Exchange market pressure in interest rate rules

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Abstract

Many central banks pursue some kind of exchange rate objective. We derive what variables the central bank should look at when setting the interest rate to implement a given objective. Exchange market pressure (EMP), the tendency of the exchange rate to change, emerges as the key variable. The resulting interest rate rule can implement many regimes, from floating to intermediate to fixed rates, and does so exactly, even after a structural change. It can be applied to many models, and we illustrate it in a New Keynesian model for a small open economy.

Key words: DSGE, exchange market pressure, exchange rate regime, fixed exchange rate, monetary policy, open economy Taylor rule.

JEL classification: E43; E52; F31; F33.

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1 Introduction

Most central banks engage in some form of exchange rate management, particularly in small open and emerging economies; IMF (2019). Our aim is to find the variables the central bank should look at when setting its policy instrument to achieve a given exchange rate objective. We provide a novel derivation for that. It reveals an important role for exchange market pressure, EMP. This variable, due to Girton and Roper (1977), is the tendency of the exchange rate to change, where positive (negative) EMP means depreciation (appreciation) pressure.[1]

We derive this answer in a general setting. That is, by exploiting the information on exchange rate determination that is already present in the theoretical model at hand, we need only few additional assumptions. Moreover, the answer applies to several policy instruments, such as the interest rate and official forex intervention. Note that this paper focuses on the interest rate, because many countries use it and it provides the simplest framework for introducing our idea. We thus conclude that EMP results from a derivation that is applicable to many settings. Apparently, EMP is a key variable for central banking.

We take the exchange rate objective as given. So, we do not derive the degree of exchange rate management central banks should pursue, which depends on the imposed economic structure.[2] Instead, we start from what they *actually* pursue. In this sense the paper is not normative but positive. This also allows us to keep the analysis general, so that the insights are not model specific but hold in many settings. The objective can be a fixed, some intermediate exchange rate regime, or the (perfectly free) float, regarding the level or change of the exchange rate.

Our derivation leads to a new interest rate rule that implements the exchange rate objective exactly. The rule has two main novelties. First, it extends a domestically-oriented rule, such as the Taylor rule, by adding EMP in deviation from the exchange

[1]The formal definition of EMP, taken from the EMP literature, follows in Section 2.3.1. The EMP literature has been further developed by Weymark (1995) and Klaassen and Jager (2011), among others. Interesting applications include the Financial Stress Index of IMF (2009), Frankel and Xie (2010), and Aizenman et al. (2017).

[2]Engel (2014) concludes that welfare-based optimal monetary policy analysis in open-economy models is still in the early stages, but that the analysis to date suggests a role for exchange rates in an optimal rule. Their importance depends on the economic structure. Schmitt-Grohé and Uribe (2016) show that in case of downward nominal wage rigidity optimal exchange rate policy calls for large devaluations during crises to ensure full employment. Davis et al. (2018) show that as central bank credibility falls and thereby the ability to commit to future policy, a highly open economy will quickly find it optimal to set the interest rate to peg the nominal exchange rate as the single mandate. Buffie et al. (2018) analyze less developed countries that pursue inflation targeting. In a float, currency substitution causes a high risk of indeterminacy (multiple equilibria), as well as escalation of inflation shocks. Both problems disappear by tight management of the nominal exchange rate.

rate change that is acceptable according to the objective. Excess pressure implies a high interest rate. This paper thus connects two strands of the literature, that on interest rate rules and EMP, and stresses that EMP, which is often used in applied work, also matters for theory and policy.

The second novelty of our rule is that the coefficient for EMP depends on the interest rate effectiveness to ward off depreciation: for given EMP, the policy maker should use the interest rate less intensively if it is more effective. If he does not adjust, the exchange rate objective is missed. This is a natural property but still a novel feature of our rule. It also helps us to reveal two structural parameters that underlie the coefficient for EMP, namely the effectiveness and the degree of exchange rate management. The former is determined by the model, while the latter is a policy choice.

What do central banks actually do? Some are explicit on this and consider what they call "pressure." For example, Danmarks Nationalbank (2019) writes that "in situations with upward or downward pressure on the krone, Danmarks Nationalbank unilaterally changes its interest rates in order to stabilise the krone." Likewise, the Hong Kong Monetary Authority (2009) describes its "automatic interest rate adjustment ... against downward pressure on the exchange rate."[3] The idea is that high selling pressure requires a high interest rate. Calvo and Reinhart (2002) provide further examples. He et al. (2011) from the HKMA write that they monitor "foreign exchange market pressure" in their daily work. Mohanty (2013) reports that in a BIS survey among central banks almost 80% said that curbing speculative pressures on the exchange rate was the most important priority.

Despite the relevance of pressure in actual policy, there is no formalization yet. We show EMP is close to what central bankers mean by pressure and derive it is natural to have EMP in a policy rule. So our derivation provides theoretical support for actual policy. The reverse is also true: actual policy confirms the realism of our approach.

The traditional approach to model the interest rate for a central bank with an exchange rate objective is to add the exchange rate gap (actual minus target value) to a Taylor rule, as in Monacelli (2004), or to the foreign interest rate, as in Benigno et al. (2007). This has contributed to valuable insights, in other papers as well.[4] However,

[3]Hong Kong has a currency board system based on an automatic interest rate adjustment mechanism. In case of downward pressure, the central bank purchases Hong Kong dollars from banks so as to increase market interest rates and thereby capital inflows and achieve exchange rate stability. Because of its focus on the interest rate, we use Hong Kong as an example in this paper. An alternative would be to model policy as unsterilized intervention, but then the main idea relevant for us would be similar: the central bank responds to pressure and exploits the interest rate.

[4]The former rule has also been used by Engel and West (2005), Corsetti and Müller (2015), and Galí and Monacelli (2016), for example. The latter rule has been applied by Benigno (2004) and Born et al. (2013), among others. These papers focus on the nominal exchange rate. Instead, some authors add

we cannot use such an approach of adding a preselected variable to answer our research question. After all, we want to know what variables to include, and how. That is why we *derive* our rule.

The derivation also makes our rule better founded. Still, one can compare the rules. There are two key differences, both favoring our rule. First, we have EMP instead of the actual exchange rate gap. For example, if the gap is zero, the existing rules imply that the central bank abstained from using the interest rate, but we allow for the possibility that the central bank sets a high rate to offset depreciation pressure so as to keep the exchange rate on target. As central bankers indicate that they look at pressure, using EMP increases realism. EMP also makes that our rule covers more exchange rate regimes, relies on weaker assumptions, and implements the objective exactly.

Second, our rule has separate parameters for the interest rate effectiveness and the exchange rate regime. These structural parameters are hidden in the traditional approach. From our rule it is thus always clear what the regime is, and in case of a structural change, our rule automatically accommodates so that the objective keeps on being implemented. This consistency makes our rule attractive for theoretical analyses.

The structure of the rest of the paper is as follows. In Section 2 we derive the interest rate rule and show the relevance of EMP. Section 3 discusses its characteristics. In Section 4 we set out a New Keynesian DSGE model for a small open economy to illustrate our method and derive the interest rate rule and EMP for that model. Section 5 illustrates their characteristics using a simulation study. Section 6 concludes.

2 Interest rate rule

For a given exchange rate regime, the goal is to derive the variables the monetary authorities should look at when setting the interest rate to implement that regime. We address this in a two-country setting. The domestic monetary authorities, being the central bank throughout this paper, pursue some degree of exchange rate management as one of the policy goals (the float is a valid special case). Foreign authorities do not try to control the exchange rate.

