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EDITORIAL

Ten years of inflation targeting in the Czech Republic has given us great experience in practical policy-making as well as in the development of theoretical models. In fact, it has generated a solid base of theoretical models, helping in policy-making. This issue of the CNB Research Bulletin is devoted to recent articles further enriching the current scope of theoretical frameworks, in particular dynamic stochastic general equilibrium (DSGE) models. DSGE models reflect the maximisation of the objectives of households and firms. The advantage of this approach is that it summarises the view of economic agents in a theoretically coherent way and imposes discipline on the interpretation of economic behaviour. The first three articles address the issue of optimal monetary policy strategy. Monetary policy rules and subsequent welfare analyses are central in their contribution to the literature. The fourth article deals with long-run trends.

The first article implements a rich structure of the economy and derives the optimal monetary policy rule. It is suggested that optimal monetary policy strategy should be concerned not only with the volatility of inflation, but also with the volatility of the output gap and the exchange rate. The second article studies the effects of an anticipated future change in the monetary policy rule. It is shown that the economy starts to behave differently even though the current monetary policy rule remains the same for the whole period before the monetary policy regime change. The third article overviews the four generations of the DSGE models. It suggests that communication with the public is essential for optimal monetary policy to be effective. It also deals with transparency issues that support effective monetary policy. The last article focuses on the long-run trends. It aims at explaining the path of a converging emerging market economy. The major contribution to the existing literature is in the inclusion of quality investment in the model, which turns out to be crucial in explaining the observed trend in the real exchange rate, in addition to capturing the dynamics of key macroeconomic variables.

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IN THIS ISSUE

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Welfare-Based Monetary Policy in a Two-Sector Economy

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In recent decades the approach to monetary policy conduct has shifted to a more systematic one. Many central banks have formulated their policy objectives explicitly and, more specifically, have announced their commitment to price stabilisation as the overriding policy goal. As a result, a new operational framework has been introduced by the most advanced central banks in order to match the officially stated goals of macroeconomic stabilisation with their practical realisation. Inflation targeting, which implies a quantitative specification of the desired level of inflation, has gained a reputation as being a strategy capable of generating stable and non-inflationary growth, thus strengthening the policy credibility and reputation of the monetary authority. At the same time, important features of modern economies, such as the social and economic consequences of unemployment, uncertainties of various types, asymmetric economic structure, and interrelations with the rest of the world, have brought about efforts to widen the range of policy objectives beyond inflation (price) stability alone. Therefore, over the past several years, the attention of economists has turned to the issue of whether strict inflation targeting indeed represents the best strategy from the welfare viewpoint.

Such an analysis has been performed in a number of studies. One thread in the literature computes optimal policy under assumed welfare objectives. In particular, the loss function of the central bank usually takes the quadratic form with terms such as inflation (CPI or domestic) and the output gap, with the weights in front of each target chosen ad hoc. This approach is very popular in applied research because it greatly simplifies the derivations and brings the model dynamics closer to the real data. At the same time, such an approach assumes certain policy objectives a priori. An alternative methodology analyses optimal monetary policy on the basis of the objective function of the central bank, which is derived from micro-foundations. This paper contributes to the second class of literature and adds to the analysis of optimal policy in open economies. It has been shown that welfare-maximising monetary policy in a closed economy should aim to completely stabilise CPI inflation and the output gap (Woodford, 2003). In the literature on open economies, the critical questions are whether the central bank should also target open economy variables, i.e. the exchange rate, and how the targeting of domestic variables changes under the exposure of the economy to external factors. Another topic which has attracted a great deal of attention from both researchers and practitioners is related to the determination of the appropriate inflation measure that has to be stabilised.

In this paper, we analyse the stabilisation objectives of optimal monetary policy and the trade-offs facing the central bank in a two-sector small open economy model obtained as a limiting case of a two-country Dynamic Stochastic General Equilibrium framework. We assess the role of openness, general preferences and structural asymmetries for monetary policy and welfare in a model with nominal rigidities.

