Abstract

This paper develops a variant of the IMF’s Global Economic Model (GEM) suitable to analyze macroeconomic dynamics in small, open, emerging economies, and uses it to assess the effectiveness of Taylor rules and Inflation-Forecast-Based (IFB) rules in stabilizing variability in output and inflation. Our findings suggest that a simple IFB rule that does not rely upon any direct estimates of either the output gap or the equilibrium real interest rate may perform better in emerging-market economies than conventional Taylor rules.

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I Introduction

Generations of policymakers have long emphasized an “unfeasible” trinity of policy objectives. Attempts to simultaneously maintain fixed exchange rates, perfect capital mobility, and independent monetary policy are bound to end either with a whimper or a bang. Over the 1990s, the intellectual underpinnings of the monetary frameworks adopted by central banks around the world have assigned increasing emphasis to a rather different trinity, one that is “both feasible and desirable” in the words of John Taylor (2000): this is the trinity of flexible exchange rates, an inflation target, and a monetary policy rule.

The idea that policy rules originally designed to fit the specific economic and institutional features of large, relatively closed, advanced economies may be successfully imported by small, open, emerging countries is nowadays taken for granted. The key open question is what kind of modifications are needed to fit the complex reality of monetary policymaking in economies with less developed financial markets, more vulnerability to external sources of uncertainty, rapid productivity catch-up, strong movements in relative prices, and destabilizing exposure to volatile capital flows.

Focusing specifically on Taylor-style interest rate rules, a frequently asked question is whether the size of the response of the instrument to inflation and output gap changes systematically with the degree of openness and the size of the country. Another recurrent theme in the literature is what role, if any, should be played by interest rate inertia — see e.g. Woodford (1999). This paper contributes to this debate in a number of respects. First, we setup a stochastic dynamic general equilibrium model (SDGE) of sufficient complexity to provide a satisfactory representation of trade and macroeconomic interdependencies between a large industrialized country and a small emerging economy. In the calibration, particular attention is put on the ability of the model to simulate realistic dynamic responses of relevant macroeconomic variables to a variety of shocks. Specifically, we show that the model is able to replicate closely the empirical properties of the monetary transmission mechanism, as estimated by central banks using institution-specific tools for policy evaluation. Next,

\footnote{In this paper we abstract from the issues underlying the choice of a fixed versus flexible exchange rate regime in emerging markets. For a recent discussion of these issues in the context of a similar theoretical apparatus see Ghironi and Rebucci (2002) and its references.}
we compare the performance of alternative interest rate rules — Generalized Taylor rules versus Inflation-Forecast-Based ones — in stabilizing variability in inflation and output across the two economies of the model.

In our simulation exercise, we identify the large country with the Euro area and the small economy with the Czech Republic, a representative transition country in Central Europe. Transition countries provide a good paradigm for “emerging” countries because their economies are sufficiently diversified and not exclusively dependent on exports of primary commodities and raw materials, their securities markets sufficiently developed to allow for a meaningful comparison of their macroeconomic properties with the ones observed in advanced industrialized countries. At the same time, their reliance on trade and their exposure to external fluctuations make them intrinsically more vulnerable to a variety of shocks, both on the demand and the supply side, than their advanced counterparts. Needless to say, our results cannot be generalized to the vast majority of emerging markets without controlling for country-specific and institutional factors. Nevertheless, our findings are meant to provide a benchmark over which further research is expected to take off.

The paper is organized as follows. Section II provides some basic facts about three transition countries and compares these data to selected historical statistics for the euro area. The specific transition countries that we focus on are the Czech Republic, Hungary, and Poland. Section III introduces the Global Economy Model (GEM), a new simulation model under development in the Research Department of the IMF to support research and policy analysis. In Section IV we calibrate the GEM to stylized facts for transition economies and the euro area discussed in Section II. Section V employs the model to investigate the potential role of Taylor and Inflation-Forecast-Based rules for stabilizing...
output and inflation in both large and small economies. Finally, Section VI presents our main conclusions and outlines directions for future work.

II Some stylized facts about emerging economies

This section reviews some basic stylized facts of the Czech Republic, Hungary and Poland—the three transition countries that are considered in this paper. However, many of the arguments also apply to other transition countries.

The analysis is divided into two parts. First, we briefly review the trends in relative productivity levels, real exchange rates, and the major macroeconomic aggregates. Next, we discuss measures of macroeconomic variability in these countries relative to the Euro area. These stylized facts are then used to calibrate a dynamic model of macroeconomic transmission between a “representative” small emerging economy (such as the Czech Republic) and a large group of industrial countries (such as the Euro area).

A Economic transformation in European transition countries

A.1 Real exchange rates and productivity catch-up

The top panels of Figure 1 compares CPI-based measures of the real exchange rate with estimates of aggregate labor productivity in the three countries, expressed as a ratio of the level of labor productivity in Germany. As the figure shows, there is a fairly strong link between productivity catch-up and the real exchange rate. To many observers, such correlation provides clear evidence in support of the Balassa-Samuleson hypothesis (BHS), according to which strong productivity growth in the tradables sector results in higher real wages in both the tradables and nontradables sectors, a trend increase in the price of nontradables relative to tradables, and a strong upward trend in CPI-based real exchange rates.

For instance, Halpern and Wyplosz (2001) provide econometric evidence of a Balassa-Samuelson effect in Eastern and European countries. Their argument is illustrated in the bottom panels of Figure 1, which compares a proxy of

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3 The original contributions are Balassa (1964) and Samuelson (1964).
the relative price of nontradables and productivity growth differentials between tradables and nontradables. As this figure shows, aggregate productivity gains have been predominantly concentrated in the tradables sector.

While certainly part of the explanation, the BSH is however unable to explain fully the underlying upward trends in these real exchange rates. For instance, in the Czech Republic the trend real appreciation is much stronger than the dynamics of the productivity catch-up. This suggests that other driving factors, such as, for example, a shift in tastes in more advanced economies towards the types of goods produced by transition countries, may have played a key role.\(^4\)

**A.2 Investment, government and consumption**

The first column of panels in Figure 2 plots the ratios of real investment to GDP in the three transition countries compared to the estimates for the Euro area. All three transition countries have experienced increases of around 10-15 percentage points of GDP since 1993, and the current ratios are well above the aggregate ratio in the Euro area.

The second column in Figure 2 plots the level of government absorption as a ratio of GDP. This measure of the relative size of government has declined much more rapidly in the transition countries than in the rest of Europe, reflecting the much higher starting level that was inherited from the previous regime. There is no clear pattern in the behavior over time of the shares of private consumption (shown in third column), which have risen in the Czech Republic, fallen in Hungary, and been roughly stable in Poland and the Euro area.

**A.3 Trade**

Trends in the volume of trade have been particularly striking in the transition countries. Figure 3 plots export-to-GDP ratios, import-to-GDP ratios, as well as the real trade balance as a share of GDP.\(^5\) In all cases, there has been an enormous increase in the degree of openness in these countries, with both the export and import ratios rising between 20 and 30 percentage points. This reflects

\(^4\)Lipschitz, Lane and Mournouras (2002) suggest that the real exchange rate may have been very low at the start of the transition because of insufficient market penetration and product reputation in Western markets.

\(^5\)The current account to GDP ratios exhibit similar features, as plotted in the last column of Figure 4.
higher investment in the tradables sectors, as well as the effects of structural reforms and a production shift toward higher-quality goods in demand from more advanced economies. The strong correlation between exports and imports that is apparent in the plots reflects the intensive use of imported intermediate inputs in the production of tradables, as well as constraints (capital controls and endogenous risk premia) that have limited the magnitude of current account imbalances in these countries.

A.4 Inflation and the monetary policy framework

The first column of panels in Figure 4 plots year-on-year CPI inflation. There has been a significant decline in inflation in all three transition countries and in two cases (the Czech Republic and Poland), inflation has closely approached the more stable rates that have been recorded in the Euro area since the early 1990s. Inflation has fallen rapidly in Hungary as well, but it remains significantly above that in the Euro area. In parallel with inflation rates, nominal interest rates have rapidly fallen in the second half of the 1990s (as shown in the second column).

Although all three countries entered the 1990s with a conventional fixed exchange rate regime in place, the disinflation process in these transition countries occurred under rather dissimilar monetary frameworks. The Czech Republic evolved from a conventional peg (1990-1995) to a crawling peg in 1996, which then quickly evolved into an explicit inflation-targeting regime (1997). Poland moved much faster to a system based on crawling pegs (1992-1994) and crawling bands (1995-1999) before moving to an independent float in 2000. Hungary maintained a conventional peg for almost as long as the Czech Republic (1990-1994) before adopting a system based on crawling bands.

A.5 Real interest rates and current account imbalances

The last two columns in Figure 4 plot measures of the real interest rate and the current account balance. The evidence suggests that high rates of returns, on average, have attracted significant capital inflows to these countries. However, the magnitude of the capital inflows appear to have been limited by endogenous

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6 The proxy for the real interest rate is simply the short-term interest rate minus the year-on-year CPI inflation rate.
movements in risk premia, as discussed by Lipschitz, Lane, and Mourmouras (2002).

B Macroeconomic variability: The Euro area versus the Czech Republic

Table 1 provides some estimates of macroeconomic variability based on standard deviations of detrended data for both the Euro area and the Czech Republic.\(^7\) As shown in the table, real GDP has been about twice as volatile in the Czech Republic as it has been in the Euro area.

Table 1 also includes estimates of variability for consumption, investment, government absorption, exports and imports. For the Euro area these measures suggest that imports are the most volatile component of real GDP (with a standard deviation of 3.1 percent), followed by investment (2.7) and exports (2.4). The data also indicate that, over the long sample period covered in our analysis, detrended consumption expenditures and government absorption have displayed less variability than real GDP.\(^8\)

The degree of variability in the measures for the Czech Republic tell a different story for the transition countries. Indeed, since 1993 all expenditure components — including consumption and government absorption — have been significantly more volatile than aggregate real GDP. Also, fluctuations of investment relative to GDP have been significantly wider in transition countries: investment has been 3.5 times more volatile than real GDP in the Czech Republic compared to 2.7 times in the Euro area. Data for Hungary and Poland present a similar pattern of relative variability and suggest similar considerations about the nature of shocks to these economies.

Measures of variability in interest rates and exchange rates are also included in Table 1. Variability in nominal interest rates has been quite high in these

\(^7\)With the exception of the measures of inflation, interest rates and the net-export-to-GDP ratios, all of the measures in Table 1 have been detrended with the HP filter using a smoothness parameter of 1600. The measures for the Euro are based on data from 1970Q1 to 2001Q4 and the measures for the Czech Republic are based on data from 1973Q1 to 2002Q4.