For the rest of the economy, one could think of a log-linearized rational expectations New Keynesian (NK) model where the home country is a small open economy, in the

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the real rate to an interest rate rule, as in Clarida et al. (1998) and Mimir and Sunel (2019). Leitemo and Söderström (2005) also study changes of nominal and real rates. All these papers add preselected variables, and we let Monacelli (2004) and Benigno et al. (2007) represent this approach.
An alternative to a rule is to simply pin down the exchange rate at the target level, as in De Paoli (2009). That can suffice for some analyses of the fixed rate. But the focus in our paper is on approaches that deliver a regime endogenously and that work for many more regimes, giving additional insights.

spirit of De Paoli (2009). Section 4 assumes this to illustrate how our approach works.

However, to enhance applicability of our answer to the question of interest we first allow for a more general framework. The exchange rate function will play a key role in our derivation, and we discuss that in Section 2.1. The derivation itself is in Section 2.2.

2.1 Exchange rate function

Let s_t be the (logarithm of the nominal) exchange rate at time t, which is the domestic currency price of one unit of foreign currency. We assume that it is possible to solve s_t from the particular model at hand as a function of the exchange rate determinants.

The interest rate i_t is one determinant, and we cluster its effects on s_t in two groups. First, i_t can operate via contemporaneous channels only. For example, a high i_t attracts capital and thus lowers s_t (appreciation). Or a high i_t weakens current consumption, reducing the home price level, increasing foreign demand for home goods, and appreciating the home currency, all in period t.

The second impact of i_t on s_t goes via expectations. For example, a high i_t may increase the currently expected interest rate next period, i_{t+1}, which then weakens expected consumption at $t+1$, and similar to the causal chain above leads to expected home appreciation at $t+1$, appreciating the home currency at t.

We now write the exchange rate function s in the form

$$s_t = s\left(i_t, E_t\right), \tag{1}$$

where the i_t argument represents the contemporaneous channels, and the vector E_t consists of expectations and all other exchange rate determinants. This separation will be convenient in the next section. It is not restrictive — it just splits the full impact of i_t on s_t into the two groups. Section 4.2 derives this (i_t, E_t)-form in our New Keynesian model, in particular formula (28), where (30) specifies E_t.

The variables in E_t depend on expectations, predetermined, and contemporaneous variables, but the separation implies that the latter no longer include the impact of i_t. So contemporaneous variables such as goods prices, interest rates concerning other maturities than the one underlying i_t, national income, and fiscal policy are first cleaned for i_t by moving the i_t dependencies to the i_t argument, and then the remainder enters E_t. For example, consider goods prices. The second example of contemporaneous channels above, that a high i_t lowers goods prices and appreciates the currency, is captured by the i_t argument. What remains in the E_t argument is, for example, that lower expected future income weakens current consumption, causing lower prices and appreciation, and that exogenous technological progress via lower prices causes appreciation.

2.2 Derivation of the rule

We want to derive an interest rate rule that implements a given exchange rate objective at every t. The derivation consists of three steps. First, realize that the model at hand determines how the interest rate i_t affects the exchange rate s_t, represented by s-function (1). To ensure that our rule implements the objective, we want an expression for i_t that is consistent with that function.

Let's impose for simplicity the s-function is linear in its first argument, that is,

$$s_t = -wi_t + s\left(0, E_t\right), \tag{2}$$

where the scalar

$$w = -\frac{\partial s}{\partial i}\left(., E_t\right) \neq 0 \tag{3}$$

reflects the effectiveness of the interest rate to counteract depreciation via all contemporaneous channels, as follows from the separation of function arguments in Section 2.1.[5] We leave out the time subscript from w for notational simplicity. Linearity holds in our NK model, where w is constant, positive, and follows from existing parameters.

We can now rewrite

$$i_t = \frac{1}{w}\left(s\left(0, E_t\right) - s_t\right). \tag{4}$$

Note that the expectations in E_t can still depend on i_t.[6] This equation is not yet an interest rate rule; it is just a rewritten version of existing equation (2). However, if we substituted s_t by some target value s^t, (4) would deliver the interest rate that exactly implements the fixed exchange rate regime where $s_t = s^t$. For other regimes, however, it is not clear how to formulate the objective and thus what to substitute for s_t. Moreover, many traditional rules have a domestically-oriented part to which an exchange rate part is appended. Our equation does not yet have that form, which hampers comparison.

The second step in our derivation helps to solve both issues by partitioning the i_t

[5] One usually considers w to be positive, that is, an interest rate increase appreciates the currency. In intuitive explanations below we will do as if w is positive, but we do not impose it in the derivation.

[6] Recall that the separation of the s-function in Section 2.1 says that the first (i_t) argument captures the impact of i_t via all contemporaneous variables, and the second (E_t) argument includes all effects of i_t via expectations. We could have moved contemporaneous variables to the E_t argument and then adjusted w accordingly. That would have resulted in equivalent versions of (4) and result (5), with the same underlying economic mechanisms at work, but such a mixing of contemporaneous variables and expectations would blur the interpretation of (5). Our separation treats all contemporaneous variables similarly and, by substituting out those endogenous variables, will lead to a more compact rule. Likewise, if the impact of i_t via E_t contains linear parts, moving such parts to the i_t argument would be equivalent and just blur interpretations. Our separation treats all expectations similarly, keeps them in the forms actually used by agents, and allows for nonlinear dependence of E_t on i_t.

rule. Let i_t^d denote the part that shows the rule for the interest rate the central bank would set without considering the exchange rate. We call i_t^d the domestically-oriented (part of the) interest rate rule. The remainder, $i_t - i_t^d$, reflects exchange rate policy. (Note that we do not introduce a different policy but just distinguish two parts of the existing policy.) Both parts typically depend on the actual economic situation, and thus on i_t, just as E_t does. For example, i_t^d could be a standard Taylor rule based on actual inflation. In a float, $i_t = i_t^d$.

Rewrite (4) by adding and subtracting i_t^d, so that

$$i_t = i_t^d + \frac{1}{w}\left(s_t^d - s_t\right), \tag{5}$$

where

$$s_t^d = s\left(i_t^d, E_t\right). \tag{6}$$

The i_t^d argument in s_t^d captures, for example, that a lower i_t^d to stimulate economic growth by itself typically weakens the currency, reflected by a higher s_t^d. Having i_t^d instead of i_t takes out the central bank exchange rate policy via all contemporaneous channels. The E_t argument captures the agents' expectations. We thus view s_t^d as a summary of forex market sentiment. Because s_t^d combines only part of i_t with E_t, we call s_t^d the intermedial exchange rate. It is simply a combination of existing variables, so it is not a necessary variable in the model.[7]

Finally, we can propose the rule

$$i_t = i_t^d + \frac{1}{w}\left(s_t^d - s_t^o\right), \tag{7}$$

where s_t^o denotes the exchange rate objective. The intuition is that a high s_t^d reflects that investors intend to sell the currency, and to the extent that it exceeds the objective s_t^o, the central bank has to set a high interest rate. For the fixed rate, s_t^o is the target s^t. In the float, $i_t = i_t^d$, so that s_t^o has to be set at s_t^d. Other regimes are handled by other choices for s_t^o, as described in Section 2.4. For example, objective (10) implies rule (11), which in the NK illustration becomes (33).

