ARE SMALL COUNTRIES ABLE TO SET THEIR OWN INTEREST RATES? ASSESSING THE IMPLICATIONS OF THE MACROECONOMIC TRILEMMA

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Are small countries able to set their own interest rates? Assessing the implications of the macroeconomic trilemma

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Abstract

According to the 'macroeconomic trilemma' the ability of small economies to pursue an independent monetary policy is jointly determined by country specific foreign exchange (FX) rate flexibility and capital mobility. In particular, free floating economies should be able to isolate domestic interest rates even under globalized capital markets. Recent evidence casts doubts if this gain in independence is substantial. Taking advantage of semiparametric functional regression models we study the trade-off among FX stability, capital mobility and monetary autonomy for a panel of 20 developed small economies. Confirming the macroeconomic trilemma, the exposure to foreign interest rates is found to increase with country specific states of exchange rate stability and capital mobility. Gains in monetary independence appear substantial for countries that abdicate to peg their FX rates, but the marginal benefit of tolerating higher exposure to FX volatility quickly vanishes. Free floating economies might therefore be able to moderately stabilize FX rates at little cost.

Keywords: monetary independence, macroeconomic trilemma, monetary policy, exchange rate regime, interest rates, functional coefficients, semiparametric models.

JEL Classification: F31, F33, F36

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1 Introduction

The macroeconomic trilemma (Obstfeld, Shambaugh and Taylor, 2005) suggests that the openness of capital markets and the flexibility of FX rates jointly determine the extent to which small economies are able to isolate domestic interest rates from world interest rates. For small open economies, achieving a certain degree of autonomy over domestic interest rates is only possible by accepting some loss of control over domestic exchange rates and vice versa. Accordingly, monetary dependence matters for small open economies that stabilize their FX rates to currencies of larger partner countries by means of FX market interventions. More indirectly, monetary dependence also matters for economies that are subjected to the notion of ‘Fear of Floating’ (Calvo and Reinhart, 2002). Though not necessarily intervening on foreign FX markets, such formally ‘floating’ economies tend to follow world market interest rate movements to prevent strong adjustments of exchange rates. In both cases, however, the autonomy over domestic interest rates is determined by the extent of FX flexibility that monetary authorities are willing to tolerate. Hence, every small open economy that allocates nonzero weight to the FX rate target in its policy function should be subjected to a certain lack of monetary independence. The possibility to choose among a number of distinct domestic policy strategies is the lead argument to allow for a floating currency (Calvo and Mishkin, 2003). Therefore, a comprehensive empirical assessment of this trade-off is of core importance for a sensible evaluation if (and to what extent) a given economy should stabilize FX rates. Recent empirical evidence casts doubt if actual gains in monetary independence are substantial. Frankel, Schmukler and Serven (2004) suggest that, similar to pegs, full transmission of global interest rates also holds for free floating regimes, at least in the long run. According to Frankel et al. (2004), only three economies were able to set their own interest rates over the 1990s, namely Germany, Japan and the US. Presuming that the decision to either pursue a peg or nonpeg (i.e. to allow for some variation in FX rates) factually matters for the monetary independence of small economies, Shambaugh (2004) and Obstfeld et al. (2005) find interest rates of pegs to follow the base countries’ rates closer in comparison with non pegs.

The issue of monetary independence has been investigated mostly by means of rather restrictive econometric models. The conventional approach is conditional on a heuristic classification with respect to an observed or declared status of FX rate flexibility. Then, assuming parameter homogeneity within class specific subsamples, (unbalanced) pooled panel
regression models for interest rate transmission are estimated. Available empirical evidence might suffer from the following shortcomings. Firstly, a conventional de facto classification of exchange rate flexibility such as pegs vs. nonpegs (Shambaugh 2004, Obstfeld et al. 2005) could be too restrictive. Moreover, the assumption of parameter homogeneity within rather general groups is likely violated and might lead to biased panel estimates. In fact, many economies do neither pursue pure pegs nor pure floats (Fischer 2001, Yeyati and Sturzenegger 2005). Furthermore, these (country specific) FX policies may also continuously vary over time according to the relative weight of FX targets in monetary policy functions. To assess the macroeconomic trilemma, the apparent time and country specific heterogeneity that prevails in the data should be fully exploited, rather than relying on restrictive (pooled) panel regressions. In addition, a lack of selectivity among country specific policy options with regard to FX flexibility limits the scope of empirical results for monetary policy advice. Hence, a continuous classification of time varying country specific (de facto) exchange rate flexibility appears to be preferable to heuristic static classifications. Secondly, former studies primarily focus at the impact of exchange rate stability on monetary independence, while the joint impact of capital mobility and exchange rate flexibility has not been sufficiently highlighted yet. While Frankel et al. (2004) indirectly consider capital mobility by modelling time specific subsamples, Shambaugh (2004) provides estimates for interest rate transmission conditional on capital mobility (classified according to the existence and absence of capital barriers) and currency regime type (peg vs. nonpeg). However, as a consequence of country specific currency risk premia, capital mobility might substantially differ across economies with liberalized capital markets, especially in case of nonpegs. Distinguishing between absence of capital barriers and capital mobility might not be essential for a comparison of transmission dynamics among (credible) pegs and nonpegs, but it matters for a comprehensive, continuous assessment of the macroeconomic trilemma. For instance, consider the case of economies following a reference countries’ interest rates to prevent fluctuations of its exchange rate. For a given (accepted) degree of FX rate variability, country specific independence crucially depends on the extent of capital mobility, as it determines the strength of reactions of FX rates to unilateral interest rate changes. Hence, cross correlation of interest rate changes should continuously increase with capital mobility for all economies that attribute nonzero weight to FX targets. In a general model, therefore, interest rate transmission should be evaluated conditional on a continuum of representative states characterized by country specific factual FX flexibility and capital mobility. Thirdly,
comovements among international interest rates have been assumed to reflect a loss of monetary autonomy in general, although the prevalence of real business cycle linkages suggests that central banks could independently choose a similar stance of monetary policy. Therefore, country specific domestic policy rules that include, for instance, observed deviations from steady states of inflation, output and FX rates might also deserve consideration in an empirical model. Lastly, an analysis of monetary independence should be conducted within an uniform empirical model. Respecting the latter premise is not trivial since the cointegration link to world interest rates is known to prevail only for a small set of nominal interest rates. To circumvent this difficulty, Frankel et al. (2004), Shambaugh (2004) and Obstfeld et al. (2005) employ an econometric approach suggested by Pesaran, Shin and Smith (2001). This methodology allows for unique model estimation irrespectively if cointegration holds. However, it somehow exchanges the problem of model choice against the selection of critical values for inferential purposes which depend on assumptions concerning a (unique) cointegration order that characterizes the data.

To address these issues, the empirical model in this work is implemented in the framework of flexible semiparametric functional coefficient models (Cai, Fan and Yao 2000, Herwartz and Xu, 2009). It allows interest rate transmission parameters to be estimated as a (nonlinear) function of both the current state of measurable FX variability and capital mobility. Moreover, country specific domestic fundamentals such as gaps of output, inflation and FX rates are included to identify if dependence of interest rates is induced by international capital flows or reflects independent policy steps under real economic linkages. Using a slightly modified concept of long run monetary dependence, we allow the domestic interest rates to adjust to a flexible (i.e. local) steady state obtained by Hodrick-Prescott (HP) filtering the interest rate differential\(^1\). Since deviations from HP implied steady states are stationary by construction, standard inferential tools apply irrespectively if cointegration features a system of international interest rates or not. Hence, adjustment dynamics can be analyzed in a unique model representation. The considered panel comprises quarterly data for 20 developed economies collected after the great moderation period 1987Q1-2008Q2.

Assessing the full trade-off among FX stability, capital mobility and monetary autonomy in a general model improves upon earlier studies since it allows to quantify the presumed effects of any given reduction in country specific exchange rate flexibility on monetary auton-
omy. Since monetary authorities might not realize substantial gains in independence when tolerating high variability in FX rates, this aspect is of natural interest for policy advice. Moreover, monetary authorities might be interested in the scope that is left for influencing domestic interest rates given the extent of FX volatility they are willing to tolerate.

