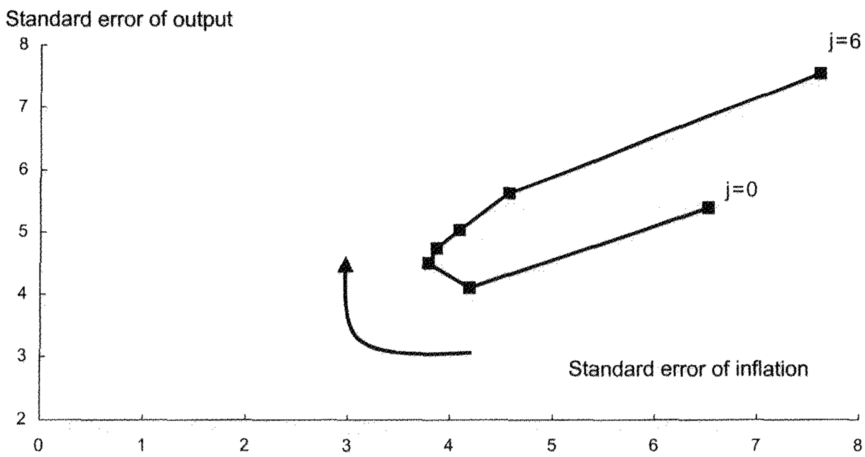

Chart 2 Trade-off between output and inflation variability at different forecasting horizons

the origin. Given the inevitable inaccuracies in our calibrations, one should be cautious in ranking the outcomes within this range. But less than one or more than five-quarter-ahead horizons can be fairly confidently considered sub-optimal in terms of inflation and output volatility. The estimate of optimal policy horizon for the United Kingdom of around two years is likely to be too long a horizon for the Czech inflation-targeting regime.

Why is the favourable horizon shorter in the Czech case? Our intuition is that the Czech Republic has quicker price dynamics than the UK.[19] The Czech economy is very open, and as we measured it, the exchange-rate pass-through is quite fast. It is true that, at least in the public sector, administered wage-setting is a common practice in the Czech Republic. But, following a tradition from the former socialist regime, wage negotiations are more or less co-ordinated at a national level (OECD, 1998) and thus may even act to speed up the transmission of nominal changes.[20] In the absence of more comparative research on nominal rigidities, our results suggest that the target horizon to be incorporated in the Czech monetary policy framework should be somewhat shorter than what is appropriate in the United Kingdom.

There is another intriguing difference between our results and those of Batini and Haldane: in the United Kingdom version of Chart 2, the arrow was pointing in the opposite direction. Taking our results at face value, targeting too recent inflation destabilises inflation more than output in the Czech case, whereas for the United Kingdom, the price of too short a horizon is paid mainly in terms of output volatility. We can hypothesise why the Czech case is different. The slope at the short-horizon end of the locus in general depends on the nominal versus real cost of *short-term* interest-rate volatility. Because the import price effect of monetary policy is quick in the Czech Republic, this short-term volatility of interest rates is passed immediately on to Czech prices without affecting real variables as much. At the longest horizons, the slope of the locus depends on the nominal versus real cost of *longer-term*, persistent interest-rate changes. Persistent unsynchronised movements in interest rates, exchange rates, and inflation rates can be relatively more destabilising for real variables.

The experiment above assumed that the output-gap effect was strong, even though there is little justification for or against any particular value. What would it mean for the targeting horizon if the Phillips-curve effect were much weaker? To answer this question, the experiment was repeated with a smaller output gap coefficient, setting $c_{52} = 0.15$. Table 3 reports the results of simulations with this lower coefficient, and Chart 3 plots the results.

The implications for the optimal forecast horizon do not vary substantially. The locus clearly shifts to the left but its shape stays the same. The optimal horizon can be expected to lie in the same range of two to five quarters.