Because the model at hand delivers exchange rate function (2), and the latter is rewritten into and thus equivalent to (5), adding rule (7) to the model is equivalent to adding $s_t = s_t^o$. This yields two insights. First, the rule implements the exchange rate

[7]Because — as always in the paper — i_t^d and the expectations in E_t are both based on the actual interest rate i_t, s_t^d is *not* the counterfactual exchange rate based on i_t^d and expectations and variables consistent with that rate. The latter would boil down to the exchange rate under a float, but that is not the regime in place, as we do not study a policy change. So s_t^d is not the exchange rate in some other equilibrium or so.

objective exactly, by construction. This is confirmed in the NK illustration.

Second, the reverse is also true: to implement the objective, the central bank should use rule (7).[8] Also this is a consequence of the fact that our approach exploits information that is already in the model, fundamental equation (2) for the exchange rate.

2.3 EMP as the key determinant

Exchange market pressure (EMP) is an existing variable, introduced by Girton and Roper (1977). Intuitively, it represents the reluctance of investors to hold the domestic currency at the forex market. This reluctance tends to affect the exchange rate, and that may trigger the central bank to act. This resembles the idea of our interest rate rule. Indeed, we will show that the rule implies a prominent role for EMP in policy.

2.3.1 EMP definition

The idea of the EMP concept is to split the actual (relative) depreciation of the home currency, resulting from the interplay of investors and authorities, into a part reflecting the reluctance of investors to hold the currency, called EMP, and the policy-based part, which usually intends to counteract EMP. EMP applies to any exchange rate regime and can be positive as well as negative, where the latter means there is pressure on the currency to appreciate. One example is a fixed exchange rate that is under attack by speculators and where the attack is successfully offset by policy. Then EMP is positive, the policy-based counteracting depreciation is negative and offsets EMP exactly.

More formally, EMP_t is defined as the relative depreciation of the home currency at time t in the absence of exchange rate policy, while keeping expectations at the levels determined by actual policy. This is the standard definition in the EMP literature, due to Weymark (1995). It does not depend on a model, so the definition of EMP_t is unique.[9] We here apply it to the setting where the interest rate is the policy instrument.

[8] Here we obviously assume that the model does not already have restrictions regarding exchange rate management, such as the convertibility restrictions of Benigno et al. (2007), because we do not use them in our rule.

[9] A model can be used to derive how EMP_t is a function of fundamentals, so the model provides the microfoundations of EMP_t. This function varies across models, and Weymark (1995) and (8) with (32) in our paper provide examples. Note further that in the EMP literature, the term "EMP" not only refers to EMP itself, but also to a *measure* of EMP. EMP measures vary across papers and include the current value of the policy instrument. In contrast, in our paper "EMP" always means EMP itself, not the measure, and we use EMP to explain the current value of the policy instrument. Note that EMP measures often include the change in foreign reserves divided by money supply. Klaassen and Jager (2011) explain why that is in line with the EMP definition (for a central bank using forex intervention as instrument) and how our EMP formula below (with the interest rate as instrument) is also consistent with the EMP definition.

One key element in the definition is the absence of exchange rate policy. The interest rate rule in this situation is i_t^d, the domestically-oriented rule introduced in Section 2.2. Without the second key element in the EMP definition, the condition on expectations, the use of i_t^d would make EMP like the depreciation under a floating exchange rate regime. But that is not what EMP intends to capture; EMP is about the reluctance of investors to hold the currency in the *actual* regime. So EMP uses the same values for the expectations as E_t defined earlier. Using our notation, EMP is thus defined as

$$EMP_t = s_t^d - s_{t-1}. \tag{8}$$

So EMP_t is a function of fundamentals excluding the actual interest rate i_t.

2.3.2 EMP in the rule

Rewriting rule (7) using (8) shows that the rule depends on $EMP_t - (s_t^o - s_{t-1})$. Given the derivation of the rule, we conclude that EMP emerges in a natural way as the key determinant of the interest rate if a central bank wants to implement an exchange rate objective. In this sense, our derivation reveals the insight that central banks should look at EMP. So our rule guides policy.

The rule says that the central bank has to set $i_t > i_t^d$ to ward off EMP_t insofar pressure exceeds the target depreciation $s_t^o - s_{t-1}$. The magnitude of $i_t - i_t^d$ is the amount of excess pressure converted into interest rate units by dividing by the effectiveness w of the interest rate instrument.

It is contemporaneous pressure that matters, not expected future pressure. This marks a difference with the inclusion of, say, expected inflation in some Taylor rules. The latter are typically used to model central bank policy to control inflation between today and a year ahead, say. Such a focus on the future is not what matters in exchange rate management. The obvious example concerns the fixed rate: if today's interest rate does not offset the pressure to move away from the target today, there will be an immediate breakdown of the peg, irrespective of expected future developments. Hence, today's EMP_t is what matters for i_t.

2.3.3 Justifying and being supported by actual policy

As argued in the introduction, central bankers consider what they call "pressure" on their currency at the forex market when implementing exchange rate management. A high s_t^d reflects that investors intend to sell the currency. That mimics what central bankers mean by pressure. The EMP variable relates s_t^d to the lagged rate s_{t-1} and the

EMP literature calls this pressure. That is in line with the phrase “downward pressure” used by Danmarks Nationalbank (2019) and Hong Kong Monetary Authority (2009), and with He et al. (2011) from the HKMA, who write that they monitor “foreign exchange market pressure.” This advocates a formalization of the word “pressure” by

$$\text{pressure} = EMP_t. \tag{9}$$

Because pressure matters in actual policy, our rule not only guides policy, but it also justifies and is supported by actual policy.

2.4 The rule for specific exchange rate regimes

Rule (7) can be combined with many exchange rate objectives s_t^o. The current section applies it to six regimes. Five are inspired by practice, namely the float, fixed rate, crawling peg without band, peg with possibly time-varying band, and a policy that moderates the rate of change (called “leaning against the wind”). IMF (2019) shows that these regimes cover the majority of the countries. Examples include the United States, Bulgaria, Nicaragua, China, and Brazil, respectively, albeit that we examine only one type of policy to implement the regime, that is, interest rate policy.

The other regime is a weighted combination of the fixed and floating exchange rate regimes, which we introduce because it will be convenient in theoretical analyses and we will focus on it in the rest of the paper to simplify the exposition.

In the float the central bank does not try to affect the exchange rate, so any tendency for the rate to move to a particular value is ignored by its interest rate policy. More formally, $s_t^o = s_t^d$. Rule (7) then sets $i_t = i_t^d$, as expected.

For the fixed exchange rate the question at hand is what i_t the central bank should choose to ensure the exchange rate equals the target s^t. Substituting $s_t^o = s^t$ into (7) gives the interest rate that hits this target.

The weighted fixed-floating exchange rate is a weighted average of the fixed and floating exchange rate regimes, where the weight $\mu \in [0, 1]$ denotes the degree of exchange rate management. The regime and the interest rule implementing it are

$$\text{Policy objective: } \; s_t^o = (1 - \mu)\, s_t^d + \mu s^t \tag{10}$$

$$\text{Interest rate rule: } i_t = i_t^d + \frac{1}{w}\mu \left(s_t^d - s^t \right). \tag{11}$$

For $\mu = 0$ this confirms the rule for the float. The higher μ, the more i_t responds to a given $s_t^d - s^t$, meaning tighter exchange rate management. For $\mu = 1$ the system represents the fixed rate. Put differently, (11) and (5) imply $w \left(i_t - i_t^d \right) = \mu \left(s_t^d - s^t \right)$

and $s_t - s^t = (1-\mu)\left(s_t^d - s^t\right)$, so that μ captures how much of $s_t^d - s^t$ the central bank offsets by policy, and the rest $1-\mu$ shows how much ends up in the actual exchange rate gap. Note that $\frac{1}{w}\mu$ in (11) discloses the two structural parts that underlie the coefficient for s_t^d, namely the model-determined interest rate effectiveness w and the degree of exchange rate management μ chosen by the policy maker. So (11) disentangles a Taylor-rule type of coefficient into two structural parameters.