\(^8\)This feature of lower variability in consumption expenditures in advanced economies such as the Euro area is not robust to the sample period chosen. For example, over the 1990s several industrial countries have recorded greater variability in consumption expenditures than in their real GDP measures.
countries, mainly reflecting the process of disinflation. The real effective exchange rate has approximately the same degree of variability as the nominal effective exchange rate, a feature shared by many other emerging and advanced economies.

III The model

A General structure

The theoretical framework we adopt in our analysis is a variant of the Global Economy Model (GEM), the new multi-country simulation model currently under development at the Research Department of the International Monetary Fund. The basic structure of the model is outlined in this section and illustrated in Figure 5.

The world economy consists of two countries, Home (a small, emerging economy) and Foreign (a large, advanced economy). Foreign variables are indexed with a star. In each country there are households, firms, and a government.

Each household is infinitely lived. Each household consumes a single non-tradable final good \( A \). Each household is the monopolistic supplier of a differentiated labor input \( \ell \) to all domestic firms. Wage contracts are subject to adjustment costs (nominal wage rigidities).

Each household owns all domestic firms, non-reproducible resources (land \( L \)), and the domestic capital stock \( K \), which it rents to domestic firms. The markets for land and capital are competitive. Capital accumulation is subject to adjustment costs. Labor, capital and land are immobile internationally.

Households trade a short-term nominal bonds, denominated in Foreign currency, and issued in zero net supply worldwide. There are intermediation costs for Home households entering the international bond market. No other asset is traded internationally.

Firms produce the final goods, a continuum of differentiated non-tradable intermediate goods \( N \), a continuum of differentiated tradable intermediate goods \( T \), raw and semifinished materials \( TO \), and provide distribution and

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9 The GEM provides an empirical development of the stylized SDGE models considered in the “new open-economy macroeconomics” literature such as Obstfeld and Rogoff (2000) and Corsetti and Pesenti (2001a). For a detailed presentation of the GEM see Pesenti (2002).
other intermediation services.

In each country the final, non-tradable good is produced by perfectly competitive firms that use all intermediate goods (domestic tradables, $Q$, or imported tradables, $M$) as inputs. The non-tradable final good can be consumed (by domestic households, $C$, or by the government, $G_A$) or used for investment ($I$).

Each intermediate good is produced by a single firm under conditions of monopolistic competition. Each intermediate good is produced by using domestic labor inputs, domestic capital, and a combination ($O$) of raw and semifinished materials, both produced domestically ($Q_O$) and imported ($M_0$). The non-tradable intermediate goods can be purchased by the government ($G_N$), used directly in the production of the non-tradable final good ($N_N$), or used in the distribution sector to make tradable intermediate goods available to firms producing the final good. Prices of intermediate goods are subject to adjustment costs (nominal price rigidities).

Firms in the distribution sector operate under perfect competition. They purchase tradable intermediate goods worldwide (at the producer price) and distribute them to firms producing the final good (at the consumer price). Local non-tradables are the only input in the provision of distribution services.

Firms produce tradable raw and semifinished materials ($T_O$) using labor, capital, and land. The market for raw materials is competitive. Prices of raw materials are flexible and the law of one price holds internationally.

Government spending falls exclusively on non-tradable goods, both final and intermediate. Government spending is financed through tax and seigniorage revenues. The government controls the national short-term nominal interest rate. Monetary policy is specified in terms of interest rate rules.

B Microeconomics of the two-country model

B.1 Final goods production

There is a continuum of symmetric Home firms producing the Home final good, indexed by $x \in [0, s]$, where $0 < s < 1$ is a measure of country size. World size is normalized to 1, and Foreign firms producing the Foreign final good are indexed by $x^* \in (s, 1]$.

Home firm $x$’s output at time (quarter) $t$ is denoted $A_t(x)$. The final good

\footnote{The convention throughout the model is that variables which are not explicitly indexed are assumed to be continuous in $x$.}
is produced with the following nested CES technology:

\[
A_t(x) \equiv \gamma^\frac{1}{\varepsilon} \left( \nu^{\frac{1}{\varepsilon_{QM}}} Q_t(x)^{1 - \frac{1}{\varepsilon_{QM}}} + (1 - \nu)^{\frac{1}{\varepsilon_{QM}}} [M_t(x)(1 - \Gamma_{M,t}(x))]^{1 - \frac{1}{\varepsilon_{QM}}} \right)^{\varepsilon_{QM} - \frac{\varepsilon_{QM} - 1}{\varepsilon_{QM}}}
+ (1 - \gamma)^\frac{1}{\varepsilon} N_{N,t}(x)^{1 - \frac{1}{\varepsilon}}
\]

Three intermediate inputs are used in the production of the final good: a basket \( Q \) of Home tradable goods, a basket \( M \) of imported Foreign tradable goods, and a basket \( N_N \) of Home non-tradable goods. \( \varepsilon \) is the elasticity of substitution between tradables and nontradables, \( \varepsilon_{QM} \) is the elasticity of substitution between domestic and imported tradable inputs. The parameters \( \gamma \) and \( \nu \) can be subject to shocks.\(^{11}\)

In the spirit of Erceg, Guerrieri and Gust (2002), we assume that it is costly to change the share of the imported goods in total production. Imports are subject to adjustment costs \( \Gamma_{M,t} \), where:\(^{12}\)

\[
\Gamma_{M,t}(x) \equiv \frac{\phi_M}{2} \left( \frac{M_t(x)}{A_t(x)} \right)^2
\]

Taking the prices of the intermediate baskets \( P_Q, P_M \) and \( P_N \) as given, the cost minimization problem of the Home firm \( x \) is:

\[
\{Q_t(x), M_t(x), N_{N,t}(x)\} = \arg \min \{P_{Q,t}Q_t(x) + P_{M,t}M_t(x) + P_{N,t}N_{N,t}(x) + P\}
\]

\[
A_t(x) - \left[ \gamma^\frac{1}{\varepsilon} \left( \nu^{\frac{1}{\varepsilon_{QM}}} Q_t(x)^{1 - \frac{1}{\varepsilon_{QM}}} + (1 - \nu)^{\frac{1}{\varepsilon_{QM}}} [M_t(x)(1 - \Gamma_{M,t}(x))]^{1 - \frac{1}{\varepsilon_{QM}}} \right)^{\varepsilon_{QM} - \frac{\varepsilon_{QM} - 1}{\varepsilon_{QM}}}
+ (1 - \gamma)^\frac{1}{\varepsilon} N_{N,t}(x)^{1 - \frac{1}{\varepsilon}} \right]^\varepsilon_{QM}
\]

where \( P \) is the consumption price of the final good, equal to its marginal cost.

Foreign variables are similarly defined.

\( (\text{to firms or households}) \) are expressed in per-capita (average) terms. For instance, \( A_t \equiv \int_0^x A_t(x)dx \).

\(^{11}\)Specifically, in our simulation we consider \( \gamma_t = \gamma_t(1 + Z_{\gamma,t}) \). The model can be easily re-interpreted as if households consumed directly a basket \( A \) of domestic and imported final goods. In this case shocks to \( \gamma \) and \( \nu \) act as preference shifters.

\(^{12}\)Different from Erceg, Guerrieri and Gust (2002), it is assumed that for the firm it is costly to adjust its current imports/output ratio relatively to the past aggregate imports/output ratio.
B.2 Demand for intermediate goods and the role of the distribution sector

The basket $N_N$ is a CES index of differentiated Home intermediate non-tradables, defined over a continuum of mass $s$. Each good is produced by a single Home firm indexed by $n \in [0, s]$. Defining as $N_N(n, x)$ the demand of the intermediate good $n$ by firm $x$, the basket $N_N(x)$ is:

\begin{equation}
N_{N,t}(x) \equiv \left( \frac{1}{s} \right)^{\frac{1}{\theta}} \int_0^s N_{N,t}(n, x)^{1-\frac{1}{\theta}} \, dn \right)^{\frac{\theta}{\theta-1}}
\end{equation}

where $\theta > 1$ denotes the elasticity of substitution among intermediate non-tradables. Similarly, the baskets $Q$ and $M$ are CES indexes of differentiated intermediate tradables, respectively produced in the Home country and imported from the Foreign country. Each good is produced by a single firm. Home firms in the tradables sector are indexed by $h \in [0, s]$, Foreign firms in the tradables sector are indexed by $f \in (s, 1]$:

\begin{equation}
Q_t(x) \equiv \left( \frac{1}{s} \right)^{\frac{1}{\theta}} \int_0^s Q_t(h, x)^{1-\frac{1}{\theta}} \, dh \right)^{\frac{\theta}{\theta-1}}
\end{equation}

\begin{equation}
M_t(x) \equiv \left( \frac{1}{1-s} \right)^{\frac{1}{\theta^*}} \int_s^1 M_t(f, x)^{1-\frac{1}{\theta^*}} \, df \right)^{\frac{\theta^*}{\theta^*-1}}
\end{equation}

where $\theta^* > 1$.

Firms producing the final good cannot purchase the intermediate tradables directly from the producers. Instead, firms in the distribution sector purchase tradables both domestically and abroad and distribute them to the firms producing the final good. The distribution technology is Leontief: to make one unit of an intermediate good available to downstream producers, firms in the distribution sector require $\eta \geq 0$ units of the non-tradables basket $N$. There are no distribution costs for non-tradables.\footnote{The specification of the distribution sector builds on Corsetti and Dedola (2002). See also Erceg and Levin (1996) and Burstein, Neves and Rebelo (2000).}

Firms in the distribution sector are perfectly competitive. Because of distribution costs, there is a wedge between producer and consumer prices (that is, between wholesale and retail prices). We denote with $p$ the consumer price (that is, the price paid by Home firms producing the final good) and with $\bar{p}$
the Home-currency producer price (that is, the price paid by Home firms in the
distribution sector) of an intermediate good. It follows that:

\[ p_t(n) = \bar{p}_t(n), \quad p_t(h) - \bar{p}_t(h) = p_t(f) - \bar{p}_t(f) = \eta P_{N,t} \]

The cost-minimizing prices of the baskets of intermediate goods \( P_N, P_Q \) and
\( P_M \) are given by:

\[ P_{N,t} = \left( \frac{1}{s} \int_0^s p_t(n)^{1-\theta} \, dn \right)^{\frac{1}{1-\theta}} \tag{8} \]

\[ P_{Q,t} = \left( \frac{1}{s} \int_0^s p_t(h)^{1-\theta} \, dh \right)^{\frac{1}{1-\theta}} \tag{9} \]

\[ P_{M,t} = \left( \frac{1}{1-s} \int_s^1 p_t(f)^{1-\theta^*} \, df \right)^{\frac{1}{1-\theta^*}} \tag{10} \]

Aggregating across firms \( x \), Home demands for the tradable intermediate goods
\( h \) and \( f \) are given by:

\[ Q_t(h) = \left( \frac{p_t(h)}{P_{Q,t}} \right)^{-\theta} Q_t \tag{11} \]

\[ M_t(f) = \frac{s}{1-s} \left( \frac{p_t(f)}{P_{M,t}} \right)^{-\theta^*} M_t \tag{12} \]

The nontradable good \( n \) is used in the production of the final good, by firms in
the distribution sector, and by the government. Denoting government spending
on nontradables by \( G_{N,t} \), total demand for \( n \) is:

\[ N^D_t(n) = \left( \frac{p_t(n)}{P_{N,t}} \right)^{-\theta} \left[ N_{N,t} + \eta (Q_t + M_t) + G_{N,t} \right] \tag{13} \]

Foreign variables are similarly characterized.