Why is there such a large shift to the left? Why does a weaker Phillips-curve relationship mean more output instability at all horizons? Some clues may be found in the model's interest-rate impulse responses presented in Chart 1 in the previous section. There it was shown that breaking the Phillips-curve link means that policy-induced nominal exchange- and

Table 3 Inflation and output outcomes with different forecast horizons and a weak output-gap effect

	Inflation		*GDP output gap*	
Horizon (in quarters)	*Mean*	*Std deviation*	*Mean*	*Std deviation*
0	8.24	5.54	1.12	5.65
1	8.29	3.76	1.24	4.77
2	8.38	3.28	1.36	4.98
3	8.48	3.27	1.48	5.15
4	8.60	3.37	1.84	5.38
5	8.87	3.43	1.88	5.93
6	9.45	5.15	1.54	7.67

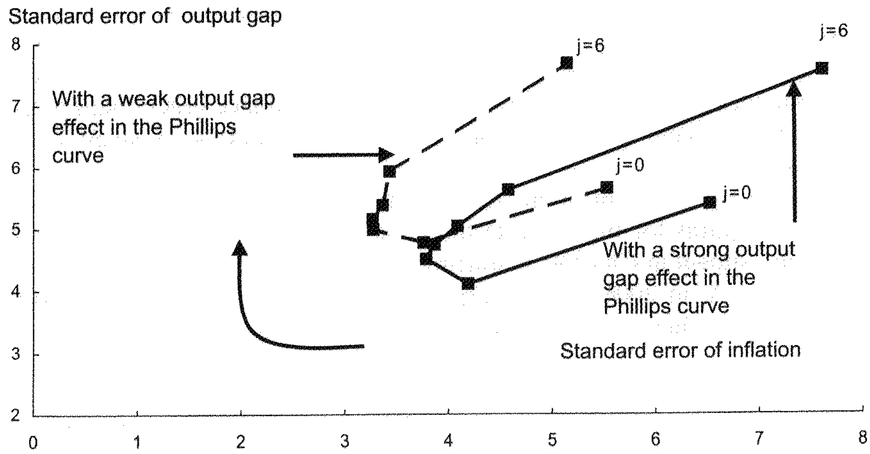

Chart 3 Trade-off between output and inflation variability over different forecasting horizons

interest-rate changes are less synchronised with domestic price movements. With less synchronised nominal variables, the real exchange rate and real interest rate, and consequently real output, can be destabilised.

Other unreported calibrations were carried out to check that the qualitative results do not change for other key parameters of the model and the policy rule.[21] For example, charts similar to Charts 2 and 3 would result from simulations with different degrees of forward-looking behaviour in the exchange-rate and inflation-expectation equations (within what is described as a plausible range in the previous section). In the policy rule, more interest-rate smoothing (a higher c_{80} in equation (10)) and less concern about deviation from target (a lower γ in equation (10)) bunches the outcomes of experiments together. That is hardly surprising; both parameters make interest rates less responsive to the deviations of expected inflation from target. But most importantly for this paper, different values do not change the shape of these trade-off curves.

4 The search for the optimal disinflation strategy

For many transitional countries the key issue is how quickly the inflation rate should converge to lower rates of inflation.[22] In the third simulation exercise, we have tried to find out what our model suggests about the relative costs of different disinflation strategies that could be embodied in a downward-sloping inflation target. We first define the criteria according to which we compare the strategies. Then we describe the alternative strategies themselves.

For this exercise, our set of indicators was expanded to include the ratio of net exports to GDP. Although the trade-off between volatility of inflation and output is still the most important outcome, the experiment now also provides some measure of whether a trade-balance crisis could jeopardise the process of disinflation for a central bank in a small open economy.

To simulate seven different strategies for disinflation, we defined seven alternative paths for the variable $target_t$ in our policy rule, equation (10). These are shown in Chart 4. A starting point of 9% in 1994 and a terminal point of a 2% in 2008 for the target rate are common to all paths. But quite early on there are large differences in the target paths. The slowest