The crawling peg generalizes the fixed rate by having a time-varying target: $s_t^o = s_t^t$.

In the peg with band the exchange rate must lie in a band $[\underline{s}_t, \overline{s}_t]$. One example, inspired by Krugman (1991), is where $s_t^o = s_t^d$ if $s_t^d \in [\underline{s}_t, \overline{s}_t]$, but once the exchange rate tends to leave the band, the central bank uses the interest rate to make sure that the exchange rate settles at the nearest boundary, so $s_t^o = \underline{s}_t$ if $s_t^d < \underline{s}_t$, and $s_t^o = \overline{s}_t$ if $s_t^d > \overline{s}_t$. A special case is the one-sided band, as applied in Switzerland until 2015 and in the Czech Republic until 2017, where $\underline{s}_t$ restricts appreciation but $\overline{s}_t$ is infinite.

In the "leaning against the wind" regime the central bank aims at mitigating the change in the exchange rate. So it counteracts the wind $s_t^d - s_{t-1}$, that is, EMP_t. This regime follows from the weighted fixed-floating regime by using s_{t-1} instead of s^t. Despite the practical relevance of leaning against the wind, the rest of this paper focuses on the exchange rate level. Substituting s^t below by s_{t-1} gives the features of our rule for the change.

3 Characteristics of the rule and relation to the literature

Because the interest rate rules in the existing literature cannot be used to address our research question, we have derived a new rule. Still, it is instructive to compare the outcome to the existing rules and see how EMP makes them different.

3.1 The rules to be compared

As explained in the introduction, the rules representing the traditional approaches rely on the gap between the actual exchange rate and its target. The first rule, due to Monacelli (2004), adds this exchange rate gap to a standard Taylor rule, formalized by

$$i_t = i_t^d + \varphi_s\left(s_t - s^t\right), \tag{12}$$

where $\varphi_s \geq 0$.

Second, the rule by Benigno et al. (2007) adds the gap to the foreign interest rate,

$$i_t = i_t^* + \varphi_s^{BBG}\left(s_t - s^t\right), \tag{13}$$

where $\varphi_s^{BBG} > 0$, and adds two assumptions. That is, the rule assumes uncovered interest parity (UIP), and that the home central bank credibly forces investors to convert the foreign into the home currency if the latter depreciates beyond some value; a similar commitment is imposed on the foreign central bank if the home currency appreciates.

Our rule, in the special case of the weighted fixed-floating regime, is (11). So we have $\frac{1}{w}\mu$, a new variable s_t^d (and thus EMP_t), and we impose neither UIP, nor the convertibility assumptions.

3.2 Implementing the exchange rate objective

The central bank wants to implement its objective, the weighted fixed-floating regime indicated by μ. We now examine whether the three rules fulfill this basic requirement.

Substituting the Monacelli (2004) rule (12) into (5) shows that the resulting s_t is a weighted average of s_t^d and s^t, with weight $\frac{w\varphi_s}{1+w\varphi_s}$ on the latter. The objective s_t^o, however, has weight μ. So by not using w, the central bank does not know which regime it implements, and its objective is missed (unless φ_s happens to be $\frac{1}{w}\frac{\mu}{1-\mu}$), which is not surprising as Monacelli does not focus on implementing a specific regime. The fixed exchange rate is not covered but is the limiting case where $\varphi_s \to \infty$.

Benigno et al. (2007) focus on the fixed rate, and they aim at implementing it without an infinite response parameter. Their rule (13) says that the central bank commits to raising i_t above i_t^* if s_t tends to exceed s^t. The authors show that without the convertibility assumptions the exchange rate would explode to plus or minus infinity with positive probability, and they prove that in equilibrium the threat of the convertibility restrictions implies $s_t = s^t$ and that the central bank will never actually need to raise i_t, that is, $i_t = i_t^*$. This holds for any $\varphi_s^{BBG} > 0$, reflecting the relevance of the convertibility assumptions.

Our rule (11) implements the regime exactly, for all μ, as shown in Section 2.2. So it is the only rule that fulfills the basic requirement. This is achieved by using the model-implied exchange rate function, so that exactly the right amount of pressure is offset. Even if we just consider the fixed rate, our rule outperforms. After all, it can implement that regime with a finite parameter, improving on Monacelli (2004), and our rule needs neither the convertibility assumptions, nor UIP, and is thus more realistic than Benigno et al. (2007).

3.3 Pressure instead of the actual gap

Taylor rules typically include the gap the central bank wants to close. The traditional rules follow this method by having the actual gap $s_t - s^t$, but we do not. Our rule is the result of a general derivation from which s_t^d, and thus EMP_t, emerges as the key determinant. Moreover, the relevance of pressure is confirmed by actual central bank policy, as shown in the Introduction. Both support our rule.

The merits of using s_t^d instead of s_t can be illustrated by considering the fixed exchange rate regime. If investors' supply weakens the currency in the sense that there is a tendency for the currency to depreciate to $s_t^d > s^t$, then our rule says that the central bank has to set $i_t > i_t^d$ to ward off the pressure. For a successful defense, the outcome is $s_t = s^t$. So our rule can explain $i_t > i_t^d$ if the actual gap $s_t - s^t = 0$. In contrast, by relying on the actual gap, traditional approaches imply that there is no need for using the interest rate. This is another indication that it is better to use pressure than the actual gap, as in reality exchange rates close to target can come together with substantial use of the interest rate.[10]

3.4 Interest rate effectiveness and the structure of the economy

The traditional rules use φ_s or φ_s^{BBG} to capture the impact of the gap $s_t - s^t$ on i_t. This is a fixed parameter, like a standard Taylor-rule parameter. It is set independently of the structure of the economy under consideration, including the exchange rate function. To illustrate the consequences, consider a change in financial openness that makes the interest rate more effective for exchange rate purposes (higher w), so that one would expect a less aggressive interest rate response for a given $s_t - s^t$.

Traditional rules, however, imply the same i_t as before the structural change, due to the unchanged φ_s and φ_s^{BBG}. The consequence when using the Monacelli (2004) rule is that after the structural change the actual regime is one of tighter exchange rate management, so that the central bank misses its objective. For the Benigno et al. (2007) rule, the impact of keeping φ_s^{BBG} constant is none, because the convertibility assumptions determine the outcome, irrespective of the value of the response parameter.

In our rule, the impact of a given pressure on i_t depends on w, and the larger w weakens the required interest rate reaction, as expected. Recall w is the effectiveness of the interest rate instrument in achieving the exchange rate objective. So the policy recommendation is that central bankers should account for the effectiveness of their

[10]For example, consider the Annual Reports of the central banks of Denmark and Hong Kong. In February 1993 (ERM turbulence) Danmarks Nationalbank increased interest rates and succeeded in keeping the krone exchange rate stable. In 2000 (Danish referendum on euro participation) and 2008 (global financial crisis) it also defended the krone by interest rate hikes. In 2015 it set a negative interest rate to fend off appreciation pressure.
Hong Kong experienced four speculative attacks in 1997-8 (East Asian financial turmoil). The central bank acted to increase market interest rates; see footnote 3 for the mechanism. It also increased the savings deposit rate. The exchange rate remained stable. In 2007 (US sub-prime mortgage problems), 2008 (Lehman collapse), and 2009 a lower interest rate counteracted appreciation pressures.

policy instrument when determining its use. This seems straightforward, but only our rule includes it. The effectiveness is determined by the structure of the economy, in particular the exchange rate function. By deriving our rule in close relation with that function, we automatically and correctly account for w and changes thereof.

