A new approach to measuring exchange market pressure

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Abstract

Currencies can be under severe pressure, but in a fixed exchange rate regime that is not visible via the exchange rate. The literature has proposed a way to measure the pressure indirectly, using the interest rate and intervention responses to the pressure. We introduce a better-founded methodology, leading to a new measure. This methodology is based on only mild assumptions and does not rely on a specific model of exchange rate determination, thereby generalizing existing approaches. We show that the interest rate should not be taken in the first-difference form used so far, but rather in level form, relative to the interest rate chosen if the country had no exchange rate objective. This makes our measure more in line with economic sense and appears highly relevant in practical applications.

Key words: EMP, ERM, exchange rate regime, monetary policy, real interest differential, Taylor rule, temporal aggregation.
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1 Introduction

From time to time exchange rates exhibit large fluctuations, reflecting tensions in the foreign exchange market. At other times exchange rates are stable. But that does not necessarily mean the absence of tensions in the market. It could be that monetary authorities have warded off exchange rate changes through policy measures. Setting a high official interest rate, buying domestic currency on the forex market, and imposing capital market restrictions are natural policy actions. Hence, even though the exchange rate change fully reflects forex market pressure in a purely floating exchange rate regime, in case of exchange rate rigidity the exchange rate change alone is no longer an appropriate measure.

Already in 1977, Girton and Roper introduced a concept to quantify pressure that applies to all exchange rate regimes, by adding reserve changes to the exchange rate change. They named it exchange market pressure (EMP). Others have generalized that idea, for instance, by including interest rate changes. In the current paper we revisit the question of how to measure pressure. Our theoretical derivation is based on much weaker assumptions, and it leads to a measure of pressure that differs from existing ones.

The main practical difference concerns the interest rate, which nowadays happens to be the most important instrument countries use for smoothing exchange rate fluctuations. And this difference is large in practice. For instance, consider the extensively documented 1992-1993 crisis in the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS). The days before "Black Wednesday" (September 16, 1992, when the United Kingdom and Italy suspended ERM membership) the traditional measure suggests there was no pressure on the pound, nor on the lira. Likewise, the existing measure shows no pressure on the French franc on August 2, 1993. But that day was the peak of the crisis for France, witnessed by the widening of the ERM fluctuation margins and a franc depreciation. Such inconsistencies do not occur in our measure.

Having a good EMP measure is relevant for at least two reasons. The first concerns policy. Nowadays many countries pursue some kind of exchange rate management.[1] Most of them are developing countries and emerging markets, such as China and the new EU member states participating in ERM II. But also in countries with de jure freely floating rates, which for example pursue an inflation target, monetary policy

[1] The IMF (2006) de facto classification of exchange rate regimes shows that 48% of 147 currencies have some sort of peg, and 35% have a managed float with no predetermined path for the exchange rate. See Husain, Mody, and Rogoff (2005) for further details.

makers sometimes intentionally influence the exchange rate. And this can be optimal in theoretical models, for instance to limit exchange rate pass through in prices or to avoid undesirable relative price movements even when inflation is controlled; see Calvo and Reinhart (2002), Devereux and Engel (2007), and Lubik and Schorfheide (2007). Consequently, for monetary policy makers it is relevant to know the magnitude of exchange market pressure, how effective their instruments are in taking it away, and how severe pressure is on other exchange rates, for instance to gauge how much pressure they can expect as a result of contagion.

A second motivation for finding a proper EMP measure is that researchers use the EMP concept to examine important other phenomena. Mody and Taylor (2007) use it to estimate regional vulnerability to crisis, and Van Poeck, Vanneste, and Veiner (2007) to examine whether fundamentals in the new EU members are strong enough to participate in ERM II. IMF (2007) takes exchange market pressure to study adequate policy responses to capital flows, while Frankel and Wei (2008) use it to estimate de facto exchange rate regimes.

As exchange market pressure indicators are relevant for both policy and research, it can be undesirable that the existing measures may generate unrealistic levels of pressure. While it is true that the traditional measure can work in specific applications (for instance, in studies that do not include interest rates), it is worthwhile to revisit the traditional approach and improve it, because the interest rate is an important instrument and to obtain better results in applications. The rest of this introduction gives a more precise idea of how we will derive the new measure.

Weymark (1995) further formalized the EMP concept introduced by Girton and Roper (1977). We follow Weymark's definition in that EMP on a currency is its excess supply on the forex market if policy makers would refrain from actions to offset that excess supply, and this excess supply is expressed in the (relative) depreciation required to remove it. Consequently, in a floating exchange rate regime EMP coincides with the observed depreciation, whereas in all other regimes EMP is the depreciation-equivalent of excess supply in the hypothetical case of a passive policy maker.

The latter case is typically unobserved, so that EMP is unobservable. However, if there is pressure, we do observe that policy variables adjust in response, possibly together with the exchange rate. This gives the opportunity to measure EMP in an indirect way, using observations on these adjustments.

Operationalization of the EMP concept raises two questions. First, which components should an EMP measure consist of; that is, which variables should be included and in what form? For example, should one include the interest rate and, if so, in level or first-difference form? Second, what are the weights of all components in the measure?

A number of authors have tried to tackle these problems. The work by Girton and Roper (1977) uses a monetary model to derive that EMP can be measured by the sum of the exchange rate change and the change in the central bank's international reserves. Weymark (1995) and Eichengreen, et al. (1996) have extended the monetary model and improved the EMP measure, and to date the most general version is an EMP measure that is a weighted average the exchange rate change, interest rate change and the change in reserves. In the extensive empirical EMP literature, all papers have used (a variant of) this EMP measure.[2]

The current paper focuses on just the components in EMP. After all, having the right components is crucial for a meaningful interpretation of the weights, whereas deriving the components does not require knowing the weights, as we will show. Therefore, a sequential analysis of first finding the right components is warranted, which is convenient. Moveover, the components alone already give useful insights into the pressure in the market; weights are not needed for that.

Our work has been inspired by three issues in the literature. First, the common view in the literature is that a theoretical (monetary) model of exchange rate determination is required to derive the components. As Eichengreen et al. (1996) argue, this is unfortunate because much research has demonstrated the difficulty of developing a good model.[3] One goal of our paper is to derive the EMP components without imposing such a model. That is, we generalize existing methods by imposing much weaker assumptions and showing that, whatever exchange rate model one uses, the EMP components are invariant. For example, in the Appendix we present our approach within the special case of the commonly-used monetary model and demonstrate that this model is indeed irrelevant for the components.

A second inspiration is the interest rate change component in existing EMP measures, because it can give uncomfortable signals of pressure. As an illustration, suppose

[2]In all studies the EMP measure includes the exchange rate change and change in reserves, usually scaled by narrow money supply. Studies differ regarding their use of an interest rate component. Several papers leave out the interest rate, such as Girton and Roper (1977), Weymark (1995), Hallwood and Marsh (2004), Siklos and Weymark (2006), IMF (2007), and Frankel and Wei (2008). Studies that include an interest rate component take the interest rate in first difference. More specifically, Mody and Taylor (2007) and Van Horen, Jager, and Klaassen (2006) have the change in the domestic interest rate only, while other authors take the change in the interest rate differential between the domestic and the reference country (U.S., Germany, or a group of countries); see Eichengreen et al. (1996), Pentecost, Van Hooydonk, and Van Poeck (2001), Haile and Pozo (2006), and Van Poeck, Vanneste, and Veiner (2007).