We contribute to the normative analysis of open economies by introducing a more complicated economic structure, namely multiple domestic sectors combined with a variety of domestic (sector-specific) and foreign shocks. In addition, we consider a general specification of preferences (non-unitary values of the risk aversion parameter and elasticity of substitution). These features of the model differentiate our work from the previous studies, which derived their results for the special cases of consumer preferences described above or, alternatively, relied on the ad hoc objective functions and welfare representations obtained for closed economy models. By abstracting from those simplifying assumptions we are able to uncover additional welfare effects specific to the open multisectoral economy and make a methodological contribution by deriving the utility-based welfare measure and the optimal reaction function of the central bank under more generalised preferences. For this purpose we employ the linear-quadratic solution methods discussed

1 This article is based on Rychalovska (2007).

in Benigno and Benigno (2006) and Benigno and Woodford (2005), which involve computation of a second-order approximation of the utility function and model structural equations. This approach enables us to analyse the determinants of optimal monetary policy and rank alternative monetary policy regimes on the basis of a rigorous welfare measure derived from micro foundations and approximated by a tractable quadratic form. The idea of this method is to explore the dynamic characteristics of the model and thus to account for the impact of the second moments of the variables on their levels.

RESULTS

The results of our study suggest that the loss function of the central bank, which describes the welfare-maximising stabilisation objectives, displays the features of an open economy and a multisectoral economic structure. Specifically, it is shown that social welfare is affected by variations in domestic inflation rates and output gaps (with sector-specific weights) as well as in relative prices (the exchange rate). The exposure of one of the domestic sectors to the external environment determines the presence of an open economy term in the loss function and also affects the decomposition of weights between domestic variables, which the central bank aims to manage. In particular, under the optimal policy, the sector that is open to trade is allowed to adjust more in response to shocks compared to the sector that produces goods for internal consumption. Such a result implies that domestic sectors (inflation rates and output gaps) respond differently to shocks and cannot be simultaneously stabilised by the monetary authority. Under the derived welfare measure, the variations in the non-traded sector variables produce higher welfare losses compared to their traded sector counterparts. Therefore, in our model specification, the optimal policy cannot attain all monetary policy targets at the same time. In addition to the inflation-output gaps policy trade-off, there is a conflict between the objectives of the domestic inflation measure and real exchange rate stabilisation. This outcome significantly complicates the task facing the policymaker, i.e.

TABLE. 1

Welfare Ranking of Optimal Simple Rules

Policy Rule	Optimised Coefficients				Loss to Optimal $\frac{V^{OSR}}{V^{OPT}}$
	k_1	k_2	k_3	k_4	
Domestic Inflation Targeting (DIT):					
1. $\pi^D = 0$	-	-	-	-	1.333
DIT-Output Targeting:					
2. $k_1\pi^D + k_2 Y = 0$	1.91	0.04	-	-	1.215
3. $k_1\pi^D + k_2 Y_H + k_3 Y_N = 0$	2.05	0.05	0.15	-	1.090
4. $k_1\pi^D + k_2 Y_H + k_3 Y_N + k_4\pi^D_{-1} = 0$	1.99	0.05	0.13	1.09	1.069
DIT-Output-Exchange Rate Targeting					
5. $k_1\pi^D + k_2 Y + k_3 ER = 0$	2.07	0.06	0.03	-	1.092
Sector-Specific Inflation Targeting:					
6. $k_1\pi_H + k_2\pi_N = 0$	0.66	1.34	-	-	1.305
7. $k_1\pi_H + k_2\pi_N + k_3 Y + k_4 ER = 0$	0.60	2.86	0.09	0.05	1.059
CPI Targeting:					
8. $\pi^{CPI} = 0$	-	-	-	-	2.532
9. PEG	-	-	-	-	2.989

to balance several to a certain degree conflicting objectives. We characterised the optimal policy by the optimal targeting rule, which is a rather complex expression.

We experiment with alternative simple rules and analyse their ability to replicate the optimal solution. Our numerical results suggest that the type of shock is an important determinant of the comparative performance of optimal versus simple policy rules. Specifically, the optimal response differs the most from the simple rules under fiscal and mark-up shocks. On the contrary, the domestic inflation targeting regime better approximates the optimal plan under foreign and productivity shocks.

Table 1 reports the relative (to optimal) welfare losses associated with various types of Optimal Simple Rules (OSRs) – rules of a simple structure but with optimised coefficients.