3.5 Observability

Having s_t^d in our interest rate rule implies that the computation of i_t requires knowledge of the functional form of the s-function in (1) and its determinants. In a theoretical model that is no problem. Indeed, in Section 4.3 we will calculate s_t^d for a DSGE model.

In practice, central bankers use indicators to monitor pressure and thus s_t^d. For example, the Hong Kong Monetary Authority uses forward exchange rates, prices of currency options, balance of payment statistics on capital flows, and market surveys; see He et al. (2011). Fundamentals suggested by theoretical models, such as the ones in Section 4.3, can extend this list and thus help policy. Moreover, our pressure-based rule can serve as a benchmark when studying rules that use indicators of pressure.

Still, traditional rules have an observable variable, s_t, and that may seem an advantage over our rule, which has s_t^d. However, this advantage is illusory. To show this, substitute rule (11) for $i_t - i_t^d$ in (5), and use the resulting s_t^d in (11). That gives

$$i_t = i_t^d + \frac{1}{w}\frac{\mu}{1-\mu}\left(s_t - s^t\right), \qquad (14)$$

for $\mu \neq 1$. So in the special case of the weighted fixed-floating regime, our approach can be reformulated such that s_t appears instead of s_t^d, implying that the presence of the observable s_t is no true advantage of the traditional rule. Even more so, having s_t entails the costs that i_t is no longer identified for $\mu = 1$ and that the rule misses the essence of policy, that is, looking at pressure. Both costs are avoided by using s_t^d.

3.6 Disentangling the reduced-form coefficient φ_s

Taylor-rule parameters such as φ_s in the Monacelli (2004) rule (12) are typically viewed as policy-choice parameters. However, special case (14) shows that

$$\varphi_s = \frac{1}{w}\frac{\mu}{1-\mu}, \qquad (15)$$

so that not only the policy choice μ, but also the effectiveness w matters (for $\mu > 0$).

So φ_s is a reduced-form coefficient for which our approach gives the two underlying structural parameters. This explains why for the traditional rule the regime is not identified, and why a change in the economy that alters w modifies the unknown regime in an unknown way.

Our rule resolves these identification issues. Interestingly, as w is determined by existing parameters only, disentangling φ_s does not increase the number of model parameters. We have simply used information in the exchange rate function, which is not exploited in the traditional rule.

3.7 Reality check: estimating the de facto regime

Because representation (14) implies

$$\frac{1}{w}\frac{\mu}{1-\mu} = \frac{\text{stdev}\left\{i_t - i_t^d\right\}}{\text{stdev}\left\{s_t\right\}}, \tag{16}$$

we can use data on $i_t - i_t^d$ and s_t to estimate the left hand side by the ratio of sample standard deviations and then, for a given w, estimate the de facto degree of exchange rate management μ.[11] This is an advantage over traditional approaches, which do not distinguish μ, and estimating μ offers a simple check of the realism of our approach.

To operationalize this, we assume that i_t^d is a linear function of domestic producer price inflation π_{Ht} with coefficient 1.5, following Monacelli (2004). One way to obtain a value of w is by specifying a model and compute it from the model parameters. We will do that in the subsequent sections. For now, we set $w = 1.62$, the value of the baseline economy in the simulation section 5.

We examine five countries, Australia, Canada, New Zealand, Denmark, and Hong Kong, the countries taken from the simulation section and the Introduction. The first three have an official inflation targeting policy, while the latter two pursue an exchange rate target. We use 15 years of quarterly data, from 2000 through 2014. This sample is for illustration only, and we leave a broad empirical study for future research.[12]

The estimates of stdev$\left\{i_t - i_t^d\right\}$/stdev$\{s_t\}$ are 0.02, 0.02, 0.02, 4.03, and 5.52 for the respective countries. Figure 1 illustrates the implied μ. For Australia, Canada, New Zealand the estimated μ is 0.03. For Denmark we obtain 0.87, and for Hong Kong 0.90, meaning that their regimes can be characterized as an about 90% fixed and 10% floating exchange rate regime.[13] All five are in line with the IMF (2019) de facto

[11] The large literature on de facto regime estimation includes Frankel and Xie (2010) and IMF (2019).

[12] The variables for quarter t are measured as follows. For i_t we take the three-month interbank interest rate, calculated as the period average of the daily rates in the quarter. Given period-average PPI values, we use year-on-year inflation for π_{Ht} and thus i_t^d. Then we express i_t and i_t^d at a quarterly basis; all interest rates in the paper are at this basis, so not annualized. The rate s_t is the log of the average daily price of one dollar (euro for Denmark). All data have been obtained from Datastream.

[13] The value of w that underlies the μ estimates is based on the core parameter values in Table 1. These

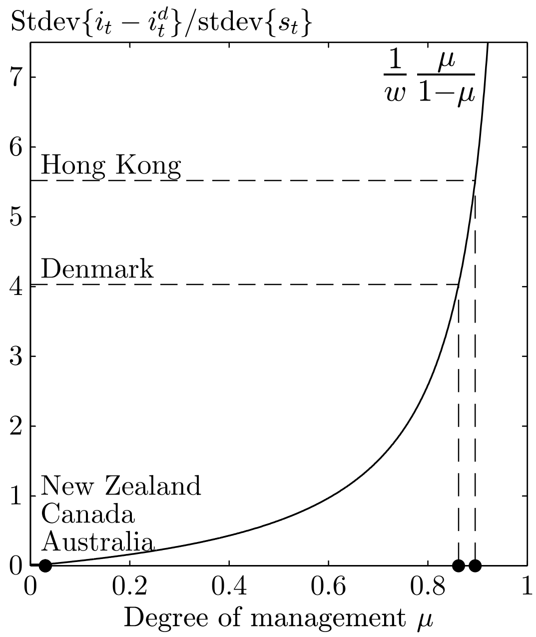

Figure 1: Estimating the degree of exchange rate management.

classification. We conclude from this simple analysis that our pressure-based interest rate rule can deliver useful insights into structural parameters such as μ.

4 Illustration in a log-linearized DSGE model

In Section 2 we have derived the key role for EMP in policy and this has resulted in a new interest rate rule. The approach is generally applicable, and the resulting insights are valid in many models. The current section presents one specific model to illustrate the computation of EMP, the rule, and some of their properties. Hence, we keep the model simple.[14] Various extensions are possible, such as a more complete description of the role of financial markets in exchange rate determination, for example based on Gabaix and Maggiori (2015), but these are left for future study.

We take a two-country rational expectations New Keynesian model where the home country is a small open economy, in the spirit of De Paoli (2009). Section 4.1 presents its

are estimates. To quantify the reliability of w, we use the information on the posterior distributions of the core parameters, as reported by Justiniano and Preston (2010), to estimate the posterior distribution of w. The resulting 95% credible interval for w is [1.39, 2.19]. The implied intervals for μ are [0.03, 0.04] for Australia, Canada, and New Zealand, [0.85, 0.90] for Denmark, and [0.88, 0.92] for Hong Kong. These are narrow, so that we simply focus on the point estimates.