To preview the empirical results of this work, we confirm the implications of the trilemma to hold throughout. Monetary autonomy appears completely lost for economies that feature low FX rate flexibility and high capital mobility, while economies with rather immobile capital and flexible FX rates are least affected by interest rate transmission. For the latter, however, transmission still appears to be quite high. Formally testing the implications of the macroeconomic trilemma, we strongly reject invariance of interest rate transmission with respect to capital mobility and FX rate flexibility for all provided semiparametric model specifications. Moreover, we provide evidence that ignoring the impact of domestic fundamentals leads to upward biased estimates of interest rate transmission especially for more flexible regimes. Thus, former evidence suggesting that floating implies only moderate advantages in monetary independence might arise from omitted variable biases.

The remainder of this study is organized as follows: In the subsequent section, we introduce our empirical model, which, in a first step, is estimated by means of conventional parametric panel models allowing for fixed effects and country specific interest rate rules. In section 3 we explain how the model is implemented in the functional coefficient framework and motivate the employed state variables. In section 4 we provide semiparametric estimation results, discuss the findings and implications for monetary policy. Section 5 concludes. Technical details about estimation and inference in semiparametric models, as well as several robustness analyses are given in the appendix.

2 Monetary independence - benchmark approaches

As a starting point, we formalize interest rate transmission in a conventional (parametric) framework to obtain a (descriptive) assessment of data inherent features that allows a meaningful comparison with conclusions available from the literature. Firstly, the empirical model is introduced, followed by a brief description of the regime classification procedures applied to measures of FX variability and capital mobility. After providing some information on the data set, parametric fixed effects panel regressions for each regime are conducted and empirical (benchmark) results are discussed.
2.1 Single country regressions

The implications of FX stability on monetary dependence have been investigated by comparing instantaneous transmission of interest rates across different FX regimes. Frankel et al. (2004) use monthly interest rate levels and unbalanced panel models with fixed effects, while Shambaugh (2004) considers first differences in yearly interest rates and pooled model estimation instead. We generalize the panel model in Shambaugh (2004) by additionally considering domestic fundamentals and a ‘pseudo error correction term’ that allows for long term adjustments to a time varying steady state. In line with Shambaugh (2004), the analysis builds on lower frequency data to minimize problems associated with heterogeneous time lags in short term adjustment dynamics. For given presample values consider single country regression models of the following form:

$$\Delta r_{it} = \alpha_i \Delta r_{jt} + \alpha_{i2}(r_{it-1} - r_{jt-1} - \phi_{ijt-1}^{hp}) + \beta_{i1} + \beta_{i2}\bar{q}_{it-1} + \beta_{i3}\bar{s}_{ijt-1} + e_{it},$$

$$\hat{y}_{it} = \alpha_i \bar{r}_i + \beta_{i1}\bar{\pi}_{it-1} + \beta_{i2}\bar{q}_{it-1} + \beta_{i3}\bar{s}_{ijt-1} + e_{it}, \quad t = 1, \ldots, T, \quad i = 1, \ldots, N,$$

(1)

where the time and cross section dimension of the sample are denoted as $T$ and $N$, respectively, $\bar{x}_i' = [\Delta r_{jt}, (r_{it-1} - r_{jt-1} - \phi_{ijt-1}^{hp})]$ and $\bar{z}_i' = [1, \bar{\pi}_{it-1}, \bar{q}_{it-1}, \bar{s}_{ijt-1}]$. Specifically, $r_{it}$ is the (quarterly) short term domestic market interest rate in country $i$, $\phi_{ijt-1}^{hp}$ is the steady state interest rate differential between country $i$ and reference country $j$ obtained by HP filtering of the nominal interest rate differential $r_{it-1} - r_{jt-1}$. For benchmarking purposes, we use either German or US interest rates, where the German rate is the reference for all European countries (except Germany and the UK), and the US rate is considered for all other economies (including Germany and the UK). This choice reflects the commonly held view that most European interest rates are predominantly subjected to German interest rates, while the US monetary policy tends to dominate world interest rates (Katsimbris and Miller, 1993, Kirchgässner and Wolters, 1993, Hassapis, Pittis and Prodromidis 1999). Turning to domestic fundamentals, the deviations from the steady states of domestic inflation, output and exchange rates are given by $\bar{\pi}_{it-1}, \bar{q}_{it-1}$ and $\bar{s}_{ijt-1}$. Throughout, HP implied steady states are recursively evaluated (and therefore ‘observable’)$^2$. As suggested by Hodrick and Prescott (1997) we use a smoothing parameter of $\lambda = 1600$ for quarterly data. For exact definitions of the variables see table 1.

$^2$To guarantee sensible HP gaps at the beginning of the sample (1987Q1) we use presample information, i.e. a gap in $t$ is derived by filtering data for the subperiod $t^*, \ldots, t$, where $t^* << 1987Q1$. 

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Obviously, the specification in (1) is similar to an error correction model restricted to a long run interest rate parity that holds up to an additional time varying intercept \( \phi_{ijt-1}^{hp} \) which is determined outside the model. In the framework of the uncovered interest rate parity, \( \phi_{ijt-1}^{hp} \) should reflect steady states of i) expected FX rate changes as e.g. implied by differences in (expected) inflation rates or ii) persistent risk premia. We choose a flexible local steady state since risk premia and cross country spreads in inflation expectations may trend in a persistent manner. Hence, imposing conventional deterministic terms such as an intercept or a time trend to enter a cointegrating relation might not be appropriate. Moreover, regression (1) is not subjected to inferential issues associated with nonstationary (and eventually not cointegrated) variables, since deviations from the Hodrick-Prescott (HP) filtered interest rate differential are stationary by construction. Lastly, accounting for domestic fundamentals such as the HP-implied inflation, output and exchange rate gap, model (1) rules out spurious evidence on monetary dependence that could be induced by real economic linkages. Notably, \( \tilde{\pi}_{it-1}, \tilde{q}_{it-1} \) and \( \tilde{s}_{ijt-1} \) likely constitute important targets or side conditions of monetary policy. According to the model in (1), monetary independence implies that an economy is able to maintain isolated interest rate adjustments from a given equilibrium interest rate differential (as it is implied by HP trends) to influence output or inflation. Thus, the impact of international transmission (parameterized by \( \alpha_{i1} \) and \( \alpha_{i2} \)) on the domestic interest rate should be insignificant or at least small in absolute terms. Moreover, the response of local interest rates to domestic fundamentals (parameterized by \( \beta_{i1}, \beta_{i2} \) and \( \beta_{i3} \)) should be (significantly) positive\(^3\). However, a positive parameter estimate \( \hat{\beta}_{i3} \) might reflect that monetary authorities adjust domestic interest rates in order to stabilize FX rates, and thus, their policy is not independent in a stricter sense. In turn, loss of autonomy occurs if \( \alpha_{i1} \) (or \( \alpha_{i2} \)) are estimated significantly positive (negative) and large in absolute value. Moreover, under high exposure to foreign interest rates, estimates of \( \beta_{i1}, \beta_{i2} \) and \( \beta_{i3} \) should be insignificant since, in such a setting, monetary authorities likely fail to adjust interest rates with respect to domestic goals. For our purposes, however, the main emphasis lies on transmission parameters \( \alpha_{i1} \) and \( \alpha_{i2} \) since insignificance of parameters \( \beta_{i1}, \beta_{i1} \) and \( \beta_{i3} \) might also signal that countries do not (try to) pursue Taylor-type policy rules. For instance, temporary currency crises, the termination of the great moderation process or the necessity to fulfill stability criteria during the pre Euro era have been likely accompanied by substantial violations of conventional policy rules. Consequently, we control for (time invariant) country specific do-

\(^3\)Note that FX rates are defined in direct quotation
mestic policy rules but discuss associated (unconditional) parameter estimates rather briefly. Partialling out \( z_{it} \) from (1) yields
\[
\hat{y}_{it} = \hat{x}_{it} \alpha_i + \hat{e}_{it},
\]
where \( \hat{y}_{it} = M_i y_{it}, \hat{x}_{it} = M_i x_{it}, \hat{e}_{it} = M_i e_{it} \) and \( M_i = (I_i - z_i (z_i' z_i)^{-1} z_i') \), with \( z_i = [z_{i1}, \ldots, z_{iT}]' \). For panel estimation of equation (2), we allow that interest rate transmission parameters \( \alpha_1 \) and \( \alpha_2 \) vary according to observable heterogeneity measured in terms of FX rate flexibility and capital market integration over countries \( i \) and for time \( t \). Different assumptions concerning the pattern of heterogeneity give rise to both conventional panel regressions with fixed effects and country specific policy rules (sections 2.2 and 2.4) as well as more flexible semiparametric functional coefficient panel regressions (section 3).

