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Model-free Measurement of Exchange Market Pressure

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Model-free measurement of exchange market pressure

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Abstract

If there is exchange market pressure (EMP), monetary authorities can use the interest rate and official interventions to offset this depreciation tendency, or they can let the exchange rate change. We introduce a new approach to derive how these three variables should be combined to measure EMP. This approach differs from existing methods, because it is model-free and requires only few assumptions. It implies that the interest rate should be taken in levels, not in the first-difference form typically used, and the level should be taken relative to the interest rate chosen if the country had no external economic objectives. This makes our measure more in line with economic sense. An illustration of EMP measures for the EMS crises in 1992-1993 shows that our adaptation also makes sense in practice.

Key words: EMP, EMS crisis, exchange rate regime, monetary policy, real interest differential, temporal aggregation.
JEL classification: E58; F31; F33; G15.

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1 Introduction

From time to time currencies can be under severe pressure. It is important to know when such pressure occurs and what its intensity is. Policy makers can then react decisively, while researchers can pinpoint events and investigate the underlying economic fundamentals.

Measuring pressure is easy in a floating exchange rate regime, because there the exchange rate change fully reflects tensions in the market. But what in case of exchange rate rigidity, either officially through application of a variant of a fixed exchange rate regime, or less systemically in case of managed floating? Then monetary authorities fully or partially ward off exchange rate changes through policy measures. Setting a high official interest rate, conducting official foreign exchange market interventions and intensifying capital market restrictions are natural policy actions. Obviously, the exchange rate change alone is no longer an appropriate measure of pressure.

To nevertheless obtain an indicator of forex market tensions, the concept of exchange market pressure (EMP) was developed (see Girton and Roper, 1977, and the further formalization by Weymark, 1995). In line with them, we define EMP for the domestic currency as the (relative) depreciation required to remove excess supply of domestic currency on the foreign exchange market in the absence of policy actions to offset that excess supply. Because we define the exchange rate as the domestic currency price of one unit of foreign currency, EMP is positive if the required exchange rate change is positive, and negative otherwise. In a floating exchange rate regime, EMP coincides with the observed depreciation. In all other regimes, EMP is the depreciation in case of a passive policy maker. Such regimes are the focus of this paper.

The situation where policy actions are absent 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 a EMP measure consist of, that is, what policy variables should be added to the exchange rate and in what form? As an illustration, should one include an interest rate and, if so, in level or in first-difference form? Second, what are the weights of all components in the measure?

A number of authors have tried to tackle these problems. First in the row were Girton and Roper (1977). They used 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, Rose, and Wyplosz (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 of 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.[1]

The current paper is inspired by two of these issues in the EMP literature, both concerning the components in an EMP measure, not the weights. First, the common view in the literature is that a theoretical (monetary) model is required to derive the components. This is unfortunate, because much research has demonstrated the difficulty of developing an appropriate theoretical model of exchange rate determination (Eichengreen et al., 1996). Therefore, we try to resolve this problem by deriving the EMP components in a model-free manner.

The second source of inspiration is the interest rate change component in existing EMP measures. As an illustration, suppose there is a multiple-day speculative attack and the central bank successfully withstands it by increasing the interest rate and keeping it at a constant 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. That is counterintuitive. One would expect something like the interest rate level instead of change in the EMP measure.[2] Moreover, in applications the interest rate change can be volatile, leading to erratic sign switches in the EMP measure, even if the interest rate itself is continually at a high level, pointing at prolonged pressure. As policy makers often use the interest rate to defend an exchange rate, an important aspect in our EMP derivation is how to resolve our uncomfortable feelings.

The paper is organized as follows. Section 2 returns to the basics of EMP in order to derive our new EMP measure. It also addresses the issue of how to aggregate this measure over time, say, from the daily to monthly frequency. Section 3 illustrates the possible consequences of our favorite choice relative to the existing EMP measures by applying them to the two crises in the Exchange Rate Mechanism (ERM) of the

[1]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 do not include the interest rate, such as Girton and Roper (1977), Roper and Turnovsky (1980), Weymark (1995, 1997, 1998), IMF (1999), Spolander (1999), Tanner (2001), and Hallwood and Marsh (2004). Studies that use an interest rate component all take the interest rate in first difference. Mody and Taylor (2003) have the change in the domestic interest rate. 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. (1995, 1996), Gelos and Sahay (2001), Pentecost, Van Hooydonk, and Van Poeck (2001), Vanneste, Van Poeck, and Veiner (2005), Haile and Pozo (2006), and Van Horen, Jager, and Klaassen (2006).

[2]Note that the interest rate change peaks on the first day of the crisis, so the change may still be a good indicator for identification of the *incidence* of crises, as is the purpose of Eichengreen et al. (1996).

European Monetary System (EMS) in September 1992 and August 1993 for five EMS countries, namely France, Ireland, Italy, the Netherlands, and the U.K. Our monthly data represent the frequencies used in existing studies, that is, monthly or lower frequencies. However, exchange rate turbulence is often short lived and asks for immediate policy action. This calls for a higher-frequency analysis. Hence we examine whether daily data provide additional insights. Section 4 concludes.

2 EMP measurement: back to basics

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 that can take away pressure, such as the interest rate and foreign exchange market interventions. Section 2.1 motivates why we confine ourselves to these two variables. Then Section 2.2 presents a model-free approach to derive our EMP measure, which we then interpret in 2.3. Section 2.4 elaborates on the measurement of the interest rate component. Finally, Section 2.5 discusses the use of our measure at various frequencies, such as daily and monthly.

We take a two-country setting, with a domestic and a foreign country. Monetary policy in the domestic country may be, at least partly, guided by managing the exchange rate (or other external economic objectives, such as current account improvement, or reserve accumulation).

To structure the discussion, we use the following sequence of events. First, pressure arises, for instance, because economic news changes investors' expectations affecting forex demand and supply. The pressure (excess supply) can be positive or negative. The policy variables and exchange rate have not yet responded to this pressure and we call this the ex ante situation. Second, the monetary authorities (the central bank throughout the paper) may use policy tools to try to offset (part of) the pressure by influencing forex excess supply. Third, the exchange rate is determined on the forex market so as to clear that market. The policy variables and exchange rate have now fully offset the pressure, and this is called the ex post situation.

2.1 Policy instruments

In reality, the central bank can use a number of policy tools to offset EMP, such as official parity realignments, changes in the width of exchange rate bands, official discount rate adjustments, open market operations, foreign exchange interventions, and 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 bandwidth adjustments affect the range for the new exchange rate and may also influence excess supply directly, for example by signaling future policy. Nevertheless, for simplicity and to stay close to the literature, we leave them out of the central bank's instrument set. In other words, we ignore the direct excess supply effect.

The second set of policy variables concerns money market tools, such as the official discount rate, open market operations, and bank reserve requirements. Instead of including all of them, we summarize them by a short-term (nominal) market interest rate r_t at time t, such as the overnight interbank rate; it does not only reflect the official discount rate, but also the effects of other money market policy tools.

The third policy instrument is official intervention on the forex market. We include this variable and define I_t as the central bank's forex market demand for domestic currency, measured in domestic currency.

Finally, we leave out capital controls. 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 controls. 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.

In summary, we account for two policy variables to offset EMP, namely r_t and I_t. We realize that this does not do full justice to the complexity of external monetary policy in reality, but we think they capture its essence. It is also consistent with the literature.

2.2 EMP measure: derivation

Given the policy tools, we now derive in what form they should enter the EMP measure. Let s_t denote the (logarithm of the nominal) exchange rate at time t. The focus variables are thus s_t, r_t, and I_t. They are determinants of excess supply on the forex market, that is, the balance of payments deficit: s_t matters due to its (contemporaneous) trade effect, trade invoicing in foreign currency, and through effects on foreign investments; r_t enters through its impact on foreign investments and international interest payments; and I_t is registered on the balance of payments directly. Therefore, s_t, r_t, and I_t can offset pressure.

Excess supply on the forex market also depends on many other variables, such as national income at home and abroad, lagged and expected future exchange rates and interest rates, foreign interest rates, and interest rates concerning other maturities than the short one underlying r_t. These determinants, both observable and unobservable, are represented by a vector x_t. Their main characteristic is that they can create pressure and are not variables the central bank can use to offset pressure.