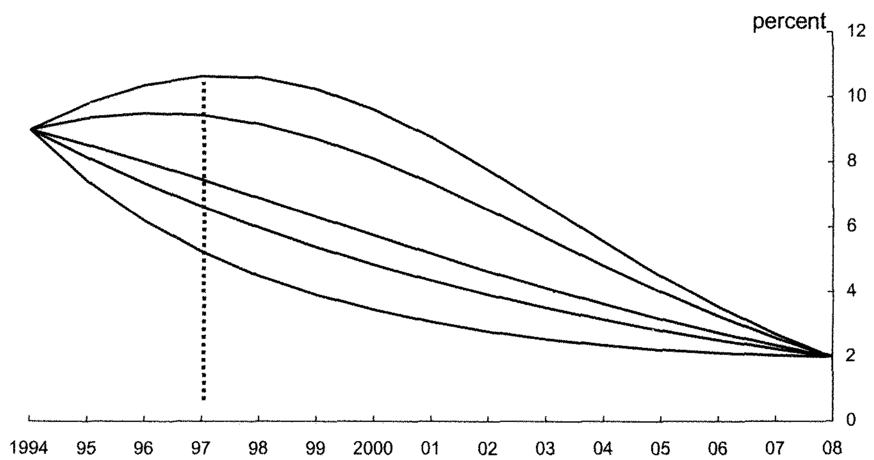

Chart 4 Different target paths for annual inflation

paths allow for a rise in inflation while the quickest paths get through much of convergence without delay. We measure the consequences of disinflation for the initial stage only, over the period 1994Q1 to 1996Q4. The exercise then tells us about the early costs and benefits of rapid versus slow purely policy-induced disinflations. We will return to what this could mean for our results below.

The seven strategies were tested with the same method as the previous exercises. The analogy is straightforward. In the first simulations, the parameter j in our policy rule was varied. Now, j is fixed to reflect a four-quarter horizon, and it is the target rate of inflation that is varied according to the different disinflation paths depicted in Chart 4.

The results of the simulations are reported in Tables 4 and 5 as the unconditional means and standard deviations for inflation, the output gap, and net exports for the two alternative assumptions about the output gap coefficient.

The more lenient, slower paths are better at limiting the volatility of inflation around their higher target rates. What is also interesting is that the tables suggest that quicker disinflation is associated with lower but more stable output gaps early on in transition. This trade-off becomes stark when the Phillips-curve relationship is weaker.

Chart 5 compares inflation and output volatility across the locus of disinflation paths. The arrow now points from fast to slow speeds of targeted disinflation. When there is a strong Phillips-curve relationship there is not

Table 4 Inflation, output, and net export outcomes with different disinflation speeds and a strong output-gap effect*

	Inflation		*GDP output gap*		*Net exports*	
Disinflation speeds	*Mean*	*Std deviation*	*Mean*	*Std deviation*	*Mean (% of GDP)*	*Std deviation (billion Korunas, 1995 prices)*
Fast	6.25	4.21	0.54	5.00	5.87	5.81
	7.15	4.13	1.05	5.01	5.77	5.45
	7.66	4.09	1.34	5.04	5.71	5.24
Linear	8.23	4.05	1.88	5.10	5.64	5.01
	8.84	4.00	2.01	5.20	5.57	4.77
	9.52	3.94	2.39	5.35	5.50	4.53
Slow	11.06	3.83	3.25	5.82	5.33	4.21

* Although the standard deviation of net exports is included for completeness, it may not describe trade flow volatility usefully, in a very open economy with a high-income elasticity of import demand. For example, a large shock that lowered exports would typically lower incomes and so also imports. The shock could even reduce the standard deviation of net exports.

Table 5 Inflation, output, and net export outcomes with different disinflation speeds and a weak output-gap effect

	Inflation		*GDP output gap*		*Net exports*	
Disinflation speeds	*Mean*	*Std deviation*	*Mean*	*Std deviation*	*Mean (% of GDP)*	*Std deviation (billion Korunas, 1995 prices)*
Fast	6.05	3.43	0.67	5.25	6.35	5.10
	6.90	3.39	1.40	5.29	6.32	4.65
	7.38	3.37	1.82	5.38	6.31	4.38
Linear	7.91	3.34	2.28	5.52	6.29	4.09
	8.49	3.31	2.78	5.74	6.27	3.78
	9.13	3.28	3.32	6.03	6.24	3.45
Slow	10.58	3.21	4.57	6.92	6.19	2.90

much grounds for discriminating against any disinflation path except the slowest, at least in terms of inflation and output volatility. With the weak Phillips curve, and a subsequent heightening of output costs, the moderate (near linear) or fastest disinflations are preferable.

Chart 6 links inflation volatility with our indicator of the trade balance – the average net exports to GDP ratio. The arrow again points from fast to slow speeds of targeted disinflation. The chart shows that the fastest disinflations are the least harmful for net exports; this follows because faster