2.2 State definitions and panel estimation

Let observable country specific FX variability \( \bar{\psi}^{fx}_{it} \) and capital (im)mobility \( \bar{\psi}^{cap}_{it} \) in quarter \( t \) be approximated as
\[
\bar{\psi}^{fx}_{it} = \sum_{m} (\Delta \ln s_{ij,m})^2 \quad \text{and} \quad \bar{\psi}^{cap}_{it} = (\rho_{it} - \rho_{jt})^2,
\]
respectively, where \( s_{ij,m} \) is the monthly price for one unit of reference currency \( j \) in terms of domestic currency \( i \) and \( \rho_{it} - \rho_{jt} \) is the quarterly real interest rate differential. Specifically, \( \rho_{it} = r_{it} - \pi^e_{it} \) is defined as the three month nominal interest rate \( r_{it} \) deflated by the three month expected rate of inflation \( \pi^e_{it} \) in time \( t \). To avoid endogeneity issues we throughout approximate \( \pi^e_{it} \) by annualized realized consumer price inflation, \( \pi^e_{it} \approx \ln(CPI_{it}) - \ln(CPI_{it-4}) \), implicitly assuming static instead of rational expectations. The FX rate regime in country \( i \) at time \( t \) is classified as relatively 'flexible' ('inflexible') if the current FX volatility is below (above) the corresponding global i.e. cross sectional median\(^4\), \( \text{Med}(\bar{\psi}^{fx}_{it}) \). Moreover, to capture potential strengthening of capital market integration over time, it is distinguished if the capital mobility in time \( t \) is below or above the country specific median reference level\(^5\), \( \text{Med}(\bar{\psi}^{cap}_{it}) \). Formally, we have

\(^4\)It has been argued (Yeyati and Sturzenegger 2005) that FX volatility might not only reflect FX flexibility, but also common exposure to shocks. It is noteworthy that defining FX volatility with respect to a global volatility benchmark might reduce this effect to some extent.

\(^5\)Note that an evaluation with respect to the cross sectional median of capital mobility \( \text{Med}(\bar{\psi}^{cap}_{it}) \) would remove global time trends as e.g. implied by the process of financial globalization.
\[
\tilde{\psi}_{it}^{fx} = \begin{cases} 
\tilde{\psi}_{it}^{fx,h} & \text{if } \tilde{\psi}_{it}^{fx} \geq Med(\tilde{\psi}_{it}^{fx}) \\
\tilde{\psi}_{it}^{fx,l} & \text{otherwise}
\end{cases}
\]
\[
\tilde{\psi}_{it}^{cap} = \begin{cases} 
\tilde{\psi}_{it}^{cap,h} & \text{if } \tilde{\psi}_{it}^{cap} < Med(\tilde{\psi}_{it}^{cap}) \\
\tilde{\psi}_{it}^{cap,l} & \text{otherwise}
\end{cases}
\]

Following the panel approach of Shambaugh (2004), we conduct regime specific pooled estimates of model (2) giving rise to the specification

\[
\bar{y}_{it} = \bar{X}_{it}' \alpha + \epsilon_{it}, \quad \forall \{i, t\} \in (\tilde{\psi}_{it}^{cap,\bullet}, \tilde{\psi}_{it}^{fx,\circ}),
\]

where \(\cdot, \circ \in \{l, h\}\). Panel model (4) implicitly includes country specific fixed effects accounting e.g. for long term moderation processes. To benchmark our model with alternative specifications that have been used earlier in this context, we complementary apply a classification scheme similar to that in Shambaugh (2004), where a country \(i\) in quarter \(t\) is labeled ‘peg’ if its (monthly) exchange rate has been within 2% bands over the last 12 months.

To measure capital mobility, Shambaugh (2004) considered (non)existence of capital barriers. Since capital markets had been liberalized over the vast majority of ‘small’ developed economies until 1987, we do not take capital controls explicitly into account.

### 2.3 Data and variable definition

This study builds on quarterly cross sectional data for the time period 1987q1-2008q3 for 20 ‘small’ economies, namely Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Ireland, Japan, South Korea, Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland and the UK. The choice is motivated by data availability.

Outlying observations quoted in the context of international crises (e.g. European currency crisis 1992/1993, the Asian financial crisis 1997) are excluded from the sample as well as quotes related to excessive interest rate volatility. In particular, strong fluctuations in South Korean interest rates observed before 1999 completely dominated sample information and therefore rendered panel coefficient estimates hardly representative. Interest rates are three month money market rates, or, if not available, three month treasury bill rates. Spot FX rates are throughout determined in direct quotation. To measure inflation we use annualized CPI inflation. Annualized real growth of output is approximated by means of GDP data whenever possible. If corresponding time series are not available, annualized real growth of industrial production is used instead. Table 1 provides more detailed information about data sources, variable definitions and removed observations.
[Insert table 1 about here!]

### 2.4 Results

Table 2 reports panel estimates for the model in equation (2) according to distinct regimes of FX flexibility and capital mobility.

[Insert table 2 about here!]

As implied by a parameter estimate of $\hat{\alpha}_1 = 0.81$, changes in world interest rates $\Delta r_{jt}$ are almost instantaneously reflected in interest rate changes of corresponding partner economies given that exchange rate volatility is low ($\tilde{\psi}_{fx,l}$) and capital mobility is high ($\tilde{\psi}_{cap,h}$). Integrated economies with low FX rate variation are therefore hardly able to adapt domestic interest rates in response to their individual positions over the business cycle. Short run transmission to economies with low FX flexibility but less mobile capital ($\tilde{\psi}_{fx,l}, \tilde{\psi}_{cap,l}$) is weaker ($\hat{\alpha}_1 = 0.65$). At a nominal level of 5%, we do not diagnose significance of error correction dynamics $\hat{\alpha}_2$ for these two regimes. Evidence in the subsequent chapter suggests considerable parameter heterogeneity to prevail within both groups. Consequently, the parameter heterogeneity not taken into account by this panel regressions appears to increase estimation uncertainty and results in imprecise panel estimates. Economies characterized by higher variation of FX rates and rather mobile capital ($\tilde{\psi}_{fx,h}, \tilde{\psi}_{cap,h}$) are less subjected to international transmission of interest rate changes ($\hat{\alpha}_1 = 0.45$) while adjustment dynamics $\hat{\alpha}_2$ towards the steady state equilibrium are insignificant. Lastly, economies with low capital mobility and rather flexible FX rates ($\tilde{\psi}_{fx,h}, \tilde{\psi}_{cap,l}$) are least affected by interest rate transmission ($\hat{\alpha}_1 = 0.34$).