**B.3 Supply of intermediate goods**

The technology of production of the Home nontradable good \( n \) is:

\[ N^S_t(n) = Z_{N,t} \left[ (1 - \alpha_N - \gamma_N) \tau_N^{\frac{1}{\tau_N}} \ell_t(n)^{\frac{1}{\tau_N}} + \alpha_N^{\tau_N} K_t(n)^{\frac{1}{\tau_N}} + \gamma_N^{\frac{1}{\tau_N}} [(1 - \Gamma_{O,t}(n)) O_t(n)]^{\frac{1}{\tau_N}} \right]^{\frac{\tau_N}{\gamma_N^{\frac{1}{\tau_N}}}} \tag{14} \]
Nontradables are produced by symmetric firms using labor \( \ell(n) \), capital \( K(n) \) and a basket \( O(n) \) of two tradable inputs\(^{14} \) produced in the Home and in the Foreign country respectively. \( \xi_N \) is the constant elasticity of input substitution, and \( Z_N \) is a productivity shock common to all producers of non-tradables. Changes in \( O(n) \) are subject to adjustment costs \( \Gamma_O \) similar to equation (2) above.

Differentiated labor inputs in the Home country are indexed by \( j \in [0, s] \).

We define:

\[
\ell_t(n) \equiv \left( \frac{1}{s} \right) \frac{1}{\phi} \int_0^s \ell(n, j)^{1 - \frac{1}{\phi}} \, dj
\]

where \( \ell(n, j) \) is the demand of labor input of type \( j \) by the producer of good \( n \) and \( \phi > 1 \) is the elasticity of substitution among labor inputs.

\( O(n) \) is a CES basket of raw materials:

\[
O_t(n) \equiv \nu_{ON} Q_{O_t}^{1 - \frac{1}{\varepsilon_{ON}}} (n) + (1 - \nu_N) \varepsilon_{ON} M_{O_t} (n) (1 - \Gamma_{MO_t} (n))^{1 - \frac{1}{\varepsilon_{ON}}}
\]

where \( Q_O(n) \) denotes Home firm \( n \)'s use of domestic raw materials and \( M_O(n) \) denotes firm \( n \)'s imports of raw materials from Foreign. \( \varepsilon_{ON} \) is the elasticity of substitution between domestic and imported materials. Once again, imports \( M_O(n) \) are subject to adjustment costs \( \Gamma_{MO}(n) \).

Firms producing intermediate goods take the prices of labor inputs, capital and raw materials as given. Cost minimization in the intermediate sector implies that the demand for labor input \( j \) by firm \( n \) is a function of the relative wage:

\[
\ell_t(n, j) = \left( \frac{1}{s} \right) \left( \frac{W_t(j)}{W_t} \right)^{-\phi} \ell_t(n)
\]

where \( W(j) \) is the nominal wage paid to Home labor input \( j \) and the wage index \( W \) is defined as:

\[
W_t = \left[ \left( \frac{1}{s} \right) \int_0^s W_t(j)^{1 - \phi} \, dj \right]^{\frac{1}{1-\phi}}
\]

Denoting by \( R \) the Home nominal rental price of capital, by \( P_{QO} \) the Home-currency price of one unit of \( Q_O \) and by \( P_{MO} \) the Home-currency price of one

\(^{14}\)Throughout the paper we refer to these upstream intermediate inputs as raw materials. It is only a matter of semantics to interpret them as parts and components to be used up in the production of manufacturing goods, or primary commodities, etc.
unit of $M_O$, Home nontradable firms solve the following cost-minimization problem:

\[
\{\ell_t(n), K_t(n), Q_{O,t}(n), M_{O,t}(n)\} = \arg \min \{W_t \ell_t(n) + R_t K_t(n) + P_{QO,t} Q_{O,t}(n) + P_{MO,t} M_{O,t}(n) + MC_t(n) \left( N^S_t(n) - Z_{N,t} \left[ (1 - \alpha_N - \gamma_N)^{\frac{\ell_t(n)}{\xi_N}} - \frac{1}{\xi_N} \right] \right) + P_{O,t}(n) \ast (O_t(n) - \left( 1 - \Gamma_{O,t}(n) \right) O_t(n)) \}.
\]

where the multipliers $MC(n)$ and $P_O(n)$ are, respectively, the nominal marginal cost in the Home nontradables sector and the shadow price of one unit of $O$ in the same sector.

Similar expressions hold for Home tradables $h$, Foreign nontradables $n^*$ and Foreign tradables $f$.

**B.4 Price setting in the intermediate sector**

Consider now profit maximization in the Home country’s intermediate sector. Each firm $n$ takes into account the demand (13) for its product and sets the nominal price $p_t(n)$ by maximizing the present discounted value of real profits. There is sluggish price adjustment due to resource costs measured in terms of total profits. The adjustment cost is denoted $\Gamma_{PN,t}$:

\[
\Gamma_{PN,t}(n) = \frac{\phi_{N1}}{2} \left( \frac{p_t(n)}{p_{t-1}(n)} - 1 \right)^2 + \frac{\phi_{N2}}{2} \left( \frac{p_t(n)/p_{t-1}(n)}{P_{N,t-1}/P_{N,t-2}} - 1 \right)^2
\]

where $\phi_{N1}, \phi_{N2} \geq 0$ and $\pi > 0$. This specification generalizes Rotemberg’s (1982) quadratic cost of price adjustment. Drawing from Ireland (2001), the adjustment cost has two components. The first one is related to changes of the nominal price relative to a parameter $\pi$, which is equal to the gross steady-state rate of inflation. The second component is related to changes in firm $n$’s price inflation relative to the past observed inflation rate in the whole nontradables sector. As costs apply to both changes in the nominal price level and the inflation rate, they allow the model to reproduce realistic inflation dynamics encompassing nominal inertias and staggering.
The price setting problem is then characterized as:

\[
\left\{ p_\tau(n) \right\}_{\tau=t}^{\infty} = \arg \max E_t \sum_{\tau=t}^{\infty} \left\{ D_{t,\tau} \left[ p_\tau(n) - MC_\tau(n) \right] p_\tau(n)^{-\theta} (P_{N,\tau})^\theta \right\} \\
[ N_{N,\tau} + \eta (Q_{\tau} + M_{\tau}) + G_{N,\tau} \left[ 1 - \Gamma_{P_{N,\tau}}(n) \right] ]
\]

where the discount rate \( D_{t,\tau} \) is the intertemporal marginal rate of substitution in consumption of the representative household, to be defined below. Note that when prices are fully flexible (\( \phi_{N1} = \phi_{N2} = 0 \)), the optimization problem comes down to the simple markup rule:

\[
p_t(n) = \frac{\theta}{\theta - 1} MC_t(n)
\]

The presence of distribution services intensive in local non-tradables implies that the elasticity of demand for any brand is not necessarily the same across markets. Firms charge different wholesale prices at Home and abroad. Consider the Home firm producing tradables. Denoting the nominal exchange rate with \( E_t \), firm \( h \)'s price setting problem is:

\[
\left\{ \bar{p}_\tau(h), \bar{p}_\tau^*(h) \right\}_{\tau=t}^{\infty} = \arg \max E_t \sum_{\tau=t}^{\infty} \left\{ \left[ \bar{p}_\tau(h) - MC_\tau(h) \right] * \left( \frac{\bar{p}_\tau(h) + \eta P_{N,\tau}}{P_{Q,\tau}} \right)^{-\theta} Q_{\tau} \left[ 1 - \Gamma_{P_{Q,\tau}}(h) \right] + \left[ \bar{p}_\tau^*(h) - MC_\tau(h) \right] * \left( \frac{\bar{p}_\tau^*(h) + \eta P_{N,\tau}^*}{P_{M,\tau}^*} \right)^{-\theta} M_{\tau}^* \left[ 1 - \Gamma_{P_{M,\tau}}(h) \right] \right\}
\]

where the costs \( \Gamma_{P_{Q,\tau}}(h) \) and \( \Gamma_{P_{M,\tau}}(h) \) are the analogs of (20).

Note that in the absence of price stickiness, prices would be equal to:

\[
\bar{p}_t(h) = \frac{\theta}{\theta - 1} MC_t(h) + \frac{\eta}{\theta - 1} P_{N,t}
\]

\[
E_t \bar{p}_t^*(h) = \frac{\theta}{\theta - 1} MC_t(h) + \frac{\eta^*}{\theta - 1} E_t P_{N,t}^*
\]

As stressed by Corsetti and Dedola (2002), exchange rate pass-through is less than perfect (that is, \( \partial \log \bar{p}_t(h)/\partial \log E_t \leq 1 \) and the law of one price does not hold (that is, \( \bar{p}_t(h) \neq E_t \bar{p}_t^*(h) \)) even if the prices of the tradable goods are flexible. Asymmetries in relative productivity, relative wages, or relative costs of capital drive a wedge between Home and Foreign prices of a good \( h \). Markups in both markets are state-contingent and vary as functions of the shocks. Similar
considerations apply to the retail (consumer) market: \( \partial \log p_t^* (h) / \partial \log \mathcal{E}_t \leq 1 \) and \( p_t(h) \neq \mathcal{E}_t p_t^*(h) \). Foreign variables are similarly characterized.

B.5 Tradable inputs

Symmetric Home firms producing raw and semifinished materials are indexed by \( o \in [0, s] \). Raw materials are produced with labor, capital, and a non-reproducible resource (land for simplicity) denoted \( L \):

\[
T_{O,t}(o) = Z_{O,t} \left[ (1 - \alpha_O - \gamma_O) \xi_O \ell_t(o)^{1 - \xi_O} + \alpha_O \xi_O K_t(o)^{1 - \xi_O} + \gamma_O \xi_O L_t(o)^{1 - \xi_O} \right]^{\xi_O / (\xi_O - 1)}
\]

where \( Z_{O,t} \) is a productivity shock common to all firms and \( \xi_O \) the elasticity of input substitution.