[3]There is recent evidence that exchange rate models are not as bad as commonly thought; see Engel, Mark, and West (2007).

there is a multiple-day speculative attack and the central bank successfully withstands it by increasing the interest rate to 100%, say, and keeping it constant at that high level during the attack. After day one, the interest rate change is zero, so having this variable in the EMP measure, one would conclude there is no longer pressure despite observing a rate of 100%. That is counterintuitive. One would expect something like the interest rate level instead of change in the EMP measure. We intend to resolve this issue, particularly because policy makers often use the interest rate to defend an exchange rate. From a practical point of view, this concerns the most important contribution of the paper. The Appendix shows within the standard monetary model where we deviate from the traditional approach and how that brings in the interest rate in level form.

The third inspiration concerns the observation frequency. Pressure on forex markets is a potentially very volatile variable and can quickly spread to other markets. These two features call for a high-frequency measure of EMP (say, daily). On the other hand, a lower frequency (say, monthly) analysis can be informative to obtain an overall view of the period around a crisis. This raises the issue of how to obtain an EMP measure that is consistent across frequencies. Present EMP measures that include the interest rate appear not to be consistent in this sense. Solving the temporal aggregation problem is the final aim of the paper.

The paper is organized as follows. Section 2 derives the new EMP measure, and in Section 3 we interpret it. The temporal aggregation problem is solved in Section 4. Section 5 discusses the practical implementation of the interest rate component. For that we introduce an extended Taylor rule, taking seriously the issues of omitted variables, forward-looking policy, real-time data and output gap determination. Although the theory already yields clear-cut advantages of our EMP measure, Section 6 focusses on the quality of the new measure in practice and the insights that daily data can provide in addition to the results from monthly data that are typically used. Section 7 concludes.

2 EMP measure

In a floating exchange rate regime, there is just one variable that offsets pressure in the forex market: the exchange rate. In any other regime, there exist additional variables, such as the interest rate and forex market interventions. We first motivate why we confine ourselves to these two variables and then derive our EMP measure.

We take a two-country setting, with a domestic and a foreign country. One of the policy goals of the domestic authorities is to manage the exchange rate (though a perfectly free float is a valid special case). This exchange rate objective can be the final target, as in case of an exchange rate peg, but it can also be an intermediate target so as to achieve something else, as in a situation where the authorities try to mitigate depreciations to curb inflation. The crucial point is that the domestic authorities aim to affect the exchange rate for some reason.

To structure the discussion, we use the following sequence of events. First, excess supply of the home currency on the forex market arises, for instance, because news changes investors' expectations affecting forex demand and supply. Excess supply can be positive or negative. The policy variables and exchange rate have not yet responded. Second, the authorities set their forex policy instruments. Third, investors respond by changing excess supply, and the exchange rate is determined on the forex market so as to clear that market. The policy variables and exchange rate have now fully removed excess supply. Because the emergence of excess supply and the determination of the new exchange rate occur within the same period, the whole sequence of events happens within that period, say, one day.

2.1 Policy instruments

Once pressure occurs, it has to be offset within the same period. Hence, only policy instruments that are able to immediately affect excess supply on the forex market are useful to offset pressure. These are typically monetary instruments.

In reality, monetary authorities (the central bank throughout the paper) can use a number of policy tools to offset pressure, such as official parity realignments, changes in the width of exchange rate bands, official discount rate adjustments, open market operations, foreign exchange interventions, and the imposition of capital controls. Instead of including all of them, for simplicity – and in line with the EMP literature – we use a more concentrated central bank instrument set.

First, realignments and band width adjustments affect the range for the new exchange rate. They may also influence investors' behavior and thus excess supply directly, for example by signaling future policy. Nevertheless, for simplicity and to stay close to the literature, we leave both tools out of the central bank's instrument set. In other words, we ignore their direct effect on excess supply. (Of course, a major part of the impact of realignments and band width adjustments comes via the exchange rate change, and we do account for that).

The second set of policy variables concerns money market tools, such as the official discount rate, open market operations, and bank reserve requirements. They affect interest rates at various maturities. This may induce investors to change their foreign investments and may affect international interest payments, so that excess supply is changed. Instead of including all money market policy tools individually, we summarize them by a short-term (nominal) market interest rate i_t at time t, such as the overnight interbank rate; this does not only reflect the official discount rate, but also the effects of the other tools. Moreover, short-term interest rates have more and more become the target variable of central banks (Whitesell, 2006).

The third policy instrument is official intervention on the forex market. We include this variable and define C_t as the central bank's forex market demand for domestic currency at time t, measured in domestic currency. The actual intervention decision, however, must account for the magnitude of the forex market. For instance, BIS (1993, p.197) states that "in the new kind of circumstances just illustrated [that is, large scale of forex turnover], it is very likely that, to be successful, ... intervention now has to be greater than in the past – perhaps far greater." Hence, we scale C_t by a measure of foreign exchange market turnover V_t, expressed in domestic currency, and use $c_t = C_t/V_t$ as the intervention policy instrument.

Finally, we leave out capital controls. They are difficult to measure. Moreover, insofar as capital controls are not used or are ineffective, there is no effect on excess supply on the forex market. This would justify excluding them, as is done in the literature. Because our empirical illustration is on the ERM crises in 1992-1993, when capital controls were indeed absent in the countries under consideration, leaving them out is a realistic simplification here.

2.2 Derivation of EMP measure

We now derive in what form the policy tools i_t and c_t should enter the EMP measure. As motivated in the Introduction, we try to impose as few assumptions as possible. In particular, we do not assume a model of exchange rate determination. Nevertheless, the Appendix demonstrates our derivation within the context of the commonly used monetary model.

Let s_t denote the (logarithm of the) nominal spot exchange rate at time t, defined as the domestic currency price of one unit of foreign currency (hence, EMP is positive if the exchange rate change required to take away excess supply is positive, and negative otherwise). The EMP offsetting variables are thus s_t, i_t, and c_t.

Excess supply on the forex market also depends on many other variables, such as lagged and expected future exchange rates and interest rates, foreign interest rates, interest rates concerning other maturities than the short one underlying i_t, national income at home and abroad, policy actions not aimed at influencing the exchange rate (fiscal contractions, policies to improve the current account), and investors' expectations and uncertainty, including on how the central bank will respond to pressure. We do not restrict what these determinants are, but simply consider the group of all potentially relevant variables. Their main characteristic is that they can create pressure but are not variables the central bank can use to offset pressure. Excess supply is thus a function of s_t, i_t, c_t, and all these other determinants.

The excess supply functional form is still unrestricted. Its arguments are flexible enough to capture all dynamics of excess supply. Hence, without loss of generality, we may assume that the functional form itself is constant over time. Moreover, define a vector x_t that captures all excess supply determinants except (s_t, i_t, c_t) but where the impact of (s_t, i_t, c_t) on these determinants has been removed; we can then take (s_t, i_t, c_t, x_t) as the full list of arguments of the excess supply function.[4] We now define ES as the excess supply function of domestic currency on the forex market with arguments s_t, i_t, c_t, and x_t. This is all just notation, and we have not imposed any restriction so far.