[14]Several model assumptions we will make, such as producer currency pricing, are relevant for the optimality of the exchange rate regime. However, recall that we take the regime as given, so from this point of view those model assumptions are not restrictive. In fact, our rule has been derived in the general setup of Section 2, so we can safely impose the assumptions to simplify the exposition.

non-policy block, where many elements and derivations will be standard, as described by Galí (2008). The sections thereafter concern our innovations.

4.1 The model: non-policy block

Web Appendix A, available from our homepages, specifies the non-policy part of the model and derives the zero-inflation and zero-depreciation, symmetric and efficient steady state. We log-linearize the equations around that steady state and use the log-linearized version from now on. The relevant equations are (17)-(27), derived in Web Appendix B, and the foreign equivalents of (17)-(21). Lowercase Latin letters denote the logarithm of variables, except for the interest rate, and an asterisk refers to the foreign country or currency. Table 1 defines all parameters, gives their ranges, and shows the values used in the simulation section 5.

$$\text{Labor supply} \quad : \quad \gamma\ell_t + \sigma c_t = \mathrm{w}_t - p_t \tag{17}$$

$$\text{Consumption Euler} \quad : \quad \sigma c_t = \sigma \mathbb{E}_t \left\{c_{t+1}\right\} - \left(i_t - \mathbb{E}_t \left\{\pi_{t+1}\right\} - \delta\right) \tag{18}$$

$$\text{Real marginal cost} \quad : \quad mc_{Ht} = \log\left(1 - 1/\theta\right) + \mathrm{w}_t - a_t - p_{Ht} \tag{19}$$

$$\text{Calvo-based pricing} \quad : \quad \pi_{Ht} = \beta \mathbb{E}_t \left\{\pi_{H,t+1}\right\} + \kappa_{mc}(mc_{Ht} - \log\left(1 - 1/\theta\right)) \tag{20}$$

$$\text{Labor market equilibrium} \quad : \quad \ell_t = y_t - a_t \tag{21}$$

$$\text{International risk sharing} \quad : \quad \sigma\left(c_t - c_t^*\right) = s_t + p_t^* - p_t \tag{22}$$

$$\text{Law of one price} \quad : \quad p_{Ft} = p_{Ft}^* + s_t \tag{23}$$

$$\text{Goods market equilibrium} \quad : \quad y_t = \nu c_t + \left(1 - \nu\right) c_t^* + \left(1 - \nu^2\right) \eta \left(p_{Ft} - p_{Ht}\right) \tag{24}$$

$$\text{Goods market eq. abroad} \quad : \quad y_t^* = c_t^* \tag{25}$$

$$\text{CPI} \quad : \quad p_t = \nu p_{Ht} + \left(1 - \nu\right) p_{Ft} \tag{26}$$

$$\text{CPI abroad} \quad : \quad p_t^* = p_{Ft}^*. \tag{27}$$

The world is populated with a continuum of households, where the population in the home country H lies in the segment $[0, n)$, while that of the rest of the world F is in $[n, 1]$. Households live forever and have identical preferences, both within and across countries. They derive utility from the consumption of domestic and foreign goods, with home bias in preferences, and disutility from supplying labor to firms. They live in cashless economies. For simplicity, capital markets are complete, both domestically and internationally, with frictionless trade in assets.

Households maximize expected lifetime utility, where expectations $\mathbb{E}_t$ are conditional on the information available in period t. Optimization yields labor supply equation (17) and consumption Euler equation (18), where ℓ_t is labor supply in period

Table 1: Model parameters

Par.	Range	Value	Description
Core parameters			
β	$(0,1)$	0.99	subjective discount factor
γ	>0	1.17	inverse of Frisch elasticity of labor supply
σ	>0	1.20	inverse of elasticity of intertemporal substitution for consumption
η	>0	0.68	elasticity of subst. between home & foreign goods
θ	>1	8.00	elasticity of subst. between varieties produced within a country
ω	$(0,1)$	0.72	Calvo fraction of firms not allowed to change prices (stickiness)
n	$(0,1)$	$\rightarrow 0$	size of the home economy
ν	$(0,1]$	0.75	home bias in preferences
φ_π	≥ 0	2.06	inflation impact on interest rate in Taylor rule
μ	$[0,1]$	—	degree of exchange rate management
Additional parameters for simulation			
ρ_a	$(-1,1)$	0.81	AR(1) coefficient in labor productivity process
σ_a	≥ 0	0.52	standard deviation of labor productivity shock (in %)
σ_i^*	≥ 0	0.12	standard deviation of foreign monetary policy shock (in %)
Derived parameters			
δ	$(0,1)$	0.01	$= -\log(\beta)$: subjective discount rate
α	$[0,1]$	$\rightarrow .75$	$= 1-(1-n)(1-\nu)$: share of home goods in home consumption
α^*	$[0,1]$	$\rightarrow 0$	$= n(1-\nu)$: share of home goods in foreign consumption
τ	$[0,1]$	0.13	$= 1-\frac{\theta-1}{\theta}$: employment subsidy
κ_{mc}	>0	0.11	$= \frac{(1-\omega)(1-\omega\beta)}{\omega}$: marginal cost impact on PPI inflation in (20)
ϖ_c	>0	2.08	$= \sigma+\gamma\nu$: consumption effect on product wage
ϖ_{tot}	≥ 0	0.60	$= 1-\nu+\gamma\left(1-\nu^2\right)\eta$: terms-of-trade effect on product wage
w	>1	1.62	$= \frac{\kappa_{mc}\varpi_c}{\sigma}+\frac{1+\kappa_{mc}\varpi_{tot}}{\nu}$: effectiveness of i_t to counteract deprec.

Foreign parameters $\beta^*, \gamma^*, \sigma^*, \theta^*, \omega^*, \varphi_\pi^*, \rho_a^*$, and σ_a^* equal their home counterparts.
The values of the core and additional parameters for simulation have been taken from Justiniano and Preston (2010). The authors estimate a small open-economy model for three countries vis-à-vis the United States, namely for Australia, Canada, and New Zealand, using Bayesian techniques, though they calibrate the values for β, θ, and ν. We take the average of their three posterior medians.

t, c_t is consumption, w_t is the wage rate, p_t is the consumer price index (CPI), and $\pi_t = p_t - p_{t-1}$ is CPI inflation.

Firms specialize in the production of one firm-specific good. Domestic firms produce the varieties in $[0, n)$ and foreign firms those in $[n, 1]$. Each firm uses labor supplied by the households and a linear technology, where a_t is labor productivity, which is common across home firms and evolves exogenously according to some stationary stochastic process. The firm receives an employment subsidy that renders the steady state efficient. Real marginal cost mc_{Ht}, expressed in terms of the producer price index (PPI) p_{Ht}, thus depends on the product wage $\mathrm{w}_t - p_{Ht}$ by (19).

The firm sells its good under monopolistic competition. It sells at home and abroad without trade frictions. Prices are set in the producer's currency, and they are sticky a la Calvo (1983). Hence, p_{Ht} depends on its lag and the price chosen by firms that are allowed to reset the price. Profit maximization then yields PPI inflation $\pi_{Ht} = p_{Ht} - p_{H,t-1}$ based on (20), showing the importance of real marginal cost mc_{Ht}, which enters the formula in deviation from its steady-state value.

Equilibrium concerns three markets. First, labor market equilibrium is (21), where y_t is domestic output. Second, the asset market is in equilibrium if the perfect international risk sharing relation (22) holds, given symmetric initial conditions, where $s_t + p_t^* - p_t$ is the real exchange rate. Third, for the goods market, free international trade implies the law of one price, so the import price index p_{Ft} follows from (23), where p_{Ft}^* is foreign PPI in foreign currency. The goods market also clears for all varieties.