Firm \( o \) takes all prices as given and solves the cost minimization problem:

\[
\{ \ell_t(o), K_t(o), L_t(o) \} = \text{arg min} \{ W_t \ell_t(o) + R_t K_t(o) + P_{L,t} L_t(o) + P_{QO,t}^* \}
\]

\[ \ast \left( T_{O,t}^S(o) - Z_{O,t} \left[ (1 - \alpha_O - \gamma_O) \xi_O \ell_t(o)^{1 - \xi_O} + \alpha_O \xi_O K_t(o)^{1 - \xi_O} + \gamma_O \xi_O L_t(o)^{1 - \xi_O} \right]^{\xi_O / (\xi_O - 1)} \right) \}
\]

where \( P_L \) is the price of land. The Home price of Home raw materials, \( P_{QO} \), is equal to firm \( o \)'s marginal cost. In the absence of pricing to market the law of one price holds internationally, and the price of Home raw materials is identical at home and abroad when expressed in terms of the same currency:

\[
P_{QO,t} = \frac{\left( (1 - \alpha_O - \gamma_O) W_t^{1-\xi_O} + \alpha_O R_t^{1-\xi_O} + \gamma_O P_{L,t}^{1-\xi_O} \right)^{\xi_O / (\xi_O - 1)}}{Z_{O,t}}
\]

(29) \( P_{MO,t}^* = P_{QO,t} / \mathcal{E}_t \)

Similar considerations hold in the Foreign country.

B.6 Consumer preferences

Households’ preferences are additively separable in consumption and labor effort. Denoting with \( W_t(j) \) the lifetime expected utility of Home agent \( j \), we have:

\[
W_t(j) = E_t \sum_{\tau=1}^{\infty} \beta^{\tau-1} [U(C_{\tau}(j)) - V(\ell_{\tau}(j))]
\]

(30)
where $\beta$ is the discount rate, identical across countries. There is habit persistence in consumption according to the specification:

$$(31) \quad U_t(j) = \frac{Z_{U,t}(C_t(j) - bC_{t-1})^{1-\sigma} - 1}{1-\sigma}$$

where $C_{t-1}$ is past per-capita Home consumption and $0 < b < 1$. The term $Z_{U,t}$ is a preference shock common to all Home residents. The parametric specification of $V$ is:

$$(32) \quad V_t(j) = \frac{Z_{V,t}(f(j))^{1+\zeta}}{1+\zeta}$$

where $\zeta > 0$ and $Z_{V,t}$ is a shock to labor disutility. Foreign agent $j^*$’s preferences are similarly specified.

**B.7 Budget constraint**

The individual flow budget constraint for agent $j$ in the Home country is:

$$(33) \quad M_t(j) + B_{t+1}(j) + \mathcal{E}_tB^*_{t+1}(j) \leq M_{t-1}(j) + (1 + i_t)B_t(j) + (1 + i_{t}^*)[1 - \Gamma_{B,t}]\mathcal{E}_tB^*(j) + R_tK_t(j)$$

$$+ P_{L,t}L_t(j) + W_t(j)\ell_t(j)[1 - \Gamma_{W,t}(j)] - P_tC_t(j)[1 + \Gamma_{S,t}(j)] - P_II_t(j) + \Pi_t - NETT_t(j)$$

Home agents hold domestic money $M$ and two bonds, $B$ and $B^*$, denominated in Home and Foreign currency, respectively. The short-term nominal rates $i_{t+1}$ and $i_{t+1}^*$ are paid at the beginning of period $t + 1$ and are known at time $t$. The two short-term rates are directly controlled by the national governments. Only the Foreign-currency bond is traded internationally: the Foreign bond is in zero net supply worldwide, while the Home bond is in zero net supply at the domestic level.

A financial friction $\Gamma_B$ is introduced to guarantee that net asset positions follow a stationary process and the economies converge asymptotically to a steady state. Drawing on Benigno (2001), Home agents face a transaction cost

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15We adopt the notation of Obstfeld and Rogoff (1996, ch.10). Specifically, our timing convention has $B_t(j)$ and $B^*_t(j)$ as agent $j$’s nominal bonds accumulated during period $t - 1$ and carried over into period $t$.

16Alternative approaches to guarantee stationarity rely on parametric assumptions as in Corsetti and Pesenti (2001a,b), time-varying discount rates or demographic dynamics as in Ghironi and Rebucci (2002).
\(\Gamma_B\) when they take a position in the Foreign bond market. This cost depends on the average net asset position of the whole economy and is zero only when Home agents do not hold any Foreign-currency assets. This implies that in a non-stochastic steady state Home agents have no incentive to hold Foreign bonds and net asset positions are zero worldwide. An appropriate parameterization allows the model to generate realistic dynamics for net asset positions and current account.

Specifically, we adopt the following functional form:

\[
\Gamma_{B,t+1} = \phi_{B1} \frac{\exp \left( \phi_{B2} \frac{E_{B,H,t+1}}{P_t} \right) - 1}{\exp \left( \phi_{B2} \frac{E_{B,H,t+1}}{P_t} \right) + 1} + Z_{B,t}
\]

with \(0 < \phi_{B1} < 1, \phi_{B2} > 0\) and \(B_{H,t}^* \equiv (1/s) \int_0^t B^*_t(j) dj\). Ignoring for the time being the component \(Z_B\), when average Home holdings of the Foreign bond are zero, \(\Gamma_B = 0\). When Home is a net lender and holdings of the Foreign bond go to infinity, \(\Gamma_B\) raises from zero to \(\phi_{B1}\), implying that Home households lose an increasing fraction of their Foreign bond returns to financial intermediaries.\(^{17}\)

Similarly when Home is a net borrower and holdings of the Foreign bond go to minus infinity, \(\Gamma_B\) falls from zero to \(-\phi_{B1}\) implying that Home households pay an increasing intermediation premium on their debt. The parameter \(\phi_{B2}\) controls the flatness of the \(\Gamma_B\) function, hence the speed of convergence to the steady state with zero net asset positions worldwide. The variable \(Z_{B,t}\) is a noise term:\(^{18}\) uncertainty in international financial intermediation plays in the GEM the same role that “uncovered interest parity shocks” or risk-premium fluctuations play in other open-economy models (such as McCallum and Nelson (1999) or Kollmann (2001)).

Home agents rent land to Home firms at the nominal rate \(P_L\) and accumulate physical capital which they rent to Home firms at the nominal rate \(R\). The law of motion of capital is:

\[
K_{t+1}(j) = (1 - \delta) K_t(j) + \Psi_t K_t(j) \quad 0 < \delta \leq 1
\]

where \(\delta\) is the depreciation rate. To simulate realistic investment flows, capital accumulation is subject to adjustment costs. Capital accumulation is denoted

\(^{17}\)It is assumed that all intermediation firms are owned by Home residents, and that their revenue is rebated to Home households in a lump-sum fashion.

\(^{18}\)Fluctuations in \(Z_B\) cannot be large enough to push \(\Gamma_B\) above 1.
\( \Psi_t K_t(j), \) where \( \Psi(.) \) is an increasing, concave, and twice-continuously differentiable function of the investment/capital ratio \( I_t(j)/K_t(j) \) with two properties entailing no adjustment costs in steady state: \( \Psi(\delta) = \delta \) and \( \Psi'(\delta) = 1. \) The specific functional form we adopt is quadratic:

\[
\Psi_t = \frac{I_t(j)}{K_t(j)} - \frac{1}{2} \delta \left( \frac{I_t(j)}{K_t(j)} - \frac{I_{t-1}}{K_{t-1}} \right)^2 - \frac{\phi_{I2}}{2} \left( \frac{I_t(j)}{K_t(j)} - \frac{I_{t-1}}{K_{t-1}} \right)^2
\]

where \( \phi_{I1}, \phi_{I2} \geq 0 \) and \( Z_{I,t} \) is a shock (an unexpected increase in \( Z_{I,t} \) is equivalent to an increase in the rate of capital depreciation that raises investment relative to baseline).

Each household is the monopolistic supplier of a labor input \( j. \) Using (17) and its analogs, total demand for type \( j \) input is:

\[
\ell_t(j) = \left( \frac{W_t(j)}{W_t} \right)^{\phi} \ell_t
\]

where \( \ell_t \) is per-capita total labor in the Home economy. Each household sets the nominal wage for input type \( j \) accounting for (37). Following Kim (2000), there is sluggish wage adjustment due to resource costs that are measured in terms of the total wage bill. The adjustment cost is denoted \( \Gamma_{W,t}, \) with:

\[
\Gamma_{W,t}(j) = \phi_{W1} \left( \frac{W_t(j)}{\pi W_{t-1}(j)} - 1 \right)^2 + \phi_{W2} \left( \frac{W_t(j)/W_{t-1}(j)}{W_{t-1}/W_{t-2}} - 1 \right)^2
\]

where \( \phi_{W1}, \phi_{W2} \geq 0. \) As was the case for prices above, wage adjustment costs have two components. The first one is related to changes of the nominal wage relative to its gross steady-state rate of inflation. The second component is related to changes in wage inflation relative to the past observed rate for the whole economy.

Consumption spending is subject to a proportional transaction cost \( \Gamma_S \) that depends on the household’s money velocity \( v, \) where:

\[
v_t(j) = \frac{P_t C_t(j)}{M_t(j)}
\]

Following Schmitt-Grohe and Uribe (2001), the particular functional form for the transaction cost is:

\[
\Gamma_S(v_t) = \phi_{S1} v_t + \frac{\phi_{S2}}{v_t} - 2 \sqrt{\phi_{S1} \phi_{S2}}
\]
Agents optimally choose their stock of real money holdings $M/P$ so that at the margin shopping costs measured in terms of foregone consumption are equal to the benefits from investing in yield-bearing assets.

Home agents own all Home firms and there is no international trade in claims on firms’ profits. The variable $\Pi$ includes all profits accruing to Home households, plus all Home-currency revenue from nominal and real adjustment rebated in a lump-sum way to all Home households, plus revenue from financial intermediation which is assumed to be provided by Home firms exclusively.

Finally, Home agents pay lump-sum (non-distortionary) net taxes $NETT_t(j)$ denominated in Home currency. Similar relations hold in the Foreign country, with the exception of the intermediation frictions in the financial market.

**B.8 Consumer optimization**

The representative Home household chooses bond and money holdings, capital and consumption paths, and sets wages to maximize its expected lifetime utility (30) subject to (33) and (35), and taking into account (37).