Our derivation of the EMP measure will be based on a global version of the implicit function theorem; see Zhang and Ge (2006). This works as follows here. Assume that ES is continuously differentiable and that there exists a constant $k > 0$ such that the derivative of ES with respect to the exchange rate satisfies $ES_s < -k$. Then there exists a unique, continuously differentiable function f such that

$$ES\left(f\left(i, c, x\right), i, c, x\right) = 0. \tag{1}$$

In less formal terms, if ES is sufficiently smooth and a depreciation reduces excess supply (by at least an arbitrarily small fixed amount), then (i, c, x) implies a unique exchange rate $f(i, c, x)$ that clears the forex market. An example of f is the exchange rate determination formula of the monetary model typically used in the past to derive an EMP measure (see Appendix).

The derivation of our EMP measure starts from the definition that exchange market pressure at time t, EMP_t, is excess supply if policy makers would refrain from using instruments to offset it, expressed as the depreciation required to remove the excess supply. The condition on the policy makers' behavior means that the central bank has no exchange rate objective. In such a case the policy objectives mainly concern domestic variables, such as inflation and output – though the central bank could also pursue

[4] Let $\widetilde{x}_t$ be the vector of all excess supply determinants except (s_t, i_t, c_t). The unrestrictedness of the excess supply function allows that, without loss of generality, any dependence of $\widetilde{x}_t$ on (s_t, i_t, c_t) can be carried over to the way these latter variables affect excess supply, and the remainder is a vector x_t that is not affected by s_t, i_t, and c_t.

an external objective, such as a current account target. Hence we simply call this counterfactual objective the "domestic" objective. The hypothetical domestically-desired level of the interest rate is denoted by i_t^d (Section 5 elaborates on the implementation of i_t^d), and for the intervention instrument it is simply zero. In this counterfactual situation, excess supply is $ES\left(s_{t-1}, i_t^d, 0, x_t\right)$, and by definition a depreciation of size EMP_t clears the forex market, so that[5]

$$ES\left(s_{t-1} + EMP_t, i_t^d, 0, x_t\right) = 0. \tag{2}$$

The global implicit function theorem gives an explicit expression for $s_{t-1} + EMP_t$, so that

$$EMP_t = f\left(i_t^d, 0, x_t\right) - s_{t-1}. \tag{3}$$

The problem is that f and x_t are not observed. The idea underlying our derivation is to get rid of them as much as possible, so as to arrive at an operational measure of EMP.

We know that when the exchange rate and policy instruments have their new values (s_t, i_t, c_t), the forex market is in equilibrium, and that the changes in these variables have not affected x_t. Hence,

$$ES\left(s_t, i_t, c_t, x_t\right) = 0. \tag{4}$$

As for the counterfactual equilibrium (2), we now apply the global implicit function theorem to the actual equilibrium (4), so that

$$\Delta s_t = f\left(i_t, c_t, x_t\right) - s_{t-1}, \tag{5}$$

where Δ is the first-difference operator.

Because the counterfactual and actual exchange rate changes (3) and (5), respectively, both depend on x_t, the difference between them is only caused by differences in interest rates and interventions. More formally, the mean value theorem implies that

$$f\left(i_t, c_t, x_t\right) - f\left(i_t^d, 0, x_t\right) = f_i\left(q_t\right)\left(i_t - i_t^d\right) + f_c\left(q_t\right) c_t, \tag{6}$$

where q_t is an intermediate vector on the line segment between $\left(i_t^d, 0, x_t\right)$ and $\left(i_t, c_t, x_t\right)$, and f_i and f_c are the derivatives of f with respect to i and c, respectively. Substitution

[5] This is in line with Weymark's (1995) EMP definition. To explain this, one could rephrase our EMP definition by adding the condition that excess supply is based on the agents' probability distribution of the actual policy decisions. This condition corresponds to Weymark's condition "given the expectations generated by the exchange rate policy actually implemented." Because $(i_t^d, 0)$ is the hypothetical policy that policy makers refrain from actions to offset excess supply, and x_t captures the agents' view on actual policy, expression (2) indeed corresponds to Weymark's EMP concept. For simplicity of exposition, we avoid explicit reference to the condition on the agents' view in the text of our paper, but the formulas do account for it. For an explanation of the relevance of the condition, see Weymark (1995).

of (3) and (5) into (6) then yields

$$EMP_t = \Delta s_t - f_i(q_t)\left(i_t - i_t^d\right) - f_c(q_t)\,c_t. \tag{7}$$

This already demonstrates that EMP depends in a direct way on three parts, namely Δs_t, $i_t - i_t^d$, and c_t. The variables collected in x_t can only indirectly enter EMP, through q_t in f_i and f_c. The exchange rate function f thus appears to be only relevant via its derivatives, not its level.

To further resolve the presence of the unobservables f and x_t, we put some structure onto $f_i(q_t)$ and $f_c(q_t)$. Let ES_i and ES_c denote the derivatives of the excess supply function with respect to i and c, respectively. ES_i is the effectiveness of the interest rate in changing excess supply, and we assume that interest rate increases reduce excess supply, so that $ES_i < 0$. An increase in intervention directly reduces excess supply and may also affect it indirectly via changes in investors' behavior. We assume the total impact is negative, so that $ES_c < 0$. Recall that $ES_s < 0$ is the exchange rate derivative introduced before. Implicit differentiation of (1) then gives

$$f_i = -\frac{ES_i}{ES_s} < 0 \text{ and } f_c = -\frac{ES_c}{ES_s} < 0. \tag{8}$$

The ratios show how the interest rate and intervention affect the equilibrium exchange rate. Their negativity reflects that a high interest rate and a positive intervention offset pressure, so that a low exchange rate is sufficient to clear the forex market. In the special case of the monetary exchange rate model, as typically used in the literature, f_i and f_c have specific values; see the Appendix.

In the EMP literature one assumes that the weights in the EMP measure are constant (over time). That corresponds to constancy of $f_i(q_t)$ and $f_c(q_t)$ in (7). However, given the time variation of q_t, this constancy is not obvious. Nevertheless, at least the signs of $f_i(q_t)$ and $f_c(q_t)$ are presumably constant (as we assumed earlier), and one may find it reasonable to assume that the effectiveness of the interest rate and scaled intervention in changing the exchange rate is approximately constant. To provide an analytical motivation, we linearize f around a fixed point q. That yields

$$f(i_t, c_t, x_t) - f\left(i_t^d, 0, x_t\right) \approx f_i(q)\left(i_t - i_t^d\right) + f_c(q)\,c_t, \tag{9}$$

so that

$$EMP_t \approx \Delta s_t - f_i(q)\left(i_t - i_t^d\right) - f_c(q)\,c_t. \tag{10}$$

Hence, as a first-order approximation x_t drops out and the EMP weights are indeed truly constant for any f (for a linear f, the weights are of course exactly constant).[6]

[6] In a second-order approximation x_t remains relevant, but only in combination with the cross derivatives f_{ix} and f_{cx}, not with f_{xx}.

Therefore, we assume constancy of the weights in the EMP measure from now on.

