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THE FINNISH EXPERIENCE OF MAINTAINING A CURRENCY BAND IN THE 1980s

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Abstract

The paper reviews the Finnish experience of maintaining an explicit currency band since its creation in 1977. The emphasis is on the latter half of the 1980s, which is a period of free capital movements and unregulated domestic money markets. The first part of the paper gives an historical account of the past experience. It is seen that the band arrangement has given some, albeit limited, freedom to monetary policy. This is reflected in a higher interest rate differential than what would have been necessary in order to keep the exchange rate completely fixed and private capital movements on balance on the average. The second part presents a brief review to theoretical models of currency bands. In the third part the predictions of these models, as regards the relationship between the interest rate differential and the exchange rate, the perceived devaluation risk and the credibility of the band, are tested with the Finnish data from 1987 onwards. According to the results the interest rate differential and the exchange rate exhibit negative correlation, except for the periods of currency unrest. The term structure of the interest rate differentials, however, does not behave in the manner predicted by the theory. The perceived devaluation risk is positive, which does not, however, imply that the band itself would have been uncredible. The tests indicate that the band has been credible up to a twelve-month horizon, but not in a five-year horizon.

Keywords: currency band, exchange rate, monetary policy

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1 INTRODUCTION

Although in the theoretical literature on exchange rate regimes, free floating and the fixed exchange rate regime are often regarded as polar cases, in the policy-oriented discussion the distinction is far from being clear-cut.

The country may have chosen free floating, but its central bank may intervene in the foreign exchange market or in the domestic money market in order to prevent the exchange rate from moving in the undesired direction. If the money demand function is stable and the central bank decides to change the money supply, it at the same time makes a decision upon the exchange rate change as well. Similarly, the regime may be that of the fixed exchange rate, but the rate may undergo frequent jumps as a result of discretionary policy decisions. The outcome may not be much different from the case of free floating with frequent discretionary changes in the money supply.

Without exception, the existing regimes are somewhere between the two polar cases. The central banks of the floating regime do intervene in the foreign exchange market and from time to time make discrete adjustments in their monetary targets. The central banks of the fixed exchange rate regime may permit some flexibility of the exchange rate within a given range and still make

discrete exchange rate adjustments either within the band or by realigning the band as well.

Recent literature on exchange rate regimes has paid much attention to target zones of exchange rates as well as to currency bands. Initially, both the research and policy debate on target zones was related to the problem of policy coordination between the major countries (cf. Williamson and Miller 1987). More recently, increasing attention has been paid to the explicit currency bands, such as the fluctuation limits of the exchange rate mechanism of the European Monetary System.

Three Nordic countries, Finland, Norway and Sweden are not members of the EMS, neither are they free floaters.[1] Instead the external value of the currency is in each country defined in terms of the currency index, which includes the currencies of the respective country's most important trading partners. Quite recently, Norway decided to change its trade-weighted currency index to the ECU-basket. The central bank of each country is committed to maintain the currency index within a predetermined fluctuation range, the size of which is ± 1½ in Sweden, ± 2¼ per cent in Norway, and ± 3 per cent in Finland. Finland and Sweden were the first countries who defined the exchange rate system in terms of the currency index and the unilateral explicit currency band.

Thus, the exchange rate system of these three countries resembles that of the EMS countries. The major difference is that a possible devaluation or revaluation of the exchange rate or a change in the fluctuation range is always a unilateral decision by the authorities of the country concerned and not the result of the multilateral decision as it is in the case of the realignment of central parities within the EMS. Another difference is that within the exchange rate mechanism of EMS joint interventions are possible and, in fact, executed.

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1 Unlike Finland, Norway and Sweden participated in the 1970s in the European Common Margins Arrangement (The Snake) which was the predecessor of the EMS. Sweden left the snake in 1977 and Norway in 1978.

The purpose of the present paper is to review and analyze the Finnish experience of maintaining the currency band since 1977, the year of its creation. The discussion will be cursory for the period 1977 to 1986, because during that period both capital movements and domestic financial markets were tightly controlled and, in spite of the formal fluctuation range, the currency index was kept practically constant, except for discrete adjustments. The period from 1987 to 1990, when exchange controls had already been to large extent relaxed and domestic money markets deregulated, is more interesting for policy analysis purposes and, therefore, deserves a closer investigation.

The latter period from 1987 onwards is interesting also in another respect, because the recent theoretical models of target zones are based on the assumption of free capital mobility and properly functioning money market. Therefore, these models serve as a useful framework to organize the discussion on how the recent Finnish experience has to be interpreted. Although any econometric testing of these models is highly tentative, due to short time period and changing institutional environment, we have, nevertheless, attempted to test some of the predictions of the theoretical models with the Finnish data.

The paper is organized as follows. Section 2 analyzes the Finnish experience with the currency band simply by describing the most important episodes and by examining the relevant data. The purpose of this section is to make a preliminary assessment on how the currency band has functioned in Finland in the recent past. Section 3 gives a brief review to some aspects of the recent theoretical literature, the emphasis being on their applicability to the Finnish experience. Section 4 examines econometrically the relationship between the interest rate differential at different maturities and the position of the currency index within its band. In addition, it presents the results of some simple tests on the credibility of the Finnish currency band. Concluding remarks are presented in Section 5.

2 A BRIEF HISTORY

2.1 Creation of the band

Since the breakdown of the Bretton Woods system in 1973, the Bank of Finland started to peg the value of the currency to an informally calculated currency index. Initially the index served as an indicator reflecting the currency movements in the foreign exchange markets. The fixed exchange rate system was thought to best serve the needs of the tradable sector.

After two discrete devaluations in 1977, the new Currency Act was introduced on November 1st of that year (Puro 1978). The new Act defined the external value of the Markka officially in terms of the currency index number. In addition, it defined the currency band, although without specifying the width of the band. That decision was left to the Government.

According to the Currency Act, the Bank of Finland is responsible of keeping the currency index within the band. The Board of Management of the Bank is free to manage the exchange rate within the band. Any realignment of the band, including changes in the width of the band, are decided upon by the Government based on the proposal by the Bank of Finland that is put forward by Bank's Parliamentary Supervisory Committee. The Government can either approve the proposal as it stands or to reject it. The Act also stipulates that the Government confirms the basis of calculating the index.[2]

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[2] Since the introduction of the new Currency Act, the tradeweighted index has been calculated using the bilateral exchange rates of the currencies most important to Finnish trade. The currencies of the countries included in the index are those whose trade have accounted for not less than 1 percent of Finland's merchandise imports and exports in each of the preceding three years. The weights are changed quarterly based on average trade shares over the last two years. At present 14 countries are included in the currency index. The Currency Act was amended in 1983 (cf. Puro 1984). The Soviet rouble was removed from the index, and the calculation of the index

The argument for the currency band at the time of its creation was the greater freedom of monetary authorities to excercise discretionary powers on the exchange rate policy in order to counteract the effects external inflationary shocks without being forced to go through the complicated procedure involving a large number of actors (the members of the Government and the Parliamentary Supervisory Committee). In the coming years, this power became, in fact, exercised only on very few occasions.

2.2 Competitivity-oriented exchange rate policy

The range of the band was initially set to ± 2¼ per cent. In spite of the band, the currency index was not allowed to change, except when it was discretely adjusted. Between the dates of discrete adjustments the standard deviation of daily changes in the currency index remained very small. In other words, the band did not change the exhange rate regime from that of fixed exchange rates to that of limited flexibility.

Since the introduction of the currency band, there have been seven discrete adjustments of the currency index, of which three were discrete changes within the band. The width of the band has been changed three times. It was widened to ± 3 per cent in (month) 1979 and was kept at that level until the October 1982 devaluation, when the range was returned back to its initial ± 2¼ per cent level. In November 1988 the fluctuation range was again widened to ± 3 per cent.

The frequent discrete adjustments in the exchange rate in the 1970s and early 1980s must be viewed against credit rationing in the Finnish financial markets and far-reaching capital controls. During that period the Bank of Finland had considerable room of manoeuvre in monetary policy, at least in principle. Interest rate

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number was based only on the convertible currencies. Moreover, the formula for calculating the index based on arithmetic mean was replaced by the geometric mean.

policy was geared mainly toward demand management and structural objectives, whereas the decisions on exchange rate policy were based mainly on competiveness of the export sector.

During this period of "competitivity-oriented exchange rate policy" the speculative attacks against the markka were carried out mainly through "leads and lags" (in 1977 and 1978) and, since 1980, also via the forward exchange market (in 1982 and 1983). In the first half of the 1980s, the effectiveness of capital controls and domestic financial market regulations became severely undermined by the widespread circumvention of regulations and the gradual emergence of the unregulated money market (cf. Swoboda 1986; and Åkerholm, 1987).