In a symmetric equilibrium in which $U'(C_t(j)) = U'(C_t)$ for all agents $j$,\(^\text{19}\) where $C$ is per-capita Home consumption, we can define the variable $D_{t,\tau}$ as:

\[
D_{t,\tau} \equiv \beta \frac{P_t U'(C_t)}{P_{\tau} U'(C_t)} \frac{[1 + \Gamma_{S,t} + \Gamma'_{S,t} v_1]}{[1 + \Gamma_{S,\tau} + \Gamma'_{S,\tau} v_{\tau}]}
\]

which is Home agents’ stochastic discount rate and the Home pricing kernel.

Accounting for the above expressions, optimal bond holdings require:

\[
1 = (1 + i_{t+1}) E_t D_{t,t+1} = (1 + i^*_{t+1}) (1 - \Gamma_{B,t+1}) E_t \left( \frac{\xi_{t+1}}{\xi_t} \right)
\]

The above expression is the risk-adjusted uncovered interest parity, recalling that the return on lending to Foreign is reduced (and the cost of borrowing from Foreign is increased) by the costs of intermediation $\Gamma_B$. Note than in a non-stochastic steady state $1 + i = \pi/\beta$, where $\pi$ is the gross steady-state inflation rate and $1/\beta$ is the gross rate of time preference, and the interest differential $(1 + i) / (1 + i^*)$ is equal to the steady-state nominal depreciation rate of the 

\(^{19}\)While markets are internally complete, guaranteeing equalization of the marginal utility across each country’s residents, markets are not complete internationally and the marginal utilities of Home and Foreign agents need not be equal.
Home currency. Also, in a non-stochastic steady state $1 + R/P$ is equal to the sum of the rate of time preference $1/\beta$ and the rate of capital depreciation $\delta$, and the real wage $W/P$ is equal to the marginal rate of substitution between consumption and leisure, $V'/U'$, augmented by the markup $\phi/(\phi - 1)$ which reflects monopoly power in the labor market.

Optimization implies that households exhaust their intertemporal budget constraint: the flow budget constraint (33) holds as equality and the transversality condition is satisfied:

$$\lim_{\tau \to \infty} E_t D_{t,\tau} [M_{t-1}(j) + (1 + i_t) B_j (j) + (1 + i^*_t) (1 - \Gamma_{B,\tau}) E_{\tau} B^*_\tau (j)] = 0$$

Similar results characterize the optimization problem of Foreign agent $j^*$.  

**B.9 Government**

Public spending falls on non-tradable goods, both final and intermediate. In the model $G_A$ is per-capita public purchases of Home final goods, and $G_N$ is per-capita public purchases of Home intermediate non-tradables. Governments finance public expenditure through net lump-sum taxes and seigniorage revenue. The budget constraint of the Home government is:

$$s P_{A,t} + s P_{N,t} G_{N,t} \leq \int_0^\delta \text{NETT}_t(j) dj + \int_0^\delta [M_t(j) - M_{t-1}(j)] dj$$

The government controls the short-term rate $i_{t+1}$. Monetary policy is specified in terms of generalized interest-rate rules of the form:

$$\left(1 + i_{t+1}\right)^4 - 1 = \omega_i \left[\left(1 + i_t\right)^4 - 1\right] + (1 - \omega_i) \left[\left(1 + \bar{i}_{t+1}\right)^4 - 1\right] + \omega_1 E_t \left[\frac{P_{t+\tau}}{P_{t-4+\tau}} - \Pi_{t+\tau}\right] + \Theta (F_t)$$

where the left hand side is the annualized interest rate, $i_t$ is the lagged interest rate, $0 < \omega_i < 1$, and $\bar{i}_{t+1}$ is the desired interest rate, defined as:

$$\left(1 + \bar{i}_{t+1}\right)^4 = \frac{1}{\beta^4} \frac{P_{t+\tau}}{P_{t-4+\tau}}$$

In the expression above, $P_{t+\tau}/P_{t-4+\tau}$ is the year-on-year gross CPI inflation rate $\tau$ quarters into the future, $\Pi_{t+\tau}$ is the year-on-year gross inflation target. Our specification facilitates the comparison with Taylor-style rules in log-linearized models.
quarters into the future. The term $\Theta$ is a function of a set $F_t$ of observable variables (the output gap, exchange rate etc.) expressed as deviations from their targets, determining feedback rules for the nominal interest rate. In a steady state in which all targets are reached, including a constant inflation target $\Pi$, it must be the case that:

$$1 + i_{t+1} = 1 + \tilde{i}_{t+1} = \frac{1}{\beta} \left( \frac{P_t}{P_{t-1}} \right)^{0.25} = \frac{\Pi^{0.25}}{\beta} = \frac{\pi}{\beta}. \quad (47)$$

Foreign variables are similarly characterized. Any steady-state discrepancy between $\tilde{i}$ and $i^*$ (thus, between $\pi$ and $\pi^*$) determines the steady-state rate of exchange rate depreciation (for $\pi > \pi^*$) or appreciation (for $\pi < \pi^*$).

### B.10 Market clearing

The model is closed by imposing the following resource constraints and market clearing conditions.

The final good can be used for private consumption $C$, government consumption $G$ and investment $I$:

$$\int_0^s A_t(x) dx \geq \int_0^s C_t(j)[1 + \Gamma_{S,t}(j)] dj + sG_{A,t} + \int_0^s I_t(j) dj \quad (48)$$

The resource constraint for good $n$ is $N_S(n) \geq N^D(n)$. In equilibrium this constraint holds as an equality and implies $p(n) = P_N$. The Home tradable $h$ can be used by Home firms or imported by Foreign firms, so that $T(h) \geq Q(h) + M^*(h)$ and, in the aggregate, $sT \geq sQ + (1-s)M^*(h)$.

The resource constraint for Home raw materials is:

$$\int_0^s T_{O,t}(o) do \geq \int_0^s Q_{O,t}(n) dn + \int_0^s Q_{O,t}(h) dh + \int_0^1 M_{O,t}^*(n^*) dn^* + \int_0^1 M_{O,t}^*(f) df \quad (49)$$

while total labor and capital are:

$$\int_0^s \ell_t(j) dj = \int_0^s \ell_t(n) dn + \int_0^s \ell_t(h) dh + \int_0^s \ell_t(o) do \quad (50)$$

$$\int_0^s K_t(j) dj = \int_0^s K_t(n) dn + \int_0^s K_t(h) dh + \int_0^s K_t(o) do \quad (51)$$

21In our simulations government absorption is subject to shocks, or $G_{A,t} = G_{A,t}(1 + Z_{G_{A,t}})$.

22Similar considerations hold for the other price indexes.
and land is in exogenous (possibly stochastic) supply:

\[ s \bar{L}_t (1 + Z_{L,t}) = \int_0^s L_t(j) dj = \int_0^s L_t(0) do. \]

Similar expressions hold abroad. Finally, market clearing in the asset market requires:

\[ \int_0^s B_t(j) dj = 0, \quad \int_0^s B^*_t(j) dj + \int_1^s B^*_t(j^*) dj^* = 0. \]

IV Calibration and model properties

The two-country quarterly model above has been calibrated to simulate realistic interdependencies between a small “representative” transition country and the block of Euro countries. In terms of the model, we refer to the Euro area as the Foreign country and the transition country as the Home country.

Our basic strategy was to develop a base-case calibration by relying when possible on parameterizations that have been used for other economies, adjusted on the basis of simulation properties or experts’ views about the behavior of transition economies relative to other countries.\(^{23}\) In general, we adopted a key guideline principle: since our purpose is to compare the properties of alternative monetary rules when varying country size and degree of openness, we decided to retain as much symmetry as possible among the two economies, at least to the extent that the imposition of similar structural parameters did not conflict with realism and did not entail an unwarranted degree of arbitrariness. In cases where there was considerable uncertainty about a parameter value, we conducted sensitivity analysis to determine how a particular conclusion might be sensitive to the specific calibration. In what follows we discuss the key aspects of our calibration.\(^{24}\)

A Baseline parameters

The Home country size \( s \) relative to World is measured in terms of (relative) GDP. We set \( s \) at 5 percent. The discount rate \( \beta \) is similar in the two countries.

\(^{23}\)Specifically, we have relied heavily on advice from the economists of the Model Development Team at the Czech National Bank. We thank them for sharing data, discussing simulation properties, and suggesting alternative parameterizations based on their assessment of the monetary transmission mechanism in transition countries.

\(^{24}\)Full details on the calibration exercise are available from the authors upon request.
The steady-state real interest rate is $1/\beta = (1 + i) / \pi$. A typical yearly calibration for the real interest rate is 3-4 percent. We follow Christiano, Eichenbaum and Evans (1999) and set $\beta = 1.03^{-0.25}$.

The elasticities of substitution among differentiated intermediate goods, $\theta$ and $\theta^*$, are evaluated by considering the steady-state price markups (for example, in the nontradables sector the markup is $\theta / (\theta - 1)$). Martins, Scarpetta and Pilat (1996) estimate the average markup for manufacturing sectors at around 1.2 in most OECD countries over the period 1980-92. Some authors rely on lower estimates (for instance Chari, Kehoe and McGrattan (2001) choose 1.1), while other authors suggest that a range between 1.2 and 1.7 may be plausible. Benigno and Thoenissen (2001) estimate $\theta$ at 6.9 (for non-tradables) and 6.5 (for tradables) in the United Kingdom, and 7.9 in the euro area. We set $\theta / (\theta - 1) = 1.2$ or $\theta = 6$ in both countries.

The elasticities of substitution among differentiated labor inputs, $\phi$ and $\phi^*$, are related to the wage markup. According to Gali, Gertler and Lopez-Salido (2002), values between 1.15 and 1.4 for the sum of the steady-state wage and price markups can be thought of as “falling within a plausible range”. Higher values however may be appropriate for the euro area. For instance, Benigno and Thoenissen (2001) estimate $\phi$ at 5.1 for the UK, and 4.0 for the Euro area. Our parameterization takes $\phi = \phi^* = 4$ in both countries.

The choice of $\gamma, \nu, \nu_N, \nu_T$ and their Foreign equivalents highlight the differences in the degrees of openness among the two economies on which our exercise is focused. We set $\gamma = .25, \gamma^* = .50, \nu^* = \nu_N^* = \nu_T^* = .98, \nu = \nu_N = .05, \nu_T = .02$. Our calibration implies that in the Home country the import share of downstream intermediate goods is equal to 19.9 percent and the import share of upstream raw materials is equal to 17.4 percent, roughly equally distributed among tradables and nontradables.26

For the Foreign country, we assume that the weight of capital in production is the same in both sectors that produce intermediate goods for final consumption and set $a_N^* = a_T^* = 0.33$. We assume a relatively higher value for the weight of capital in the Home country based on estimates provided by the Czech National Bank ($a_N = a_T = 0.40$). The weights of raw materials are $\gamma_N^* = \gamma_T^* = 0.3$.