This gives our proposed measure of exchange market pressure:

$$EMP_t = \Delta s_t + w_i \left(i_t - i_t^d\right) + w_c c_t, \tag{11}$$

where the EMP weights are $w_i = -f_i(q_t) > 0$ and $w_c = -f_c(q_t) > 0$. EMP thus turns out to be equal to a simple weighted combination of three components, namely the actual exchange rate change Δs_t, the relative interest rate level $i_t - i_t^d$ and the (scaled) intervention magnitude c_t.

The above derivation can be summarized as follows. The definition of EMP_t implies that it depends on x_t and the function ES (or f). Both are unobservable. We have addressed this problem by rewriting EMP_t, using the policy responses to the pressure to get rid of x_t and ES. This has led to (11), where $\Delta s_t, i_t$, and c_t are observable, but i_t^d and the EMP weights are not. Hence, we have narrowed down the initial unobservability problem to the unobservability of i_t^d and the EMP weights.

Because modeling exchange rates (that is, f) is known to be very difficult, whereas the literature has made substantial progress in modeling interest rates, our derivation is a useful step forward. If we can find an acceptable model for i_t^d, then all components are known and these alone could already provide a good insight into the development of EMP; the weights are not needed for that. Section 5 proposes such a proxy.

We have derived these results under relatively weak assumptions, just smoothness of the excess supply function, three sign restrictions (namely, excess supply of domestic currency is reduced by a depreciation, interest rate increase, or official purchase of domestic currency), and constancy of the weights. In all other respects the excess supply function is unrestricted, and particularly the allowance for any possible excess supply determinant (through x_t) makes the analysis general. We have also not imposed behavioral functional forms regarding, for instance, exchange rate and money demand determinations, which are typically used in the literature. In these senses, the above derivation is model free. More precisely, whatever exchange rate model one uses, under the assumptions just described the EMP measure remains (11).

3 Interpretation of the EMP measure

3.1 Intuition and relation to the literature

The EMP measure is in terms of relative exchange rate changes. This is convenient in practice, because it makes the EMP measure comparable across time and countries. We now provide the intuition for the three EMP components individually and relate them to the components proposed in the literature.

First, regarding Δs_t, suppose that the exchange rate is floating, so that $i_t = i_t^d$ and $c_t = 0$. Then, $EMP_t = \Delta s_t$, as should be. This is in accordance with existing papers on EMP.

Second, for the scaled intervention component the counterfactual value is zero, so that c_t naturally enters the EMP measure directly. This term is present in all existing studies, although they most often scale interventions by domestic money supply instead of forex market turnover.

Third, consider the interest rate component $i_t - i_t^d$. The presence of the interest rate in the EMP expression is due to the prominent role interest rates play in the set of forex policy instruments. This presence differs from the models of Girton and Roper (1977) and Weymark (1995), where EMP does not include an interest rate term. On the other hand, Eichengreen et al., 1996, and Pentecost et al., 2001, among others, account for the interest rate, but use it in first-difference form, that is, Δi_t (actually most often in deviation from the foreign interest rate change Δi_t^*). Suppose there is a multi-period episode of high pressure (such as a speculative attack) and the central bank successfully withstands that pressure by a high but constant interest rate over that time span. Then, except for the first and the last dates, $\Delta i_t = 0$, indicating no pressure, despite the existence of high pressure. This inconsistency does not occur if the interest rate is taken in level form. Therefore, we prefer a level over a first-difference approach and the theory in Section 2.2 supports this.

A high interest rate by itself, however, does not necessarily point at pressure, because it may just be a reflection of tight monetary policy to cool down the domestic economy, irrespective of forex market conditions. This explains that i_t is not an appropriate EMP component in itself. The only way to capture the extent to which the central bank uses the interest rate instrument for exchange rate purposes is by comparing i_t to the level i_t^d the central bank would have chosen if it had pursued no exchange rate objective. Our view that $i_t - i_t^d$ has to be a component of EMP is novel in the literature. Its great relevance in practice will be demonstrated in the empirical Section 6.

The main difference between our EMP measure (11) and the standard measure is thus that we have $i_t - i_t^d$ instead of Δi_t. But where does this difference come from? The reason is not that we somehow impose that capital flows depend on the interest rate in level and not in first-difference form. In fact, our excess supply function is unrestricted in this sense, because the collection term x_t may include i_{t-1}, so that together with the i_t argument, we allow for i_t and Δi_t as determinants of excess supply.

Perhaps surprisingly, the reason for the difference is also not our avoidance of the typically-used monetary model. After all, if we apply our method within that framework, the difference between the EMP measures remains, as the Appendix demonstrates. Hence it is not that the monetary model somehow implies $i_t^d = i_{t-1}$.

The true reason for the difference between our and existing EMP measures is that traditional derivations use the difference between the actual equilibrium exchange rate formula (5) and its lag to construct the EMP measure. In contrast, we use the difference between the actual formula (5) and the counterfactual formula (3). Only the latter approach is consistent with how EMP is defined, because that is in terms of the counterfactual. By using the lag the traditional derivation brings in i_{t-1}, which explains the interest rate term Δi_t in existing EMP measures, whereas our use of the counterfactual introduces i_t^d, leading to EMP component $i_t - i_t^d$. (The Appendix provides a complete analysis of the implications.)

3.2 Case studies

As a plausibility check of EMP measure (11), we examine the effects in reality of a specific forex market shock on EMP over time. We verify whether the sign of the perceived EMP_t, so irrespective of the way we measure EMP_t, corresponds with that of the right-hand-side of (11). Suppose there is one shock leading to a higher supply of domestic currency on the forex market in periods $t = 1$ and $t = 2$, while i_t^d is not affected. Therefore, without using (11), we know $EMP_1 > 0$. The consequences are as follows. In a flexible exchange rate regime the domestic currency will depreciate, so $\Delta s_1 > 0$. This new exchange rate equalizes supply and demand in period two, so we know $EMP_2 = 0$ and $\Delta s_2 = 0$. Hence, the perceived EMP_1 and EMP_2 are consistent with the EMP measure (11). In a fixed regime where the central bank only uses the interest rate, the pressure in period 1 forces the central bank to raise the interest rate, so $i_1 - i_1^d > 0$. In the second period, the exchange rate is still at the original non-market-clearing value, which leads to prolonged tensions. Hence $EMP_2 > 0$. This can only be offset by continuing the high interest rate, so $i_2 - i_2^d > 0$. We conclude that the signs of EMP_t, Δs_t and $i_t - i_t^d$ in reality are in line with expression (11).

It is interesting to observe that the profile of EMP over time depends on the exchange rate regime, as in the floating regime there exists no pressure in period 2, but in the fixed regime there is. The reason is that the exchange rate is the market-clearing variable on the forex market, whereas application of central bank policy instruments leaves the exchange rate at a level triggering pressure. This resembles the situation on goods markets disturbed by minimum prices. Deregulation in the form of price flexibility would cause a one-time price adjustment and the market would be in equilibrium after that. But if the minimum price is maintained, the intervening authorities have to keep on buying the good to offset downward pressure on the price.

4 Temporal aggregation

The discussion so far has not specified the length of the time period t, in other words, the observation frequency. As explained in the Introduction, high-frequency EMP measurement can be important for crisis management and analysis. In addition, a lower-frequency analysis may provide useful overall insights in EMP tendencies over the years. This section derives how to aggregate over time the EMP measure developed earlier, so as to obtain a measure that is consistent across frequencies. We consider aggregation from the daily to the monthly frequency, and ignore potential intra-day aggregation issues.