2.3 Exchange rate as an intermediary target

The deregulation of financial markets and the removal of exchange controls, which by now is almost complete, have resulted in a drastic change in the role of exchange rate policy. It can no more be separated from domestic monetary policy: interventions in the domestic money market affect the interest rate and hence the capital flows, which in turn affect either the exchange rate or reserve flows. The latter would imply offsetting liquidity effects in the domestic money market.

The process of financial market deregulation has changed the argument for an explicit currency band rather profoundly. It has been claimed that the band gives the central bank some degree of autonomy, though admittedly limited, in conducting monetary policy for demand management purposes.

Against this background, the exchange rate defined in terms of the currency band has become the medium-term intermediate target, while in the short run the exchange rate can fluctuate within the band reflecting capital flows and interest rate developments. Although it is open to debate whether the central bank should define its ultimate targets in terms of nominal or real variables or whether the authorities should follow fixed rules or reactive rules responding to macroeconomic outcomes, the present arrangement in Finland defines price stability as its most important ultimate target, the targeted rate of inflation being the average inflation in the countries included in the currency index.

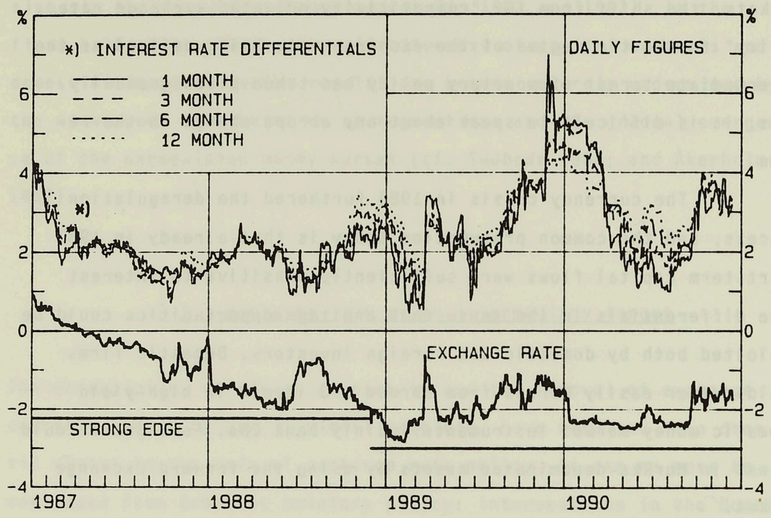
As a result of the institutional changes in the financial markets, the shift from the "competitivity-oriented exchange rate policy" to the the regime of the exchange rate being defined as the intermediate target of monetary policy has taken place gradually. Thus, it is difficult to speak about any abrupt change in the regime.

The currency crisis in 1986 furthered the deregulation process, and the common presumption today is that already in 1987 short-term capital flows were sufficiently sensitive to interest rate differentials in the sense that arbitage opportunities could be exploited both by domestic and foreign investors. Domestic firms could rather easily borrow from abroad and invest in high-yield domestic money market instruments, mainly bank CDs. Foreigners could invest in Markka-denominated assets by using the forward exchange market.

2.4 The past four years

The recent development of the exchange rate and the interest rate differentials is depicted in Figure 1. The exchange rate is defined as a percentage deviation of the currency index from the mid-point of the band. During the past four years, the exchange rate has remained below the mid-point, except for the beginning of 1987. Despite large short-term fluctuations, the interest rate differentials (measured against the weighted average of foreign interest rates) center around 2 per cent level for various maturities. The largest deviations have occured in autumn 1989 and again in autumn 1990.

Figure 1 **Interest rate differentials and the exchange rate**



Explanations: The exchange rate is the percentage deviation of the currency index from the mid-point of its band. The interest rate differentials are measured against the weighted average of foreign interest rates using the weights of the Bank of Finland currency index.

After the 1986 currency unrest, the restored confidence in the Markka was reflected in substantial capital inflows in the early 1987. As a result, the interest rates were on a declining trend and the currency was strengthening until the index almost hit the lower edge of the then ± 2¼ per cent band in June 1988. By that date the interest rate differential had shrunk to one per cent from four per cent in the beginning of 1987. Throughout the first half of 1987 the

Bank of Finland intervened in the foreign exchange market as a buyer in order to restore the exchange reserves to an acceptable level. At the same time, the Bank of Finland intervened in the domestic money market as a seller which compensated, in part, for the liquidity effects of rising exchange reserves. Without foreign exchange interventions the currency would have quickly strengthened to its lower edge already in the first half of 1987.

In 1988 it was evident that the economy was in the middle of the boom. The driving forces behind this development, which later led to the overheating of the economy, were the continously improving terms-of-trade as well as the consumption boom following the financial market deregulation. As these fundamentals were not counteracted by tighter fiscal policy, the pressure was toward the real appreciation of the currency. Given the counter-inflationary stance of monetary policy, the Markka remained strong, staying close to the strong edge of the band from mid-1988 to September 1989.

In November 1988, the the fluctuation range of the currency index was widened from ± 2¼ percent to ± 3 percent, which move gave room for some further appreciation of the Markka. By February 1989, the currency index was again hitting the strong edge of the band. Although it was hoped that the widening of the currency band would help maintain higher interest rate differentials because of higher exchange rate risk, strong capital inflows continued in the first quarter of 1989 leading to declining interest rates. The interest rate differential vis à vis the average interest rate of the index currencies shrank to below 1 per cent in March 1989, on the eve of the surprise realignment of the currency band.

In March 16, 1989, the fluctuation range of the currency index was shifted downward by about 4 per cent. As a result the Markka stregthened immediately and the interest rates rose steeply by about 2 percentage points. Within two weeks the exchange rate was again very close to the strong edge of the realigned band. Despite some decline in the interest rates, the differential vis à vis the index currencies remained at a somewhat higher level than before the realignment.

Between March and August 1989 the Bank of Finland was absent from the foreign exchange market, but intervened in the money market for liquidity management purposes. In the autumn the Markka was under pressure on three occasions, during which the Bank of Finland lost reserves by some FIM 7 billion (USD 1.75 billion), a small amount as such compared to earlier speculative attacks. The uncertainty in the foreign exchange market pushed interest rates up steeply, and the interest rate differential rose from a 2 to 2.5 per cent range to a 4 to 6 per cent range, which was sufficient to stop the capital outflow and to prevent major weakening of the Markka.

The confidence was restored in January 1990. Thanks to the one-month labour dispute in the banking sector in February, the sharp decline in domestic interest rates was postponed to March/April. Over the summer the tendency was, once again, toward capital imports, which contributed to the strength of the currency and brought the interest rate differential back to its "normal" level of around 2 percentage points. As the currency index remained very close to its lower limit, the Bank of Finland had to intervene in the foreign exchange market as a buyer.

The restoration of confidence, however, proved temporary. The weakening of the economy and the uncertainty about the national budget led to an expectations-driven upward drift of domestic interest rates in September and October 1990, as a result of which the interest rate gap widened from 2 to around 4 per cent.

2.5 Preliminary assessment

The argument, according to which the band should give the central bank some degree of policy autonomy despite free capital movements is based on the following two premises.

First, if the fundamentals, including tight monetary policy, drive the exchange rate to the strong edge of the band, this

should create an expectation of future depreciation because further appreciation is not possible in the case of a credible band. As a result, domestic interest rates should rise in order to maintain the interest rate parity. It follows from the latter argument that widening of the band should increase the monetary independence of the central bank. This was the justification for the widening of the band of the Markka in November 1988.

Secondly, the higher exchange rate volatility, facilitated by the existence of the band, should raise the risk premium and make domestic and foreign assets more imperfect substitutes for risk averse investors. From the point of vof view of an individual investor, the risk premium should depend, among other things, on the exogenous exchange rate volatility.

In retrospect it would appear that the present band arrangement has indeed given some degree of policy autonomy to the Bank of Finland, although any quantitative assessment of its significance is most uncertain. As noted above, the average interest rate differential in the post-1986 period has tended to fluctuate around two per cent level for all maturities up to 12 months.

Figure 1 reveals that each time when the interest rate differential has shrunk to around one per cent level, the exchange rate has shown tendency toward depreciation. These kinds of episodes are observed in late 1987, summer 1988, early 1989, summer 1989 and, again, in summer 1990. On the other hand, when the interest rate differential has stayed at its average level of two per cent or above, the currency has shown tendency toward appreciation. This is especially true in summer 1987, in spring and autumn 1988, as well as in spring 1990.

On the whole, the swings in the the exchange rate, on the one hand, and the interest rate differentials, on the other hand, exhibit negative correlation. There are, however, important exceptions. One is the early 1987 when the Bank of Finland had to intervene in the foreign exchange market in order to restore the exchange reserves to an acceptable level. The other is the period from October 1989 to March 1990, when the Markka was under pressure and when

the return to "normality" was postponed by the one-month bank strike in early 1990. The third exception is the autumn 1990 when the interest rate gap widened and the exchange rate again showed tendency towards depreciation.