Turning to estimates based on a similar classification as in Shambaugh (2004), pegs are characterized by high transmission of interest rate changes $\hat{\alpha}_1 = 0.83$, while also adjustment dynamics $\hat{\alpha}_2 = -0.13$ are negative with 5% significance. By contrast, contemporaneous transmission of nonpegs’ interest rate changes is weaker ($\hat{\alpha}_1 = 0.45$) and adjustment dynamics are insignificant. The counterpart estimates for $\hat{\alpha}_1$ in Shambaugh (2004, p.325) are 0.79 for pegs and 0.55 for nonpegs under absence of capital controls. However, comparing this evidence to our results is only justified if observed correlation of interest rates fully reflects monetary dependence. Therefore, it is of immediate interest if an exclusion of control variables $\pi_{it-1}, \tilde{q}_{it-1}$ and $\tilde{s}_{ijt-1}$ from (1) yields (upward) biased estimates of monetary
dependence especially for more flexible regimes under synchronized business cycles. To address this point, consider the restricted panel model

\[ \Delta r^*_{it} = \theta_1 \Delta r^*_{jt} + \theta_2 (r_{it-1} - r_{jt-1} - \phi_{ijt-1}^{hp})^* + \bar{e}_{it}, \]

\[ \equiv y^*_{it} = x^*_{it}'\theta + \bar{e}_{it}, \quad \forall \{i, t\} \in (\bar{\psi}_{cap}, \bar{\psi}_{fx}), \]

(5)

where e.g. \( y^*_{it} \equiv y_{it} - \bar{y}_i \) with \( \bar{y}_i \) denoting the sample mean of \( y_{it} \). Table 2 provides regime specific estimates for panel model (5). Overall, ignoring the impact of domestic fundamentals appears to have two distinct effects. On the one hand interest rate transmission seems strongly upward biased for economies that are presumed most independent (\( \bar{\psi}_{fx,h}, \bar{\psi}_{cap,l} \) or 'nonpegs'), since estimates \( \hat{\alpha}_1 \) exceed corresponding quantities \( \hat{\alpha}_1 \) up to \( \hat{\theta}_1 - \hat{\alpha}_1 = 0.11 \).

In turn, there is hardly any difference between \( \hat{\theta}_1 \) and \( \hat{\alpha}_1 \) for economies that should suffer from loss of monetary autonomy (\( \bar{\psi}_{fx,l}, \bar{\psi}_{cap,h} \) or 'pegs'). These findings underline the argument that interest rates of (presumably) more independent economies should ceteris paribus incorporate more information about domestic fundamentals. Interestingly, estimated interest rate transmission obtained under absence of control variables for the group of nonpegs (\( \hat{\theta}_1 = 0.54 \)) is very close to the corresponding estimate of 0.55 in Shambaugh (2004). This might be a hint that the lack of control variables in former studies implies an understatement of independence especially for more flexible FX regimes. On the other hand, somewhat 'odd' parameter estimates \( \hat{\theta}_2 \) are more reasonable after controlling for domestic policy rules.

As already suspected by Frankel et al. (2004) and Shambaugh (2004), our empirical findings support an economically significant share of common movements in interest rates to reflect synchronized business cycle behavior. Thus, evaluating monetary dependence merely in terms of interest rate comovement might not be fully appropriate. Moreover, the "Fear of Floating" phenomenon implying comovements in interest rates under de jure flexible FX rates could be less relevant if one adequately controls for domestic policy rules and real economic linkages.

Unconditional (i.e. state invariant) country specific policy parameter estimates obtained from the regression in (1) are given in table 3.

[Insert table 3 about here!]

Under the assumption that monetary authorities set interest rates in reflection of fluctuations in output and/or inflation rates, we see that, in line with Frankel et al. (2004),
especially Germany and Japan are able to target domestic goals. By contrast to Frankel et al. (2004), there is also evidence that some smaller countries characterized by high FX flexibility (New Zealand) and even economies with intermediate to low FX variation (Netherlands and Switzerland) might be capable to target domestic output and/or inflation. Moreover, significant but counterintuitive policy parameter estimates $\hat{\beta}_{11}$ are diagnosed for South Korea and Italy. Rather tautological, countries with minor FX flexibility such as Belgium, Denmark, France, Italy and Sweden are 'autonomous' in the sense that they seem to have adjusted domestic interest rates to attenuate fluctuations in the valuation of their currencies over longer time horizons. By contrast, insignificant policy response parameter estimates $\hat{\beta}_{11}, \hat{\beta}_{i2}$ that prevail for most of these countries suggest that inflation and output targets cannot be addressed properly. Hence, by adjusting interest rates according to an (intermediate) FX target, it appears if these economies lose their ability to directly address inflation and output targets via interest rates.

Concerning panel estimation of interest rate transmission, overly general classifications as used in this section might not be fully appropriate due to within group parameter heterogeneity. Moreover, such classifications are of limited applicability for policy advice since each economy might have its individual preference with regard to an acceptable degree of FX rate variation. The requirement for a thorough differentiation among states of FX flexibility motivates an assessment based on continuous functional coefficient panel models.

3 Functional coefficient panel models

In theory, the macroeconomic trilemma formalizes that the exposure of small economies’ interest rates to world market rates should exhibit a continuous relation to its factual FX flexibility and the state of capital mobility. In the spirit of the functional model in Herwartz and Xu (2009) consider a semiparametric extension of (2)

$$\tilde{y}_{it} = \tilde{x}_{it}^\prime \alpha(\omega) + u_{it}, \quad \alpha(\omega) = (\alpha_1(\omega), \alpha_2(\omega)),$$

(6)

where $\tilde{y}_{it}, \tilde{x}_{it}$ are obtained from the partial regression in (2). The specification in (6) is a local model for interest rate transmission dynamics in the sense that its parameters $\alpha(\omega)$ depend on a representative continuum of states $\omega$ that, for instance, summarize i) country specific exchange rate variability (discussed in section 3.1), or ii) both country specific exchange rate
variability and capital mobility (section 3.2). Semiparametric functional coefficient estimators are subject to the curse of (factor) dimensionality. With respect to subsequent choices of factor variables, note that the factor dimension will not exceed 2 given the available sample size of quarterly observations. Technical details on estimation and inference in functional coefficient models are given in appendix A and appendix B, respectively.

### 3.1 Dynamic state definitions: FX flexibility

For the moment assume that, during the last two decades, capital has been sufficiently and uniformly mobile such that the ability of small developed economies to influence domestic interest rates has been predominantly determined by the flexibility of FX rates. Let \( \psi_{it}^{fx} \) denote the logarithmic realized exchange rate volatility in economy \( i \) over the last quarter6, i.e.

\[
\psi_{it}^{fx} = \ln(RV_{t=1}^{fx,i,j}), \quad RV_{t}^{fx,i,j} = \sum_{m \in t} (\Delta \ln s_{ij,m})^2,
\]

where \( s_{ij,m} \) is the price of benchmark currency \( j \) in terms of domestic currency \( i \) in month \( m \). In the following, all state variables (or factors, henceforth) are given in standardized form to facilitate (cross sectional) overall comparability. Let

\[
\omega_{it}^{(1)} = (\psi_{it}^{fx} - \bar{\psi}_{i}^{fx})/\sigma_i(\psi_{i}^{fx}),
\]

with \( \bar{\psi}_{i}^{fx} = \frac{1}{T} \sum_{t=1}^{T} \psi_{it}^{fx} \), \( \sigma_i(\psi_{i}^{fx}) = \sqrt{\frac{1}{T-1} \sum_{t=1}^{T} (\psi_{it}^{fx} - \bar{\psi}_{i}^{fx})^2} \)

be a measure of FX variability that characterizes the time path of (standardized) realized FX volatility for a given country. To contrast the state of FX flexibility for an economy in time \( t \) against other markets, define a standardized state variable

\[
\omega_{it}^{(2)} = (\psi_{it}^{fx} - \bar{\psi}_{t}^{fx})/\sigma_t(\psi_{t}^{fx}),
\]

with \( \bar{\psi}_{t}^{fx} = \frac{1}{N} \sum_{i=1}^{N} \psi_{it}^{fx} \), \( \sigma_t(\psi_{t}^{fx}) = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (\psi_{it}^{fx} - \bar{\psi}_{t}^{fx})^2} \).

Finally, let \( \omega = (\omega^{(1)}, \omega^{(2)})' \) summarize the observable states of country specific exchange rate flexibility. For illustrational purposes, figure (1) sketches time paths of observed states

---

6Taking logs improves the distributional features of realized volatilities which tend to be strongly skewed to the left. Since, especially for the EMU members, FX volatilities may become zero, we add a small constant of 0.01 to all volatilities before taking logs.
\(\omega_{it}^{(1)}\) and \(\omega_{it}^{(2)}\) for Austria, Switzerland and Japan which may be seen to represent economies with unconditionally low, intermediate and high FX flexibility. Obviously, with respect to country specific variability over time and measured against other economies, we diagnose state dependence in both directions.