Let ES denote the excess supply function of domestic currency on the forex market. Although its determinants are known (s_t, r_t, I_t, and x_t), the functional form is not known. It is left unrestricted and may vary over time, but for simplicity of notation we write ES instead of ES_t. Without loss of generality, x_t is treated as independent of s_t, r_t, and I_t.

Our derivation is 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 $c < 0$ such that the derivative with respect to the exchange rate satisfies $ES_s < c$. Then there exists a unique, continuously differentiable function f such that

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

In less formal terms, if ES is sufficiently smooth and a depreciation reduces excess supply (by at least an arbitrarily small fixed amount), then (r, I, x) implies a unique exchange rate $f\left(r, I, x\right)$ that clears the forex market. An example of f is the exchange rate determination formula of the standard monetary model (see Appendix).

The derivation of our EMP measure is as follows. There is pressure on the forex market if there is excess supply of the home currency before EMP-offsetting variables are set (the ex ante situation). For the exchange rate the ex ante value is the previous value s_{t-1}. The ex ante interest rate is the rate that would result if monetary policy had no external economic objective and could purely focus on the domestic economy. This hypothetical domestically-desired rate is denoted by r_t^d (Section 2.4 elaborates on the implementation of r_t^d). The ex ante amount of interventions is obviously zero.

Because EMP is the exchange rate change required to remove ex ante excess supply in the counterfactual situation where the interest rate and intervention are not employed, exchange market pressure at time t, EMP_t, is defined by

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

The global implicit function theorem gives an explicit expression for the exchange rate $s_{t-1} + EMP_t$ that would result in case of no policy actions, which is $f\left(r_t^d, 0, x_t\right)$. Thus

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

The remaining problem is that f and x_t are not observed. For the same x_t we know that ex post, that is, after the exchange rate and policy instruments have their new values (s_t, r_t, I_t), the forex market is in equilibrium:

$$ES(s_t, r_t, I_t, x_t) = 0. \tag{4}$$

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

$$\Delta s_t = f(r_t, I_t, x_t) - s_{t-1}, \tag{5}$$

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

$$f(r_t, I_t, x_t) = f\left(r_t^d, 0, x_t\right) + f_r(q_t)\left(r_t - r_t^d\right) + f_I(q_t)\, I_t, \tag{6}$$

where q_t is an intermediate vector on the line segment between $\left(r_t^d, 0, x_t\right)$ and (r_t, I_t, x_t). Substitution of (3) and (5) into (6) removes x_t, so that

$$EMP_t = \Delta s_t - f_r(q_t)\left(r_t - r_t^d\right) - f_I(q_t)\, I_t. \tag{7}$$

This already demonstrates that EMP depends on three components, namely the exchange rate change Δs_t, the relative interest rate level $r_t - r_t^d$ and the intervention magnitude I_t. We have derived this result under weak assumptions, just smoothness of the excess supply function and the fact that a depreciation reduces excess supply. We have not imposed behavioral assumptions regarding exchange rate and money demand determinations, for instance, which are typically used in the literature. In this sense, our derivation is model-free. Result (7) is also an exact equality (no approximation), and it is simple.

To develop (7) into an operational measure of EMP, we have to put some structure onto the unobserved and unrestricted derivatives $f_r(q_t)$ and $f_I(q_t)$. These derivatives follow from implicit differentiation of (1). Let ES_r and ES_I denote the derivatives of the excess supply function with respect to r and I, respectively. ES_r is the effectiveness of the interest rate in changing excess supply, and we assume that interest rate increases reduce excess supply, so that $ES_r < 0$. Because interventions enter excess supply linearly with coefficient -1, we have $ES_I = -1$. Therefore,

$$f_r = -\frac{ES_r}{ES_s} < 0 \text{ and } f_I = \frac{1}{ES_s} < 0. \tag{8}$$

These show how changes in interest rates and interventions affect the equilibrium exchange rate. Their negativity reflects that interest rate increases and interventions offset pressure, so that a lower exchange rate is sufficient to clear the forex market. Examples of f_r and f_I follow from the monetary exchange rate model, which expresses them in structural parameters; see the Appendix.

Both $f_r(q_t)$ and $f_I(q_t)$ may vary over time, not only because of q_t, but also because the functional form of ES may vary. If the number of time periods t under consideration is small, it seems a reasonable approximation to assume that $f_r(q_t)$ and $f_I(q_t)$ are constant. If EMP is considered over a long time span, we at least know that the signs of $f_r(q_t)$ and $f_I(q_t)$ are constant. Because the ongoing expansion of the forex market implies that a given exchange or interest rate change will have larger effects on excess supply now than it had years ago, the underlying derivatives ES_s and ES_r presumably grow over time (in absolute value). As these effects occur in both the numerator and denominator of the interest rate coefficient $f_r(q_t)$, we assume this coefficient is not trending. The intervention impact $f_I(q_t)$, however, shrinks towards zero over time, reflecting that "it is very likely that, to be successful, ... intervention now has to be greater than in the past – perhaps far greater" (BIS, 1993, p.197). To neutralize this, we multiply $f_I(q_t)$ by a measure of foreign exchange market turnover V_t, expressed in domestic currency. To compensate, we divide I_t by V_t. This gives our proposed measure of exchange market pressure:

$$EMP_t = \Delta s_t + w_r \left(r_t - r_t^d \right) + w_I \frac{I_t}{V_t}, \tag{9}$$

where the "EMP weights" are $w_r = -f_r(q_t) > 0$ and $w_I = -V_t f_I(q_t) > 0$. We assume for simplicity that they are constant. This is in line with the typical assumption in existing EMP studies.

2.3 EMP measure: interpretation

By definition, EMP is the relative counterfactual exchange rate change. Therefore, it is not surprising that the components in EMP measure (9) are also in relative terms and that Δs_t enters directly. 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 $r_t = r_t^d$ and $I_t = 0$. Then, $EMP_t = \Delta s_t$, as should be. Furthermore, any ex ante excess supply will lead to a change in the exchange rate, and for this, it is irrelevant at what level the exchange rate is, so s_t cannot be an EMP component by itself. Moreover, if a shock at time t makes the economy jump from one equilibrium to another, the exchange rate moves from its initial to the new equilibrium value, so that the exchange rate relative to its (contemporaneous) equilibrium level is zero in both cases. Because there was ex ante excess supply on the forex market due to the shock, taking s_t relative to its equilibrium level is apparently also inappropriate as EMP component. The appropriate transformation is the first difference of s_t. This is in accordance with existing papers on EMP.

Second, consider the interest rate component $r_t - r_t^d$. The presence of the interest rate in the EMP expression is due to the prominent role interest rates play in the set of 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, Δr_t (actually most often in relation to the foreign interest rate change Δr_t^*, so $\Delta r_t - \Delta r_t^*$). 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, $\Delta r_t = 0$, 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. 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 r_t is not an 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 r_t to the level r_t^d the central bank would have chosen if it had pursued only domestic economic objectives. Our result that $r_t - r_t^d$ is a component of EMP is novel in the literature. Its usefulness in practice will be demonstrated in the empirical section below.

The last component in (9) is the intervention. Here it is obvious that the reference value is zero, so that I_t naturally enters directly in the EMP measure. This term is present in all existing studies, although it is most often scaled by domestic money supply.

Where does the difference between our EMP measure (9) and the typical formula in the literature, $\Delta s_t + w_2 \Delta r_t + w_3 I_t / M_{t-1}$, come from? Perhaps surprisingly, the reason is 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. The true reason for the difference is that traditional derivations use the lag of the actual equilibrium exchange rate formula, (5) in our terminology, whereas we use the ex ante version of (5), that is, (3), because this is how EMP is actually defined. An illustrative implication of this different route is that the traditional derivation brings in r_{t-1}, which explains the interest rate term Δr_t in existing EMP measures, whereas our approach introduces r_t^d, leading to EMP component $r_t - r_t^d$. (The Appendix provides a complete analysis of the implications.)