Neglecting the exceptional periods, these observations suggest that the interest rate differential that would have kept currency flows on balance for most of the post-1986 period is somewhere between one and two per cent, or 0.5 to 1 percentage points below the average actual outcome.

The tentative conclusion of this inspection of historical data is that the currency band arrangement has made it possible for the Bank of Finland to maintain an interest rate level that is roughly one percentage points higher than what would have been possible in a fixed exchange rate regime with full credibility. Whether this achievement was of any major significance for demand management purposes is open to debate. In any case, it did not prevent the economy from overheating.

The fundamentals, such as the declining household sector savings ratio and the improving terms of trade in, were moving in the wrong direction from the point of view of macroeconomic stability. To compensate for their expansionary effects would have required much tighter fiscal policy than what actually was the case. It is, perhaps, worth noting that changes in both of the above-mentioned fundamentals were unanticipated. From these the terms of trade improvement was repeated each year from 1986 to 1989, suggesting that over this period there was a drift in the fundamentals.

The visual inspection of Figure 1 also reveals that both the day-to-day and the month-to-month variability of interest rate differentials has been greater in the period since late 1988 than before, whereas the exchange rate volatility has remained roughly constant. The interest rate volatility increased especially in the short end of the maturity structure. The widening of the band by 1.5 percentage points in November 1988 may have contributed to this outcome, although the more likely explanation is the increased uncertainty on the future economic development as the awareness of

economic imbalances became more wide-spread. In addition, the discretionary measures by the Bank of Finland in the course of 1989, such as the surprise realignment of the band, the introduction of supplementary reserve requirements on banks and the changes in operational mechanisms of liquidity control aiming at limiting the banks' access to central bank borrowing, all contributed to increased interest rate variability (cf. Suvanto 1990).

Before the band was widened in November 1988, the currency index (measured as percentage deviation from the middle point) varied around -1.5 per cent level. Thereafter the fluctuations have centered around -2 per cent level. The fact that the fluctuations have been limited to the lower half of the band can be accounted to the drift in the fundamentals associated with the use of the limited policy independence in the manner described above. Because the central bank has succeeded in maintaining the domestic interest rates at somewhat higher level than what would have been necessary to equilibriate the the currency flows on the average, the exchange rate has been driven toward the stronger edge of the band.

The historical evidence does not suggest that there would have been wide-spread unconfidence on the currency band in the short term, except, perhaps, in autumn 1989. When the exchange rate is close to the strong edge of the band, the interest rate differential of 1 to 1.5 percentage points required to balance the currency flows on the average is consistent with the credibility of the official band of ± 2¼ to 3 per cent at least in the horizon of less than one year.

This is what we are able to conclude simply by looking at the historical data in Finland over the past few years. In order to gain deeper insight to the functioning of the currency band regime, we need sharper analytical tools. In the next section we attempt to find such tools from recent theoretical literature.

3 THEORETICAL ANALYSIS OF CURRENCY BANDS

3.1 Background

The idea of adopting target zones for the exchange rates stems from the growing concern in the 1980s on excessive volatility of nominal and real exchange rates both in the short run and in the long run (cf. Frenkel and Goldstein 1986; and Williamson and Miller 1987). This concern has resulted in a rapid growth in a theoretical literature on target zones and currency bands. This literature has in recent years expanded in various directions, including empirical applications.

The macroeconomic structures in the theoretical models of the currency bands are normally fairly simple versions of textbook models of an open economy with flexible exchange rates and rational expectations. The policy implications of these models depend on a particular model used and the way in which the stochastic processes driving the fundamentals of the exchange rates are specified.

Krugman (1987, 1988) was the first to show that the knowledge that the authorities will defend the target zone or the explicit currency band exerts a stabilizing effect on the behaviour of the exchange rate within the band, even when the authorities are not actively intervening. He showed that the extent of this stabilizing effect depended not only on the sensitivity of the current exchange rate to exchange rate expectations but also on the volatility of the underlying determinants of the exchange rate, so called fundamentals, as well as on the credibility of the commitment by the authorities to defend the currency band.

In Krugman's monetary model of exchange rate determination the source of the dynamics is in the stochastic behaviour of money demand; i.e., the velocity of money. Full price flexibility guarantees that the purchasing-power-parity condition is always fullfilled

and output is always at the full employment level. A decrease in the velocity of money brings about an appreciation of the currency, assuming that the money supply is kept constant. The range of the fluctuation of the exchange rate, however, is limited because of the band arrangement.

Miller and Weller (1989, 1990) have explored the implications of the well-known Dornbush model to the exchange rate determination within the currency band (Dornbusch 1976). In this model the demand for money is a stable function of output and the interest rate, but prices are not fully flexible, for which reason the purchasing power parity need not always hold. Changes in the real exchange rate affect output, which now may deviate from its full employment level. These deviations force domestic prices to move gradually along the Phillips-curve, which, however, is augmented by stochastic shocks.

Rather than attempting to develop new model variants to the growing target zone literature, we use the standard Krugman-type monetary model with flexible prices. Following Svensson (1989, 1990a, 1990b) we derive some theoretical predictions, first, on the relationship between the interest rate differentials and the exchange rate and, secondly, on the credibility of the currency band. These results are then used in our empirical analysis in Section 4 below.

3.2 A Target zone model

In the monetary model of exchange rates with flexible prices, the exchange rate is determined by the equilibrium in the money market. The equilibrium condition for the money market at time t can be written as follows:

$$(1) \qquad m(t) = -\alpha i(t) + \beta y(t) + p(t) + u(t), \quad \alpha, \beta > 0,$$

where m(t) is the log of the money supply, y(t) the log of real output, i(t) the domestic interest rate, and p(t) is the log of the domestic price level. The remaining variable u(t) stands for stochastic shocks to money demand.

Assuming that the agents are risk neutral, then according to the arbitrage condition the domestic interest rate is equal to the foreign interest rate plus the expected rate of depreciation, or

$$(2) \qquad i(t) = i^*(t) + E_t[de(t)]/dt,$$

where $i^*(t)$ is the foreign interest rate, and e(t) is the log of the exchange rate defined as a domestic-currency price of one unit of foreign currency. E_t stands for the expectation conditional on the information set at time t. Assuming that the purchasing-power-parity condition is always fulfilled, the domestic price is equal to the sum of the foreign price level and the exchange rate, all in logs.

By these assumptions equation (1) can be rewritten as follows:

$$(3) \qquad e(t) = k(t) + \alpha E_t[de(t)]/dt.$$

Accordingly, the exchange rate is proportional to the fundamental k(t), and depends on the expected rate of change of the exchange rate with the coefficient α (interest rate semi-elasticity of money demand). The fundamental k(t), driving the exchange rate, is composed of two parts

$$(4) \qquad k(t) = m(t) + v(t),$$

The former component is an exogenous money supply, which is the intervention variable of the authorities. The latter variable v(t) collects together all determinants of the demand for money; i.e., $v(t) = \alpha i^*(t) - \beta y(t) - p^*(t) - u(t)$. With m(t) constant, an increase in the foreign interest rate calls for currency depreciation. A positive productivity shock leads to an exogenous increase in

output and currency appreciation. Also an increase in the foreign price level leads to currency appreciation, as does an upward shift in the demand for money function (decrease in velocity). In the following, the composite of these fundamentals, the velocity shocks, are assumed to behave in a stochastic manner.

The exchange rate at time t can be now be obtained by finding the saddle-path solution to the differential equation (3).[3] It is

$$(5) \qquad e(t) = \alpha^{-1} \int_t^{\infty} e^{(t-s)/\alpha} E_t[k(s)]ds$$

In other words, the current exchange rate depends entirely on the expected future course of the fundamental discounted by factor $1/\alpha$.

The solution of (5) depends on whether or not the monetary authorities are willing to influence the exchange rate by affecting the fundamental through changes in the money supply. Under a free float, the authorities are assumed never to intervene in order to offset shocks to velocity. Assuming that dm(t) = 0, dk(t) = dv(t), which, in turn, is assumed to evolve as a Brownian motion with a drift, or

$$(6) \qquad dv(t) = \mu dt + \sigma dz,$$

where μ is the expected change in v, and dz is a Wiener process with an instantaneous variance σ^2. In this case the solution to (5) is simply $e(t) = k(t) + \alpha\mu$. It is, however, important to note that this is true only if the authorities are committed to maintain the free float regime indefinitely, and if the fundamental evolves as stated by (6). If the process driving the evolution of the fundamental deviates from (6), the solution to (5) is likely to be very difficult to calculate (cf. Froot and Obstfeld 1989).

The analysis so far is valid only for a free float regime. The presence of the exchange rate band sets limits to how far the

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3 Following Svensson (1990a), we exclude the possibility of pubbles.

fundamentals are allowed to wander before the authorities step in and start to offset the effects of the velocity shocks in order to prevent the exchange rate from depreciating above or from appreciating below the predetermined limits.