Table 1 indicates that the welfare losses under the OSRs are on average (except for the CPI and PEG regimes) 10–30% larger compared to the optimal rule. The ranking of alternative regimes suggests that strict targeting of domestic or CPI inflation rates is not the best approximation for the optimal policy, and social welfare can be improved by accounting for other policy objectives, namely the output gap and the exchange rate. The rules that account for sector-specific output gaps perform better compared to the case of targeting the aggregate variable. At the same time, augmenting the rule that responds to domestic inflation and total output with an exchange rate term allows one to achieve a welfare result that is nearly equivalent to the case of targeting the traded and non-traded output gaps separately. Such an outcome is important because a strategy which differentiates the response between domestic sectors is difficult to design and implement in practice. Stabilisation of the appropriately weighted average of the sectoral inflation rates (rules 6 and 7) produces better results than DIT. The poor performance of CPI targeting can be explained by the excess smoothness of relative prices which this regime entails. Generally, the simple rules can perform quite well in terms of macroeconomic stabilisation (relative to the optimal rule) and deliver reasonable welfare results.

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The Effects of an Anticipated Future Change in Monetary Policy Regime

Juraj Antal and František Brázdik[1]

The dynamic stochastic general equilibrium (DSGE) model structure of the New Keynesian models is consistent with the underlying behaviour of optimising economic agents. Most central banks today use a short-term nominal interest rate as their instrument for implementing monetary policy. The nominal quantity of money is then endogenously determined to achieve the desired nominal interest rate. The predictability of money demand becomes less relevant. Instead, the link between short-term and long-term interest rates as well as the link between interest rates and exchange rates become of crucial importance. Cashless economy models approximate the interest rate operating procedure type of monetary policy in the economy, where monetary aggregates have negligible effects on equilibrium outcomes. Woodford (2003) illustrates the major conceptual ideas in modern monetary economics with well-specified forward-looking elements in a cashless general equilibrium closed economy framework.

Studies of open economy DSGE models, such as Devereux and Engel (2003), Sutherland (2005a), Sutherland (2005b) and Benigno and Benigno (2003), show that optimal monetary policy should involve some consideration of exchange rate volatility. It is argued that incomplete pass-through from the exchange rate to local currency prices implies that exchange rate volatility can directly affect welfare. Paoli (2006) generalises the optimal loss function for a small open economy from the utility of a representative household. It is shown that the loss function is a quadratic expression in domestic producer inflation, the output gap and the real exchange rate. The weights given to these variables depend on the structural parameters of the model. Movements in international relative prices can create a wedge between the marginal utility of consumption and the marginal disutility of production, which directly affect welfare. Hence, there are incentives to manage fluctuations in the exchange rate in order to affect this wedge. Allowing some additional volatility of inflation in order to reduce the volatility in the other variables in the loss function may turn out to be welfare improving. It is argued that that pegging of the exchange rate outperforms an inflation targeting regime when the economy is relatively open, demand is sensitive to exchange rate movements (the intratemporal elasticity of substitution between domestic and foreign goods is high) and the intertemporal elasticity of substitution is small.

Recent literature on monetary policy shows that the optimal monetary policy rule can be implemented by minimising the optimal loss function. However, practical implementation of such an optimal rule may be difficult. As Sutherland (2005a) shows, even in a relatively simple model the coefficients in the optimal loss function are quite complicated combinations of the model parameters. The structure of the optimal loss function is sensitive to uncertainty about the structure of the model and to uncertainty about the true values of the model parameters. It is therefore useful and typical to analyse the welfare performance of non-optimal but simple monetary policy rules.

This paper adopts a simple inflation targeting and exchange rate targeting rule, and a future change in the rules. The impact of an announced future change in monetary policy regime on small open economies is analysed. We focus on inflation targeting and exchange rate targeting economies in order to compare this effect on different monetary policy regimes. The economies are considering joining a monetary union in the future. Therefore, we assume that the economies will imitate the monetary union regime by operating strict exchange rate targeting. Two alternative versions of exchange rate targeting, differing in the weight put on nominal exchange rate stabilisation, are investigated.