As a final check of the plausibility of EMP measure (9), we examine the effects in reality of a specific forex market shock on the development of EMP over time. We verify whether the sign of EMP_t without using the right-hand-side of (9), so irrespective of the way we measure EMP, corresponds with that of the right-hand-side. Suppose the shock consists of a higher supply of domestic currency in periods $t = 1$ and $t = 2$, while r_t^d is not affected. Therefore, $EMP_1 > 0$. The consequences are as follows. In a flexible exchange rate regime the domestic currency will depreciate, so $\Delta s_1 > 0$, and in period two this new exchange rate equalizes supply and demand, so $EMP_2 = 0$ and $\Delta s_2 = 0$. This is consistent with (9). 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 that $r_1 - r_1^d > 0$. In the second period, from an ex ante point of view there is again excess supply, because the exchange rate is still at the original non-market-clearing value. Hence $EMP_2 > 0$. This can only be offset by again setting a high interest rate, so $r_2 - r_2^d > 0$. We conclude that the signs of EMP_t, Δs_t and $r_t - r_t^d$ in reality are in line with expression (9).

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 central bank instruments leave 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 is in equilibrium afterwards. But if the minimum price is maintained, the intervening authorities have to keep on buying the good to offset downward pressure on the price.

2.4 Implementation of the relative interest rate component

The interest rate component $r_t - r_t^d$ in EMP measure (9) introduces a practical difficulty, because it is not clear how to measure the theoretical domestically-desired rate r_t^d. Moreover, it is not even obvious which interest rate series to take for r_t. This section provides a practical solution and offers some guidelines for extensions.

The purpose of the interest rate r_t in the EMP measure is to capture the conduct of monetary policy for external 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 r_t^d is the rate the central bank would choose if it had no external economic goals. This rate is unobservable, so we need a proxy. One candidate is a rate based on the Taylor (1993) rule, which states that the short-term policy interest rate should be set equal to the annual rate of inflation plus the equilibrium real rate of interest plus half the inflation gap (current inflation minus the target) plus half the output gap (current real GDP minus potential GDP). However, the equilibrium real interest rate is difficult to estimate (Clark and Kozicki, 2005), and for practical application it is not clear which variables to include and what factors to take instead of a half (see Gerberding et al., 2005, for Germany).

We follow a simpler route by assuming that r_t^d is such that the corresponding real interest rate equals the foreign real interest rate. This uses the theoretical concept of real interest parity, but only for the hypothetical situation where there is no external economic goal for the home country. We do allow for deviations from real interest rate parity in reality, as the central bank may set the actual rate r_t to support the exchange rate. For simplicity, expected inflation at home and abroad are approximated by current inflation, more specifically, year-on-year inflation (π_t and π_t^*, respectively) as this is more relevant for central banks than short-run inflation. Hence we take

$$r_t^d = r_t^* + \pi_t - \pi_t^*, \tag{10}$$

so that $r_t - r_t^d$ is the real interest rate differential.

The reference value r_t^d generally differs from the foreign interest rate r_t^*, as the domestic central bank may prefer a higher nominal rate to account for higher inflation. Moreover, if the bank is forced to set $r_t = r_t^*$ to maintain exchange rate stability despite an economic downturn with low inflation ($\pi_t < \pi_t^*$), the positive $r_t - r_t^d$ correctly indicates the pressure, whereas taking $r_t - r_t^*$ would incorrectly suggest there is no pressure. Hence, r_t^d cannot be just r_t^*.

Nevertheless, (10) is only a rough approximation of reality, as it still ignores other potentially relevant variables, such as inflation targets, inflation expectations, economic growth, international business cycle differences, unemployment rates, and stock market valuations. Because the most volatile part of $r_t - r_t^d$ is presumably r_t (which can easily reach values of 50% or higher on an annual basis during speculative attacks), we think that fine tuning (10) will not affect the results much, particularly for stable economies such as the European countries that will be examined here.

This completes the theoretical description of our proposed EMP measurement, given by the combined formulas (9) and (10).

2.5 Temporal aggregation

The discussion so far has not specified the length of the time period t, in other words, the observation frequency. In case of low-frequency data, one needs to know whether one should take end-of-period or period-average values for the EMP components. This section addresses that issue by deriving how to aggregate over time the EMP measure developed above. 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_m is the exchange rate change in month m required to offset excess supply in the absence of policy actions, and this monthly exchange rate change is the sum of the daily changes, EMP is an additive concept:

$$EMP_m = \sum_{d \in M_m} EMP_d, \tag{11}$$

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

Substitution of (7) yields

$$EMP_m = \sum_{d \in M_m} \Delta s_d - \sum_{d \in M_m} f_r\left(q_d\right)\left(r_d - r_d^d\right) - \sum_{d \in M_m} f_I\left(q_d\right) I_d. \tag{12}$$

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

$$EMP_m = \Delta s_m - f_r\left(q_m\right) D_m \left(\overline{r}_m - \overline{r^d}_m\right) - f_I(q_m) I_m, \tag{13}$$

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

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 exchange rates, but $\overline{r}_m$ and $\overline{r^d}_m$ are monthly-average interest rates and I_m is total monthly interventions. End-of-month interest rates and interventions are obviously not sufficient, because they do not fully incorporate the use of both instruments during the month.

As in Section 2.2, to operationalize EMP_m we scale interventions by total monthly forex market turnover, V_m, which is the sum of daily turnovers, and assume that the resulting EMP weights are constant over time. The monthly EMP measure then becomes

$$EMP_m = \Delta s_m + w_{mr}\left(\overline{r}_m - \overline{r^d}_m\right) + w_{mI}\frac{I_m}{V_m}, \tag{14}$$

where for simplicity D_m is treated as a constant and is included in the monthly interest rate weight w_{mr}. We conclude that our EMP measure has a similar structure across frequencies, which is convenient.

3 Empirical illustration: EMS crises in 1992-1993

To illustrate the practical relevance of our approach, we examine the well-known currency crisis period 1992-1993 of the EMS. This is an attractive case for us, because there were virtually no capital controls in the EMS countries at the time, so that leaving them out of the EMP measure, as we did in Section 2.1, does not cause a bias. We focus on France, Ireland, Italy, the Netherlands, and the U.K., all with Germany as the reference country.[3] Thus we have currencies under speculative attack that left the ERM (lira and pound sterling), currencies that stayed in the ERM after a crisis (franc and Irish pound), and a currency that speculators did not attack heavily (guilder). We consider both the daily and monthly frequencies.

3.1 Data

The daily data for Δs_t are from Reuters. Daily interest rates r_t are overnight interbank rates. They concern onshore rates for Germany, Ireland and Italy, but Financial Times offshore rates for France, the Netherlands, and the U.K. due to irregularities in the corresponding onshore rates. To construct the hypothetical rate r_t^d in (10) we use data on consumer prices (CPI) from the IMF's International Financial Statistics (IFS), line 64.[4] To obtain daily inflation figures π_t, we linearly interpolate the monthly price

[3]For all countries except Ireland, capital controls were completely absent in 1992-1993. Ireland accomplished full liberalization of capital movements only at the end of 1992. Because for Ireland we will concentrate on the January-February 1993 period, ignoring capital controls is also acceptable there.

[4]Irish CPI data are from the Central Statistics Office, because the IFS series starts only in 1997. The German CPI series in the IFS have a break in January 1991. Data from the Statistisches Bundesamt

indices. All data have been downloaded from Datastream. Monthly data have been derived from daily data using the temporal aggregation approach of Section 2.5, so we take end-of-month exchange rates and monthly-average interest rates.

Unfortunately, we have not yet been able to obtain forex intervention data for the countries under consideration. One could use data on the change in central bank reserves as a proxy, which is often done in the literature. However, such data are not available at the daily frequency, and here interpolation is not a workable approximation, because interventions alternate erratically between days of no and of intensive activity. Moreover, reserve changes consist of more than just interventions, such as revaluations of reserve asset components and periodic interest payments. Finally, the quote of the BIS in Section 2.2 suggests that interventions were small compared with the forex turnover in the case in question. Hence we leave out the intervention variable.[5]

3.2 EMP developments by country

Figures 1-5 show the movements in the EMP components Δs_t and $r_t - r_t^d$ and the EMP measure EMP_t for each country. The top three graphs concern the monthly frequency and provide an overview over 1992-1993. The bottom three graphs zoom in on the two major crisis months for the currency involved, edged with dots on the monthly time axes, and provide daily data (the tick mark dates are Mondays).