For example, if the velocity shocks would drive k(t) above k^u, the authorities are known to reduce the money supply by open market or by foreign exchange sales in order to maintain $k(t) < k^u$. Similarly, if v(t) is driving k(t) below some lower limit k_l, the authorities are known to step in and increase the money supply by open market or foreign exchange purchases. If the band is fully credible, the future behaviour of the authorities at the edges of the band is known. This knowledge affects the behaviour of the market participants in advance.

More precisely, we assume that intervention will occur only when the fundamental k(t), and therefore the exchange rate e(t), would move outside the predetermined limits. Otherwise m(t) is constant, and the fundamental obeys the Brownian motion as expressed in (6). With these assumptions, we postulate that any particular solution to the differential equation (3) can be expressed as a function of the fundamental; i.e., e(t) = e(k(t)). Using Ito's lemma, we obtain

$$(7) \qquad E_t[de(t)] = [e_k\mu + (1/2)e_{kk}\sigma^2]dt$$

Substituting $E_t[de(t)]/dt$ from (7) into equation (3), we obtain the following expression for the exchange rate:

$$(8) \qquad e[k(t)] = k(t) + \alpha\mu e_k + (1/2)\alpha\sigma^2 e_{kk}$$

A general solution to this second order differential equation is

$$(9) \qquad e[k(t)] = k(t) + \alpha\mu + A_1\exp[\delta_1 k(t)] + A_2\exp[\delta_2 k(t)]$$

where δ_1 and δ_2 are the roots of the characteristic function $(1/2)\alpha\sigma^2\delta^2 + \alpha\mu\delta - 1 = 0$. The constant terms A_1 and A_2 can be solved by using the so called smooth pasting condition, which states that

the exchange rate function e[k(t)] should have a zero slope at that point where it hits either of the two edges of the fundamental band; i.e., $e_k(k^u) = e_k(k_l) = 0$.

Using the smooth pasting condition and equation (9) we obtain

$$(10) \qquad 1 + A_1\delta_1\exp(\delta_1 k_l) + A_2\delta_2\exp(\delta_2 k_l) = 0$$

$$(11) \qquad 1 + A_1\delta_1\exp(\delta_1 k^u) + A_2\delta_2\exp(\delta_2 k^u) = 0$$

from which A_1 and A_2 can be solved

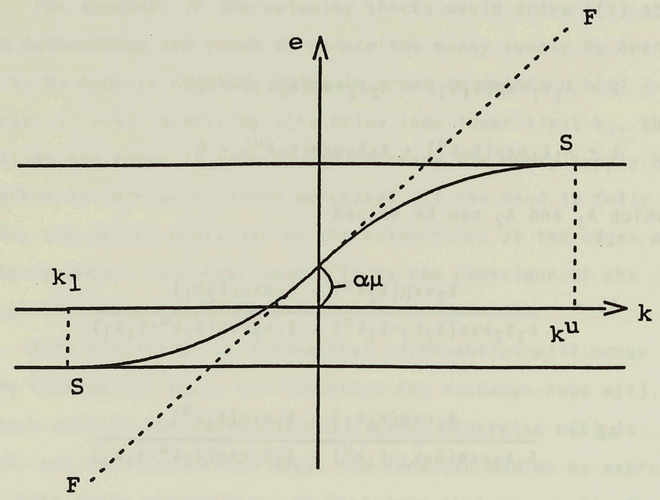
$$(12) \qquad A1 = \frac{\delta_2\exp(\delta_2 k^u) - \delta_2\exp(\delta_2 k_l)}{\delta_1\delta_2\exp(\delta_2 k_l + \delta_1 k^u) - \delta_1\delta_2\exp(\delta_2 k^u + \delta_1 k_l)}$$

$$(13) \qquad A2 = \frac{\delta_1\exp(\delta_1 k_l) - \delta_1\exp(\delta_1 k^u)}{\delta_1\delta_2\exp(\delta_2 k_l + \delta_1 k^u) - \delta_1\delta_2\exp(\delta_2 k^u + \delta_1 k_l)}$$

From (9), (12) and (13) it can be seen that the exchange rate is a function of the fundamental k(t) and the two barriers k_l and k^u.

Figure 2 shows the exchange rate (SS-curve) with a symmetrical fundamental band as a function of the fundamental. Its shape reflects the expectation that the authorities will intervene at the edges of the band in order to regulate the movements in k(t). In the middle of the band, the equilibrium solution behaves much like the solution in the free float solution, which is described by the 45-degree line (FF-line). The SS-curve becomes flatter as the fundamental approaches its limits, which shows the stabilizing effect on the exchange rate of the currency band arrangement. Due to the smooth pasting condition, the exchange rate curve is tangent to the edges of the band. If the distance between the fluctuation boundaries k_l and k^u are widened indefinitely, the equilibrium will ultimately coincide with the free float line FF. The SS-line is in Figure 2 drawn with a positive drift in the velocity v(t); i.e., $\mu > 0$. With

Figure 2 **Exchange rate and the fundamentals**



zero drift the intercept would be in the origin and the currency band would be symmetrical.

3.3 Interest rate differentials

In equation (3) the interest rate differential is equal to the expected rate of depreciation per unit of time. In continous-time models the unit of time is infinitesimally short. For interest rates with zero maturity, the interest rate differential is obtained directly from (2) and (3),

$$r[k(t),0] = \{e[k(t)] - k(t)\}/\alpha. \tag{14}$$

Substituting e[k(t)] from (9) into equation (14) we obtain the following expression for the zero-term interest differential

$$r[k(t),0] = \{\alpha\mu + A_1\exp[\delta_1 k(t)] + A_2\exp[\delta_2 k(t)]\}/\alpha. \tag{15}$$

It is easy to see that with a zero drift r[k(t),0] is zero in the middle of the band. The exchange rate is expected to fall in the upper half of the fundamental band, and therefore the interest rate differential is negative. The reverse is true in the lower half of the fundamental band.

We have already seen in equation (9) that the current exchange rate can be expressed as a function of the current fundamental. In a similar fashion, the future exchange rate at time $t+\tau$ can be written as a function of the fundamental at the same future time. The interest rate differential for an arbitrary positive term τ is accordingly[4]

$$r[k(t),\tau] = \{E_t[e(k(t+\tau))] - e(k(t)\}/\tau. \tag{16}$$

Because the exchange rate is bounded to remain inside the band, it is immediately seen that the interest rate differential approaches zero as the term τ approaches infinity.

The computation of $r(t,\tau)$ would be easy if the expected future exchange rate were easily computable. Unfortunately, this is not the case. Although the process driving the fundamental without interventions is itself very simple, the exchange rate follows a complicated nonlinear stochastic process. The nonlinearity implies that $E_t[e(k(t+\tau))]$ is not equal to $e(E_t[k(t+\tau)])$, except for infinite term in which case the expected future fundamental is equal to its unconditional mean. With zero drift this is equal to the middle point of the fundamental range $[k_1,k^u]$. For all other positive terms the expected future fundamental, and hence the expected future exchange rate, depends on state of the current fundamental k(t), as well as on the term τ itself.

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4 This holds only approximatively, the reason being that the expected rate of depreciation is defined as a logarithmic difference, whereas the interest rate differential is in percentage terms.

For brevity, let us denote the expected future exchange rate by $f[k(t),\tau]$. Note that in the case of risk neutrality this would be equal to the forward exchange rate. Svensson (1990a) has shown that $f[k(t),\tau]$ can be obtained as a solution to the following partial differential equation

$$(17) \qquad df[k(t),\tau]/d\tau = \mu f_k[k(t),\tau] + (1/2)\sigma^2 f_{kk}[k(t),\tau],$$

$$k_1 \leq k(t) \leq k^u, \ \tau > 0,$$

with the initial condition $f[k(t),0] = e[k(t)]$ and the boundary conditions $f_k(k_1,\tau) = f_k(k^u,\tau) = 0$.

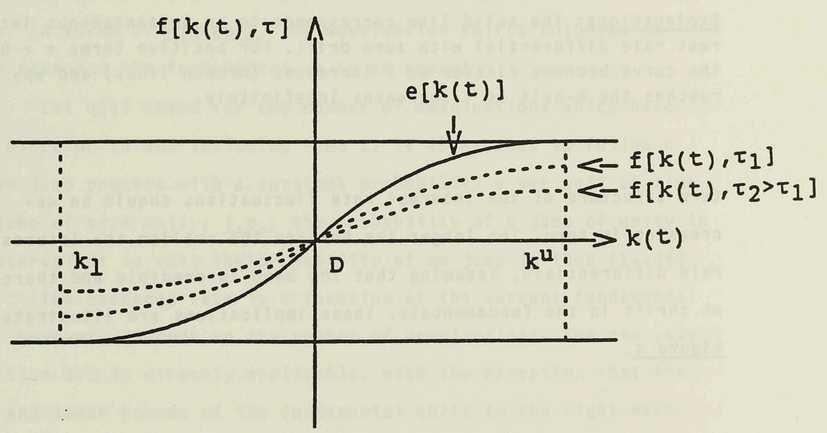
Assuming zero drift, $\mu = 0$, the second derivative f_{kk} determines the shape of the function $f[k(t),\tau]$. f_{kk} is positive and the expected future exchange rate is above its current value, when the current fundamental is below the mid-point k_0 of the fundamental range, $k(t) < k_0$. When $k(t) > 0$, f_{kk} is negative and the future excnage rate is below its current position. The general shape is thus the familiar S-shape as in the case of the current exchange rate (cf. Figure 2). If the current exchange rate is close to its strong edge $e(k_1)$ and if the term τ is short, the expected future exchange rate is above the current rate but below its unconditional mean $f(k_0,\tau|\tau\rightarrow\infty)$. The expected future exchange rate rises as the term increases and approaches the mid-point of the currency band from below. The same reasoning applies also in other direction. If the current exchange rate is close to its weak edge $e(k^u)$, the expected future exchange rate is somewhere between the current rate and mid-point of the currency band.