Let EMP_d denote EMP at day d and likewise EMP_m for month m (slight abuse of notation). Because EMP is excess supply on the forex market and excess supply over multiple days is the sum of the daily excess supplies, EMP is an additive concept. Thus EMP at the monthly frequency is given by

$$EMP_m = \sum_{d \in M_m} EMP_d, \tag{12}$$

where M_m is the set of trading days in month m.

Substitution of (7) yields

$$EMP_m = \sum_{d \in M_m} \Delta s_d - \sum_{d \in M_m} f_i\left(q_d\right)\left(i_d - i_d^d\right) - \sum_{d \in M_m} f_c\left(q_d\right) c_d. \tag{13}$$

We presume that the effectivenesses of the interest rate and (scaled) intervention in changing the exchange rate do not vary much within a month and approximate them by month-specific constants $f_i\left(q_m\right)$ and $f_c\left(q_m\right)$, respectively. Thus we have approximately

$$EMP_m = \Delta s_m - f_i\left(q_m\right) D_m\left(\bar{i}_m - \overline{i^d}_m\right) - f_c(q_m) D_m \bar{c}_m, \tag{14}$$

where Δs_m is the exchange rate change in month m, D_m is the number of trading days in month m, $\bar{i}_m$ and $\overline{i^d}_m$ are the monthly-average interest rates, and $\bar{c}_m$ is the average scaled intervention in the month.

As in Section 2.2, we assume that the EMP weights are constant over time. The monthly EMP measure then becomes

$$EMP_m = \Delta s_m + w_{mi}\left(\bar{i}_m - \overline{i^d}_m\right) + w_{mc}\bar{c}_m, \tag{15}$$

where for simplicity D_m is treated as a constant and is included in the monthly weights w_{mi} and w_{mc}. Hence, as for the daily frequency, the components in monthly EMP are the change in the exchange rate and the levels of the relative interest rate and intervention. The additivity of EMP has resolved the question of how to form these components: for Δs_m one needs only end-of-month values, but for $\bar{i}_m$, $\overline{i^d}_m$, and $\bar{c}_m$ monthly averages are required. End-of-month interest rates and interventions would obviously be insufficient, because they do not incorporate the use of both instruments during other days in the month.

We conclude that both the EMP concept and our EMP measure are additive over time. The fact that the EMP measure has the same structure across frequencies is convenient and enables consistent EMP measurement across frequencies.

This represents another difference with the existing EMP measure, because there the Δi_d in daily EMP implies $\sum_{d \in M_m} \Delta i_d$ in monthly EMP, which equals the change in the end-of-month instead of monthly-average interest rates. As described before, end-of-month interest rates only partially reflect pressure during the month. Thus the existing EMP measure has undesirable consequences under temporal aggregation. Authors typically circumvent this by using monthly-average rates instead, thereby implicitly accepting a reduced comparability of the EMP measure across frequencies.

5 Implementation of the interest rate component

The interest rate component $i_t - i_t^d$ in EMP measure (11) introduces a practical difficulty, because it is not yet clear how to measure the theoretical domestically-desired rate i_t^d. (Note that this is not a problem specific to our approach, because also in the typical monetary framework one has to specify i_t^d and it is not true that there $i_t^d = i_{t-1}$; see Appendix.) It is not even obvious which interest rate series to take for i_t itself. This section provides some practical solutions.

The purpose of the interest rate i_t in the EMP measure is to capture the conduct of monetary policy for exchange rate purposes. The central bank has various tools of monetary policy. They are intended to affect market interest rates, in particular the interbank rate. Hence, we suggest taking an interbank interest rate to summarize the monetary policy stance. Because the most direct link between the policy stance and the term structure of interest rates occurs at the short end, we propose using a short-maturity rate, such as the overnight rate. This is also the rate that strongly correlates with the rates applicable to speculators during speculative attacks.

The reference rate i_t^d is the rate the central bank would choose if it had no exchange rate objective. This rate is unobservable. In reality, however, there exist central banks that do not or to a minor extent consider exchange rates, for instance, the U.S. Federal Reserve. Research has suggested that for such banks the main determinants are inflation and output. One way to formalize this is by a Taylor rule (Taylor, 1993), which specifies the short-term interest rate as a linear function of the equilibrium real interest rate, current inflation and inflation gap (that is, inflation minus target), and the current output gap (percentage deviation of real GDP from its potential). On theoretical and empirical grounds this idea has been generalized by numerous authors to include expected future instead of realized current values of both inflation and output gap, omitted variables correction, interest rate smoothing, and other elements; see Orphanides (2007) for a review. As the focus of the Taylor rule corresponds with that of i_t^d, and given the influence of the Taylor rule on policy and research, we follow this approach for i_t^d.

More specifically, we take

$$i_t^d = r_t^{eq} + \pi_t^e + \gamma g_t + \lambda_t, \tag{16}$$

where r_t^{eq} is the (potentially time-varying) equilibrium real interest rate and π_t^e is expected inflation using information available at time t. The forecast horizon is rather long because that is more relevant for central banks than short-run inflation; for instance, one could use a one year horizon, as motivated by Clarida, Galí and Gertler (1998). The column vector of relevant gaps is g_t, which typically consists of the inflation and output gaps. The row vector γ gives the policy preferences regarding the gaps. Of course, one could add other variables such as economic growth, unemployment gaps, and stock market valuations to i_t^d via g_t. It is thus a case-specific variable. Finally, λ_t captures omitted monetary policy determinants. We leave out interest rate smoothing, stimulated by Rudebusch's (2002) conclusion that it is a modest phenomenon in practice.

Implementation of (16) is hampered by the fact that the observed policy of the domestic central bank differs from the counterfactual policy embodied in i_t^d, so that (16) cannot be directly estimated. One could simply impose the standard Taylor (1993) values $r_t^{eq} = 2\%$ and $\gamma = (0.5, 0.5)$ and restrict $\lambda_t = 0$. We will develop a more sophisticated approach that in practice can be even easier to implement than (16).

We start from the fact that the domestically-desired policy is observable for the foreign (reference) country. Because the domestic country follows the foreign country due to the peg, the domestic policy preferences will to some extent be similar to those of the foreign country. Moreover, both countries will be hit by common shocks. We want to somehow exploit these links. Clarida et al. (1998), in a related counterfactual analysis, set the unknowns r_t^{eq} and γ for the non-German ERM countries exactly equal to the estimated German rule parameters (and they implicitly impose $\lambda_t = 0$). We follow a somewhat more general route.

Denote the foreign monetary policy rule by

$$i_t^* = r_t^{*eq} + \pi_t^{*e} + \gamma^* g_t^* + \lambda_t^*, \tag{17}$$

which determines the actual foreign rate i_t^*, not a counterfactual one. Symbols with an asterisk refer to the foreign country.

To link the two rules, we exploit the fact that the omitted variables, λ_t and λ_t^*, will partly overlap due to the high integration of financial markets. For instance, they both contain world-wide variables, such as the world interest rate and the impact of the recent world financial crisis that have led to similar central bank actions. Insofar as the domestic and the reference countries are in close proximity, also regional shocks affect λ_t as well as λ_t^*. Hence, λ_t and λ_t^* share common factors. We impose

$$\lambda_t = \lambda_t^*. \tag{18}$$

Of course, this is restrictive and can be generalized, but that goes beyond the scope of this paper. Still, the variation of the common value of λ_t and λ_t^* over time is left completely unrestricted. We thus follow the typical assumption on time effects in the panel data literature.