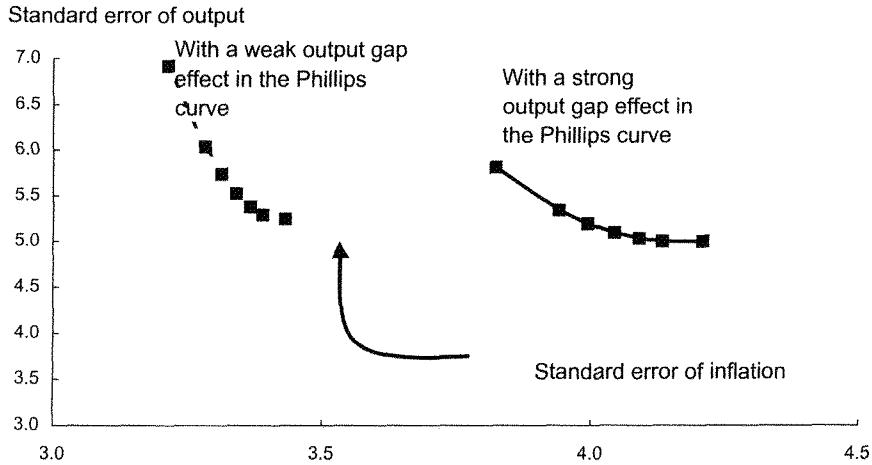

Chart 5 Trade-off between output and inflation variability at different disinflation speeds

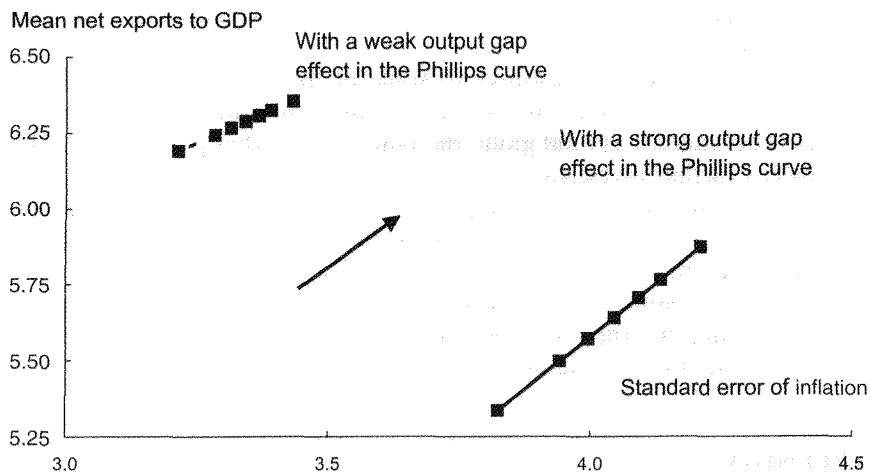

Chart 6 Trade-off between inflation variability and trade balance at different disinflation speeds

disinflations imply lower output gaps and large output gaps a tendency to spill over into trade imbalances, through a greater demand for imports.

To summarise the results of our disinflation simulations, policy rules that aim at moderate or fast disinflations seem to be superior to those aiming at slower disinflation. This conclusion is based only on estimated outcomes over the early years of disinflation. With faster disinflations, costs can be expected to concentrate in the early stage of convergence, while with slower disinflations, they are probably postponed for later. Thus, comparing the costs over the total disinflation period is, if anything, likely to favour faster disinflations.

5 Conclusions

This paper makes a first step towards asking the questions that are important for inflation targeting in the Czech Republic. A small model is presented to capture what constrains policy in a small, open, transitional economy. The transmission mechanism of the Czech Republic is thus analysed in a way that should be informative to monetary policy. Our main finding is that the transmission mechanism in the Czech Republic is substantially quicker than that, for example, in the United Kingdom, with the import price effect being relatively important in transmitting at least temporary interest-rate changes.

We have two main conclusions about the Czech Republic from stochastic simulations with this model. First, the optimal targeting horizon is probably less than a year. Second, postponing the initial disinflation does not imply significant gains in terms of lower output volatility or a smaller external imbalance.

Clearly the results are sensitive to some of the calibrations and this is brought out by repeating simulations for different values of these parameters. This exercise should guide the reader as to what part of the structure merits further investigation and monitoring. In particular, the output gap effect on inflation is a very important calibration in the model simulations and it was not possible to estimate this parameter due to a lack of data. We hope that the results presented here at least prove that it is possible to discover some features of the transmission mechanism of a transitional economy like the Czech Republic and thus provide some basis for decisions about the most suitable Czech policy framework.