The results are illustrated in Figure 3, which shows the current exchange rate and the expected future exchange rates as a function of the current fundamental. The solution for the expected future exchange rates exhibits the same S-shape as the SS-curve, but they are flatter. It follows from this that, when $k(t) < k_0$, the expected future exchange rates are above the current rate, the more so the longer the term τ. For $k(t) > k_0$ the expected future exchange

rates are below the current rate, the more so the longer the term. Translated into the dimension of the interest rate differentials, the maturity premiums or discounts have to be divided by τ, cf. equation (16).

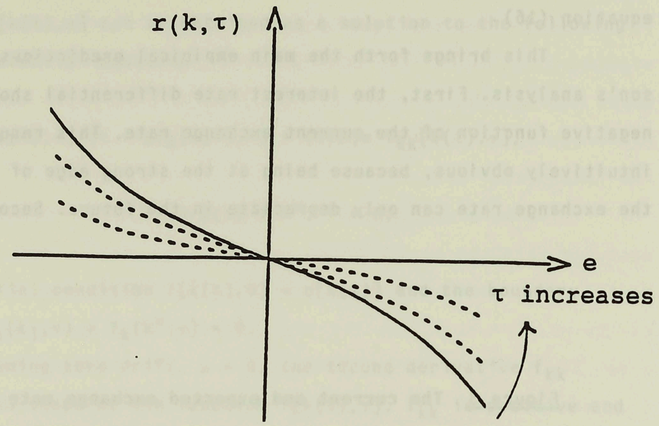
This brings forth the main empirical predictions of Svensson's analysis. First, the interest rate differential should be a negative function of the current exchange rate. This result is intuitively obvious, because being at the strong edge of the band, the exchange rate can only depreciate in the future. Secondly, the

Figure 3 **The current and expected exchange rate**



Explanations: The solid line is the current exchange rate, and the broken lines show the expected future exchnage rate for two different maturities $\tau_1 < \tau_2$.

Figure 4 **The interest rate differential and the exchange rate**



Explanations: The solid line corresponds to an instantaneous interest rate differential with zero drift. For positive terms $\tau > 0$, the curve becomes flatter as τ increases (broken lines) and approaches the e-axis as τ increases indefinitely.

term structure of the interest rate fluctuations should be decreasing in term. The longer the horizon the smaller the interest rate differentials, assuming that the band is credible and there is no thrift in the fundamentals. These implications are illustrated in Figure 4.

3.4 Realignment risk

So far we have assumed that the market participants regard the currency band as fully credible. In reality, however, high interest rate differentials are often caused by the possibility of a discrete devaluation. Such a situation can be analysed in terms of the target zone models. For instance, Miller and Weller (1989) have examined realigments that occur when the exchange rate reaches its upper or

lower edge. Delgano and Dumas (1990) have presented an analysis of the regime collapse, where the fixed exchange rate or a target zone regime cannot be maintened and the currency is allowed to float. Also Svensson (1989, 1990a) has extended the target zone model to include the possibility of a discrete devaluation with a given probability. Unlike in Miller and Weller (1989), a devaluation can take place at equal probability whatever is the position of the exchange rate within its band.

For the subsequent analysis, a devaluation is defined as an upward shift of the entire currency band. It follows from the model of Section 3.2 that a devaluation implies a shift also in the fundamental; i.e., k_l and k^u are shifted upwards by a given magnitude g. It is convenient to define a shift in the fundamental by a discrete increase in m(t), because it keeps the relative position of the fundamental k(t) unchanged within their upper and lower bounds. In terms of Figure 2, the devaluation shifts both the exchange rate and the fundamental up by an amount g.

Let q(t) stand for the number of devaluations which have taken place up to and including time t. It is assumed to follow a Poisson jump process with a constant probability v per unit of time of a jump of size unity; i.e., the probability of a jump of unity in the interval dt is vdt. The probability of no jump is thus (1-vdt).

The exchange rate is a function of the current fundamental which, however, depends on the number of devaluations. The analysis of Section 3.2 is directly applicable, with the exception that the upper and lower bounds of the fundamental shift to the right each time as an realignment is done. Without loss of generality we can normalize the effect of previous devaluations to be equal to zero by denoting q(t) = 0. Equation (3) is still valid, although one has to take into account the possibility of an instant devaluation; see Svensson (1990a) for the solution. It turns out that the possibility of an instant devaluation raises the current exchange rate by an amount $\alpha v g$, or

$$(18) \qquad e[k(t)|v>0] = e[k(t)|v=0] + \alpha v g.$$

In terms of Figure 2, the possibility of the devaluation would show up as an upward shift of the SS-curve by an amount αvg. If the devaluation occurs at time t, the SS-curve will jump up and to the right by the magnitude g of the devaluation.

The solution for the interest rate differential changes accordingly. The expected level of the exchange rate at some future time $t+\tau$ is

$$(19) \qquad f[k(t),\tau|v>0] = f[k(t),\tau|v=0] + \alpha vg + vg\tau.$$

The first term in the right hand side is the expected future exchange rate in time $t+\tau$ in the absence of devaluation expectations. The second term takes into account the possibility of an instant devaluation, and the last term is equal to the expected upward shift of the band during the term τ.

Subtracting (18) from (19) yields an expression for the interst rate differentials for positive maturities

$$(20) \qquad r(t,\tau|v>0) = \{f[k(t),\tau|v>0] - e[k(t)|v>0\}/\tau$$

$$= \{f[k(t),\tau|v=0] - e[k(t)|v=0\}/\tau + vg.$$

The first term in the latter equality is the interest rate differential in the absence of a realignment possibility, and the latter term is equal to the probability per unit of time of a devaluation times the size of a devaluation.

In terms of Figure 4, the relationship between the interest rate differential and the current exchange rate maintains its slope but is shifted upwards by an amount vg. For empirical purposes this is an important result, because it provides a possibility, at least in principle, to make quantitative evaluations on the perceived devaluation risk.

3.5 Credibility of the currency band

A credible currency band implies maximum and minimum values for the interest rate differential. The wider the band the greater is the distance between these values. In Section 3.3 it was shown that the term structure of interest rate differentials decreases in the term. It follows from this that also the distance between the maximum and the minimum interest rate differential should decline as the term to maturity increases. In Section 3.4 it was shown that the possibility of the devaluation raises the interest rate differential for all positive terms by a given amount which depends on the probability and the expected size of a devaluation. These observations imply a possibility to test whether or not the currency band is credible. The basic idea of the credibility test is fairly simple. It is presented in Svensson (1990b).

The maximum appreciation of the domestic currency in a credible band is the width of the band. In this case the exchange rate is at the strong edge of the band. The interest rate differential is positive at its maximum level. Similarly, the maximum depreciation is equal to the width of the band in a situation where the exchange rate is at its weak edge and the interest rate differential is negative at its minimum level.

Given the bounds on the size of the maximum depreciation or appreciation, the foreign interest rates and the terms to maturity, the domestic-currency rates of return on foreign-currency investments are bounded to a given interval, the size of which depends on the term. Let $I(t,\tau)$ stand for the annualized expected domestic-currency rate of return on investment in τ-term foreign assets. The annualized τ-term foreign interest rate is denoted by $i^*(t,\tau)$. The relationship between the two rates of returns depends on the current exchange rate and the expected future exchange rate in a following manner:

(21) $$I(t,\tau) = \{E_t[e(t+\tau)]/e(t)\}^{12/\tau}[1+i^*(t,\tau)] - 1,$$

where the term τ is measured in months. A credible band implies that $e(t+\tau)$ must lie between the lower edge of the band e_l and upper edge of the band e^u. Therefore, the rates of return must also lay between certain bounds $I_l(t,\tau)$ and $I^u(t,\tau)$. These are given by

(22) $$I_l(t,\tau) = [e_l/e(t)]^{12/\tau}[1+i^*(t,\tau)] - 1$$

(23) $$I^u(t,\tau) = [e^u/e(t)]^{12/\tau}[1+i^*(t,\tau)] - 1$$

For each positive term the limits of the rate of return band depend on the current exchange rate negatively and on the foreign interest rate positively. The stronger the currency inside its band the higher the maximum return on foreign investment. The bounds approach each other as the term τ increases. It disappears when τ grows indefinitely.