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25See e.g. Morrison (1990) or Domowitz, Hubbard and Petersen (1988).
26These import shares figures are based on recent estimates by the Czech National Bank of the trade volumes between the Czech Republic and the Euro area.
\( \gamma_N = 0.1 \), and \( \gamma_T = 0.5 \). The production of raw materials and semi-finished goods is assumed to use a non-reproducible resource (referred to as “land”) in exogenous supply. In both countries the combined income shares of capital and land are assumed to be 0.3, with two thirds of this income stream accruing to capital and one third to land \( (a_O = a_O^* = 0.20 \text{ and } \gamma_O = \gamma_O^* = 0.10) \). These parameters values interact with the import shares and generate steady-state labor shares in total GDP of about 65 percent both in the euro area and in the transition country.

The elasticity of substitution between tradables and nontradables in final good production \( \varepsilon \) is set at 1.1 in both countries. The elasticity of substitution between intermediate exportables and importables in the Home country is also set at 1.1, but is significantly higher in the Foreign country, where \( \varepsilon_{QM}^* = 4 \). These choices are broadly in line with other studies, although the range of plausible options is rather large. Empirical studies of the price elasticity of import demand such as Hooper and Marquez (1995) report a median value of 0.6 for Japan, Germany and UK. Gali and Monacelli (2002) choose \( \varepsilon = 1 \) as their baseline. Other studies (including Chari, Kehoe and McGrattan (2001), and Smets and Wouters (2002a)) set the elasticity of substitution between Home and Foreign goods at 1.5.

The elasticities of input substitution in the production of intermediate tradables and nontradables and raw materials \( (\xi_N, \xi_T, \xi_O) \) are all set at .75 in both countries, significantly below the customary unit elasticity associated with Cobb-Douglas production functions. This choice allows us to simulate a lesser response of capital to interest rate changes than would be the case under a Cobb-Douglas calibration. As opposed to labor and capital, domestic and imported raw materials are highly substitutable in production. Correspondingly, we set the elasticities \( (\xi_{ON}, \xi_{OT}) \) at 3 in both countries.

Burstein, Neves and Rebelo (2000) highlight the link between \( \eta \) and the wholesale/retail margin and set the parameters \( \eta \) and \( \eta^* \) equal to 1. However, in our model the wholesale/retail margin is a function of other structural parameters such as the demand elasticities, and the choice of the distribution parameter \( \eta \) also affects the degree of exchange rate pass-through. Our baseline is \( \eta = .2 \) in the Home country and \( \eta^* = .35 \) in the euro area, implying \textit{ceteris paribus} a higher degree of pass-through in the emerging economy, consistent
with empirical evidence.27

The parameterization of the marginal utility of consumption relies on a combination of high habit persistence \( b = .95 \) and high intertemporal substitution \( \sigma = 1/3 \). This specification is unorthodox but certainly not unprecedented: for instance, Rotemberg and Woodford (1998) adopt \( \sigma = 0.16 \) coupled with the assumption that households choose their index of purchases \( C_t \) at time \( t - 2 \), thus making expenditures decisions predetermined with respect to the timing of interest rate shocks. Experiments with alternative parameters are conducted in sensitivity analysis.

The marginal disutility of labor effort is \( V' = \ell \zeta \). Micro-data estimates of \( \zeta \) consider \([3, 20]\) as a reasonable range. For instance, Gali, Gertler and Lopez-Salido (2002) take \( \zeta = 5 \) as their baseline. But other authors, e.g. Kollmann (2001), choose \( \zeta = 0 \) (linear disutility of labor) following the real business cycle literature. Our benchmark parameterization is \( \zeta = 2.5 \) in both countries.

Aggregate data suggest an annual depreciation rate for capital of about 10 percent, so \( \delta = \delta^* = 0.025 \). The adjustment cost parameters for capital accumulation, \( \phi_{I1} \) and \( \phi_{I2} \), are chosen as to match the fact that the standard deviation of investment is typically observed to be 3-4 times larger than the standard deviation of GDP.

The transaction cost parameters in the bond market are \( \phi_{B1} = 0.05 \) and \( \phi_{B2} = 0.1 \), leading to a very slow reversion of the net asset position between Home and Foreign to its steady-state value. This feature guarantees that in the short and medium term the properties of the model — especially the degree of persistence of bond holdings and the dynamics of the current account — are virtually unaffected by the asymptotic convergence condition. Money demand plays a residual role in our model. We follow Schmitt-Grohe and Uribe (2001) and set \( \phi_{S1} = 0.011 \) and \( \phi_{S2} = 0.075 \) in both countries, consistent with their estimates of money demand in the US.

As ratios of steady-state GDP, government spending \( G_N \) is set at 10 percent and \( G_A \) is set at 5 percent in the two countries, broadly in line with the observed shares of government consumption (assumed to fall exclusively on intermediate nontradables) and investment (assumed to have the same composition of private investment).

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The base-case calibration of the model assumes a significant degree of structural inflation persistence in wages and prices of the intermediate goods in both the tradables and nontradables sectors (controlled by $\phi_{N2}, \phi_{T2}, \phi_{W2}$), but it does not assume any adjustment costs for changes in the level of prices ($\phi_{N1} = \phi_{T1} = \phi_{W1} = \phi_{N1} = \phi_{T1} = \phi_{W1} = 0$). In addition, the base-case calibration of the model assumes that the prices of imported goods that are purchased by wholesalers respond instantaneously to changes in exchange rates ($\phi_{M1} = \phi_{M2} = \phi_{M1} = \phi_{M2} = 0$): as discussed above, because of the presence of a distribution sector there will be incomplete pass-through of the exchange rate to the prices of intermediate goods even when export prices are fully flexible.

The adjustment cost parameters that determine the degree of structural inflation persistence were calibrated to be consistent with a sacrifice ratio of 2.1 in the Foreign country and 1.1 in the Home country. This assumption implies values for $\phi_{N2}, \phi_{T2}, \phi_{W2}$ equal to 400 in the Home country and twice this magnitude for the Foreign country.

B Simulating the monetary transmission mechanism

As mentioned earlier, our model has been calibrated to mimic closely the empirical features of the monetary transmission mechanism as estimated and relied upon for forecasting and policy analysis by central banks. In most empirical models of the monetary transmission mechanism it is not possible for the monetary authority to change the target rate of inflation without having significant short-run effects on real variables in the economy. In addition, in the same empirically-based estimates of the monetary transmission mechanism, hikes in interest rates do not usually result in instantaneous jumps in real activity, but require several quarters to work their effects through the economy. Similar features, both qualitatively and quantitatively, appear in our simulations.

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28The sacrifice ratio is defined to be the cumulative annual output gap that is required to permanently reduce inflation by one percentage point. Estimates of sacrifice ratios are typically smaller in emerging market economies than in relatively closed economies like the Euro area. The estimate of the sacrifice ratio of 1.1 for the Home country was based on the results of a simulation conducted at the Czech National Bank, suggesting that this is a plausible estimate of the transitory output costs of disinflation. A sacrifice ratio around 2.0 for the Foreign country is well within the range of estimates produced by other models of the Euro area.
To illustrate differences and similarities between the two economies of our model, in this section we study the dynamic adjustment patterns in response to two types of policy shocks: a permanent one-percentage point disinflation shock, and a 100 basis point hike in the short-term policy rate.

B.1 Permanent reduction in the target rate of inflation

Figure 6 reports the results of an experiment where the inflation target in the Foreign country is reduced permanently by 1 percentage point. In each panel, the solid line refers to the Home country and the dashed line refers to the Foreign country. As can be seen in the two top panels of Figure 6, the presence of stickiness in the inflation process requires an increase in the nominal interest rate and leads to an appreciation of the real exchange rate. This results in a hump-shaped profile for real GDP that troughs after about four quarters, when monetary conditions ease to prevent an undershooting of the new inflation target. Since the Foreign country’s external trade is relatively small (our two-country setup ignores any trade linkages between the euro area and the rest of the world outside the emerging country), the response of real GDP is mainly determined by the response of aggregate consumption and investment expenditures. The response of investment to this type of aggregate demand shock is approximately three times the response of aggregate GDP, whereas consumption responds slightly less than GDP over the cycle.

The cumulative quarterly effect on the output gap in the Foreign country is 8.5, implying a sacrifice ratio of around 2.1. This is consistent with a fairly large body of empirical evidence according to which disinflation results in significant output costs in the short run. 29 The appreciation of the real exchange rate in the Foreign country results in a loss in competitiveness and a deterioration in real exports of the Foreign country. Note, that because the Home country has significant trade linkages with the Foreign country, the overall spillover effects are contractionary on both investment and consumption in the Home country.

29 Micro-founded models like the GEM also feature interesting asymmetries where the temporary output gains associated with inflating are actually less than the temporary output losses associated with disinflation. In the GEM, monetary-induced cycles caused by positive and negative shifts in the inflation target not only reduce welfare by imposing an additional source of uncertainty on the economy, they also have significant first-order effects on welfare by shrinking the production frontier of the economy.
Figure 7 repeats the above experiment, but this time the reduction in the inflation target occurs in the Home country. Our assumptions on the relative levels of nominal rigidities at home and abroad have obvious implications for the dynamics of the adjustment process. Real GDP in the Home country declines by a similar amount as real GDP in the Foreign country when the shock originated in the Foreign country, but in this case the cycle is significantly less protracted. Indeed, in Figure 7 the quarterly output gap of the Home country cumulates to 4.5 percent, implying a sacrifice ratio of 1.1. As the Home country is small, the Home shock has no discernible effect on the levels of consumption and investment in the Foreign country.

Figure 8 compares our results for a disinflation shock in the Home country with the same experiment conducted on the Czech National Bank’s Quarterly Projection Model (CNB-QPM). In the panels of Figure 8 the solid line refers to the Home country as considered in the GEM, while the dashed line refers now to the Home country as considered in the CNB-QPM.\textsuperscript{30} To make the results more easily comparable across models, the interest rate response in GEM has been tuned to equal the response from CNB-QPM for the first three-quarters of the simulation horizon. The bottom lower panels compare the responses of real GDP and CPI inflation. As Figure 8 shows, the GEM’s theory-based dynamics fits quite well the reduced-form impulse responses at the CNB, and provides a satisfactory representation of the monetary transmission mechanism as embedded in the tools for policy evaluation currently in use in the Czech Republic.\textsuperscript{31} Notice that the responses of real GDP and inflation occur a bit sooner in GEM because expenditure choices are not subject to any decision lags. The introduction of predetermined expenditure\textsuperscript{32} would be necessary in the GEM to explain the type of dynamics that are quite common in empirically-motivated reduced-form models.