As the interest rate component $r_t - r_t^d$ is our main focus, its figures compare $r_t - r_t^d$ to the interest rate term that is typically used in EMP research, $\Delta r_t - \Delta r_t^*$. As an intermediate measure, we also plot the exact level transformation of $\Delta r_t - \Delta r_t^*$, that is, $r_t - r_t^*$, to examine the impact of the inflation correction in (10). These comparisons will demonstrate the main point of the paper.

For completeness, we also plot the whole EMP measure. This requires a value for the weight w_r in (9). Eichengreen et al. (1996) suggest weighting the components such that the volatilities of the weight-component multiples are equal, so as to prevent that one component dominates the EMP measure. This approach has been followed most frequently and, for simplicity and comparability, we use it as well. Therefore, we set w_r equal to the standard deviation of Δs_t divided by that of $r_t - r_t^d$, where the

website show that this is caused by a switch from West German data to data for entire Germany. In addition, around that period inflation in eastern Germany was substantially higher than in the western part (13.4% versus 3.9%). Finally, the Bundesbank used West German data for policy purposes; see Deutsche Bundesbank (1999). Hence, we conclude that it is better to use West German data here (available from Datastream under mnemonic WGUU01FAF). If we had used data for entire Germany, our conclusions would have been amplified.

[5] In Jager and Klaassen (2006) we exemplify the use of intervention and forex turnover data for a country that provides such data (Mexico).

standard deviations are computed over the sample period of the graph in question. This generates the plot for EMP_t. The same procedure is applied to the EMP measures for the alternative interest rate terms, resulting in $EMP_{t,\Delta r_t - \Delta r_t^*}$ (based on $\Delta r_t - \Delta r_t^*$ instead of $r_t - r_t^d$) and $EMP_{t,r_t - r_t^*}$ (based on $r_t - r_t^*$).

To assess the differences between the approaches, we will employ some stylized facts about the forex markets and the economic situations in the EMS countries in 1992-1993. To get a good notion of these facts, keep in mind that in 1992 inflation in Germany was high (3.5%), given the traditionally inflation-shy nature of the country, so that the Bundesbank set high interest rates (9.4% on average). At the same time, most of the other countries experienced low economic growth: France 1.3%, Ireland 3.3%, Italy 0.7%, the Netherlands 1.5%, and the UK 0.2% (growth of real GDP from the OECD Economic Outlook). This economic situation caused tensions between the policy makers, as the two next citations illustrate: "Therefore, it is not surprising that several countries asked the Bundesbank for a reduction in official interest rates, ... because they considered German's high interest rate ... as a burden" (Deutsche Bundesbank, 1993, p. 83), and "A source of growing concern in a number of countries was the fact that exchange rate commitments left little scope for taking the weakness of economic activity into consideration in setting interest rate policy" (BIS, 1993, p.139).

The stylized facts to be used are:

1. **Growing pressure summer 1992**

   "By the summer of 1992 there was growing tension between monetary policy requirements in Germany and monetary policy requirements elsewhere. Tight monetary policies in Germany ... were transmitting an excessive disinflationary impulse to other ERM countries, ... contributing to tensions within the ERM" (Bank of England, 1993, p. 5). This view was shared by DNB (1993, p. 83) and Banca d'Italia (1993, p. 18). The pressure culminated on "Black Wednesday" (September 16, 1992), when Italy and the U.K. suspended ERM membership.

2. **Post-crisis pressure September 1992 - February 1993**

   ". . . exchange market pressures persisted into October and, particularly, November. Many currencies were involved, including sterling, as UK interest rates were lowered. . . . end October the Irish pound came under intense pressure. . . . Pressure soon encompassed the French franc again. . . . throughout December 1992 and January 1993 the French franc . . . and the Irish pound continued to come under intermittent heavy pressure, ..." (BIS, 1993, p. 188-189). Similar statements were provided by DNB (1993, p. 83) and Bank of England (1993, p. 5).

3. **Persistent pressure French franc February - July 1993**
"Following the devaluation of the Irish pound [February 1, 1993], tensions persisted intermittently in the ERM, with the French franc in particular near its floor in the narrow band until well in April, as the Bundesbank cut interest rates fairly steadily but cautiously. ... Towards the end of June, however, a further rise in French unemployment was announced. This seemed to serve as a reminder to the markets of the limits to which domestic interest rates could be raised to defend fixed parities in depressed economies, no matter how sound the 'traditional' fundamentals. ... In the final week of July the French franc started to come under massive selling pressure and the Bank of France raised interest rates" (BIS, 1994, p. 166-167).

4. **Interest rates after 1993 crisis kept on supporting currencies**
"The official communiqué [of the weekend of July 31 and August 1, 1993] that announced a large pre-emptive widening of the ERM's fluctuation margins, stressed that the existing grid of central rates was still thought to be 'fully justified', and expressed confidence that market rates would soon approach these parities again. To back this up, no immediate or significant advantage was taken of the apparently increased room for manoeuvre in interest rate policy" (BIS, 1994, p. 168). Moreover, Banca d'Italia (1994, p. 19) wrote that "Interest rates in France ... were lowered with extreme caution and ... remained anchored to German rates despite the persistence of adverse economic conditions and lower inflation than in Germany. The authorities thus signaled their intention to continue to give priority to the objective of exchange rate stability."

France

The stylized facts allow us to assess the quality of the EMP measures. The second graph in Figure 1 indicates that, according to $r_t - r_t^d$ and $r_t - r_t^*$, the Banque de France used the interest rate to offset pressure on the franc against the mark at least from September 1992 through August 1993. In contrast, the interest rate change variable $\Delta r_t - \Delta r_t^*$ suggests that in most of these months there was negative pressure, that is, a tendency for the French franc to appreciate. Stylized facts 2 and 3 support the suggestion provided by the two level approaches, not the one from the first-difference approach. The two level EMP measures also express stylized facts 1 and 4 correctly, whereas the first-difference approach is only in agreement with 1. In summary, for quantifying French EMP, $r_t - r_t^d$ and $r_t - r_t^*$ prove to be superior to $\Delta r_t - \Delta r_t^*$.

Focusing on the real and nominal interest differentials, $r_t - r_t^d$ and $r_t - r_t^*$, respectively, we observe that they move up and down in the same way. However, $r_t - r_t^d$ is substantially higher for the entire period of two years, which is due to the relatively low inflation in France compared to Germany. The stylized facts suggest that for the summer 1992 through 1993 period the franc experienced pressure. This is better reflected by the pressure based on $r_t - r_t^d$ than on $r_t - r_t^*$. It is apparently real instead of nominal interest rate differentials that reflect the price the French authorities paid for trying to keep the franc-mark rate stable, which is not surprising in view of the weak economic activity. Moreover, the EMP measure using $r_t - r_t^d$ points out that the franc was already under some pressure from the beginning of 1992, not just in the summer.[6]

Zooming in on the July-August 1993 crisis period by looking at the daily observations (lower three graphs of Figure 1) reveals some additional insights. For instance, on August 2, $\Delta r_t - \Delta r_t^*$ was substantially negative, leading to an almost zero $EMP_{t,\Delta r_t - \Delta r_t^*}$. But that day was the peak of the crisis, witnessed by the widening of the ERM fluctuation margins from 2.25% to 15% and a franc depreciation of 2%. Hence, for that day $\Delta r_t - \Delta r_t^*$ produces an incorrect clue for pressure. The two interest rate level variants perform much better. They also indicate much better the tension in the franc-mark market during the final week of July, as indicated by stylized fact 3. For Monday through Wednesday (26-28 July) the first-difference variant even points at a small appreciation tendency of the franc, fully at variance with fact 3. Further, the level variants nicely exhibit the continuation of the interest rate policy directed at stable exchange rates instead of fostering employment, as reflected by fact 4. They keep on indicating pressure, whereas the first-difference variant fails in this respect.

Finally, the bottom graph shows that for daily data correcting $r_t - r_t^*$ by inflation figures, as we propose, is less relevant than for the monthly frequency. The reason is that here daily interest rate hikes overshadow inflation differentials.