Note that for a maturity of 12 months the distance between the upper and lower bounds is approximatively equal to the width of the band measured in terms of percentages. For short maturities and weak currency, the lower limit $I_l[e_l/e(t)|e(t) \rightarrow e^u]$ is likely to go below zero.

Under free capital mobility and perfect substitution between domestic and foreign assets, the domestic interest rate $i(t,\tau)$ must lie inside the the rate of return band for each positive maturity. If this were not the case, investors would face a riskless arbitrage opportunity. For instance, if the domestic interest rate $i(t,\tau) > I^u(t,\tau)$, it would be profitable to borrow from abroad and invest at home with no risk of making a capital loss. Arbitrage of this kind would quickly lead to appreciation of the currency, which would raise the bounds upwards, and later, perhaps, to an increase in the money supply, which would put a downward pressure on domestic interest rates. If $i(t,\tau) < I_l(t,\tau)$, the riskless arbitrage would go in the opposite direction.

In the case of a credible band the domestic interest rate should never go beyond the range $[I_l, I^u]$. Therefore, if such a deviation is observed, it must be a reflection of the fact that some of the underlying assumptions are not fulfilled. If exchange restrictions are not binding for a marginal investor, then the observed deviations indicate that the band is not credible.

4 EMPIRICAL ANALYSES

4.1 The data

In this section we present some empirical results based on the theoretical predictions of the currency band models. In particular, we are interested in seeing whether the Finnish data is consistent with the negative relationship between the interest rate differential and the exhange rate and whether the slope of this relationship declines when the term to maturity increases. Oher points of interest are the perceived devaluation risk and, related to it, the credibility of the band.

The daily data used in the regression analysis is depicted in Figure 2 and was commented already in Section 2.4. As noted there, the negative correlation between the interest rate differentials and the exchange rate is evident for most of the period between mid-1987 and autumn 1989. In our regressions we decided to concentrate on the period from October 1, 1987, to March 9, 1989. The widening of the band in November 1988 is hence included, but the surprise alignment of the band in March 16, 1989 is excluded from the sample. In order to check the robustness of the results for the different sample frequency, the regressions were run also with weekly data.

The data set used in our tests of the credibility of the currency band for the three-month term covers the past four years, except for a three-month term, which starts from the beginning of 1984. The credibility test was done also for a 5-year maturity, although in this case the data is deficient. The average of the foreign 5-year interest covers only two-thirds of the currencies included in the official basket, and the data is available from the beginning of 1988 onwards.

Table 1 gives the summary statistics for the daily observations on the interest rate differentials on the interest rate differentials and the exchange rate. The upper panel shows that for the period October 1, 1988 to March 9, 1989, the mean interest rate differential for the one-month maturity is 1.8 per cent and that it increases monotonically in term and is 2.1 per cent for twelve-month maturity. Both the standard deviation and the range of fluctuation of the interest rate differential increases in term. This is in conflict with the predictions of the theory. In this respect, the Finnish data differs from from that of Sweden (cf. Svensson 1990a). The exchange rate has fluctuated near the strong edge of the band, the mean being 1.6 percent below the mid-point of the official band.

Table 1 **Summary statistics**
(daily data)

Variable	Mean	Std.dev.	Min	Max
October 1, 1987, to March 9, 1989				
e(t)	-1.58	0.59	-2.85	-0.15
r(t,1)	1.78	0.48	0.44	2.73
r(t,3)	1.85	0.50	0.77	2.96
r(t,6)	1.93	0.55	0.69	3.20
r(t,12)	2.13	0.58	0.95	3.42
March 26, 1989, to June 29, 1990				
e(t)	-1.97	0.41	-2.53	-1.09
r(t,1)	3.10	1.36	0.75	6.98
r(t,3)	3.16	1.17	1.28	5.36
r(t,6)	3.14	0.93	1.50	4.85
r(t,12)	3.14	0.72	1.91	4.47

Explanations: The exchange rate e(t) is defined as the percentage deviation of the currency index from the mid-point of the official band. The interest rate differential $r(t,\tau)$ for term τ is measured as the difference between the domestic rate and the basket-weighted average of foreign interest rates.

The lower panel of Table 1 shows the similar statistics for the period from March 26, 1989, through June 1990. Because of the currency unrest and the bank strike, the means of the interest rate differential are high, above 3 per cent for all maturities. Both the standard deviation and the range of fluctuation are now declining with the maturity, which is in accordance with the theory.

Table 2 shows that the correlation between the interest rate differential and the exchange rate is negative and increases with the maturity. In the first sub-period, the correlation coefficients are comparativcely high, except for the one-month term. The correlations are negative also for the post-realignment period, although their magnitude is very small.

Table 2 **Correlation coefficients**
(daily data)

Variable	e(t)	r(t,1)	r(t,2)	r(t,6)	r(t,12)
October 1, 1987, to March 9, 1989					
e(t)	1.00				
r(t,1)	-0.26	1.00			
r(t,3)	-0.57	0.89	1.00		
r(t,6)	-0.65	0.79	0.97	1.00	
r(t,12)	-0.70	0.70	0.92	0.98	1.00
March 26, 1989, to June 29, 1990					
e(t)	1.00				
r(t,1)	-0.05	1.00			
r(t,3)	-0.12	0.98	1.00		
r(t,6)	-0.15	0.93	0.98	1.00	
r(t,12)	-0.19	0.85	0.92	0.97	1.00

For explanations, see Table 1.

4.2 The term structure of interest rate differentials

Following Svensson (1990a), we regressed the interest rate differential for four different maturities on the constant term and the exchange rate (measured as a percentage deviation from the middle point). The error term was assumed to be uncorrelated with the exchange rate, which is, of course, a critical assumption.

The equations were estimated with and without the dummy, which takes the value zero for the period before the widening of the band on November 30, 1988, and is one thereafter. Except for the dummy, the specification is thus exactly the same linear approximation of the theoretical model as Svensson used in his study with the Swedish data. The hypothesis is that the relationship is downward sloping and the slope declines as the term to maturity increases, cf. Figure 4.

Because it is the large swings, and not the day-to-day or week-to-week, fluctuations which appear to account for a large part of the covariation between the interest rate differential and the exchange rate, strong serial correlation is to be expected. Therefore, in calculating the standard errors, we have applied the Hansen-White techniques (available in RATS) in order to allow for both serial correlation and heteroscedasticity in the error terms. Estimators themselves coincide with the OLS estimators.[5] The results did not appear to be sensitive to the number of lags chosen in the Hansen-White estimation.

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5 A problem associated with this procedure is that the parameter estimators may have non-normal limiting distributions, in which case the t-test for significance is not exactly valid. This would be true if the interest rate differentials and the exchange rate have unit-roots and are not co-integrated.

Table 3 **Regressions of interest rate differentials on the exchange rate**
(daily data)

Dependent variable	Constant	Coefficient	Dummy	R^2	DW
	(1)	(2)	(3)	(4)	(5)
r(t,1)	1.64	-0.09		0.02	0.07
	(6.3)	(-2.1)			
	1.31	-0.37	-0.59	0.12	0.09
	(6.6)	(-2.4)	(-1.2)		
r(t,3)	1.19	-0.41		0.23	0.06
	(5.2)	(-2.4)			
	0.95	-0.62	-0.43	0.29	0.08
	(4.6)	(-3.9)	(-1.0)		
r(t,6)	1.06	-0.55		0.34	0.06
	(4.8)	(-3.3)			
	0.87	-0.70	-0.32	0.37	0.07
	(3.6)	(-3.7)	(-0.7)		
r(t,12)	1.13	-0.63		0.41	0.05
	(5.9)	(-4.2)			
	1.05	-0.70	-0.14	0.42	0.06
	(4.3)	(-3.3)	(-0.3)		

Explanations: Data is daily. The period of estimation is from October 1, 1987, to March 9, 1989. The dummy takes the value zero for the period up to November, 30, 1988, and is one thereafter. Hansen-White techniques has been used in estimation in order to correct for heteroscedasticity and serial correlation (15 lags). Corrected t-statistics are given in the parenthesis.

Table 4 **Regressions of interest rate differentials on the exchange rate**
(weekly data)

Dependent variable	Constant	Coefficient	Dummy	R^2	DW
	(1)	(2)	(3)	(4)	(5)
r(1)	1.67	-0.06		0.01	0.41
	(6.3)	(-0.3)			
	1.33	-0.34	-0.59	0.11	0.55
	(7.0)	(-2.3)	(-1.2)		
r(3)	1.21	-0.39		0.21	0.33
	(5.2)	(-2.2)			
	0.97	-0.59	-0.44	0.27	0.43
	(4.6)	(-3.7)	(-1.0)		
r(6)	1.08	-0.53		0.31	0.31
	(4.7)	(-3.0)			
	0.88	-0.70	-0.35	0.34	0.39
	(3.5)	(-3.5)	(-0.7)		
r(12)	1.17	-0.60		0.40	0.27
	(7.9)	(-7.0)			
	1.08	-0.68	-0.16	0.40	0.31
	(4.4)	(-3.2)	(-0.4)		

Explanations: Weekly data are taken from Wednesdays. For other explanations, see Table 3.