APPENDIX

Table 6 Data list*

Name	*Description*
PRIBOR	Czech Interbank Market Rate (Three month maturity, annualised, end of month)
P	Consumer price index
PNET	Net consumer prices
PREGUL	Regulated consumer prices
PF	A weighted average of the German and US export prices, with weights 0.65 and 0.35, respectively
IF	A weighted average of the German and US money-market interest rates, with weights 0.65 and 0.35, respectively (three month maturity, annualised, end of month)
YF	A weighted average of German and US real GDP, with weights 0.65 and 0.35, respectively
PCF	A weighted average of the German and US consumer prices with weights 0.65 and 0.35, respectively
E	A weighted average of the Czech koruna-DM and Czech koruna USD exchange rate with weights 0.65 and 0.35, respectively. A rise indicates a depreciation
DD	Real private sector domestic demand. The sum of private consumption, investment and stock-building (all in real terms)
Y	Real private sector GDP. DD + X − M
X	Real exports (goods and services)
M	Real imports (goods and services)

* Source: IFS and Czech National Bank.

Estimates of the parameters of the model of the Czech economy are presented in the rest of the appendix.

The price system and a Phillips curve: some useful results with monthly data

Three features of the Phillips curve that are important to the model's properties are the long-run pass-through between import prices and consumer prices and the lag structure of this pass-through. Because there is a lack of quarterly data points, these relationships are investigated using monthly data.

The long-run pass-through between import prices and consumer prices

The Johansen and Juselius test of cointegration is well known. The Pesaran, Shin, and Smith (1996) test has the advantage of being robust to whether the variables are I(1) or I(0). It is based on two statistics: a Wald test and an F-statistic whose critical values have been tabulated by the authors.

The Pesaran *et al.* test accepts the null hypothesis of cointegration whereas the Johansen-Juselius test rejects cointegration. The former single-equation tests can be favoured if annual import price inflation is weakly exogenous. Some evidence is reported below that this is indeed the case. Whether the inflation series are I(0) or I(1) cannot be accurately determined using statistical criteria. As the Pesaran *et al.* test is robust to either possibility, we are more inclined to accept the null hypothesis that the series are cointegrated.

The long-run coefficients of the relationship between the two series are estimated by a variety of techniques. First, the coefficient estimates from a Vector Error Correction Mechanism with two lags in each variable are reported. The t-statistics are based on Newey–West standard errors so as

Table 7 Cointegration tests between annual CPI inflation and annual import price inflation[†]

	Null hypothesis	*Alternative hypothesis*	*Sample estimate*	*No. of observations*
Johansen–	R = 0	R = 1	**11.47**	32
Juselius	R <=1	R = 2	**4.16***	
Pesaran *et al.* Wald statistic	Cointegrated if variables I(0) or I(1)		**6.06****	44
Pesaran *et al.* F statistic	Cointegrated if variables I(0) or I(1)		**12.12****	44

[†] * significance at 10%. ** significance at 5%.
Note: R is the number of cointegrating vectors.

Table 8 Estimates of the long-run relationship between annual CPI inflation and annual import price inflation[†]

	No. of observations	*Estimate of c51*	*Asymptotic t-stat*
Johansen	32	**0.18**	1.70
Inders	43	**0.48**	1.73
ARDL IV	43	**0.38**	2.06**
Engle–Granger	32	**0.50**	

[†]* significance at 10%. ** significance at 5%.

to be more robust to any serial correlation arising from estimating annual inflation on a monthly frequency. A second set of values are provided by Inder's (1993) version of the Phillips–Hansen fully modified estimator (1990) which may have good small-sample properties. Third, the Pesaran Instrumental Variable method (ARDL IV) may be useful because (i) it should have good small-sample properties, and (ii) is robust to whether the inflation rates are difference-stationary or stationary. Finally, the results from a simple OLS estimation of the inflation rates, which would be consistent with the Engle–Granger approach, are reported.

The range of estimates of the long-run elasticity from import prices to consumer prices is 0.18 to 0.5 with the upper end more reliable if import prices are weakly exogenous.

To test the exogeneity of import prices, Vector Error Correction Mechanisms between annual domestic price inflation and annual import inflation were estimated with lag lengths varying from 1 to 4. In each case, the coefficient of the cointegrating equation involving these two series and a constant in the dynamic import price inflation equation is insignificant and incorrectly signed. This can be taken as convincing evidence of the weak exogeneity of import prices. As the estimates of the long-run relationship that assume import prices are exogenous are more likely to be valid, we calibrated the parameter c51 in equation (7) to be 0.3.