[6] The pressure on the franc in early 1992 may seem at odds with the notion that the September 1992 crisis came largely by surprise, because realignment expectations were low before late August 1992, as Rose and Svensson (1994) demonstrate. However, it is important to realize that EMP differs from realignment expectations in an important way. The EMP concept concerns the forex market before policy instruments are set (this is why r_t^d instead of r_t must be used in (2)), but realignment expectations are typically defined when actual instrument values are known (after r_t is set). This makes it possible that, despite the existence of pressure on the forex market, parities are perfectly credible. After all, if there is pressure and the central bank sets $r_t > r_t^d$, this may be enough to convince speculators of the determination of the central bank to defend the exchange rate, so that the expected exchange rate change may be zero despite the pressure. Hence, our claim of pressure on the franc before September 1992 is not inconsistent with the Rose and Svensson (1994) conclusion. Moreover, if we follow Rose and Svensson by using nominal interest rate differentials, that is, imposing $r_t^d = r_t^*$, we find no clue for pressure in the interest rate component of EMP before September, which is in line with their result. We conclude that nominal interest differentials indicated no credibility problems before September, but that real interest differentials revealed that there were nevertheless tensions in the forex market, which were not interpreted by market participants as indications of an upcoming crisis.

Ireland

Stylized fact 2 states that from the first crisis until February 1993 the Irish pound experienced "intense" and "heavy" pressure. It culminated in the devaluation of the Irish pound by 10% on February 1. The two level EMP measures show this extreme pressure strikingly, with pressure rates in November - February substantially exceeding the French pressure peak of August 1993. The first-difference measure stays far behind, indicating only moderate pressure.

For the daily frequency, Figure 2 also reveal clear differences between the level approaches ($r_t - r_t^d$, $r_t - r_t^*$) and the first-difference approach ($\Delta r_t - \Delta r_t^*$). The levels suggest high pressure on February 1, when the Irish pound devalued by 10%, following the sharp decrease in interest rates that were close to 100%. According to $\Delta r_t - \Delta r_t^*$, however, there is virtually no pressure on that date. This cannot be true.

The Irish data also exemplify two more general issues. First, as discussed in Section 2.3, a high interest rate can offset pressure but leave the exchange rate at the value that speculators find inappropriate, so that the interest rate has to be kept at a high level in the next period to again offset speculative pressure. An exchange rate change, in contrast, provides a vent for pressure, and is able to soothe the market. This is illustrated by the events on January 30 through February 1, 1993.

Second, the figure exemplifies the usefulness of having an EMP concept that is broader than just the exchange rate change itself to grasp pressure in fixed exchange rate regimes. After all, the interest rate development before the February 1993 devaluation is crucial for understanding that this devaluation did not come out of the blue.

Italy

Figure 3 again shows the importance of using interest rate levels instead of changes. The levels reveal that the September 1992 crisis did not come as a surprise, but that it was the climax of a period of gradually increasing interest rates to offset accumulating pressure on the lira. From early 1992 "prolonged financial economic problems put pressure on the exchange rate of the lira" (DNB, 1993, p. 82). This is only observable in the level-based measures. Both the monthly and daily observations for the first-difference measure have disappointingly low values just prior to the 7% lira devaluation on September 14 and the crisis of 16 September 1992. On September 14 this measure even points at negative pressure. In contrast, the level-based measures have large deflections in those periods, and this is supported by stylized fact 1.

Figure 3 is also a typical example of the fact that using interest rate levels provides a less erratic EMP measure with fewer sign switches than using interest rate changes.

We think a certain amount of smoothness is plausible, and the gradual developments witnessed by facts 1-4 are in line with this.

The Netherlands

Figure 4 concerns the ERM currency that survived the 1992-1993 turbulence, as the central rate and width of the fluctuation band of the guilder against the mark were not changed. Nevertheless, "the [Dutch] short-term interest rate increased in the first part of the year [to August 1992] due to the restrictive German monetary policy" (DNB, 1993, p. 81). Apparently, for exchange rate purposes the Dutch central bank was forced to set the interest rate somewhat higher than desirable considering weak economic activity. This indicates some pressure on the guilder against the mark, thereby exemplifying the possibility of pressure coming together with credibility of a peg.

The pressure is consistent with the positive $r_t - r_t^d$ for the whole period, but not with the time series of $\Delta r_t - \Delta r_t^*$ and $r_t - r_t^*$ (see Figure 4). The explanation is that $\Delta r_t - \Delta r_t^*$ and $r_t - r_t^*$ only account for the Dutch interest rate being close to the German rate, whereas $r_t - r_t^d$ also incorporates that Dutch inflation was lower so that real interest rates were higher.

Apparently, inflation differentials matter for EMP measurement. This holds not only at the monthly, but also at the daily frequency. The latter is in contrast to our conclusion for France, where inflation correction was unimportant for daily data. This difference is explained by the fact that for the Netherlands interest rate hikes did not overshadow inflation differentials.

Finally, Figure 4 demonstrates that the pressure on the guilder versus the mark was low, with a maximum of under 1%. It was at least much lower than pressure in the other currencies under consideration.

United Kingdom

The second graph of Figure 5 shows that from January through August 1992 the interest rate in the UK was set above the German level despite the equal or lower inflation in the UK. To stimulate the economy, the Bank of England gradually lowered the interest rate, but with a gradually lower sterling in the forex market in June through August as a result. Thus our EMP measure indicates pressure from January up to the crisis. Apparently, "Black Wednesday" did not come unexpectedly. The suggestion of prolonged pressure is in line with stylized fact 1. The pressure, however, is missed by the first-difference variant of EMP. Its representation in Figure 5, third graph, only indicates pressure in July, and not even in August.

Stylized fact 2 implies there was pressure in October, and this is picked up by all EMP variants. After that, the Bank of England used the acquired monetary freedom to cut interest rates. Using $r_t - r_t^*$ one would conclude that the bank used the interest rate to compensate for pound appreciation tendencies. However, the negative interest differential came together with a negative inflation differential. The latter caused $r_t - r_t^d$ to be zero on average up to the summer of 1993, and it led to a positive $r_t - r_t^d$ in July and August 1993. We find this pressure development more plausible than that by $r_t - r_t^*$, because the Bank of England gave priority to internal economic objectives after leaving the ERM in 1992 (which is consistent with a zero $r_t - r_t^d$). Some pressure on the pound in August 1993, the month of the other ERM crisis, also seems plausible.

Summary

We conclude from Figures 1-5 that $r_t - r_t^d$ and $r_t - r_t^*$ clearly outperform $\Delta r_t - \Delta r_t^*$ as a component in a measure of exchange market pressure. The preference ordering of $r_t - r_t^d$ and $r_t - r_t^*$ is less obvious, as they usually have similar variation over time. However, their levels can differ, and when they do, $r_t - r_t^d$ provides a more correct indication of pressure. This confirms the theory of Section 2.

As the main variation in $r_t - r_t^d$ comes from r_t, we doubt whether sophistications of r_t^d beyond (10), such as business-cycle adjustments, are worth the effort, particularly for studies on stable economies like the ERM countries. Hence we prefer $r_t - r_t^d$ using r_t^d from (10) as the interest rate component in a measure of exchange market pressure.

Finally, daily data provide additional insights that are hidden in monthly figures.

4 Conclusion

Knowing the 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 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 by using the monetary model of exchange rate determination to derive a measure of EMP, we have introduced a new approach. It is model-free, imposes much weaker assumptions, and is still simple. Therefore, it is an improvement over the traditional method. Our EMP measure depends on the relative exchange rate change, the interest rate level relative to a benchmark rate, and on interventions.

We have argued that the ideal benchmark interest rate is the counterfactual rate the monetary authorities would have chosen if they had no external policy goal (such as an exchange rate target) and could purely focus on the domestic economy. A practical difficulty is how to proxy this rate. We have introduced a simple approximation and have motivated why it seems good enough in practice. It is the nominal interest rate of the reference country plus the inflation differential. Thus the interest rate term we propose in the EMP measure is the real interest rate differential.

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

For practitioners, the main contribution of the paper is that we have the interest rate level instead of the typically-used first difference in our EMP measure. This resolves some uncomfortable a priori feelings we had regarding the use of interest rate changes.