Combining (16)-(18) yields our choice for the counterfactual interest rate

$$i_t^d = i_t^* + \left(\pi_t^e - \pi_t^{*e}\right) + \gamma^* \left(g_t - g_t^*\right) + \left(\gamma - \gamma^*\right) g_t + \left(r_t^{eq} - r_t^{*eq}\right). \tag{19}$$

Hence the information in the foreign variables on λ_t^* and thus λ_t is used to filter out λ_t in (16). The advantage is that an unobservable element, λ_t, has been transformed into observable variables. Proposal (19) implies a expression for the EMP component $i_t - i_t^d$, our final variable of interest.

Rule (19) has a convenient step-by-step interpretation, going from important to less important components. As a first approximation one could use $i_t^d = i_t^*$, so that the interest component in EMP becomes $i_t - i_t^d = i_t - i_t^*$, which is the nominal interest differential.

A natural refinement is to add the inflation differential $\pi_t^e - \pi_t^{*e}$ to i_t^* to determine i_t^d, so as to account for the fact that central banks usually set a higher nominal rate in case of higher inflation. In terms of measuring EMP, the advantage of $i_t^d = i_t^* + \left(\pi_t^e - \pi_t^{*e}\right)$ is that in case the domestic central bank is forced to set $i_t = i_t^*$ to maintain exchange rate stability despite experiencing low inflation ($\pi_t^e < \pi_t^{*e}$), the now positive $i_t - i_t^d$ correctly indicates the apparent pressure. On the other hand, without the inflation correction $i_t - i_t^d$ would be zero, thus incorrectly suggesting the absence of exchange market pressure. Using the inflation correction means that the central bank would pursue real interest parity, but only in the counterfactual. Now $i_t - i_t^d = r_t - r_t^*$, where $r_t = i_t - \pi_t^e$, so that the EMP component is the real interest rate differential. Hence, this approach does allow for deviations from parity in reality, insofar as the central bank sets the actual rate i_t to support the exchange rate objective.

The next refinement is to account for cross-country gap differences $g_t - g_t^*$. If domestic inflation is more above target and output is more above potential than in the foreign country, the domestic central bank will set a higher interest rate i_t^d. The impact of the gap differentials is evaluated at the reference country policy preferences, because these can be estimated from data on that country.

The term $(\gamma - \gamma^*)\, g_t$ in (19) captures differences in policy preferences. For instance, an activist domestic central bank has less weight on the inflation gap and more on the output gap.

Finally, the equilibrium real interest rate differential $r_t^{eq} - r_t^{*eq}$ can be used. This equals the expected real exchange rate change plus the risk premium on the domestic currency, both in equilibrium. If in equilibrium the real exchange rate is expected to be constant (ex ante relative PPP holds), then the equilibrium real interest rate differential is just the equilibrium risk premium RP_t^{eq}. This risk premium applies to the counterfactual of floating exchange rates, so it does not include the increments in risk premia during currency crises.

For practical application, three issues are relevant. First, the importance of the various refinements depends on the specific application. However, the most volatile part of $i_t - i_t^d$ is presumably i_t (which can easily reach values of 50% or higher on an annual basis during speculative attacks), so the typically relatively small cross-country differences in expected gaps, policy parameters, and equilibrium real interest rates may not matter much, particularly if a short time period is considered. Hence, simply using $i_t^d = i_t^* + \pi_t^e - \pi_t^{*e}$ (or even just $i_t^d = i_t^*$), so that the EMP component is the real (nominal) interest differential, could already capture a substantial part of the pressure on the forex market and at least provide a useful first insight into pressure in case of high i_t. This EMP component is easy to comprehend and requires no estimation, so that it may already be a convenient option in practice. Its quality is confirmed by the empirical results in Klaassen and Jager (2008).

Second, restricting RP_t^{eq} to be constant, or even zero, will probably be harmless, given the presence of volatile variables as i_t and i_t^* in the EMP component. Moreover, if the EMP measure is used in a regression framework, a constant RP_t^{eq} may well end up in the constant term of the regression equation anyway.

As the third practical issue we emphasize that an EMP component based on (19) has mainly variables in (cross-country) differential form. This can be very convenient in practice. For instance, nation-specific output gaps are difficult to estimate (Orphanides and Van Norden, 2002), but if one does not have to worry about common elements (such as world-wide technology developments) because they drop out, the estimation problem may become manageable. The same holds for r_t^{eq}. It is difficult to estimate (Clark and Kozicki, 2005), but we have just argued that the differential $r_t^{eq} - r_t^{*eq}$ can presumably simply be ignored.

This completes the theoretical description of our proposed EMP measurement. It is given by formula (11), where (19) is a defensible proxy for i_t^d, which can be varied across applications.

6 Quality of new EMP measure in practice: ERM crisis

From a theoretical point of view, the new EMP measure outperforms the existing approach. Nevertheless, it is informative to examine whether this gets convincing support in practice. Detailed comparisons between the new measure and the existing one are described by Klaassen and Jager (2008). We now briefly discuss some of their findings that are relevant for the current paper.

Klaassen and Jager (2008) focus on the 1992-1993 currency crisis in the ERM. There were virtually no capital controls during the crisis and other, further complicating issues (for instance insolvency of governments, or a banking crisis) were absent. So we have a relatively clean and stable setting. The crisis is also well documented, and the fact that multiple comparable countries were struck by the same crisis facilitates robustness checks. Finally, the main value added of our EMP measure in practical work concerns the interest rate and that was used extensively during the ERM crisis. Hence, studying the ERM crisis is very useful for a first quality exploration of a new EMP approach.

In the present paper we consider the three largest ERM members, namely France, Italy, and the United Kingdom, all with Germany as the reference country. We consider the daily as well as monthly frequency; the latter represents the monthly or lower frequencies that are used in the literature. We focus on the interest rate component. More specifically, we compare our level-based $i_t - i_t^d$, where i_t^d is given by (19), to the traditional first-difference component Δi_t.

6.1 Real-time expectations data

The daily interest rate data for i_t are overnight interbank rates. To construct the counterfactual rate i_t^d we need inflation, inflation gaps, output gaps, and equilibrium real interest rates. The literature on the Taylor rule has stressed the importance of using forward looking variables (Clarida et al., 1998), measured in real time (Orphanides, 2001). Obtaining such data is more complicated than just using the currently available, revised realizations. Fortunately, i_t dominates i_t^d in times of crisis, and most variables show up in i_t^d only in (cross-country) differential form. In addition, the countries involved are quite stable, so that also i_t^d is expected to be quite stable (in line with what we observe for countries that focus on domestic variables in reality), particularly in the short time span we consider. Hence, the precise measurement of the components within i_t^d is not so relevant in our case as in the standard Taylor rule literature; see also Section 5. Nevertheless, Klaassen and Jager (2008) have built a real-time data set of expected inflation and expected output gaps (both one year ahead) to verify that claim, so we just use it here as well.