Lag structure

The dynamics of domestic consumer price inflation is tested with the following assumptions: (i) based on the above finding discussed immediately above, annual import price inflation is supposed to be weakly exogenous; and (ii) consumer prices are disaggregated into their regulated and net price components, as this more general form is expected to provide more information about the structure.

The lag structure between the price components indicates a short pass-through, as a lag of two months is favoured by the criteria in Table 9.

Table 9 Choice of lag length in a monthly VAR with annual net price inflation and regulated price inflation (1994M1–1997M12)†

No. of lags in VAR	*AIC*	*SBC*	*Q-stat test of serial correlation in residuals of net price inflation equation*
2	−12.084	−11.762	insignificant
3	−11.916	−11.434	26.66*
4	−11.776	−11.134	insignificant
12	−11.660	−10.860	insignificant

† Annual import price inflation is exogenous. * significance at 10%. ** significance at 5%.

The IS curve

$$dd_t = dd_t^s + c_{10} + c_{11}(i_t - \exp \mathrm{inf}_{t+1}) + c_{12}(dd_{t-1} - dd_{t-1}^s) + \epsilon_{1t}. \tag{2}$$

Table 10 Estimates of the IS curve†

	TSLS, 1994Q1–1997Q4 *Coefficient*	*Estimates*	*Std. error*	*t-stat*
	C10	0.027	0.008	3.39**
	C11	−0.37	0.177	−2.06**
	C12	0.51	0.135	3.67**
R2		0.38	Durbin Watson	1.8
RBAR2		0.30		
Equation std. Error		0.034		
Sum of squared residuals		0.02		
No. of observations		16		
LM test of 4th order serial correlation (chi sqrd 4)		1.79		
Ramsey RESET (chi sqrd 1)		0.23		

† Actual inflation was used instead of unobservable expected future inflation. Lagged inflation and lagged growth were used as instruments. * significance at 10%. ** significance at 5%.

The import and export equations

$$m_t = c_{20} + c_{21}dd_{t-1} + c_{22}(pf_{t-1} + e_{t-1} - p_{t-1}) + c_{23}\Delta dd_t + \epsilon_{2t}. \tag{3}$$

$$x_t = c_{30} + c_{31}yf_t + c_{32}(pf_t + e_t - p_t) + c_{33}x_{t-1} + \epsilon_{3t}. \tag{4}$$

Table 11 Estimates of the import and export equations†

OLS, 1994Q1–1997Q4 Coefficient	*Estimate*	*Std. error*	*t-stat*	*Coefficient*	*Estimate*	*Std. error*	*t-stat*
C20	2.82	0.70	−0.88	**C30**	−55.17	21.63	−2.55
C21	0.93	0.13	3.56**	**C31**	1.95	2.66	2.67**
C22	−0.82	0.32	−2.77**	**C32**	0.27	0.23	1.17
C23	0.51	0.24	2.15**	**C33**	0.60	0.19	3.02**
R2	0.91	Durbin Watson	2.13		0.32	Durbin Watson	2.91
RBAR2	0.89				0.23		
Equation std. error	0.052				0.082		
Sum of squared residuals	0.033				0.107		
No. of observations	16				16		
LM Test of 4th order serial correlation (chi sqrd 4)	1.37				8.37*		
Ramsey RESET (chi sqrd 1)	0.05				0.04		

† * significance at 10%. ** significance at 5%.

The Phillips curve

$$\Delta_4 p_t = \exp \inf_{t+1} + c_{50}(\Delta_4 p_{t-1} + c_{51}(\Delta_4 pf_{t-1} + \Delta_4 e_{t-1})) + c_{52}(y_{t-1} - y^s_{t-1}) + \epsilon_{5t} \quad (7)$$

where c_{51} is calibrated at 0.3 and c_{52} is calibrated first at 0.5 and then 0.15.

Table 12 Estimates of the Phillips curve[†]

TSLS, 1994Q1–1997Q4 *Coefficient*	*Estimates*	*Std. error*	*t-stat*
C50	−0.47	0.134	−3.50**
Constant not significant			
R2	0.50	Durbin Watson	2.30
RBAR2	0.43		
Equation std. error	0.007		
Sum of squared residuals	0.001		
No. of observations	16		
LM test of 4th order serial correlation (chi sqrd 4)	4.36		
Ramsey RESET (chi sqrd 1)	1.53		

[†] Using lagged inflation and growth as instruments. * significance at 10%. ** significance at 5%.