A study on EMS crises in 1992-1993 for five countries has confirmed the theoretically expected improvement of EMP measurement, because our measure is much more consistent with a number of stylized facts on pressure at the time. An interesting suggestion from the new EMP measure is that the EMP crises did not come out of the blue, but were the culmination of periods of growing pressure. The EMS application has also shown that our measure, with the real interest rate differential, outperforms an intermediate measure that uses the nominal interest rate differential instead, though this outperformance is minor in some periods. Finally, the EMS figures have revealed that daily data can provide valuable insights that are hidden in monthly observations.

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, bandwidth adjustments and capital controls. A generalization of the counterfactual domestic interest rate can be incorporated as well. From an empirical point of view, access to good data on interventions is important to study whether interventions are a relevant component of the EMP measure in practice. Moreover, many authors have applied the traditional EMP measure in policy-relevant directions, for instance, Vanneste, Van Poeck and Veiner (2005) on pressure on the ERM-II currencies, and Tanner (2001) on the interaction between EMP and monetary policy for Asia and Latin America in the 1990s. 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. These issues are left for future research.

Appendix: EMP in the typical monetary model

EMP expressions in the literature are derived within a 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 describe our EMP measure, the existing measure, and 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

$$m_t = \log(D_t + R_t) = p_t + \beta y_t - \alpha r_t, \tag{15}$$

where $m_t = \log(M_t)$, p_t is the log price level, y_t is log real income, r_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)

$$s_t = p_t - p_t^* \tag{16}$$

then gives the usual equilibrium formula for the exchange rate:

$$s_t = \log(D_t + R_t) - m_t^* - \beta(y_t - y_t^*) + \alpha(r_t - r_t^*). \tag{17}$$

Our EMP measure

The monetary model outcome (17) is a specific choice of the function f in the implicit function result (1). That is,

$$\begin{aligned} f(r_t, I_t, x_t) &= \log(D_t + R_{t-1} - I_t) - m_t^* - \beta(y_t - y_t^*) + \alpha(r_t - r_t^*) \quad (18) \\ f_r(r_t, I_t, x_t) &= \alpha \\ f_I(r_t, I_t, x_t) &= \frac{-1}{M_t}, \end{aligned}$$

where $x_t = (D_t, R_{t-1}, m_t^*, y_t, y_t^*, r_t^*)$. The resulting EMP measure is thus (9), with the monetary model giving particular weights:

$$EMP_t = \Delta s_t - \alpha\left(r_t - r_t^d\right) + \gamma\frac{I_t}{V_t}, \tag{19}$$

where $\gamma = V_t/q_t$ is assumed to be constant, and q_t is here a point between $D_t + R_{t-1}$ and $D_t + R_{t-1} - I_t$.

Existing EMP measure

In the literature one typically starts the EMP derivation from the final monetary model equilibrium (17). Next, one takes the first lag:

$$s_{t-1} = \log\left(D_{t-1} + R_{t-1}\right) - m^*_{t-1} - \beta\left(y_{t-1} - y^*_{t-1}\right) + \alpha\left(r_{t-1} - r^*_{t-1}\right). \qquad (20)$$

Subtracting this from (17), using a linear approximation for $\Delta\log\left(D_t + R_t\right)$, and bringing the EMP-offsetting variables to the left-hand-side gives

$$\Delta s_t - \alpha\Delta r_t - \frac{\Delta R_t}{M_{t-1}} = \frac{\Delta D_t}{M_{t-1}} - \Delta m^*_t - \beta\left(\Delta y_t - \Delta y^*_t\right) - \alpha\Delta r^*_t. \qquad (21)$$

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

$$EMP_t = \Delta s_t - \alpha\Delta r_t - \frac{\Delta R_t}{M_{t-1}}. \qquad (22)$$

Difference between our and the existing EMP measures

The most important difference between our measure (19) and the typical measure (22) is that the former has $\left(r_t - r^d_t\right)$ instead of $r_t - r_{t-1}$. The r_{t-1} originates from taking the lag of (17) to obtain (20). However, if s_t is governed by (17), then only contemporaneous values of the policy variables r_t and I_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 r_t and I_t (viz. r^d_t and 0) and on x_t. Hence an EMP measure that includes s_{t-1} should not have r_{t-1}.

To show that the lags step is the crucial reason for the difference in EMP measures, let us substitute $R_{t-1} = R_{t-2} - I_{t-1}$ in (20) and then remove the lags by substituting $\left(s_{t-1}, r_{t-1}, I_{t-1}\right)$ by the passive values $\left(s_{t-1}, r^d_t, 0\right)$ and x_{t-1} by x_t. Obviously, the equality then becomes an inequality, but the discrepancy is exactly EMP_t, as substitution of (18) into (3) shows. Hence, (20) becomes

$$s_{t-1} + EMP_t = \log\left(D_t + R_{t-1}\right) - m^*_t - \beta\left(y_t - y^*_t\right) + \alpha\left(r^d_t - r^*_t\right). \qquad (23)$$

Subtracting this from (17) gives our measure (19).

We conclude that the crucial difference between the standard approach and our method is the use of lags of (17) instead of the passive values $\left(s_{t-1}, r^d_t, 0\right)$ and x_t.

[7] Note that the sign of Δr_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 Δr^*_t and $\Delta R^*_t/M^*_{t-1}$ in EMP_t, as Eichengreen et al. (1996) do.

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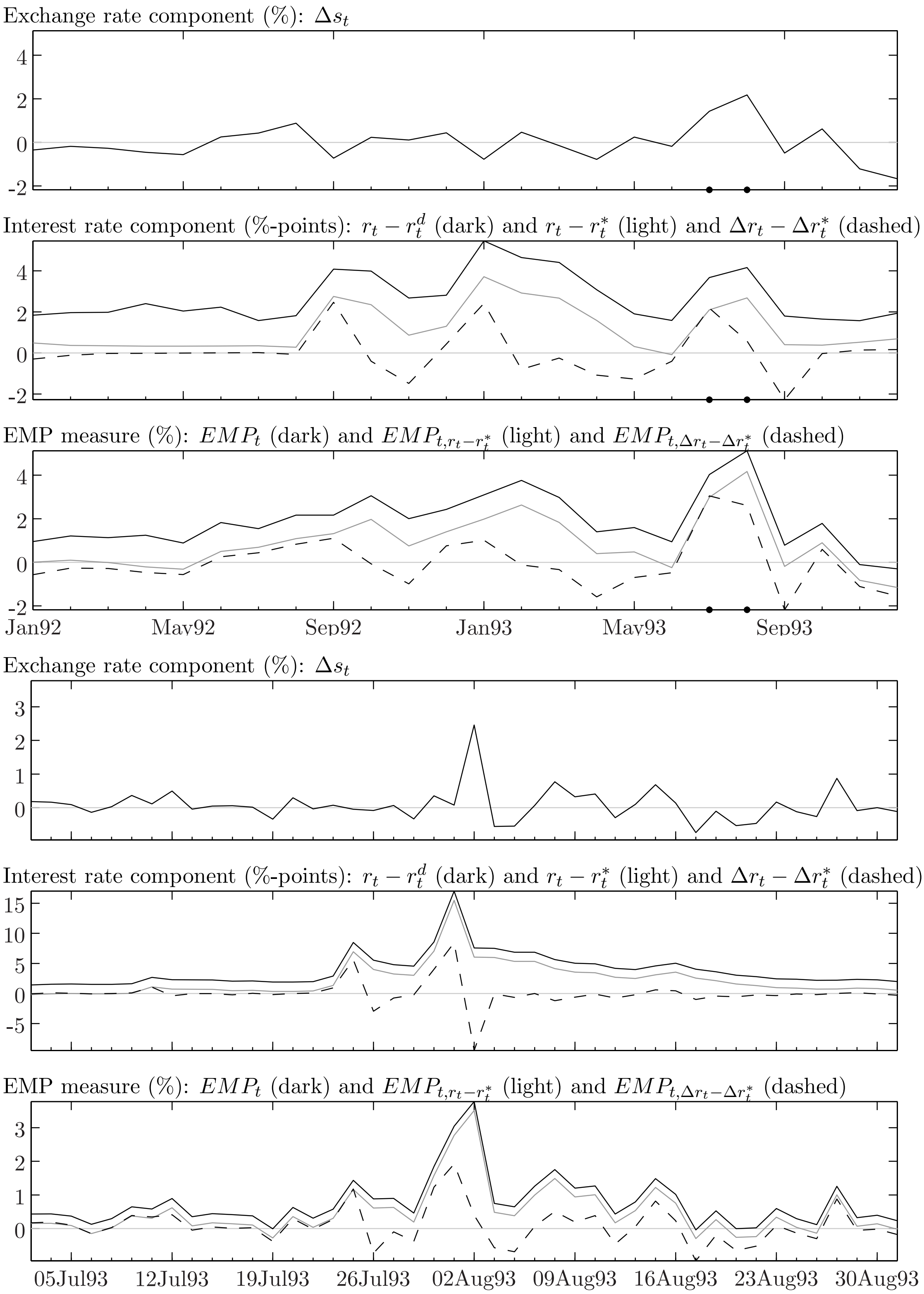