As long as the domestic and monetary union business cycles and inflation developments are not perfectly synchronised, the nominal interest rates of the independent inflation targeting economy will be different from those in the monetary union. Since the nominal interest rate differential is required to be close to zero in both alternative future regimes, the determination of domestic nominal interest rates will change after either regime change. Under both alternative future regimes, the nominal interest rate trajectory of the economy will be driven exogenously by the foreign (monetary union) interest rate. The future adoption of the regime can be viewed as a test of the economy's readiness to operate strict exchange rate targeting and to

1 This article is based on Antal and Brázdik (2007).

maintain a fixed exchange rate against the union's currency. The fact that the domestic economy may even be required to undergo this test before joining the union (e.g. ERM2) motivates our analysis of the future adoption of exchange rate targeting. Before the announcement of the future regime change, we refer to the economies as independent. After the regime change announcement but before the regime change itself, we refer the economies to as transitory. In the transitory economy, the model thus allows for the regime change. After the regime change, we refer to the economy as a unilateral peg. In the unilateral peg economy, agents do not foresee a future change in the monetary policy rule (the rule in the monetary union). Thus, we model not the entry into the monetary union but the change in the monetary policy rule. However, the change in the monetary policy rule is triggered by prospective future entry into the monetary union.

As soon as the independent economy becomes transitory, expectations change due to the change in the future monetary policy rule. Changes in the responses of the economy to shocks and changes in macroeconomic volatility are induced.

We aim to analyse the changes in an inflation targeting economy (transitory relative to independent) and an exchange rate targeting economy (transitory relative to independent) due to the anticipated future change in monetary policy in two alternative versions. A comparison of macroeconomic stability and welfare between the independent and transitory economies is provided.

A New Keynesian framework attributing the short-run real effects of monetary policy to the presence of nominal rigidities and monopolistic competition is implemented. We deliberately ignore other potential effects that might be triggered by the transition to a monetary union (productivity gains, foreign investment flows, etc.). Likewise, we avoid building a model structure that would go beyond our needs. Therefore, we abstract from the use of capital, the productivity growth trend, trend real exchange rate appreciation, risk premia, etc. Similarly, perfect sustainability of exchange rate targeting is assumed and thus no speculation on exchange rate crises is allowed. The effect of the announced monetary regime change on the inflation targeting and exchange rate targeting small open economy and on macroeconomic stabilisation within these economies constitutes the main contribution of our paper.

We show that the announcement of the future regime change triggers an immediate change in the behaviour of households and firms, which translates to different responses of variables before and after the announcement. The behaviour of economic agents depends not only on the current monetary policy rule, but also on the future anticipated monetary policy rule. Economic agents start to care about exchange rate stabilisation after the announcement of the regime change, because they prefer a smooth transition to the new regime. Thus, as soon as future exchange rate targeting is announced, the agents in the transitory inflation targeting economy start to behave such that the resulting inflation directs interest rates to stabilise the nominal exchange rate. They make the exchange rate more stable even though there is no weight on nominal exchange rate stabilisation in the monetary policy rule before the regime change.

Our model predicts that in an inflation targeting economy the nominal exchange rate is stabilised at the cost of higher inflation volatility after the announcement of the future regime change. This results in a difference in macroeconomic volatility and impulse responses between inflation and exchange rate targeting economies, which is lower after the announcement due to the common future monetary policy regime.

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Issues in Adopting DSGE Models for Use in the Policy Process

Martin Fukač and Adrian Pagan[1]

That the literature on dynamic stochastic general equilibrium (DSGE) models and the resources devoted to experimenting with them by central banks has been rapidly growing can scarcely be disputed. Not only do we see many papers being produced with DSGEs by central bank researchers, but we also see advertisements for employment that specify this as an area of expertise. However, since ultimately most research in central banks is designed to assist in making policy choices, it is natural to ask what issues arise if DSGE models are to be given a greater role in this process, today and in the future.

Our discussion in the paper is structured by three concerns – model design, matching the data and operational requirements. We distinguish between the role that DSGE models have played as vehicles for experimenting with new ideas and the role that they might eventually play as policy-oriented models.

We distinguish four generations of models that have been constructed in central banks for macro policy analysis. We detail how the emerging current generation, which are often referred to as DSGE models, differs from the previous generations. In particular, since DSGE models have the fundamental feature of being driven by shocks, we enquire into whether this feature is to be found in the latest (fourth) generation of models, and in what sense.