To complete the computation of i_t^d, in this paper we simply assume that the counterfactual inflation targets, gap impact parameters (γ and γ^*), and equilibrium real interest rates of the domestic and foreign central bank coincide. We follow Taylor (1993) by setting $\gamma = (0.5, 0.5)$.

6.2 Quality comparison

Our comparison of $i_t - i_t^d$ to Δi_t is based on Figure 1. The top three graphs present the variables for each country at the monthly frequency and provide an overview of 1992-1993. The bottom three graphs zoom in on the two major crisis months for each country, edged with dots on the monthly time axes, and provide daily data (the tick mark dates are Mondays). Each graph contains $i_t - i_t^d$ (solid) and Δi_t (dashed).

We assess how well the graphs describe some facts about the forex markets in the EMS countries in 1992-1993, as reflected in quotes by policy makers (such as central banks and BIS). These facts can be summarized by (i) growing pressure in the summer of 1992, (ii) post-crisis pressure in September 1992 - February 1993, (iii) persistent pressure on the French franc in February - July 1993, and (iv) interest rates kept on supporting the ERM central exchange rates after the August 1993 crisis. At the time the main reason for this pressure was considered to be that the Bundesbank policy was tighter than the monetary policy required elsewhere, given the weak economic circumstances outside Germany.

The monthly graphs for all three countries show that $i_t - i_t^d$ is in line with all four facts, but Δi_t only reflects fact (i), and only for Italy. In fact, Δi_t suggests that several times the authorities had to ward off appreciation instead of depreciation pressure during 1992-1993. Hence, $i_t - i_t^d$ clearly outperforms Δi_t. It is interesting to see that $i_t - i_t^d$ points out that the currencies were already under some pressure even from the beginning of 1992, not just in the summer, emphasizing that the crisis did not come out of the blue. The reason is that the three countries were forced to set a high i_t to avoid devaluation, despite their economic problems.

Zooming in on the crisis months using daily data reveals additional insights. For France the two days before the crash, Δi_t indicates positive pressure, which is consistent with statements by the policy makers. But then it switches sign and turns substantially negative on August 2, 1993. Using Δi_t as an EMP component thus suggests that the Banque de France was worried about a strong franc on the day that the franc fell. That cannot be true. For Italy and the United Kingdom Δi_t provides similar peculiar signals in the sense that on September 15, 1992, the day before Black Wednesday, the central banks of both countries would not have used the interest rate to offset pressure on their currencies. In contrast, $i_t - i_t^d$ provides much more realistic signals and correctly reflects the weakness of the franc, lira and pound in the days and weeks before their crashes as well as on the crash dates themselves.

We conclude that $i_t - i_t^d$ clearly outperforms Δi_t in reflecting the situation on the forex market at the time of the two ERM crises. The more complete analysis in Klaassen and Jager (2008) is consistent with this. This confirms the theory of Section 2.

7 Conclusion

Knowing the magnitude of pressure on a currency in the forex market is important for both policy makers and economists. However, a problem regarding the use of exchange market pressure (EMP) in practice is that it is not directly observable. This study has revisited the question of indirect measurement of EMP. Instead of following the traditional route of using the monetary model of exchange rate determination to derive a measure of EMP, we have introduced a new approach. It generalizes traditional methods by imposing much weaker assumptions. It implies a dichotomy between the EMP components and weights: the form of the components proves to be independent of an exchange rate model, whereas the weights may be derived from a model. The EMP measure is still simple and is a weighted combination of the relative exchange rate change, the interest rate level relative to a counterfactual benchmark rate, and official forex interventions scaled by forex market turnover. For practitioners, the main contribution of the paper is that we have shown that the (relative) interest rate level instead of the typically-used first difference should be in the EMP measure.

The main idea behind our derivation is that we narrow down the unobservability problem of EMP to the unobservability of the counterfactual interest rate and the weights. Because the EMP components alone already provide a good insight into the development of EMP (weights are not needed for that), and the literature has made substantial progress in modeling interest rates, our derivation is a useful step forward.

We have argued that the benchmark for the interest rate is the counterfactual rate the monetary authorities would have chosen if they had no exchange rate objective. The paper proposes a model for that counterfactual rate, using extended Taylor rules that correct for omitted monetary policy determinants. In several cases, however, a simple special case will already provide useful insights into EMP. This is the nominal interest rate of the reference country plus the expected inflation differential with that country.

We have also addressed how to aggregate the EMP measure over time from, say, daily to monthly observations. The derivation shows that one should take end-of-period exchange rates, but period-average values of interest rates and interventions. The structure of our EMP measure is equal across frequencies; it is additive, which is convenient in theoretical and empirical work.

A study on EMS crises in 1992-1993 for France, Italy, and the United Kingdom, using real-time forward looking data for the Taylor rule variables, has confirmed the theoretically expected improvement of EMP measurement. After all, our measure is much more consistent with the views that policy makers had on EMP in those years.

There are a number of possible extensions and applications of our method. One can allow for a broader monetary policy instrument set, by including realignments, band width adjustments and capital controls. From an empirical point of view, our measure could be applied to other crises. Moreover, many authors have used the traditional EMP measure to examine policy-relevant questions. It would be interesting to apply our measure to their data and check whether the improvement we have found for the EMS is also relevant there.

Appendix: EMP in the typical monetary model

EMP expressions in the literature are derived from variants of the monetary model (Girton and Roper, 1977, Weymark, 1995, Eichengreen et al., 1996, and Pentecost et al., 2001). This appendix presents a stylized version of that model, and within that framework we derive our EMP measure, the existing one, and analyse the difference.

Let M_t denote (base-)money supply, which consists of domestic credit, D_t, and reserves measured in domestic currency, R_t, so that $M_t = D_t + R_t$. Assuming a standard money demand function, money market equilibrium is

$$m_t = \log(D_t + R_t) = p_t + \beta y_t - \alpha i_t, \tag{20}$$

where $m_t = \log(M_t)$, p_t is the log price level, y_t is log real income, i_t is the interest rate, and the (semi-)elasticities β and α are positive. A similar expression holds for the foreign money market, using asterisks to denote foreign variables. Purchasing power parity (PPP)

$$s_t = p_t - p_t^* \tag{21}$$

then gives the usual monetary model equilibrium for the exchange rate:

$$s_t = \log(D_t + R_t) - m_t^* - \beta(y_t - y_t^*) + \alpha(i_t - i_t^*). \tag{22}$$

Our EMP measure

The monetary model outcome (22) is a specific choice of the function f in the implicit function result (1):

$$f(i_t, c_t, x_t) = \log(D_t + R_{t-1} - c_t V_t) - m_t^* - \beta(y_t - y_t^*) + \alpha(i_t - i_t^*), \tag{23}$$

where $-c_t V_t = \Delta R_t$ and $x_t = (D_t, R_{t-1}, V_t, m_t^*, y_t, y_t^*, i_t^*)$.

Taking (7) and substituting $f_i(q_t) = \alpha$ and $f_c(q_t) = -V_t/(D_t + R_{t-1} - q_{t2} V_t)$, where q_{t2} is the second element of the intermediate vector q_t described above (7), gives

$$EMP_t = \Delta s_t - \alpha\left(i_t - i_t^d\right) + \gamma c_t, \tag{24}$$

where $\gamma = V_t/(D_t + R_{t-1} - q_{t2} V_t)$ is assumed to be constant. Hence the monetary approach is a special case of our framework and it helps interpret the weights.