For example, the Swiss Franc is characterized by an increase in FX rate volatility \(\omega_{it}^{(1)}\) after 1999. Moreover, this increase led to a reclassification (due to \(\omega_{it}^{(2)}\)) in the sense that the Swiss Franc moved from a low FX volatility regime to more flexible states compared with other currencies. Notably, a high realization \(\omega_{it}^{(1)}\) does not necessarily imply flexible FX rates. It rather measures if an economy is characterized by a relatively high FX variation compared with its own historical experience. Accordingly, a high \(\omega_{it}^{(1)}\) in combination with a low \(\omega_{it}^{(2)}\) might reflect that a pegging economy has difficulties to maintain the peg.

Histograms of factor variables \(\omega_{it}^{(1)}, \omega_{it}^{(2)}\) are shown in the upper panel of figure 2. The apparent peaks featuring FX based factors reflect quotes belonging to EMU members after the introduction of the Euro. Since intra EMU FX rates have been fixed since then, FX volatilities of all EMU countries were zero, implying a high concentration of observations in the corresponding area of the empirical support. Note that though the latter FX volatilities are zero, there are some observations falling below EMU implied state measures, which is due to the cross sectional standardization. In appendix C, additional empirical results are provided for a subsample 1987Q1-1998Q12 to show that quotes associated with the EMU are not decisive for our quantitative assessment of the macroeconomic trilemma and its implications for monetary dependence.

3.2 Dynamic state definitions: The macroeconomic trilemma

The macroeconomic trilemma suggests that monetary autonomy is lost if capital is fully mobile and exchange rates are stable. Hence, in addition to measures of FX rate stability, (country specific) measures of capital mobility should be taken into account explicitly as determinants of monetary dependence. We rely on \(\omega_{it}^{(2)}\) (i.e. cross sectionally evaluated FX volatility) for measuring FX variation. Capital mobility and capital market globalization has often been approximated by the extent of international real interest rate equalization (e.g.
Mishkin 1984, Obstfeld and Taylor 2002). Let $\psi_{it}$ denote the logarithmic\(^7\) absolute real interest rate differential between economy $i$ and benchmark country $j$ prevailing in time $t - 1$. Formally, $\psi_{it} = \ln(|\rho_{it} - 1 - \rho_{jt} - 1|)$. We define real interest rates $\rho_{it}$ as before in section 2.2. Moreover, real interest rate differentials enter in lagged form to avoid endogeneity problems. Summarizing country specific time paths of capital mobility over the last 20 years, a state measure for capital mobility is defined as

$$\omega_{it}^{(3)} = \frac{\psi_{it}^{in} - \bar{\psi}_{i}^{in}}{\sigma_{i}(\psi_{i}^{in})},$$

with $\bar{\psi}_{i}^{in} = \frac{1}{T} \sum_{t=1}^{T} \psi_{it}^{in}$, $\sigma_{i}(\psi_{i}^{in}) = \sqrt{\frac{1}{T - 1} \sum_{t=1}^{T} (\psi_{it}^{in} - \bar{\psi}_{i}^{in})^2}$.

Since this choice for time specific features leaves cross sectional specific characteristics unconsidered, we additionally provide results using a state variable that subsumes both cross sectional and time specific features of real interest rate convergence in the appendix. Finally, let $\omega = (\omega^{(2)}, \omega^{(3)})'$ summarize states of exchange rate stability and country specific capital market integration. Dynamic and unconditional characteristics of the estimated states of capital market integration are displayed in figures 1 and 2, respectively.

### 3.3 Results

#### 3.3.1 Monetary independence as a function of FX rate flexibility

Figure 3 displays parameter estimates for the two-factor functional coefficient model obtained over a representative continuum of states measuring exchange rate flexibility defined in section 3.1. At first, one observes that, quantified by $\hat{\alpha}_1(\omega)$ and $\hat{\alpha}_2(\omega)$, international transmission decreases over states of relatively high FX variation. Accordingly, results for global tests for factor invariance of transmission dynamics given in table 4 suggest this functional relationship to be globally significant.

[Insert figure 3 about here!]

[Insert table 4 about here!]

Locally, figure 3 shows that economies which are characterized by a low realized FX volatility in comparison with other economies suffer from the highest contemporaneous

---

\(^7\)Similar to section 3.1, we add a small constant and take logs to reduce the skewness of the factor distribution.
transmission $\hat{\alpha}_1(\omega)$ of reference nominal interest rates. Given that a currency is in a state of relatively low country specific FX variability (i.e. $\omega^{(1)} \approx -1$), and, moreover, this variation is rather small with respect to the other currencies in the sample (e.g. $\omega^{(2)} \approx -1$), monthly contemporaneous interest rate transmission $\hat{\alpha}_1(\omega) = 0.9$ is close to unity, implying almost full transmission of world interest rates. In turn, economies with relatively high realized FX volatility ($\omega^{(2)} \approx 1$) are less severely subjected to contemporaneous interest rate transmission varying between $\hat{\alpha}_1(\omega) = 0.4$ and $\hat{\alpha}_1(\omega) = 0.5$. Since corresponding local confidence intervals do not include zero transmission $\alpha_1(\omega) = 0$, we reject interest rate autonomy for small economies with rather flexible FX rates. Generally, state dependence of $\hat{\alpha}_1(\omega)$ is locally significant, since estimates often go beyond bootstrap based 95% confidence intervals which are derived under the assumption of state invariance (see appendix A). For example, given that country specific FX variation is close to its historic average ($\omega^{(1)} \approx 0$), we observe transmission parameter estimates below confidence intervals if corresponding FX variation exceeds the global mean ($\omega^{(2)} \geq 0$). In turn, functional transmission estimates are above confidence bounds if observed FX variation falls short of $\omega^{(2)} \leq -0.5$.

Measuring the adjustment speed towards a steady state nominal interest rate differential, we observe two state specific characteristics for $\hat{\alpha}_2(\omega)$. Firstly, nominal interest rates adjust (significantly) faster when exchange rate volatility is relatively low in comparison with the cross sectional average level of FX rate volatility ($\omega^{(2)} \approx -1$). Moreover, if the domestic currency features higher variability than most other currencies (e.g. $\omega^{(2)} \approx 1$), parameter estimates are close to or even above zero which means that domestic rates do not adjust to the steady state. In line with adjustment parameter estimates from conventional parametric panel models in section 2.4, state invariance implied local confidence intervals include $\hat{\alpha}_1(\omega) = 0$. By contrast, highlighting the merits of local estimation, state dependent estimates are often not included in the interval. For all levels of country specific variation, the speed of adjustment significantly increases in the cross sectional measure of FX stability $\omega^{(2)}$. For low values of $\omega^{(2)}$, $\hat{\alpha}_2(\omega)$ approaches $-0.2$, implying a half life of deviations from steady state interest differentials of approximately three quarters. Secondly, we observe that the adjustment speed also significantly increases in $\omega^{(1)}$, with fastest estimated adjustment diagnosed conditional on states of high country specific volatilities $\omega^{(1)}$ and relatively low states $\omega^{(2)}$. This observation might reflect scenarios in which the stability of (pegged) currencies is threatened by speculative market forces. By reducing the monetary base, monetary authorities might then rise interest rates so markedly that speculators refrain from going
short in the domestic currency (Obstfeld and Rogoff, 1995). Such (short lived) peaks might tend to dominate the estimated adjustment of interest rates locally for states characterized by \( \{\omega^{(1)} > 1, \omega^{(2)} < -1\} \).

3.3.2 Monetary independence implied by the macroeconomic trilemma

Figure 4 shows parameter estimates for the two-factor functional coefficient model obtained over different (i.e. representative) states summarizing FX variability \( (\omega^{(2)}) \) and capital market integration \( (\omega^{(3)}) \) as defined in section 3.2. Refining the overall evidence from parametric panel based evidence in section 2.4, functional estimates \( \hat{\alpha}_1(\omega) \) and \( \hat{\alpha}_2(\omega) \) suggest a marked trade-off among FX stability, capital mobility and monetary independence. Hence, the implications of the macroeconomic trilemma seem to hold throughout for developed economies over the last two decades.