The first model generation was largely driven by the IS/LM framework and involved writing down equations which described the determinants of variables in the national accounting identity for GDP, e.g. investment and consumption. Dynamics were introduced through distributed lag relations. Many issues relating to model construction and evaluation were posed and solved by workers with these models.

Second generation (2G) models, such as the Canadian model RDX2 – Helliwell et al. (1971) – and the MPS model at the Fed[2], introduced much stronger supply side features and also moved towards deriving some of the relationships as the consequence of static optimisation problems solved by agents – in particular the consumption decision and factor choices often came from this perspective. Dynamics were again introduced by modifying the static relationships with the use of distributed lag ideas. But a new development was that the latter were often implemented through an error correction form, the use of which had been popularised in the late 1970s by Davidson et al. (1978), in which the static solution represented a target to which the decision variable adjusted. Like the previous generation of models there was considerable diversity within this class and it expanded over time. Often this diversity was the result of a continual incorporation of new features, e.g. rational expectations were introduced into financial market decisions. However, it was often the case that these new features were not easy to satisfactorily reconcile with the existing large-scale models and this often led to a good deal of dissatisfaction with the adapted versions – see the discussion in Coletti et al. (1996).

Third generation (3G) models responded to the latter difficulties, in particular the fact that these models rarely converged to a steady state solution when simulated.[3] Consequently, these models became much smaller and emphasis was placed on the need to initiate their construction by designing a steady state that they were to converge to (more often a steady state growth path), and to fully account for stock-flow interactions. In particular, stocks had to change in such a way as to eventually exhibit constant ratios to flow variables. It was much easier to ensure that these characteristics held by setting up a model in which there were well-defined optimisation choices for households and firms, along with rules for monetary and fiscal authorities, than trying to force them upon models in which these decisions were largely ad-hoc. An early version of this class of models that was used for forecasting and policy work was Murphy (1988), which was distinguished by the fact that it possessed a well-defined steady state.[4]

Today we are seeing the emergence of a fourth generation (4G) of models. Some of the early

1 This article is based on Fukač and Pagan (2006).

2 Gramlich (2004) observes that this was also called the Federal Reserve-MIT-Penn model and this is probably a better name given the Fed's role in its construction.

3 Gramlich (2004) comments on his work on the MPS model that "... the aspect of the model that still recalls frustration was that whenever we ran dynamic full-model simulations, the simulations would blow up".

4 The model was more fully described in Powell and Murphy (1995).

representatives are TOTEM (Murchison and Rennison, 2006), MAS (the Modelling and Simulation model of the Bank of Chile, Medina and Soto, 2005), GEM (the Global Economic Model of the IMF, Laxton and Pesenti, 2003), BEQM (Bank of England Quarterly Model, Harrison et al., 2004), NEMO (Norwegian Economic Model at the Bank of Norway, Brubakk et al., 2005), The New Area Wide Model (NAWM) at the European Central Bank, and KITT at the Reserve Bank of New Zealand

These new models have two striking general characteristics. First, they feature considerable heterogeneity. Thus a variety of types of labour services are available, there are many intermediate goods produced, and there may be a number of final goods produced, rather than the single good of the previous generation of models. This heterogeneity is often associated with monopolistic and monopsonistic behaviour rather than the competitive markets of the 3G models. Second, the degree of intrinsic dynamics has been expanded a great deal, with a large number of constraints upon agents when making decisions, including habit persistence in consumption and labour choices, adjustment costs in investment and labour, capital utilisation variations, and wages and prices being adjusted according to various staggered price setting and contractual arrangements. Thus the base model now has much more of the dynamic structure coming from optimal decisions than was the case in the previous generation of models. 4G models do maintain some of the 3G model characteristics though.

In Fukač and Pagan (2006), we investigate a variety of topics involving the estimation and evaluation of DSGE (4G) models. We look at identification and estimation methods. We ask questions such as how well does the model track the data, and how well does the model match selected characteristics of the data (such as integration, cointegration, moments and dynamic responses), as they are important for adopting the model as a central forecasting tool. The evaluation has two dimensions to it. One is largely focused upon the operating characteristics of the model and whether these are "sensible". The other is more about the ability of the model to match the data along a variety of dimensions. The two themes are not really independent, but it is useful to make the distinction. Thus it might be that, while a model could produce reasonable impulse responses, it may not produce a close match to the data, and conversely. In the paper, we provide some general analysis of the estimation and evaluation issues, and illustrate the arguments by reference to an open economy model constructed by Lubik and Schorfheide (2007) for the UK.