Table 3 presents the results with the daily data, and Table 4 with the weekly data. Except for the Durbin-Watson statistics, the two data sets give almost identical results. The R^2 varies between 0.2 and 0.5 for three to twelve-month terms, and is rather low for one-month term. As expected, the Durbin-Watson statistics is extremely low in all equations with the daily data. Weekly data shows less serial correlation, the DW-statistics being in the range of 0.3 to 0.6. Strong serial correlation was evident also in Svensson's estimations with the monthly Swedish data, the DW statistics varying between 0.5 and 0.9.

From column (1) of either of the tables it is seen that the constant terms are positive and highly significant. The estimations without the dummy yield a constant term of 1.6 for one-month term, while for longer terms it is in the range of 1.1 to 1.2. Column (2) shows the coefficients for the exchange rate, which are negative and significantly different from zero. The absolute value of the coefficient is however increasing with the maturity, which is in conflict with the predictions of the theory.

Introducing the dummy for the period of the wider official band does not alter the results dramatically. The dummy itself obtains a negative value for all maturities but is statistically insignificant. The constant terms are smaller, and the slopes of the regression lines are steeper, but their ordering remains unchanged. Although the negative slope of the relationship between the interest rate differential and the exchange rate appears evident for all terms to maturity, except for the one-month term, the absolute values of the slope coefficients are increasing in the term. This is in conflict with the theory. It is also contrary to the evidence with the Swedish data, covering approximately the same period.

The serial correlation of residuals indicates that, in addition to the exchange rate, there are other important factors influencing the interest rate differentials. The remaining exchange controls may have had an effect, not only on transactions costs, but also on the maturity preferences of domestic firms and institutions, as well as of foreign investors. The risk premium may itself have

been serially correlated, and the perceived devaluation risk may have been dependent on the exchange rate. In the latter case, of course, the assumption that the error term is uncorrelated with the exchange rate would not hold.

We have no obvious explanation for the fact that the slopes of the regression lines are in conflict with the predictions of the theory. For instance, during the period of estimation short-term borrowing from abroad by domestic firms was still restricted, and the direct access of non-residents to the domestic money and bond markets was not possible. On the other hand, non-residents could operate freely on the forward exchange market, and big domestic exporting companies had ample room for arbitrage and speculation in all maturities. Therefore, it remains an open question of whether or not the remaining exchange controls were binding for marginal investors.

Given that relatively free capital movements and properly functioning domestic money markets were new phenomena in Finland still in 1987, it is possible that the learning process has been slow. The reactions to news and to the central bank's actions and announcements may have changed. It is, therefore, possible that neither the exchange risk premium nor the perceived devaluation risk have not remained constant, which may explain much of the serial correlation and, perhaps, to some extent also the slopes of the regression lines.

4.3 The perceived devaluation risk

According to the theoretical model, the constant term is the interest differential that would prevail at the mid-point of the band, assuming that there is no drift in the fundamentals and no interventions when the exchange rate is inside the band. In the absence of the devaluation risk and the drift, the constant term should be zero, indicating equal probability of appreciation and depreciation inside the band.

The fact that the constant terms in the estimated equations are positive suggests that the average perceived devaluation risk in the period before the widening of the band was about one per cent.

The devaluation risk of this size is consistent with a number of combinations of the probability per year, on the one hand, and the size of the expected devaluation, on the other hand. It is equally consistent, for instance, with a 10 per cent probability per year of a 10 per cent upward realignment of the band than with a 50 per cent probability per year of a 2 per cent discrete devaluation within the band. Thus, if a discrete adjustment inside the band is regarded as possible, a positive constant term does not necessarily imply that the band itself would be incredible.

The negative value of the dummy would imply that the perceived devaluation risk did decline in November 1988, as the band was widened from ± 2¼ to ± 3 per cent. The evidence for this conclusion is not strong, however, owing to the statistical insignificance of the dummies.

In Section 2 we paid attention to the fact that the exchange rate has fluctuated inside the strong half of the official band and that the general tendency for most of the pre-1989 period was towards appreciation of the currency. Since March 1989, there has been no trend in the exchange rate, although the fluctuations have remained in the strong half of the band. This is consistent with the interpretation, supported by casual evidence, that before 1989 there was a negative drift in the fundamentals calling for a currency appreciation (cf. Figure 4 where k(t) drifts to the left). If this was the case, then the constant term in our equations is the sum the devaluation risk and the drift effect. If the latter term is negative, the perceived devaluation risk is higher than what was indicated above.

The data is also consistent with the interpretation that the central bank has attempted to exercise its limited autonomy by defending a narrow inofficial band in the strong half of the wider official band. The strong currency policy of this kind implies higher interest rate differentials compared to hands-out policy of

no interventions inside the official band. Higher interest rates result from the possibility of an upward realignment of the narrow inofficial band.

Assume, for instance, that the narrow band in the period of estimation was 1 to 2 per cent below the mid-point of the official band. The mid-point of the narrow band would then have been -1.5. If the narrow band would have been fully credible, the regression line should have intercepted the zero interest rate differential line at that level of the exchange rate. On the basis of the regression line for three-month maturity, for example, the interest rate differential in the middle point of the narrow band was 1.9 before November 1988, and 1.5 thereafter. Assuming that participants in the market had learned the limits of the narrow band, this would imply a 1.9 per cent devaluation risk, which is consistent, for instance, with an average expectation of a 4 percent upward jump in the exchange rate with an almost 50 per cent probability per year.

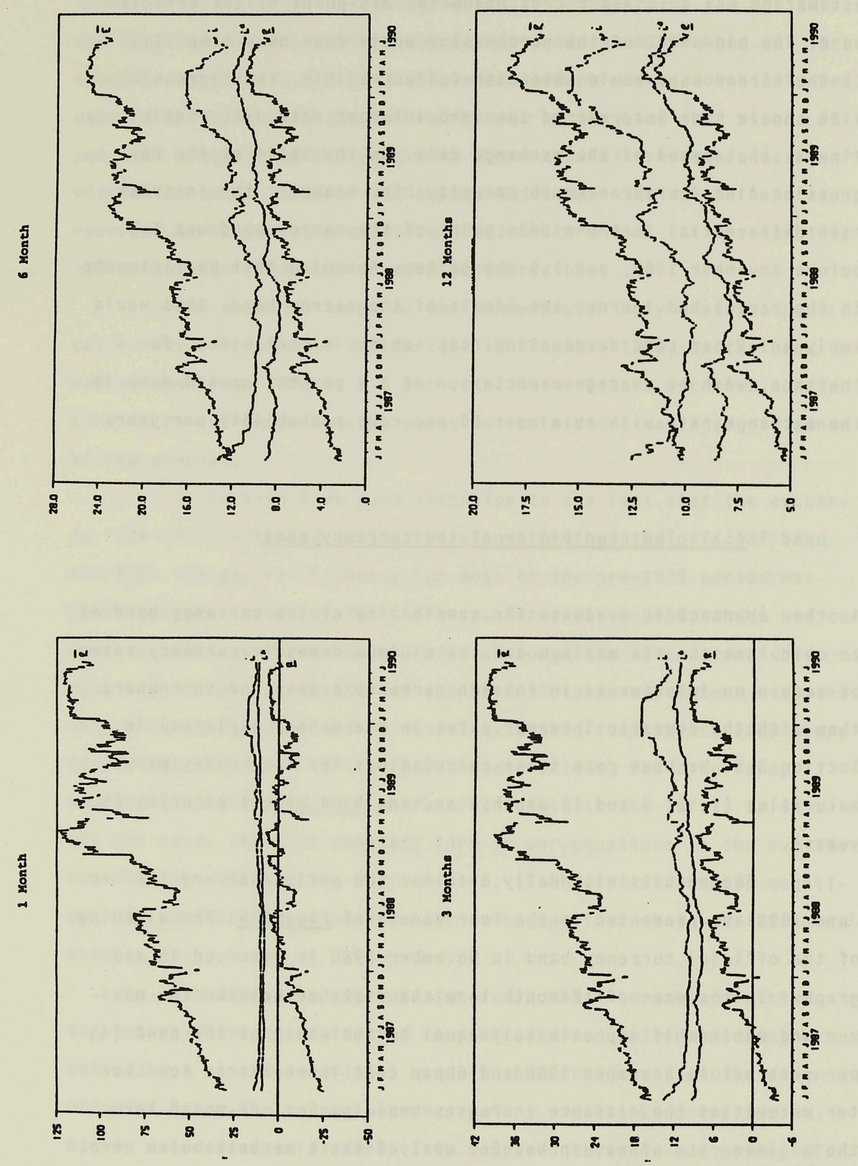
4.3 The credibility of the currency band

Another approach to evaluate the credibility of the currency band is to calculate the the maximum and the minimum domestic-currency rates of return on investments in foreign currency assets and to compare them with the domestic interest rates in the manner explained in Section 3.5. We have done these calculations for four money market maturities (1, 3, 6 and 12 months) and one bond market maturity (5 years).