Figure 1: Monthly and daily EMP measures and their components - France

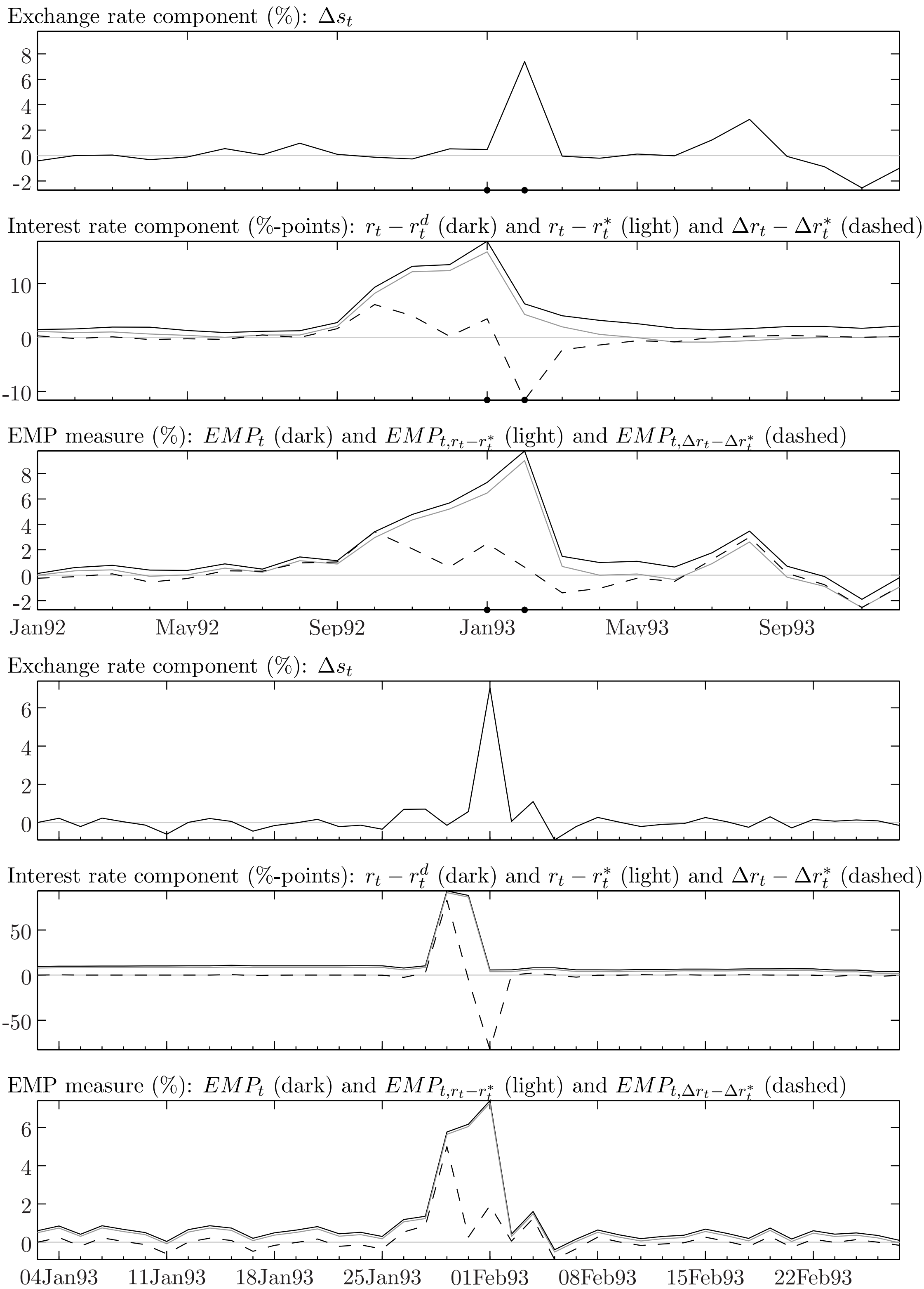

Figure 2: Monthly and daily EMP measures and their components - Ireland

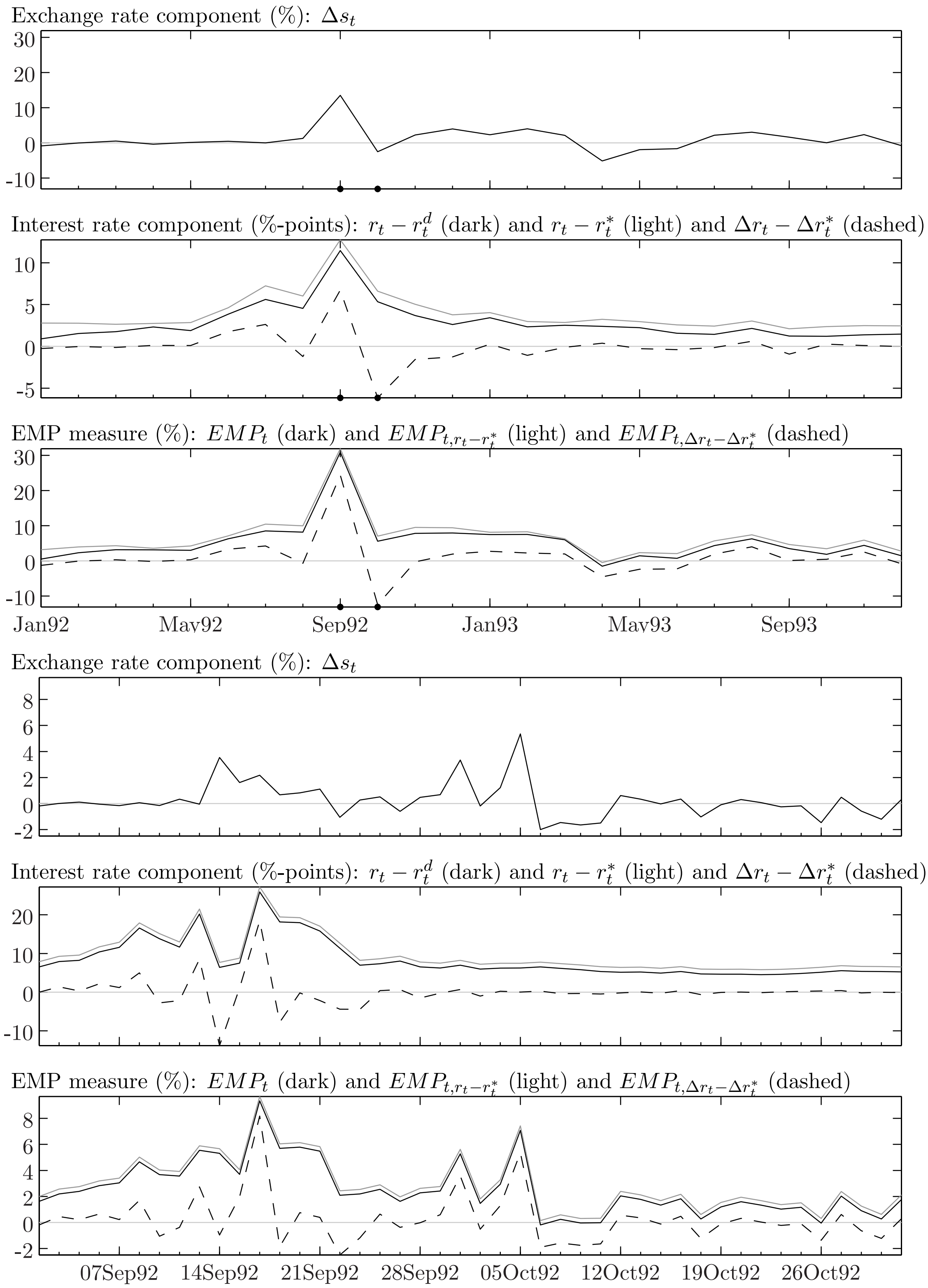

Figure 3: Monthly and daily EMP measures and their components - Italy