Finally, we consider in the paper a miscellany of issues relating to the problems of making DSGE models operational. One of the issues is model flexibility. Any model used for policy has to be flexible. It needs to be adaptable so as to meet policy makers' changing preferences and to be able to incorporate their opinions and attitudes. This constraint goes to the nub of what a policy model is about. Do we want an economic story, or the ability to effectively utilise a lot of numbers? 2G models handled many pieces of information. They generally had a story, but often it was a bit confused, and it was left to their owners to make sense of it. Later generation models have a better story but perhaps less flexibility, and one needs methods to produce the desired degree of flexibility.

We conclude that the more information that a central bank needs to provide in terms of forecasts and explanations of policy decisions, the more there is a tendency to utilise 3G and 4G (DSGE) models. For example, a central bank like the Reserve Bank of Australia, which has to publish little in the way of forecasts, still works with a small 2G model – see Stone et al. (2005). But since it seems unlikely that the future will see a decline in the amount of information and explanation that is demanded, dynamic stochastic general equilibrium type models are almost certainly here to stay.

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The Convergence Dynamics of a Transition Economy: The Case of the Czech Republic

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One of the most challenging tasks for policy-makers in an emerging market converging open economy is to correctly judge and predict the dynamics of endogenously determined key policy-relevant variables. The long-term trajectories of these variables constitute the "equilibrium" trends and thereby anchor the monetary policy models in practice. Actual deviations from these trends represent the rationale of the "gap forecast models" that are currently used by many inflation-targeting countries, among them the Czech Republic. Therefore, a coherent explanation of the trends, and simulations of those trends into the future, are of utmost importance for appropriate policy implementation. To contribute to this task, the two-country dynamic general equilibrium modelling framework is extended to include an additional investment margin – investment in quality. The extended model is calibrated for the Czech Republic and is used to derive the consistent convergence trajectories.

Indeed, many studies have suggested that quality improvements might play a role among the determinants of the real exchange rate appreciation of transition economies. In particular, empirical studies reflect the symptoms of quality investments in transition economies. Fabrizio et al. (2007) show that the Visegrad-4 countries, i.e. the Czech Republic, Hungary, Poland and Slovakia, started with a low proportion of high-tech products and have experienced a significant but gradual shift towards high-tech products and have recorded trend real exchange rate appreciation. In the case of the Czech Republic, Podpiera (2005) shows that large gains in exported volumes were associated with improving terms of trade, which, in turn, implies quality improvements.

The extension of the quality margin is necessary because the recent significant trend real exchange rate appreciation observed in the majority of the Central and Eastern European transition economies (including the Czech Republic) constitutes a puzzle and renders the standard models incomplete for the explanation of transition economy dynamics. Since the dominant part stems from the real exchange rate for tradable goods (see Égert et al., 2007, and Cincibuch and Podpiera, 2006), it leaves very limited scope for the mainstream theoretical explanation of real exchange rate appreciation, i.e. the Harrod-Balassa-Samuelson type of convergence. In addition, in the absence of the Harrod-Balassa-Samuelson effect on the real exchange rate, the mainstream theory would predict real exchange rate depreciation, not appreciation, for the converging economy, because of the downward-sloping demand curve. At the same time, quality improvements are not accounted for by the statistical offices in transition economies such as the Czech Republic (see Ahnert and Kenny, 2004, for a comprehensive survey). Therefore, quality-unadjusted price indexes might well be responsible for a substantial part of the pace of real exchange rate appreciation in a transition economy.

The contribution of the extension is that it formalises the idea of quality improvements as the force driving the real exchange rate appreciation in a model which (i) shows the mechanism by which quality is accumulated, and (ii) can be simulated in a quantitative experiment. In addition, the model allows for non-trivial cross-border asset ownership, i.e. modelling of foreign direct and portfolio investment. The model is solved for the transition dynamics of a transition country which is converging to its more advanced counterpart. Thus, it contrasts with the standard DSGE models, which aim at explaining deviations from exogenously given long-run trends.