Confirming this overall impression formally, we reject global factor invariance of transmission dynamics at conventional significance levels according to test results in table 4. Moreover, observed transmission depends on both capital mobility and FX flexibility since partial factor invariance is rejected throughout. Thus, the extent of FX flexibility and capital market integration matters for interest rate transmission in general. Locally, figure 4 shows estimated contemporaneous interest rate transmission \( \hat{\alpha}_1(\omega) \) to increase with exchange rate stability and capital market integration (note that high values of \( \omega^{(3)} \) indicate states of relative market disintegration). States of rather low FX rate volatility and high capital mobility are characterized by contemporaneous transmission estimates \( \hat{\alpha}_1(\omega) \) close to unity that steadily decay to \( \hat{\alpha}_1(\omega) = 0.6 \) if capital mobility decreases (ceteris paribus). In turn, if FX flexibility (i.e. \( \omega^{(2)} \)) increases, estimated transmission quickly drops to values close to \( \hat{\alpha}_1(\omega) = 0.4 \). Overall, it appears that a higher share of coefficient variation is caused by FX flexibility in comparison with capital mobility induced variation. This seems intuitive since free flow of capital had been already established for the period under investigation. Local confidence intervals underline that states of high FX flexibility (low capital mobility) are characterized by local state invariance of capital mobility (FX flexibility). Hence, under relatively immobile capital (flexible FX rates), interest rate transmission is not subjected to FX stability (capital mobility) any longer. However, confidence bands never include \( \hat{\alpha}_1(\omega) = 0 \) and thus, full independence might not prevail for small economies even under high FX flexibility and/or
low capital mobility. Accordingly, the predictions of the macroeconomic trilemma most likely hold in a 'relative' form. Similar to the evidence in figure 3, it seems that interest rate transmission rises if $\omega^{(2)}$ falls below a certain threshold value $\omega^{(2)} \approx 0$. Therefore, an economy with high FX flexibility might stabilize its currency to a certain extent without suffering from an increasing exposure to changes in foreign interest rates. Functional estimates $\hat{\alpha}_2(\omega)$ reveal that the adjustment of domestic interest rates to their steady state differential tends to be the faster the less flexible are corresponding FX rates. Again, parameter variation seems to be predominantly governed by states of FX flexibility $\omega^{(2)}$, while (in line with evidence based on parametric models) we also diagnose higher adjustment speed in states of lower capital market integration. Since market integration is measured by means of the real interest rate differential, relatively high capital market disintegration coupled with relatively low FX variability implies raised currency risk premia for a given economy. To some extent, this state (and corresponding local adjustment parameter estimates) should coincide with the case where (target) FX rates are threatened by speculative market forces discussed in section 3.3.1. By contrast to the local behavior of $\hat{\alpha}_1(\omega)$, we find that the foreign influence on domestic rates in terms of $\hat{\alpha}_2(\omega)$ increases whenever FX rate volatility decreases. Thus, even stabilizing the domestic currency moderately might be accompanied by a stronger adjustment to the steady state interest rate differential. Also reflecting empirical results from section 3.3.1, we conclude that free floating economies might moderately attenuate FX rate movements without substantially increasing their exposure to foreign interest rates. However, economies with average FX rate flexibility substantially forfeit remaining degrees of freedom of domestic monetary policy by further decreasing flexibility.

4 Conclusions

The macroeconomic trilemma suggests a binding trade-off among three fundamental aims of monetary authorities: To benefit from full capital mobility, to minimize variation in FX rates and to be able to conduct an independent monetary policy targeting at domestic goals. Since presumed gains in monetary autonomy are the main motivation to accept some variation in FX rates, a comprehensive assessment of this trade-off is a core prerequisite for monetary policymakers’ decisions on the appropriate extent of FX rate flexibility. In this study we put particular effort on providing an extensive empirical assessment of the macroeconomic trilemma and its implications for monetary independence of developed economies by means
Evidence from conventional parametric panel models indicates that, in line with Sham-baugh (2004) and by contrast to Frankel et al. (2004), interest rates of more flexible currency regimes are less subjected to exposure to foreign interest rates. Moreover, we argue that former evidence might have suffered from biased transmission estimates due to the lack of control variables ruling out the effects of synchronized business cycle behavior. Flexible semiparametric panel model estimates and corresponding tests strongly support the general validity of the macroeconomic trilemma, where transmission seems to be a positive (non-linear) function of FX rate stability and capital mobility. Countries with fixed FX rates and closely integrated capital markets share one-to-one interest rate movements with their reference economies, while states that are either characterized by higher FX variation or lower capital mobility (or both) feature markedly less transmission. However, as interest rate transmission does not appear to linearly increase in FX rate flexibility and capital mobility, there is some scope for attenuating FX rate fluctuations at little cost, since (at least for more flexible regimes) marginal decreases in FX rate flexibility do not necessarily imply a marked strengthening of transmission. Accordingly, gains in monetary independence are substantial if a country abdicates pegging its FX rate, but the marginal benefit of tolerating higher FX flexibility quickly vanishes. Lastly, this study focuses on monetary dependence of developed economies. Besides data availability problems, developing economies are not considered since they deserve a different (separate) treatment with respect to their excessively volatile interest rate characteristics, risk premia and choice of domestic fundamentals. Studying determinants of monetary autonomy for developing countries in a modified (semiparametric) model is considered as an issue for future research.
References


Appendix A

Estimation and Inference

Estimation of the functional coefficient vector $\alpha(\omega)$ is implemented as a multivariate version of the Nadaraya Watson estimator (Nadaraya, 1964; Watson, 1964). The estimator is defined as $\hat{\alpha}(\omega) = X^{-1}(\omega)Y(\omega)$ and may be seen as a pooled weighted least squares estimator where observations $\omega_{it}$ close to $\omega$ enter with higher weights than observations $\omega_{it}$ deviating more from $\omega$. The latter weighting procedure is implemented via multiplicative kernel functions. Formally,

$$X(w^{(p)}, w^{(q)}) = \frac{N}{\sum_{i=1}^{N} \sum_{t=1}^{T} \tilde{x}_{it}^t \tilde{x}_{it}' K_h(\omega_{it}^{(p)} - \omega^{(p)}) K_h(\omega_{it}^{(q)} - \omega^{(q)})},$$

$$Y(w^{(p)}, w^{(q)}) = \frac{N}{\sum_{i=1}^{N} \sum_{t=1}^{T} \tilde{y}_{it}^t \tilde{y}_{it}' K_h(\omega_{it}^{(p)} - \omega^{(p)}) K_h(\omega_{it}^{(q)} - \omega^{(q)})},$$

where $\{(p, q)\} \in \{(1, 2); (2, 3)\}$. Moreover, $K_h(\bullet) = \frac{1}{h}K(\frac{\bullet}{h})$ and $K$ denotes a quartic kernel function, i.e. $K(u) = \frac{15}{16}(1 - u^2)^2I(|u| \leq 1)$. For bandwidth selection, we use Scott’s rule of thumb (Scott, 1992), multiplied by a factor of 1.8. Smaller bandwidths turn out to eventually result in numerical problems that occur in regions of very sparse data involving singularity of local regression design matrices.