Existing EMP measure

In the literature one typically starts the EMP derivation from the final monetary model equilibrium (22). Next, one takes the first lag:

$$s_{t-1} = \log(D_{t-1} + R_{t-1}) - m_{t-1}^* - \beta\left(y_{t-1} - y_{t-1}^*\right) + \alpha\left(i_{t-1} - i_{t-1}^*\right). \tag{25}$$

Subtracting this from (22), using a linear approximation for $\Delta \log (D_t + R_t)$, and bringing the EMP-offsetting variables to the left-hand-side gives

$$\Delta s_t - \alpha \Delta i_t - \frac{\Delta R_t}{M_{t-1}} = \frac{\Delta D_t}{M_{t-1}} - \Delta m_t^* - \beta (\Delta y_t - \Delta y_t^*) - \alpha \Delta i_t^*. \tag{26}$$

One then defines exchange market pressure as the left-hand-side[7]

$$EMP_t = \Delta s_t - \alpha \Delta i_t - \frac{\Delta R_t}{M_{t-1}}. \tag{27}$$

Difference between our and the existing EMP measures

The most important difference between our measure (24) and the typical measure (27) is that the former has $\left(i_t - i_t^d\right)$ instead of $i_t - i_{t-1}$ (the intervention terms are essentially the same, because $\Delta R_t = -c_t V_t$ and $M_{t-1} \approx D_t + R_{t-1} - q_{t2} V_t$). The i_{t-1} originates from taking the lag of (22) to obtain (25). However, if s_t is governed by (22), then only contemporaneous values of the policy variables i_t and c_t and the remaining variables x_t matter for s_t. Then the definition of EMP (the $s_t - s_{t-1}$ required in the counterfactual situation of a passive central bank) implies that EMP only depends on s_{t-1}, the passive values corresponding to i_t and c_t (viz. i_t^d and 0) and on x_t. Hence, to be consistent with the EMP definition, an EMP measure that includes s_{t-1} should not have i_{t-1}.

To show that the lags step is the crucial reason for the difference in EMP measures, let us substitute $R_{t-1} = R_{t-2} - c_{t-1} V_{t-1}$ in (25) and then remove the lags by substituting (i_{t-1}, c_{t-1}) by the passive values $\left(i_t^d, 0\right)$ and x_{t-1} by x_t. Obviously, the equality then becomes an inequality, but the discrepancy is exactly EMP_t, as substitution of (23) into (3) shows. Hence, (25) becomes

$$s_{t-1} + EMP_t = \log (D_t + R_{t-1}) - m_t^* - \beta (y_t - y_t^*) + \alpha \left(i_t^d - i_t^*\right). \tag{28}$$

Subtracting this from (22) gives our measure (24).

We conclude that the crucial difference between the standard approach and our method is the use of lags of (22) instead of the passive values $\left(i_t^d, 0\right)$ and x_t.

[7] Note that the sign of Δi_t in this EMP measure is negative, which would indicate that raising the interest rate points at lower pressure, which is counterintuitive. Eichengreen et al. (1996) and Pentecost et al. (2001) provide ways to circumvent this. Moreover, one could include Δi_t^* and $\Delta R_t^* / M_{t-1}^*$ in EMP_t, as Eichengreen et al. (1996) do.

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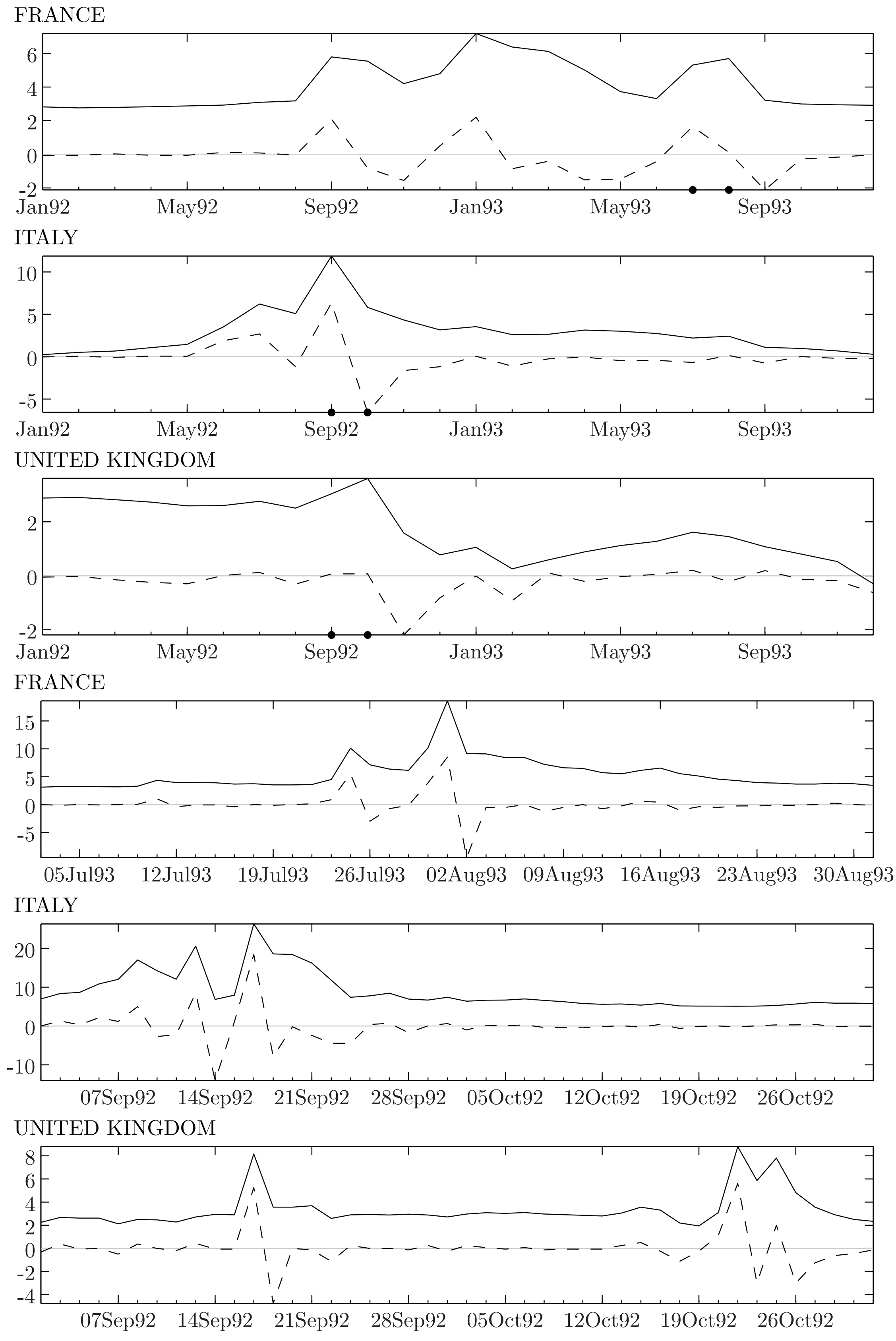

Figure 1: New (solid) and traditional (dashed) interest components; monthly and daily