To mimic that the domestic country is small, we now take the limit $n \to 0$. That gives goods market clearing at home (24) and abroad (25). The former captures that higher prices for imports relative to domestically produced goods (higher terms of trade $tot_t = p_{Ft} - p_{Ht}$) cause substitution towards domestic goods, stimulating domestic production. The limit also implies that home CPI in (26) follows from home PPI and the import price index, and that foreign CPI p_t^* is simply foreign PPI, as (27) shows.

4.2 Exchange rate function

Our interest rate rule requires the intermedial exchange rate s_t^d, so we first derive the exchange rate function (1) that the model implies, in line with Section 2.1. Web Appendix B presents a streamlined derivation, which gives

$$s_t = -wi_t + v'E_t, \tag{28}$$

where

$$w = \frac{\kappa_{mc}\varpi_c}{\sigma} + \frac{1+\kappa_{mc}\varpi_{tot}}{\nu} \tag{29}$$

and

$$v = \begin{bmatrix} w \\ w \\ 1 \\ w\sigma \\ \beta \\ -\kappa_{mc}(\gamma+1) \end{bmatrix} \text{ and } E_t = \begin{bmatrix} i_t^* \\ \mathbb{E}_t\pi_{t+1} - \mathbb{E}_t\pi_{t+1}^* \\ s_{t-1} - tot_{t-1} \\ \mathbb{E}_t c_{t+1} - \mathbb{E}_t c_{t+1}^* \\ \mathbb{E}_t\pi_{H,t+1} - \mathbb{E}_t\pi_{F,t+1}^* \\ a_t - a_t^* \end{bmatrix}. \tag{30}$$

Formula (29) is the model-implied version of (3), the effectiveness of the interest rate to counteract depreciation while keeping E_t constant. It is fully determined by the structural parameters of the model. We get $w > 0$, so an interest rate increase strengthens the home currency.

Expression (30) for E_t discloses what else matters for the exchange rate according to the model. Most determinants occur in a simple relative form, an attractive consequence of our streamlined derivation of the s-function. Because s_{t-1} has a unit coefficient in v, one could also write (28) in terms of Δs_t and the adjusted E_t would then consist of stationary variables only. However, that does not imply that s_t is non-stationary, because to implement an exchange rate regime the interest rate i_t may depend on the exchange rate level so as to counteract deviations from target, and that can result in a stationary s_t, similar to an error-correction specification.

4.3 Interest rate rule

Suppose the central bank pursues the weighted fixed-floating exchange rate regime (10). To implement this, the central bank should use interest rate rule (11). The ingredients of the rule are as follows. For the domestically-oriented rate we take

$$i_t^d = \delta + \varphi_\pi \pi_{Ht}, \tag{31}$$

though one could also use a Taylor rule with CPI inflation and output gap. The effectiveness w follows from (29), and the degree of exchange rate management μ and the target rate s^t are both taken as given.

The final ingredient, the intermedial exchange rate s_t^d, follows directly from definition (6) and the model-implied s-function (28), so that

$$s_t^d = -w i_t^d + v' E_t. \tag{32}$$

Note that this also shows what variables determine $EMP_t = s_t^d - s_{t-1}$ in this economy, namely π_{Ht} via (31) and E_t in (30).

Substituting (32) in (11) gives our rule

$$i_t = (1-\mu)\, i_t^d + \mu \frac{1}{w} \left(v' E_t - s^t \right). \tag{33}$$

So the interest rate is a weighted average of i_t^d and $\frac{1}{w}\left(v'E_t - s^t\right)$. For example, in a float ($\mu = 0$), the interest rate is simply the domestically-oriented rule i_t^d, as usual.

To implement a fixed rate ($\mu = 1$), the central bank cannot pursue i_t^d at all, in line with the well-known incompatible trinity. For example, a one percentage point lower i_t^d by itself motivates an equally lower i_t, but implementing that would cause pressure and thereby a w %-points higher s_t, which would have to be offset by a one %-point higher i_t to maintain the peg, making i_t^d on balance irrelevant for the actual interest rate. Instead of looking at i_t^d, the central bank should focus on $v'E_t - s^t$. If market sentiment in $v'E_t$ creates pressure and thereby tends to move the exchange rate away from the target, the excess change $v'E_t - s^t$, converted into interest rate units by $1/w$, pins down the interest rate.

The foreign central bank follows a rule with a stationary monetary policy shock ε_{it}^*:

$$i_t^* = \delta + \varphi_\pi \pi_t^* + \varepsilon_{it}^*. \tag{34}$$

4.4 Comparison to the literature

Rule (33) illustrates some of the improvements over the Monacelli (2004) rule (12) analyzed in Section 3: our rule covers the fixed exchange rate regime, accounts for the instrument effectiveness w, and our rule recognizes the separate roles of w and μ instead of using the reduced-form parameter φ_s. A new improvement is that our rule automatically accounts for the incompatible trinity.

The Benigno et al. (2007) rule (13) concerns the fixed exchange rate, and for that case our rule can be rewritten as

$$i_t = i_t^* + \frac{1}{w} \left(v_2' E_{2t} - s^t \right), \tag{35}$$

where v_2 and E_{2t} equal v and E_t in (30) with the top element left out. Hence, our rule uses a specific model-driven parameter w instead of the undetermined φ_s^{BBG}, and does not need convertibility assumptions. A common feature is that also in our rule following i_t^* is important for implementing the peg.

5 Simulations from the model

To further illustrate EMP and our interest rate rule, we now simulate from the model just developed. The main insights from these simulations are not specific to the model, parameter values, or draws of the shocks.

5.1 Model calibration, solution, and simulation

One period in the model is one quarter. For the simulations we assume that (the log of) home labor productivity a_t follows an AR(1) process with autoregressive coefficient ρ_a and that the i.i.d. shock involved has mean zero and standard deviation σ_a. The same holds for foreign productivity a_t^*. The foreign monetary policy shock ε_{it}^* is i.i.d. with zero mean and standard deviation σ_i^*.

We set the target $s^t = 0$. All parameter values are based on Justiniano and Preston (2010). Table 1 presents them, and its note provides further motivation.

We solve the model numerically using the Sims (2002) algorithm. The solution can be cast as a reduced-form VAR model of the 20×1-vector with elements $c_t, \mathbb{E}_t c_{t+1}, c_t^*, \mathbb{E}_t c_{t+1}^*, \pi_{Ht}, \mathbb{E}_t \pi_{H,t+1}, \pi_t, \mathbb{E}_t \pi_{t+1}, \pi_t^*, \mathbb{E}_t \pi_{t+1}^*, y_t, y_t^*, i_t, i_t^*, s_t, \mathbb{E}_t s_{t+1}, tot_t, EMP_t, a_t, a_t^*$. We focus on unique stationary solutions, abstracting thus from sunspot equilibria.

The necessary and sufficient condition for equilibrium determinacy is as follows, given our parameter space and thus the symmetry assumption $\varphi_\pi = \varphi_\pi^*$. Under the float, the condition follows from Bullard and Mitra (2002), and it here reduces to satisfying the Taylor principle $\varphi_\pi > 1$. For the other regimes, from the managed float to the fixed rate, we verify determinacy for a grid of parameter values, using the Sims (2002) algorithm. Also here the condition turns out to be $\varphi_\pi > 1$. So the same condition applies whatever the regime. It holds for all parameter values we study.

We set $s_0 = 0$ and initialize other variables at their steady-state values. The three shocks are drawn from independent normal distributions. We draw them for 60 periods (15 years), from which we compute the paths of the variables of interest. For ease of comparison we keep the realized shocks the same across the plotted paths.