The model calibrated for the Czech economy and the EU-15 shows that the symptoms of the convergence in selected policy-relevant variables can be explained by decreasing export costs (direct investment enhanced) and by growing productivity in the converging country. The development of the economy is described by the endogenously determined trajectories of a large set of variables,

1 This article is based on Brůha, Podpiera and Polák (2007).

starting with gross domestic product, consumption, investment, exports and imports, and direct foreign investment, and ending with the real exchange rate and the excess real return on domestic assets. The calibration succeeded in finding consistent trend trajectories in all the endogenously modelled variables, such as the real exchange rate, the consumption and investment to GDP ratios, foreign direct and other investment balances, exports, imports and the trade balance to GDP ratio, as well as the real return on assets.

First, the model replicates the convergence of output per capita to the average of the EU-15. Starting with GDP per capita at 60% of the EU-15 average in the mid-1990s, and remaining at that level for the rest of the 1990s, the Czech economy started to converge more noticeably in the early 2000s and stood at roughly 70% in 2005.

Second, we aim at replicating the real exchange rate appreciation, which has reflected the economic convergence. The real exchange rate has been appreciating and stood approximately 30% stronger in 2005 compared to the base of 1997. The model can explain the real exchange rate appreciation owing to the presence of two factors. The first is the fact that the CES aggregation implies a love for variety, which means that the expansion in the number of domestic production varieties can be considered a quality improvement in the domestic goods basket. This is the effect which is responsible for the results of Ghironi and Melitz (2005). However, in a related paper, Brůha and Podpiera (2007b) show that it is unlikely that this effect alone can achieve the real exchange rate appreciation observed in the Visegrad-4 countries. This is why a second feature has been introduced: quality investment.

Quality improvements in the domestic composite basket explain why the converging country is able to sell more and – at the same time – at a relatively higher price as its total factor productivity increases. It is worth noting that the pace of real exchange rate appreciation in the model is obtained without any explicit assumption of an exogenous productivity differential between the tradable and non-tradable sectors (although the model displays an endogenous productivity differential between traded and non-traded goods). In fact, the reason for the appreciation is an improvement in the domestic composite good through variety expansion and explicit investment in quality. Moreover, hypotheses explaining the real exchange rate appreciation based on the exogenous productivity differential (the Harrod-Balassa-Samuelson hypothesis) are empirically insufficient (Mihaljek and Klau, 2006, and Flek et al., 2003). Indeed, models with an exogenous productivity differential imply that the terms of trade will remain constant.

The third crucial piece of information for monetary policy implementation is the implicit "equilibrium" trajectory of the return on domestic assets relative to foreign assets. Since a small, open emerging market economy exhibits convergence in output, the corresponding (neutral) level of the real interest rate is hard to judge based on the historical averages of output growth (a standard approach in developed economies). This stands in contrast to the developed foreign country in the model, where the neutral interest rate is easily set to the average of long-run output growth.

Nevertheless, deriving the neutral interest-rate level from output growth seems intuitive, as any economy can pay a return on assets equal to the growth in value added. Therefore, the interest rate trajectory can be derived from the excess of domestic long-term output growth over long-term growth in the foreign country. It is apparent that as the domestic economy develops and converges to the foreign one, real output per capita increases and the domestic country gets richer. The convergence-implied neutral cumulative return on investment made at the beginning of the convergence process is derived from the speed of convergence.

To summarise, the model aims at providing an essential input for Czech monetary policy-makers –

the long-run trend in key policy-relevant variables. Unlike a developed economy, which exhibits standard and settled characteristics for sufficiently long period of time and for which long-run values (sometimes called equilibria) can be obtained by averaging past observations, every emerging market economy falls short in this respect. In order to find and assess these variables for an emerging market economy, one needs a specific model that delivers simultaneously determined long-term trajectories. The model succeeded inter alia in delivering successful simultaneous replication of GDP per capita convergence to the EU and real exchange rate appreciation.

The presented modelling framework can be used to answer a number of policy questions, since the derived trends can be used for assessing the size of the medium-term deviations of the output gap, the real exchange rate gap and the gap in the excess return on Czech assets. In particular, the real monetary policy conditions (the excess return on assets in the converging economy) speak directly to monetary policy. In addition, the long-run trajectories might be of great importance when considering the timing of the monetary integration of the Czech Republic and other new EU member states. For such an application, see Brůha and Podpiera (2007a).

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