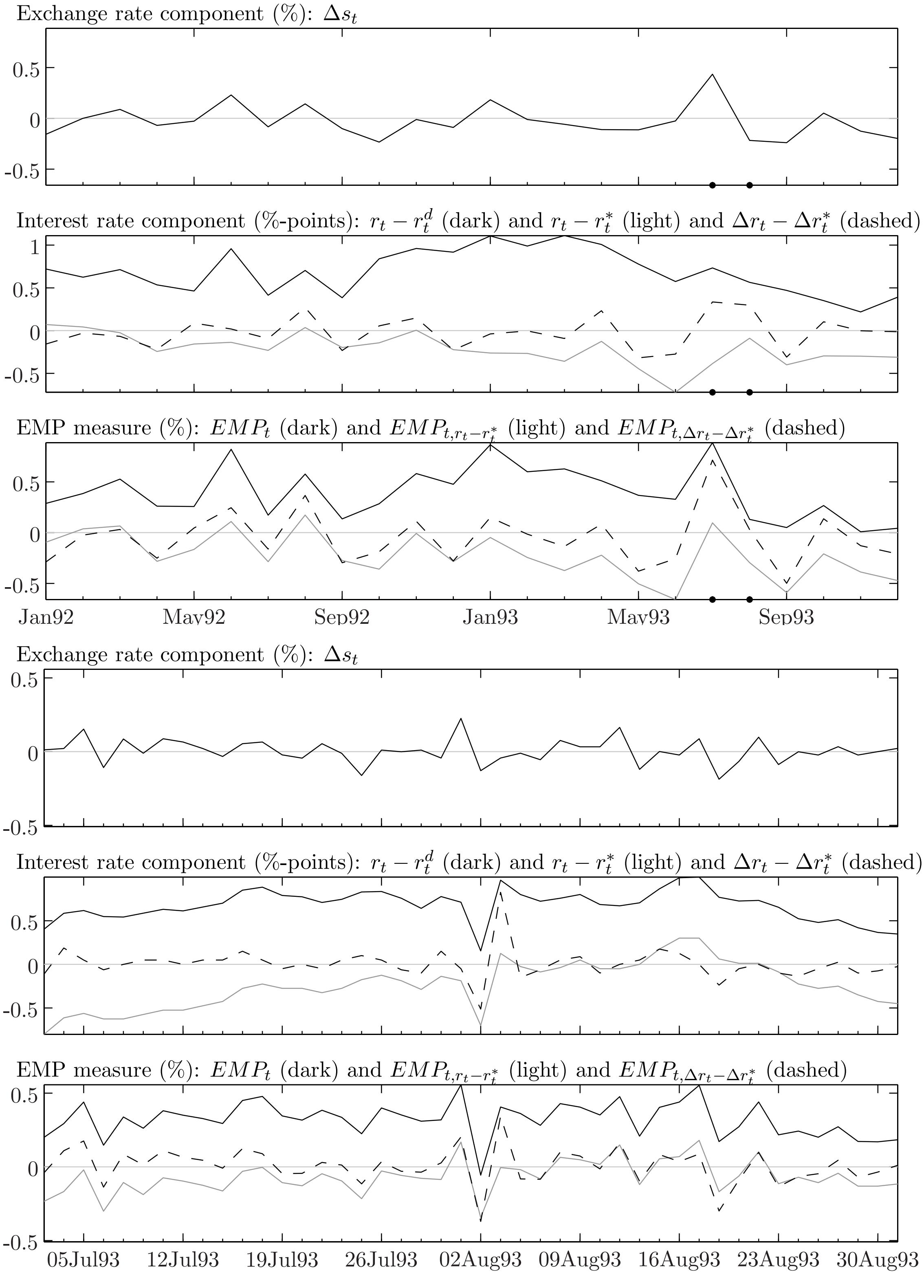

Figure 4: Monthly and daily EMP measures and their components - The Netherlands

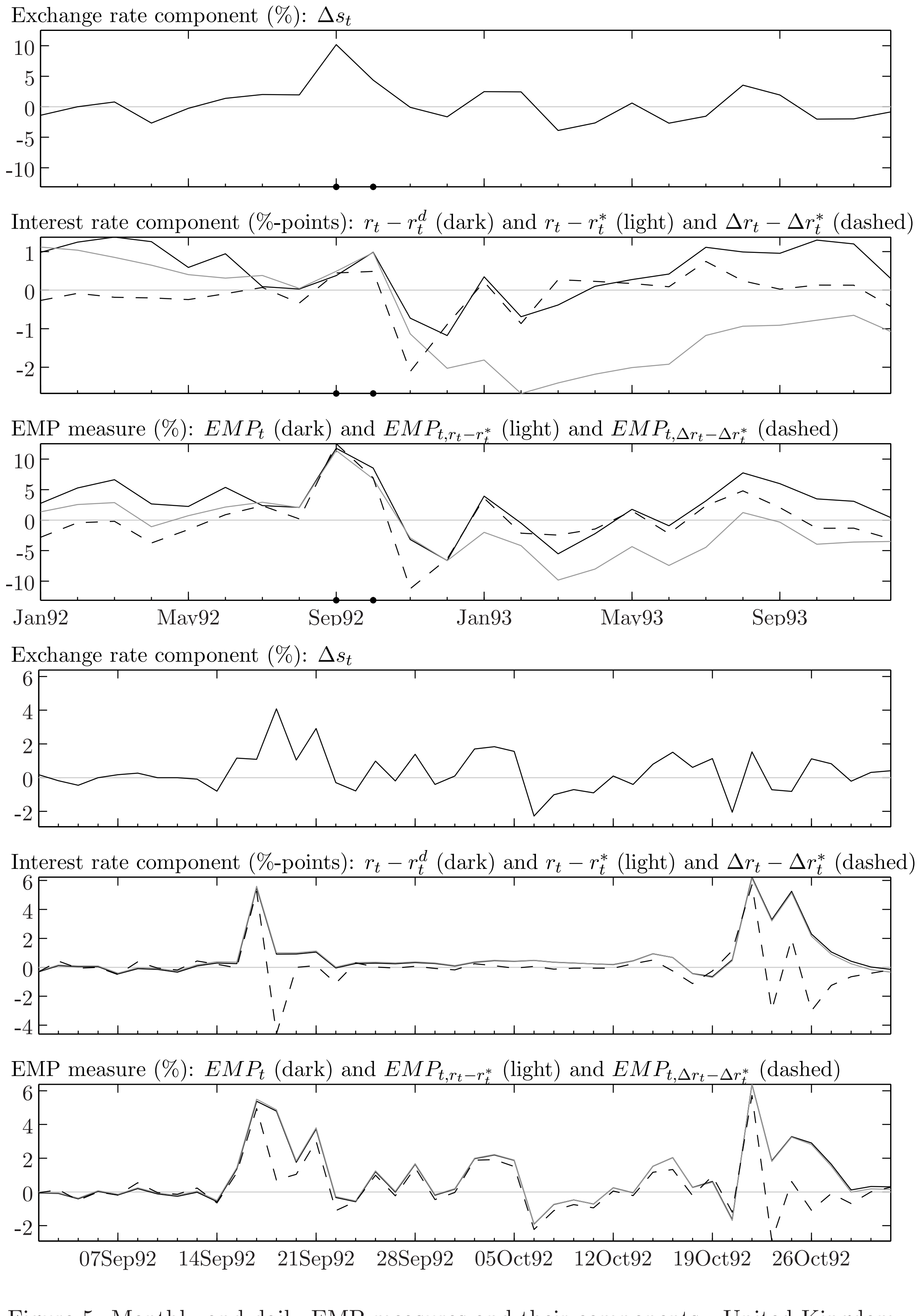

Figure 5: Monthly and daily EMP measures and their components - United Kingdom