The results with daily data for the period January 1987 to June 1990 are presented in the four panels of Figure 5. The widening of the official currency band in November 1988 is observed in all graphs. In the case of 12-month term the distance between the maximum and minimum is approximately equal to the width of the band (4½ per cent before November 1988 and 6 per cent thereafter). For shorter maturities the distance increases rapidly. For one-month term the minimum rate of return has for most of the time been below zero.

Figure 5 **Currency Band Credibility**

(money market interest rates)



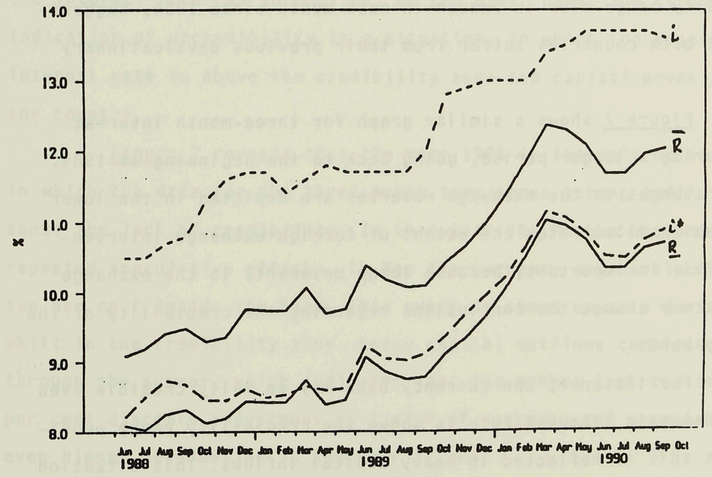
Explanations: The area between I_l and I^u is the credibility zone for the exchange rate. The domestic interest rate i is denoted by i and the foreign rate by i*. The currency band is credible over the horizon indicated by the term if the domestic interest rate is inside the credibility zone.

What interests us is the position of the domestic interest rate in relation to the maximum and minimum rates of returns on foreign currency investment. In all four cases the domestic interest rate has remained within the these limits. This implies that throughout the past four years the band has been regarded as credible. This was true also for the twelve-month term in November 1989, at the height of an speculative attack.

Figure 6 presents the results of similar calculations for the 5-year interest rate. Because of data availability the period is now shorter. Data is monthly and covers the period from January 1988 to September 1990. It is seen that the distance between the minimum and maximum rates of return on foreign investment is relatively small, 1 to 1.5 percentage points. The domestic interest rate is constantly above the range of the rate of return that corresponds to

Figure 6 **Currency band credibility**

(5 year bond rates)



For explanations, see Figure 5.

a credible band by about 1.5 to 2 percentage points. Thus, the perceived risk of devaluation seems to have been comparatively large in a five-year horizon.

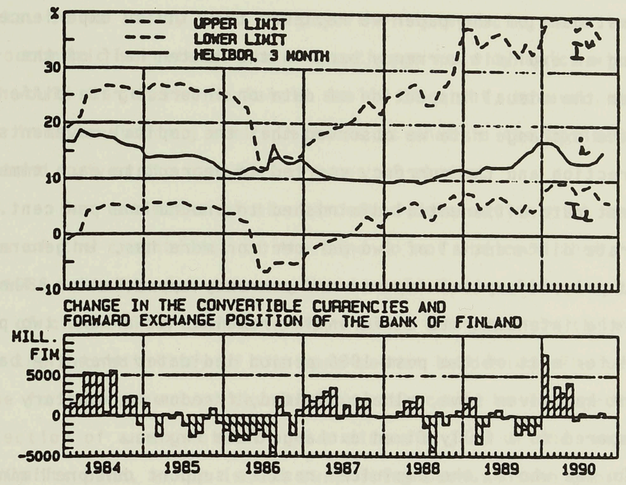
This conclusion should be qualified on two grounds. First, the foreign interest rate used in the calculations does not include all the currencies included in the official basket. With a more complete basket, the limits would probably have been somewhat higher. Secondly, it is a well known fact that the Finnish bond market is undeveloped and illiquid. In addition, the access of foreigners to the bond market was highly restricted until February 1990. It is, therefore, likely that the investors in Markka-denominated bonds demand a liquidity premium on their investment to compensate for poor liquidity. It is, however, most unlikely that these qualifications are sufficient to refute the general conclusion that the Finnish currency band has not been regarded by the market as fully credible in a medium-term horizon.

Our results are very similar to those of Svensson (1990b) with the Swedish data. Also in Sweden the short term interest rates remained in the credibility range, except for the twelve month rate in the time of the currency unrest in early 1990. The long-term interest rate has, as in Finland, been above the corresponding credibility range also in Sweden in each month since 1986, suggesting that both countries suffer from their previous devaluationary history.

Figure 7 shows a similar graph for three-month interest rates during a longer period, going back to the beginning of 1984. Monthly changes in the exchange reserves are depicted in the lower panel, which illustrates the extent of foreign exchange interventions. This is important, because large movements in the exchange reserves may change the conclusions regarding the credibility of the currency band.

For instance, the currency band may be fully credible even if the domestic interest rate is above the credibility range provided that this is reflected in heavy capital inflows. This situation can hardly last for long, because sooner or later the currency has

Figure 7 **Currency band credibility and reserve flows**



to appreciate, raising the credibility range upwards, or the domestic interest rate has to decline. On the other hand, the strongest indication of uncredibility is a situation, in which the domestic interest rate is above the credibility zone and capital moves out of the country.

Figure 7 reveals that the year 1986 is the only occasion, in which the data for the three-month term shows strong indications about the lack of credibility. In that year the Markka was under repeated speculative attacks. In May the currency was devalued by two per cent inside the band. This event is shown up as a downward shift in the credibility zone. Heavy capital outflows continued through the summer, which indicates that the market took the two per cent discrete adjustment as a sign of weakness and expected even bigger devaluation in the near future.

6 CONCLUDING REMARKS

In the first part of the paper we reviewed the Finnish experience of maintaining an explicit currency band in the latter half of the 1980s. From the visual inspection of data on interest rate differential and the exchange rate we observed that the capital movements turned direction and the currency started to depreciate each time as the interest rate differential diminished to around one per cent. An interest rate differential of two per cent or more has, in general, led toward private capital imports and currency appreciation. The fact that the interest rate differential remained at around two per cent level for most of the post-1986 period indicates that the band arrangement has given some, albeit limited, freedom to monetary policy compared to a fully fixed exchange rate regime.

On the whole, the empirical results support our preliminary assessment. The relationship between the interest rate differentials and the exchange rate exhibits negative slope in the period from mid-1987 to early 1989. This relationship was disturbed by the unrest in the foreign exchange market in autumn 1989. The currency unrest was a direct response to a series of negative "news" on macroeconomic imbalances linked with uncertainty on future economic policy. In terms of our model, what happened was that the perceived devaluation risk rose and the whole relationship between the interest rate differentials and the exchange rate shifted upwards.

This observation raises the question of whether the perceived realignment risk itself is a variable that may change in response to the development of the fundamentals. If this is the case the theoretical model underlying our empirical estimations has to be developed, which is an interesting topic for further research.

The treatment of the fundamentals in the theoretical model of Section 3 is extremely simple. It has, however, important pedagocial advantages, because more complicated and more realistic sto-

chastic specifications are hardly managable analytically. We have referred to some fundamentals, such as the terms-of-trade shocks, which are apparently of great importance for resource-dependent economies, such as Finland. It would, therefore, be interesting to expand the empirical analysis in order to acount for terms-of-trade shocks. It is likely that the payoff of integrating more involved macroeconomic structures and the exchange rate dynamics within the band would in general be fairly small. It might, however, be important in understanding such questions as what is the optimal width of the band, given the particular types of shocks.

Our estimates of the perceived devaluation risk and our tests of the credibility of the band do not indicate that, except for 1986, the Finnish currency band would have suffered from severe lack of credibility over a horizon up to one year. In the medium term the uncredibility of the band cannot be denied. The positive value for the perceived devaluation risk could be interpreted as a reflection of an expectation of a discrete jump of the exchange rate within its band, which is not surprising because such jumps have occured in the past. It might be interesting to analyze theoretically the extent of limited monetary policy autonomy in terms of discrete realignments in inofficial targets for the exchange rate inside a wider official band. This is yet another topic for further research.

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