\textsuperscript{30}We thank David Vavra and his colleagues at the CNB for supplying us with these simulation results from CNB-QPM.
\textsuperscript{31}In future versions of GEM, the strategy of estimation will consider information provided by models like CNB-QPM as priors, and then use Bayesian techniques to adjust these priors according to available data. See Smets and Wouters (2002b) for an application of this approach to an SDGE model of the Euro area.
\textsuperscript{32}See Woodford (2002) for a textbook treatment.
B.2 Dynamic effects of a temporary interest rate hike

Table 2 reports the responses of key macro-variables in our model to a 1-year hike in the policy rate in the Foreign country, followed by reversal to the base-case Taylor rule. Fagan, Henry and Mestre (2001) consider the same experiment by using the ECB’s Area-Wide Model (AWM), whose empirical apparatus does not build upon a choice-theoretic structural model. For comparison purposes, Table 2 also reports their estimates. As shown in the Table, the responses for many aggregates display a very similar profile and there are only three key exceptions that are noteworthy.

First, the response of investment is significantly longer lived in AWM, reflecting significant accelerator effects that are not uncommon in empirical reduced-form models of the monetary transmission mechanism. Such effects may be difficult to mimic in choice-theoretic models of the business cycle and indeed may reflect a misattribution of the role of supply shocks in reduced-form models that cause more persistent movements in investment, but this remains an issue that needs to be addressed in future research.

The second difference is the response of the exchange rate. In GEM the exchange rate jumps more in the very short run than it does in AWM, reflecting rational behavior by forward-looking market participants as opposed to the ad-hoc treatment of expectations in empirical models. The third difference is the response of imports, which is considerably weaker in the GEM than in the AWM. This is not a surprise: the two-country GEM can only account for bilateral trade between the small and large economies, while the simulation of plausible imports dynamics in the Euro would require an analytical framework in which trade linkages with third markets play a key role.\footnote{A potentially problematic aspect that may deserve further study is the assumption in GEM that interest-rate sensitive demand components such as investment expenditures have the same import propensity of less-interest rate sensitive components. This extension may be incorporated into future versions of the model.}
V Monetary policy rules

A Taylor rules and Inflation-Forecast-Based rules

Over the last decade, the literature on the performance of interest rate rules in macroeconomic models has principally focused on two types of rules, both extensively used in research and policy analysis in central banks. The first one has come to be known universally as the Taylor rule, following the seminal contribution by Taylor (1993) showing that a simple interest rate reaction function, which depended on contemporaneous values for inflation and the output gap, could provide both policymakers and researchers a useful organizational paradigm for thinking about monetary policy issues. The second type of monetary policy rule has come to be known as an Inflation-Forecast-Based (IFB) rule, but IFB rules are simply more “forward-looking” versions of a Taylor rule, as the short-term policy rate is assumed to respond to a forecast of future inflation rather than the contemporaneous level of inflation.\(^{34}\)

Recalling expression 54 above, the specific forms of the Taylor and IFB rules considered in this paper can be nested into our general rule of the form:

\[
\begin{aligned}
(1 + i_{t+1})^4 - 1 &= \omega_1 \left[ (1 + i_t)^4 - 1 \right] \\
+ (1 - \omega_1) \left[ (1 + \bar{i}_{t+1})^4 - 1 \right] + \omega_1 E_t \left[ \frac{P_{t+\tau}}{P_{t-1+\tau}} - \Pi_{t+\tau} \right] + \omega_2 (\text{ygap}_t)
\end{aligned}
\]

where \(\Theta (F_t)\) includes now the output gap (ygap) with parameter \(\omega_2\). Note that, when \(\omega_1, \omega_2 = 0.5\), and \(\omega_1\) and \(\tau\) are set to zero, expression (54) becomes the original Taylor (1993) rule. Because the original Taylor rule did not allow for inertia in the interest rate, we will refer to Taylor rules with inertia as Generalized-Taylor rules, or simply GT rules. By contrast, when \(\tau > 0\), we will refer to the rule as an IFB rule, because the interest rate in this case will depend on a forecast of the year-on-year inflation rate \(\tau\) quarters into the future. In our simulations, the output gap is defined as the deviation of real GDP from the model’s stationary equilibrium.

Taylor rules shed light on the fundamental role of monetary policy under a flexible exchange rate regime, which is to adjust the policy rate in response to changes in inflation and the output gap.
to movements in inflation as to provide an anchor for inflation and inflation expectations. Specifically, in a class of linear rational expectations models the response of the policy rate with respect to inflation has to be greater than one for these models to be stable, and response coefficients below one would be associated with poor macroeconomic performance. This stability property is sometimes referred to as the Taylor principle — see McCallum (2002) and Woodford (1999). In this paper we will be relying upon linearized versions of the GEM that satisfy the Taylor principle.\footnote{The stability conditions in nonlinear models are more complicated. For example, using a nonlinear model, Isard and Laxton (1999) show that the economy may enter the region of instability if the weight on the output gap is too high relative to the weight on inflation, even if the weight on inflation is greater than one. The emphasis on the Taylor rule and the Taylor principle was also instrumental in improving the methodology that was used to build models for monetary policy analysis. For example, it was not uncommon even as late as the 1980s to find models in policy institutions that could be simulated with exogenous interest rates. Such models by definition did not satisfy the Taylor principle.}

A fairly comprehensive study by Levin, Wieland and Williams (2001) (hereinafter LWW) examined the robustness of IFB rules in five macroeconomic models of the US economy. The basic conclusion of their analysis was that IFB rules should respond to a one-year-ahead forecast of inflation and the current output gap, and incorporate a substantial degree of policy inertia. Indeed, the degree of inertia in the models that they studied was estimated to be approximately 1, so LWW went on to formulate a very simple IFB rule of the following form:

\begin{equation}
(55) \quad (1 + i_{t+1})^4 - 1 = \omega_1 \left( (1 + i_t)^4 - 1 \right) + \omega_1 \left[ \frac{P_{t+\tau}}{P_{t-4+\tau}} - \Pi_{t+\tau} \right] + \omega_2 (ygap_t)
\end{equation}

where $\tau = 4$, $\omega_1$ was 1.0, and the weight on inflation and the output gap were both equal to 0.4. We will refer to this simple rule as the LWW rule. An important potential advantage of the LWW rule is that it does not depend on any direct measure of the equilibrium real interest rate, which could be a significant advantage for emerging market economies that typically experience large fluctuations in their equilibrium real rate.\footnote{To the extent that measures of the equilibrium real interest rate are useful for forecasting future inflation, or even measuring the output gap, it is not clear whether problems associated with uncertainty in the equilibrium real interest rate can be overcome entirely by the simple LWW rule.}
B Taylor efficiency frontiers

Figure 9 summarizes the main results of our paper. The two curves plot the trade-off between output and inflation variability in both the Home and Foreign countries, based on the GT rule that allows for interest rate smoothing. The curves were generated by choosing the most efficient pairs of standard deviations for inflation and output by searching over 10,000 combinations of $\omega_1$, $\omega_2$. The implications of openness can be seen clearly in Figure 9. Because the Foreign country is assumed to be relatively closed and exposed to smaller disturbances than the Home country, it is possible for the GT rule to deliver much lower variability in both output and inflation in the Foreign country than in the Home country.

B.1 Results for the relatively-closed Foreign country

The results reported in Figure 9 are consistent with previous work by LWW that studied the robustness of the LWW rule in different models of the US economy. First, the generalized Taylor rule delivers low variability in both inflation and output. Second, and more importantly, the simple LWW rule, which was found to be robust in models for the United States, lies very close to the efficiency frontier of our economy. This provides another confirmation of their result that a simple IFB rule, which places a weight of 0.4 on both inflation and output, is robust across simulation models of a relatively closed economy, not necessarily confined to the US case.

Figure 9 also shows the values for output and inflation variability in the Foreign country based on the original Taylor (1993) rule. As can be seen in the Figure, the Taylor rule lies further away from the efficiency frontier than the LWW rule. Because the original Taylor (1993) rule did not include interest rate smoothing, the distance between the point associated with the original Taylor (1993) rule and the frontier can be interpreted as the benefits that can be derived by generating optimal inertia in the policy rate — see Woodford (1999). In the GEM, these benefits are significant even when we restrict ourselves to comparing

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37 The calculations reported in Figure 9 are based on our base-case set of assumptions for the distributions of the disturbance terms in the model, which were derived to be roughly consistent with the second-order moments in the measures of real activity that were reported in Table 1. Details on the calibration of the distributions can be found in Appendix A.
the differences between GT rules and the original Taylor (1993) rule.\textsuperscript{38}

\section*{B.2 Results for the relatively-open Home country}

We can now assess how rules designed for large and relatively closed economies perform in a small and relatively open economy. The first striking result is that the original Taylor (1993) rule lies directly on the efficiency frontier and appears consistent with policy preferences that place a very high weight on stabilizing output relative to inflation. Indeed, in this case, the standard deviation of inflation is over 2.5 percent and the standard deviation of output is 1.7 percent.

The simple LWW rule does not perform very well in the relatively-open Home economy. In this case the standard deviation of inflation is over 3.0 percent and the standard deviation of output is 1.8 percent. While we have confirmed that the LWW rule is robust for the relatively closed Foreign economy, we must conclude that it is not a particularly robust rule for the relatively open Home country that we are studying here.

This result need not suggest that LWW rules deliver inferior performances in small open economy models. A significant body of research has shown that it may be suboptimal to place too high a weight on output in reaction functions, even in some cases when output variability has a high weight in the objective function. This will be the case, for example, when there is considerable uncertainty in measures of the output gap, or if the economy is dominated by shocks that make it difficult for the monetary authorities to stabilize output without requiring enormous sacrifices in stabilizing inflation variability. This appears to be the case in GEM, at least when we define the output gap as the deviation of real GDP from the model’s stationary equilibrium.\textsuperscript{39}

Figure 9 also includes another LWW rule where the weights on output and inflation have been optimized to minimize a standard loss function that places equal weights of one on both output and inflation variability and a weight of 1/2 on interest rate variability (defined as the change in the interest rate). This calibration process produces a zero weight on the output gap and a weight of

\textsuperscript{38}We conducted some limited experiments allowing the lagged dependent variable to rise above one in IFB rules to check whether inertia in the interest rate might deliver even larger benefits, but at this stage our results are inconclusive.