Notes

1 We would like to thank Nicoletta Batini and Jagjit Chadha for helpful comments and suggestions. The views and opinions are those of the authors alone and do not represent the Czech National Bank or the Bank of England.
2 'One of the main features of the inflation targeting strategy is its transparency. In the regimes of exchange rate targeting and monetary targeting, inflation targets are usually implicit. Moreover the speed and timing of the disinflation process are not specified properly in those regimes. In the inflation targeting regime, the central bank, through its inflation report, openly announces its disinflation intentions and acquaints the public as much as possible with the implementation of its policy' ('Introduction' in *Inflation Report*, April 1998, Czech National Bank).
3 See also Batini and Haldane (1999(b)).
4 The optimum forecast horizon is conceptually different to the optimum targeting horizon. The former strictly refers to how far in the future is the expected inflation that interest rates should react to in a policy rule. The latter refers to the point at which expected inflation and the target are in line in policy discussions. Estimating the former should provide us with some approximate guide as to where the latter lies.
5 Although re-exporting seems to be a feature of the Czech economy, we did not find that exports were separately significant in the import equation.

6 It could be argued that any degree of dynamic exchange adjustment is inappropriate to model exchange rates on quarterly data; uncovered interest parity should hold at all times. But a fully forward-looking exchange rate makes the model of this open, transitional economy unstable. And our results emphasise how quickly monetary transmission through the exchange rate occurs in the Czech Republic. By slowing it down artificially, we are, if anything, providing further support for our findings.

7 The hypothesis is based on several observations. There are no substitutes for imported raw materials and some intermediate-good inputs. And although in the final-goods markets for tradables there is enough competition between domestically produced goods and imports to mean that these domestic producers are forced to be price-takers, in the non-tradable goods sector production cost increases are passed on to consumers.

8 An absence of stable Phillips curves estimated on 1970s US and Western European data did not negate the emergency of more robust relationships in the 1980s. See, for example, Di Nardo and Moore (1999).

9 As an example, Britton and Whitley (1997) report the following values for output gap parameter in Phillips curve: 0.5 in the United Kingdom, 0.2 in France and 0.3 in Germany.

10 Indeed one of the reasons that the CNB chose inflation targeting was the feeling that it was important to anchor inflation expectations in wage-setting with a transparent framework (CNB, *Inflation Report*, April 1998).

11 Theoretical models of the Phillips curve associate a lower coefficient for the output gap with more nominal rigidities. For example the coefficient would rise with a higher cost of nominal price adjustment. More nominal rigidities mean more real effects of monetary policy.

12 The transitional shocks and their consequences are described by several studies. See for example Hájek (1997).

13 An assessment of the importance of external shocks is reviewed in inflation reports. See, for example, *Inflation Report*, July 1998 and October 1998, Czech National Bank.

14 Richard Pierse, University of Surrey, United Kingdom.

15 Svensson (1988) develops a small model in this mould that explicitly incorporates interest rate transmission and allows for expectations of monetary policy to influence this channel.

16 For the problem of targeting too short a horizon, see the voluminous literature on forward-looking versus current or backward-looking rules (e.g. Svensson (1997)). Difficulties with using too long a horizon are usually explained with reference to Woodford (1994) and Bernanke and Woodford (1997).

17 The precise optimum horizon would depend on the society's relative welfare preferences over output and inflation volatility.

18 The unconditional standard deviations of the variables of interest were estimated by the following method: first we estimated the standard deviation across time for each simulation and then we averaged these estimates across simulations.

19 Erceg *et al.* (1999) relate the trade-off between output and inflation volatility to wage and price stickiness.

20 Vávra (1999) suggests that Czech wage-setting displays real rigidity but not as much nominal rigidity. See Grubb *et al.* (1983) for a distinction between real and nominal rigidity in wage setting.

21 In order to establish a constraint for one parameter in the policy rule, we have to assume a particular functional form for the policy rule and near optimal values for the other parameters. In principle it is possible to vary more than one policy parameter according to a grid and so explore the policy-makers'

constraint in many dimensions but we leave this as a topic for further research.

22 Sargent (1982) and Gordon (1982) provide contrasting evidence about the costs of disinflation. Ireland (1997) reconciles their views in a model with large fixed costs of price adjustments. He suggests that an optimal strategy might be to target a quick disinflation initially and replace with a gradual disinflation once the lower inflation rates are reached. This strategy would be represented by our fastest disinflation paths.

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