Local inference on $\alpha(\omega)$ is based on bootstrap-based confidence intervals for parameters associated with international interest rate transmission $\alpha_1(\omega), \alpha_2(\omega)$. To infer if functional coefficient estimates are locally state dependent, the following factor based resampling scheme has been proposed by Herwartz and Xu (2009):

1. Local parameter estimates for model (6) can be considered as a function of the data and the chosen bandwidth parameter, i.e.

$$\hat{\alpha}_i(\omega) = f(\tilde{y}_{it}, \tilde{x}_{it}', \omega_{it} = (\omega_{it}^{(p)}, \omega_{it}^{(q)}), h, i = 1, \ldots, N, t = 1, \ldots, T).$$  

2. Factor dependence and invariance of coefficients in model (7) are distinguished by a comparison among local coefficient estimates and corresponding bootstrap coefficient estimates

$$\hat{\alpha}_i^*(\omega) = f(\tilde{y}_{it}, \tilde{x}_{it}', \omega_{it}^* = (\omega_{it}^{(p)*}, \omega_{it}^{(q)*}), h, i = 1, \ldots, N, t = 1, \ldots, T).$$
Bivariate tuples $\omega_{it}^* = (\omega_{it}^{(p)*}, \omega_{it}^{(q)*})$ are drawn with replacement from the set of bivariate variables $\{\{\omega_{it}^{(p)}, \omega_{it}^{(q)}\}_{t=1}^N\}_{i=1}^T$. Note that sample information on $\bar{y}_{it}, \bar{x}'_{it}$ is not affected by the bootstrap. Therefore, the proposed scheme will generate a factor variable that, per construction, is independent of the functional coefficients. If the null hypothesis of state invariance is true, estimates $\hat{\alpha}(\omega)$ and $\hat{\alpha}^*(\omega)$ should only marginally deviate from each other if evaluated over the support of the factor variable.

3. A large number of draws, $R = 1000$ say, of bootstrap estimates $\hat{\alpha}^*(\omega)$ is considered as sufficient to approximate the underlying distribution under the null hypothesis of state invariance. For inferential purposes, estimates $\hat{\alpha}(\omega)$ are shown with confidence intervals that present the 25th and 975th order statistic of $\hat{\alpha}^*(\omega)$. In this sense, the actual estimate is regarded to differ locally from the unconditional relation with 5% significance if the local confidence interval does not include the local estimate $\hat{\alpha}(\omega)$.

Local inference by means of confidence intervals is informative to characterize functional relationships conditional on specific economic states $\omega$. The same factor based resampling scheme applies to test for 'overall' factor dependence of interest rate transmission $\alpha_1(\omega)$ and long term adjustment $\alpha_2(\omega)$. For this purpose we consider the residual sum of squares (RSS) of the functional regression

$$\bar{y}_{it} = \bar{x}'_{it} \alpha(\omega) + u_{it}.$$ 

The null hypothesis of overall factor invariance, $H_0 : \alpha(\omega) = \alpha$ is rejected with 5% significance if the sample based RSS statistic exceeds the 95% quantile of the respective distribution of bootstrap based counterparts. Notably, the introduced factor resampling scheme applies for testing the hypothesis of global joint factor invariance. To test for partial factor invariance, we draw with replacement from one factor only, while letting the other factor (and thus its potential link to the data) unchanged.
Appendix B

Robustness of empirical results

B.1 Using an exchange rate band based factor variable

One natural alternative to approximate FX flexibility is to use the realized size of (hypothetical) FX bands. Define

\[ \psi_{it}^{fab} = \ln(\max(|\ln(s_{ij,m}) - \ln(\overline{s}_{ij,z})|)) \quad \forall m \in z; z = \{t - 1, \ldots, t - 4\}, \]

where \(\overline{s}_{ij,z}\) denotes the median FX rate (i.e. the presumed target value) that prevailed over the last twelve months. Moreover, \(\max(|\ln(s_{ij,m}) - \ln(\overline{s}_{ij,z})|)\) is the corresponding maximum percentaged absolute deviation from \(\overline{s}_{ij,z}\) which is considered in logs to reduce the skewness of the factor distribution. Furthermore, \(\omega_{it}^{(2b)} = (\psi_{it}^{fab} - \overline{\psi}_{it}^{fab})/\sigma_{t}(\psi_{it}^{fab})\), where \(\overline{\psi}_{it}^{fab}\) is the empirical (time dependent) cross sectional mean of all country specific factors \(\psi_{it}^{fab} = \frac{1}{N} \sum_{i=1}^{N} \psi_{it}^{fab}\), and correspondingly, \(\sigma_{t}(\psi_{it}^{fab}) = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (\psi_{it}^{fab} - \overline{\psi}_{it}^{fab})^2}\) is their cross sectional dispersion.

Functional parameter estimates in the upper panel of figure 5 suggest that the overall result remains robust when substituting realized FX volatility with the realized width of a presumed FX band.

B.2 Using a different measure for capital mobility

In section 3.2 we argued that our choice of a time specific measure for capital mobility \(\omega_{it}^{(3)}\) leaves cross sectional specific characteristics unconsidered. As a robustness check, we additionally provide estimation results based on an alternative state variable that subsumes both cross sectional and time specific features of real interest rate convergence. Formally,

\[ \omega_{it}^{(3b)} = (\psi_{it}^{capb} - \overline{\psi}_{it}^{capb})/\sigma(\psi_{it}^{capb}), \]

with \(\overline{\psi}_{it}^{capb} = \frac{1}{TN} \sum_{i=1}^{N} \sum_{t=1}^{T} \psi_{it}^{capb}\), and correspondingly, \(\sigma(\psi_{it}^{capb}) = \sqrt{\frac{1}{TN-1} \sum_{i=1}^{N} \sum_{t=1}^{T} (\psi_{it}^{capb} - \overline{\psi}_{it}^{capb})^2}\).

Eyeballing the medium panel in figure 5 reveals similar basic empirical functional patterns of \(\alpha_1\) and \(\alpha_2\) as discussed in section 4.
B.3 Excluding the EMU period

One might conjecture that observed functional characteristics in figure 4 just reflect two states implied by EMU and non-EMU observations. Hence, we additionally provide estimates for a subsample of panel data excluding the EMU era to show that these quotes are not decisive for our conclusions. Interest rate transmission estimates conditional on \((\omega^{(2)}, \omega^{(3)})\) for the subsample 1987Q1 – 1998Q4 are given in the lower panel of figure 5. At first sight, the same basic conclusions can be drawn for the substantially smaller data set that excludes quotes on EMU and non-EMU economies after 1998Q4. Most importantly, local estimates that might be presumed to predominantly reflect observed transmission patterns within the EMU (i.e. \(\hat{\alpha}_1 \approx 1\) and \(\hat{\alpha}_2 \leq -0.2\) located in states of high capital mobility and low FX flexibility) hardly change after excluding the most recent decade. In comparison with the full sample estimate, however, subsample based transmission estimates \(\hat{\alpha}_1\) seem locally stronger in states of low to medium capital mobility and high FX variability. Though global factor invariance in general is rejected, this less clear cut pattern of factor dependence for \(\hat{\alpha}_1\) is reflected in the \(p\)-value 0.13 for testing partial (FX implied) global state invariance provided in table 4. In fact, however, this finding reflects more the exclusion of non-EMU economies after 1999 since solely discarding EMU observations yields results very close to full sample based evidence in figure 4 and table 4.
Table 1: Variable definitions, data sources and removed observations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
<th>Removed Observations</th>
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<tr>
<td>$r_{it}$</td>
<td>3 Month MM/TB Rate</td>
<td>IFS</td>
<td>Bel 1992Q2-1993Q4*</td>
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<tr>
<td>$\pi_{it}$, $\pi_{it}^{e}$</td>
<td>$\ln(CPI_{it}) - \ln(CPI_{it-4})$</td>
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<td>Den 1992Q2-1993Q4*</td>
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<tr>
<td>$q_{it}$</td>
<td>$\ln(GDP_{it}) - \ln(GDP_{it-4}) - \pi_{it}$</td>
<td>Datastream</td>
<td>FR 1992Q2-1993Q4*</td>
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<td>$\ln(IP_{it}) - \ln(IP_{it-4}) - \pi_{it}$</td>
<td>Datastream</td>
<td>IT 1992Q2-1993Q4*</td>
</tr>
<tr>
<td>$s_{ij}$</td>
<td>Price currency $i$ / Price currency $j$</td>
<td>Datastream</td>
<td>Ko 1987Q1-1999Q1+</td>
</tr>
<tr>
<td>$\rho_{it}$</td>
<td>$r_{it} - \pi_{it}$</td>
<td>-</td>
<td>Nor 1992Q2-1993Q4*</td>
</tr>
<tr>
<td>$\bar{\pi}_{it}$</td>
<td>$\pi_{it} - \text{HP}(\pi_{it}, \lambda = 1600</td>
<td>I_t)$</td>
<td>-</td>
</tr>
<tr>
<td>$\tilde{q}_{it}$</td>
<td>$q_{it} - \text{HP}(q_{it}, \lambda = 1600</td>
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<td>-</td>
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<tr>
<td>$\tilde{s}_{ij,t}$</td>
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<tr>
<td>$\phi_{ij,t}^{hp}$</td>
<td>$r_{it} - r_{jt} - \text{HP}(r_{it} - r_{jt}, \lambda = 1600</td>
<td>I_t)$</td>
<td>-</td>
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Variable definitions and sources are given in the left panel of table 1. In particular, the notion $\text{HP}(q_{it}, \lambda = 1600|I_t)$ refers to the HP implied trend of $q_{it}$ using a smoothing parameter of $\lambda = 1600$ and only quotes on $q_{it}$ available until $t$. The right hand side panel lists observations discarded from the estimation procedure. Time periods marked with ’*’ denote exclusion due to unusual fluctuations in corresponding interest rates in the line of the European currency crisis. Periods marked with ’+’ denote exclusion due to excess interest rate volatility.
Table 2: Panel estimates for model 2