\textsuperscript{39}It is left to future investigations to assess how our results might change if we defined potential output as the level that is consistent with flexible prices.
around 2.2 on the inflation forecast. According to this LWW rule, the one-year-ahead inflation forecast already embodies sufficient information about the output gap, making redundant the addition of the output gap as a separate argument in the reaction function. Not only is this rule simpler than the original LWW rule, Figure 9 shows that it produces significantly better macroeconomic performance than Taylor rules that allow for interest-rate inertia.40

One obvious question remains to be answered before we move to a more formal comparison of GT and IFB rules. If rules designed for relatively closed economies do not result in good macroeconomic performance in small, open economies, how do rules designed for small open economies perform in relatively closed economies? Point A in Figure 8 provides a preliminary answer to this question. It takes the LWW rule that has been optimized for the Home country and asks how it might perform in a relatively closed economy such as the Foreign country of our model. As can be seen in the Figure, the rule is efficient in the sense that it lies along the efficiency frontier, but the aggressive response of this rule to inflation would only be consistent with preferences that place a high weight on inflation variability relative to variability in output.

C Comparing optimally calibrated GT and IFB rules for the Home country

Table 3 reports the results for the optimal calibration of GT rules for the Home country, using a standard loss function41 that depends on unconditional variances of inflation, the output gap, and the first difference of interest rates. In each case, the weights on inflation variability and interest rate variability are imposed to be 1.0 and 0.5, respectively. The four rows in Table 3 report estimates that are based on varying the weight on the output gap (θ) in the objective function from 0.5 to 2.0 in increments of 0.5. As can be seen in the Table, optimally calibrated GT rules result in significant inertia in the policy rate (estimates of ωi range from 0.81 to 0.87) and plausible coefficients on inflation and the output gap. Relative to the Taylor (1993) rule and the LWW rule, the main difference

40Similar results characterize other studies of policy rules in emerging markets. For instance, in their model of the Argentinian economy Ghironi and Rebuucci (2002) show that, within the class of GT rules, rules that place a large coefficient on inflation perform better.

41The loss function \( L = (P_t/P_{t-4} - \Pi)^2 + \theta \text{gap}_t^2 + \nu (\iota_{t+1} - \iota_t)^2 \). Recall that \( \iota_{t+1} \) is determined at time t.
is that these rules place a significantly higher weight on inflation relative to the output gap.

Table 4 repeats the same exercise for an IFB rule that assumes that the policy rate depends on a one-year-ahead measure of future inflation — that is, $\tau = 4$ in equation (54) above. These results are interesting for a number of reasons. First, the parameter on the lagged interest rate term approaches its upper bound of 1.0 — in these experiments it is not allowed to go above 0.99. Second, the coefficient on the output gap drops to zero. Third, the outcomes for inflation and output variability do not vary significantly over different preferences, and in all cases the model generates almost the same variability for inflation as it does for output. The only significant difference is that a higher weight on output variability in the objective function causes higher interest rate variability.

If one compares the values of the loss functions in Table 3 and Table 4, it can be seen that the IFB rule strictly dominates the GT rule and the difference becomes wider the larger the weight that is placed on output variability in the objective function. However, as can be seen in the Tables, the IFB rule does not offer a substantial improvement over the GT rule when one examines the resulting improvement in macro variability. This result is consistent with other studies that find that IFB rules offer a fairly small improvement over GT rules in linearized models of the economy — see for example, LWW(2001) and Taylor (2001).

VI Conclusion

We have found that rules that perform well in models of the US economy also perform well in our simulation model of a relatively closed economy. But some of these rules — such as the simple LWW rule — are not robust when they are applied to small open economies because they respond too weakly to forecasts of inflation and too strongly to movements in the output gap. However, we have shown that a simple LWW rule modified to exclude the output gap not only gains in terms of simplicity, but it also delivers a more effective macroeconomic performance in small open economies.

There are a number of extensions that need to be taken into account before drawing strong conclusions. First, it may be worthwhile to study the implica-
tions of an alternative measure of the output gap that is based on a flexible-price measure of potential output. Second, to be consistent with the historical data, the model has been calibrated to account for high degrees of structural persistence in the inflation process. However, as argued by Erceg and Levin (2001), estimates of inflation persistence based on historical data, which cover periods of large disinflations, may overestimate the degree of structural inflation persistence, as the observed inflation inertias may stem from a slow adaptation of expectations to the shift from a high to a low inflation regime. Therefore, sensitivity analysis should consider this issue explicitly by discussing an alternative parameterization with significantly lower structural inflation persistence. Third, a maintained assumption has been that imperfect exchange-rate pass-through into the CPI exists solely because of the presence of a distribution sector that uses nontradables intensively to produce final goods in the economy. While this feature may be appropriate for the Czech Republic, an interesting extension would be to allow for inertia in import prices to be consistent with broader empirical evidence according to which the pass-through elasticity of import prices may be significantly lower in the short run than in the long run.

References


Appendix A: Calibrating the distributions for the shocks

We consider several types of stochastic shocks in both countries, as well as a risk premium shock $Z_B$ — see Table A1. These include shocks to productivity in all the sectors ($Z_T$, $Z_N$, $Z_O$) as well as shocks to aggregate investment (the depreciation rate $Z_l$), consumption (the marginal utility of consumption $Z_U$), labor effort (the marginal disutility of labor effort $Z_V$), government spending ($Z_G$), and the weight of tradables in final good production ($Z_{\gamma}$). The productivity shocks are perfectly correlated in all the sectors in each country. The distributions of the shocks have been calibrated to match the moments reported in Table A2.

Relative to the historical data, the model generates considerably less variability in inflation (and interest rates) and considerably more variability in the real exchange rate. This is to be expected because a maintained assumption of the analysis is that monetary policy is being governed by either an explicit (or implicit) inflation-targeting regime, where interest rates are adjusted to provide an anchor for inflation expectations. The base-case assumption for the calibration of the model assumes a Generalized Taylor rule with an interest rate smoothing parameter of 0.5 and a weight on inflation equal to one— see equation 54 in the text. Inflation and interest rate variability is considerably lower than in the historical data because the latter were affected by monetary policy regimes designed to reduce inflation from high levels to low levels.

The model’s measure of the real exchange rate for the Czech republic is considerably higher than the historical data. The historical estimates of variability in the real exchange rate based on data going back to 1993 are biased downward because the monetary policy regimes in place before the adoption of inflation targeting in May 1997 were designed to explicitly reduce variability in the real exchange rate. The sample period is rather limited, but variability in the detrended real exchange rate has been significantly higher since 1997. In GEM, shocks to the risk premium may explain why consumption variability is typically higher than variability in real GDP in emerging economies.
Table 1: Measures of Macro Variability for the Euro Area and Czech Republic

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Table 2: A Comparison of GEM’s Monetary Transmission Mechanism with the ECB’s Area Wide Model (AWM) (Responses to 100 Basis Point Interest Rate Hike)

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Table 3. Optimal Calibrations of Taylor Rules for the Home Country

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1/ Loss function is $L_t = (P_t/P_{t-4} - \Pi)^2 + \theta (ygap_t)^2 + \nu (i_{t+1} - i)^2$

2/ Reaction function is

$(1 + i_{t+1})^4 - 1 = \omega_1 ((1 + i)^4 - 1) + (1 - \omega_1) [(1/\beta^4)(P_t/P_{t-4}) - 1] + \omega_1 [P_t/P_{t-4} - \Pi] + \omega_2 [ygap_t]$
Table 4. Optimal Calibrations of Inflation-Forecast-Based Rules for the Home Country

<table>
<thead>
<tr>
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<th>Loss Function 1/</th>
<th>Optimal Weights 2/</th>
<th>Measures of Macro Variability</th>
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1/ Loss function is $L_t = \left( \frac{P_t}{P_{t-4}} - \Pi \right)^2 + \theta (ygap_t)^2 + \nu (i_{t+1} - i_t)^2$

2/ Reaction function is

$$(1 + i_{t+1})^4 - 1 = \omega_i [(1 + i_t)^4 - 1] + (1 - \omega_i) \left[ \left( \frac{P_t}{P_{t-4}} - 1 \right) + \omega_1 \left[ \frac{P_t}{P_{t-4}} - \Pi_t \right] + \omega_2 [ygap_t] \right]$$
Figure 1. Measures of Productivity and Real Exchange Rates

(Indices: 1993=1)

Ratios of GDP/Employment vs. Germany and Real Exchange Rate Against the Euro
(Solid line=real exchange rate against euro, dashed line=GDP/employment ratio)

Ratios of GDP/Employment vs. Germany and Real Exchange Rate Against the Euro
(Solid line=real exchange rate against euro, dashed line=GDP/employment ratio)

Relative Price and Relative Productivity Levels (Tradables/Nontradables)
(Solid line=relative price, dashed line=relative productivity)

Relative Price and Relative Productivity Levels (Tradables/Nontradables)
(Solid line=relative price, dashed line=relative productivity)
Figure 2. Real Investment, Government and Private Consumption Ratios
(Expressed as a ratio of real GDP; solid line=actual, dashed line=trend)
Figure 3. Real Export, Import and Trade Balance Ratios
(Expressed as a ratio of real GDP; solid line=actual, dashed line=trend)
Figure 4. Inflation, Interest Rates and Current Account Balance to GDP Ratios
(In percent; solid line=actual, dashed line=trend)
Figure 5: The Global Economic Model (GEM)
Figure 6: Foreign Country: Permanent One Percentage Point Disinflation Shock: Deviation From Control
(In percent)
Figure 7: Home Country: Permanent One Percentage Point Disinflation Shock: Deviation From Control

(In percent)

Nominal Interest Rate

Real Exchange Rate

Absorption National Accounts Concept

Real GDP National Accounts Concept

Consumption National Accounts Concept

Investment National Accounts Concept

Real Exports National Accounts Concept

Total Capital Stock

Real Imports National Accounts Concept

CPI Inflation (y-o-y)
Figure 8. A Comparison of a Disinflation Shock in the Home Country of GEM and in the Czech National Bank’s Quarterly Projection Model

Nominal Interest Rate (deviation from control)

Real GDP National Accounts Concept (% deviation from control)

CPI Inflation (y-o-y) (deviation from control)
Figure 9: A Comparison of the Taylor-Rule Based Output-Inflation Efficiency Frontiers for the Home Country and the Foreign Country

- Taylor (1993) Rule
- Simple LWW (2001) Rule
- Optimized LWW Rule

Taylor-Rule Based Efficiency Frontier for the Relatively Open Home Country
Taylor-Rule Based Efficiency Frontier for the Relatively Closed Foreign Country

Standard deviation of CPI inflation
Standard deviation of output
Table A1: Assumptions About the Shocks

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Table A2: Calibration of the Shock Distributions for the Euro Area and Czech Republic

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