5.2 Implementing multiple regimes

Our rule (33) implements many exchange rate objectives and does so exactly, with a key role for EMP_t, determined by (32). To illustrate their properties, we simulate paths of the economy in three different regimes, the float ($\mu = 0$), an intermediate regime (say $\mu = 0.5$), and the peg ($\mu = 1$). A representative set of paths is depicted in Figure 2. The variables $EMP_t, i_t, i_t^d, i_t^*, s_t$ in the graphs are in percentage terms.

Under the float ($\mu = 0$), the interest rate i_t equals the domestically-oriented rate i_t^d, visualized by the horizontal line in the second panel. As i_t^d is driven by inflation, the interest rate does not stabilize the exchange rate s_t. That is, the exchange market pressures EMP_t indicated by the grey line in the top panel are not offset by policy and they equal the actual depreciations. This makes that the grey line for s_t in the bottom panel does not revert to zero.

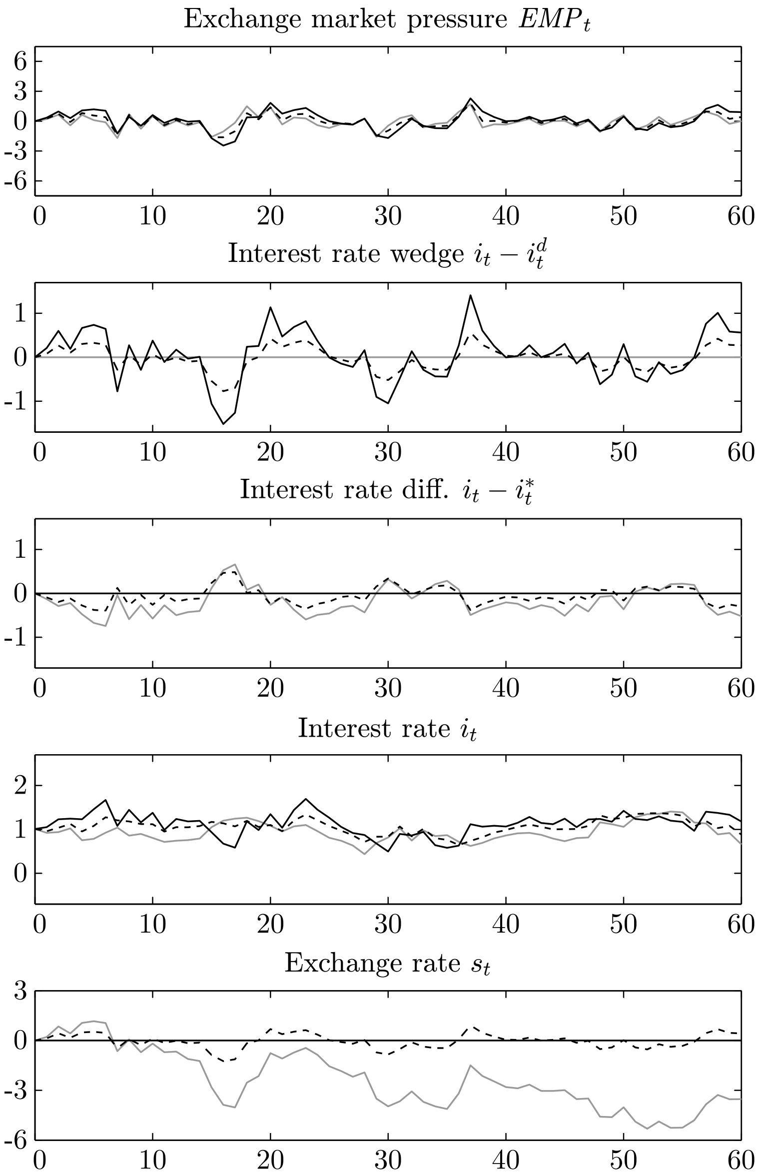

Figure 2: Paths implied by our rule (33) in various exchange rate regimes: from float ($\mu = 0$, grey) to intermediate ($\mu = 0.5$, dashed) to fixed ($\mu = 1$, black).

The stronger the exchange rate management, the more the central bank has to account for exchange rate fundamentals when setting the interest rate, making i_t^d less and E_t in our rule more relevant. The dashed line in the bottom panel visualizes that $\mu = 0.5$ here already stabilizes the exchange rate considerably. The line also suggests that the weighted fixed-floating regime can be a practical linear approximation of various other exchange rate policies, such as the peg with band.

If the central bank pursues a fixed exchange rate ($\mu = 1$), then the black line in the middle panel visualizes that $i_t = i_t^*$ in equilibrium, and the bottom panel shows that the exchange rate stays on target continuously, as expected. This corroborates that the model contains UIP, by virtue of (22). Still, the top panel reveals that shocks cause periods of noticeable pressure EMP_t on the peg. There the central bank has to accept an interest rate that differs substantially from the domestically-oriented rate (second panel), which in practice may induce policy makers to give up the peg.

Finally, let us discuss the traditional rules. Section 3 gives an overview of the advantages of our rule over them. These advantages do not depend on specific simulations. Still, it may be instructive to compare the simulated paths. In this special case of the weighted fixed-floating regime, one can replicate our simulated paths of i_t and s_t for $\mu < 1$ by using the Monacelli (2004) rule and setting φ_s based on (15). The problem is that this requires w (except for $\mu = 0$), which is not available in his approach. This makes that simulations from his and our rules generally differ, and not knowing w implies that one generally does not know the exchange rate regime underlying his simulations. For $\mu = 1$ one can replicate our simulations with the Benigno et al. (2007) rule. But that necessitates imposing the convertibility assumptions, which we avoid. Our rule is the only rule that covers all μ in one framework.

6 Conclusion

This paper has derived that EMP is a key variable for a central bank when setting the interest rate to implement a given exchange rate objective. This guides policy and, vice versa, actual policy confirms the relevance of EMP. We have formalized this in a new interest rate rule that contains EMP.

We have also derived that the economic structure matters for the EMP coefficient in the rule: the more effective the interest rate, the less it should be used to offset a given pressure. The feature helps to get that our rule exactly implements the exchange rate objective, it does so for many regimes and models, and our rule automatically accounts for changes in the economic structure. All these features improve on traditional rules.

We have introduced the weighted fixed-floating regime, with weight μ on the fixed regime. Our rule can be conveniently combined with this regime. This leads to a coefficient of EMP in the rule that discloses two structural parts, namely the model-determined interest rate effectiveness w and the degree of exchange rate management μ chosen by the policy maker. We have thus disentangled a Taylor-rule type of coefficient into two underlying structural parameters. We have exploited this to show how the de facto exchange rate regime can be estimated in a novel way.

We have extended the EMP literature by refining the EMP formalization and computing EMP in a modern sticky-price model, as the EMP literature typically relies on some variant of the flexible-price monetary model. We have also formalized how EMP is an ingredient for policy, and how the sticky-price model helps the policy maker to learn the determinants of EMP. All this may stimulate further research on EMP.

The general applicability of our rule and the inherent consistency with the regime and model can facilitate future research. Think of studies on the optimal degree of exchange rate management, further eased by our new structural parameter μ, and research on models with incomplete markets and risk premia. For example, in another paper we apply our idea to analyze foreign exchange interventions by the central bank under capital controls. This could then facilitate studies on emerging markets where central banks use forex intervention to pursue leaning-against-the-wind exchange rate management. This is left for future research.

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