<table>
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<th></th>
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<th>$\tilde{\psi}<em>{fx,l}$, $\tilde{\psi}</em>{cap,l}$</th>
<th>$\tilde{\psi}<em>{fx,h}$, $\tilde{\psi}</em>{cap,h}$</th>
<th>$\tilde{\psi}<em>{fx,h}$, $\tilde{\psi}</em>{cap,l}$</th>
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<td>0.344</td>
<td>0.825</td>
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<td></td>
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<td>(11.95)</td>
<td>(9.11)</td>
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<td>(2.13)</td>
<td>(-1.21)</td>
<td>(2.93)</td>
<td>(-0.12)</td>
<td>(0.23)</td>
<td>(0.75)</td>
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</table>

Parametric panel estimates for model $y_{it} = \tilde{x}_{it}'\alpha + \epsilon_{it}$ (upper part), as well as for the model $y_{it}^* = x_{it}'\theta + \tilde{\epsilon}_{it}$ (lower part) where the impact of domestic policy rules is not taken into account. Transmission parameter estimates are provided for the full sample as well as for subsamples that are defined by capital mobility ($\tilde{\psi}_{cap,it}$) and FX rate volatility ($\tilde{\psi}_{fx,it}$) in country $i$ and time $t$. The four different states are given by: $\tilde{\psi}_{fx,h,it} \iff \tilde{\psi}_{fx,it} \geq Med(\tilde{\psi}_{fx,it})$; $\tilde{\psi}_{fx,l,it} \iff \tilde{\psi}_{fx,it} < Med(\tilde{\psi}_{fx,it})$; $\tilde{\psi}_{cap,h,it} \iff \tilde{\psi}_{cap,it} < Med(\tilde{\psi}_{cap,it})$ and $\tilde{\psi}_{cap,l,it} \iff \tilde{\psi}_{cap,it} \geq Med(\tilde{\psi}_{cap,it})$. $t$-statistics based on Newey-West standard errors are given in parentheses. Panel estimates according to the classification in Shambaugh (2004) are given in the right panel. The corresponding coefficient estimate $\hat{\theta}_1$ for yearly data in Shambaugh (2004, p.325) is 0.79 for pegs and 0.55 for nonpegs under absence of capital controls.
Policy parameter estimates for single country regressions according to model (1). $t$-statistics based on Newey-West standard errors are given in parentheses.

<table>
<thead>
<tr>
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<th>Aut</th>
<th>Be</th>
<th>Ca</th>
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<td>0.071</td>
<td>0.009</td>
<td>0.048</td>
<td>−0.022</td>
<td>0.098</td>
<td>0.337</td>
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<td>(1.15)</td>
<td>(0.11)</td>
<td>(0.41)</td>
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<td>(1.66)</td>
<td>(7.34)</td>
<td>(−2.44)</td>
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<td>$\hat{\beta}_3$</td>
<td>0.088</td>
<td>0.042</td>
<td>0.002</td>
<td>0.031</td>
<td>0.006</td>
<td>0.038</td>
<td>0.092</td>
<td>0.042</td>
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<td>(1.71)</td>
<td>(1.66)</td>
<td>(0.33)</td>
<td>(0.98)</td>
<td>(0.57)</td>
<td>(1.16)</td>
<td>(1.90)</td>
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<td>−3.821</td>
<td>1.141</td>
<td>−0.285</td>
<td>3.627</td>
<td>−1.300</td>
<td>3.602</td>
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<td>(6.16)</td>
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<td>(2.68)</td>
<td>(−1.37)</td>
<td>(2.48)</td>
<td>(1.55)</td>
<td>(3.36)</td>
<td>(−1.95)</td>
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<td>(2.13)</td>
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<td>(0.36)</td>
<td>(0.29)</td>
<td>(0.04)</td>
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<td>(2.41)</td>
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<td>(1.19)</td>
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<td>(0.70)</td>
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Test for global factor dependence based on the fit $\hat{u}'\hat{u}/Tk$ of model (6). $p$-values obtained by resampling according to appendix A are given in the lower three rows. Resampling is denoted with asterisks. For instance, $(\omega^{(p)*}, \omega^{(q)})$ implies that only the first factor is resampled, while $(\omega^{(p)*}, \omega^{(q)*})$ indicates a 2-tupel wise resampling from $(\omega^{(p)}, \omega^{(q)})$. Accordingly, these tests account for partial and joint factor invariance of interest rate transmission, respectively.
Figure 1: Selection of observed state variables and corresponding interest rates

Factor variables and interest rates including the corresponding reference rates (dashed) for a selection of economies (Austria, Switzerland and Japan). According to $\omega^{(2)}$, these economies might be (on average) considered representative for not flexible, intermediate and flexible currency regimes.
Histograms of factor variables measuring states of FX flexibility (i.e. $\omega_{i,t}^{(1)}$, $\omega_{i,t}^{(2)}$, $\omega_{i,t}^{(2b)}$) and capital mobility ($\omega_{i,t}^{(3)}$, $\omega_{i,t}^{(3b)}$). Formal definitions are given in section 3.1, section 3.2 and appendix B.
The upper (lower) panel presents a three dimensional plot of functional coefficient estimates $\hat{\alpha}_1(\omega), \hat{\alpha}_2(\omega)$, where $\omega = (w^{(1)}, w^{(2)})$ and corresponding selected partial (i.e. two dimensional) functional relations with confidence intervals given in dashed lines. For instance, the first row in the upper right panel shows selected relationships $\hat{\alpha}_1(w^{(1)}, -1), \hat{\alpha}_1(w^{(1)}, 0)$ and $\hat{\alpha}_1(w^{(1)}, 1)$, while the second row presents $\hat{\alpha}_1(-1, w^{(2)}), \hat{\alpha}_1(0, w^{(2)})$ and $\hat{\alpha}_1(1, w^{(2)})$. 
The upper (lower) panel presents a three dimensional plot of the functional coefficient estimates $\hat{\alpha}_1(\omega), \hat{\alpha}_2(\omega)$, where $\omega = (w(2), w(3))$ and corresponding partial (i.e., two dimensional) functional relations with confidence intervals given in dashed lines. For instance, the first row in the upper right panel shows selected relationships $\hat{\alpha}_1(w(2), -1), \hat{\alpha}_1(w(2), 0), \hat{\alpha}_1(w(2), 1)$, while the second row presents $\hat{\alpha}_1(1, w(3)), \hat{\alpha}_1(0, w(3))$ and $\hat{\alpha}_1(-1, w(3))$. The macroeconomic trilemma.
The upper panel presents functional coefficient estimates evaluated conditional on \( \omega = (w^{(2b)}, w^{(3)}) \) while the medium panel provides functional coefficient estimates conditional on \( \omega = (w^{(2)}, w^{(3b)}) \). The lower panel provides functional coefficient estimates evaluated conditional on \( \omega = (w^{(2)}, w^{(3)})^b \) for a subsample of 1987Q1 – 1998Q4.