# The Law of One Price in Scandinavian Duty-Free Stores

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Many empirical studies have rejected the law of one price. That prices of a good differ across locations has been explained by differences in product attributes and costs of local inputs, transport costs, trade barriers, and that buyers have imperfect information about prices in different locations; see Penelopi K. Goldberg and Michael M. Knetter (1997) for a survey. We examine the law of one price in situations where none of the mentioned reasons for its failure can be invoked. It has also been suggested that deviations from the law of one price are a consequence of rigid nominal prices and that different countries typically have different currencies. We explore if this can contribute to our understanding of deviations from the law of one price.

Our data is taken from three Scandinavian duty-free outlets where each product (at the same location) has price tags in at least two currencies. Hence, a consumer has the option to choose between several prices for the same identical good. In such a setting there is a strong prior that the law of one price (LOP henceforward) holds well. However, the potential for arbitrage will arise since nominal prices are not continuously adjusted while exchange rates fluctuate daily.

Based on standard tests, we reject LOP at all duty-free outlets. Given that LOP does not hold here, it is less surprising that many previous studies have found that prices of *similar* products at *different* locations differ significantly. Nevertheless, the main conclusion of the paper is that in this "natural experiment", LOP remains a useful guide to the behavior of relative prices. As deviations become large, nominal prices are adjusted to reduce the deviation from LOP, thereby limiting arbitrage opportunities. The patterns at the duty-free outlets suggest that there is a band of inaction so that "small" deviations from LOP may persist (for almost a decade in one case), but that large deviations quickly lead firms to adjust relative prices. The findings are consistent with costly arbitrage and fixed costs of adjusting nominal prices.

## I. Price setting in duty-free outlets - some considerations

To introduce the issues involved we begin with a brief discussion of the factors underlying decisions by the duty-free outlets to adjust prices. We use Birka Line, with ferry operations between Sweden and Finland, as our example. Birka Line sells an array of products imported from different countries and until 1992 prices each product in its catalogue in both Swedish kronor (SEK) and Finnish markka (FIM). The prices on the shelves in the duty-free store are the same as those in the catalogue. Printing a new catalogue involves at least some fixed cost and therefore nominal prices will not change continuously. The decision to print a new catalogue can be either time or state dependent. With a time dependent rule, prices are renewed at a given frequency, whereas with a state dependent rule new prices are posted when cost or demand conditions have changed sufficiently to motivate taking the cost of adjusting price; see John B. Taylor (1999) for a discussion. For Birka Line the costs are affected by exchange rates vis-à-vis producing countries and demand is affected by on shore excise taxes. Inflation influences both demand and costs.

Focus now on the problem of setting each product's price in two currencies. Given that products are available at the same location and time, and that Birka Line wishes to minimize arbitrage opportunities, one would expect LOP to hold when a new catalogue is printed.[1] Thus, the relative price should be adjusted to restore LOP once the SEK/FIM exchange rate has moved sufficiently upward or downward. This begs the question of *why* the firm offers consumers the option to choose between two rigid nominal prices. There are two rationales. The first is that dual prices are a service to consumers who value a simple comparison of the duty-free price in their own currency with prices at home. If this is the sole motive for dual currency pricing, we expect LOP to hold after prices are adjusted. The second reason is price discrimination. Demand for duty-free items is likely to differ because of differences in income, tastes and onshore prices in the two countries. Under price discrimination, new relative prices will again be set once the movement in the SEK/FIM exchange rate has been sufficiently large, but LOP will not hold after adjustment.

Both these rationales for dual pricing require that not all consumers engage in arbitrage. There are two potential arbitrage costs - with different implications for price setting. Firstly, individual consumers will typically have costs of exchanging currency. The relevance of this will differ across consumers: some will carry both currencies, some will exchange on board the ferry and others will use credit cards in which case the practices of the issuing bank determine the transaction cost. We will return to a more thorough discussion of these costs; for now note that there is no fixed charge associated with exchanging currency on the boats or when using a credit card. Also, the consumer gets the same exchange rate regardless of

whether she exchanges SEK 6 or SEK 600. The equalizing pressure of arbitrage is therefore independent of the price level of the good if this is the only cost of arbitrage. Secondly, there may be costs associated with finding out the current exchange rate and making the price comparison. It is no more difficult to compare SEK 600 to FIM 400 than it is to compare SEK 6 to FIM 4, and since the potential gains are greater the more expensive the good is, we expect lower percentage deviations from LOP on big-ticket items. Irrespective of the source of arbitrage costs we conjecture that the greater the deviation from LOP, the larger the share of customers who pay the lower price.

## II Deviations from LOP and the decision to adjust prices

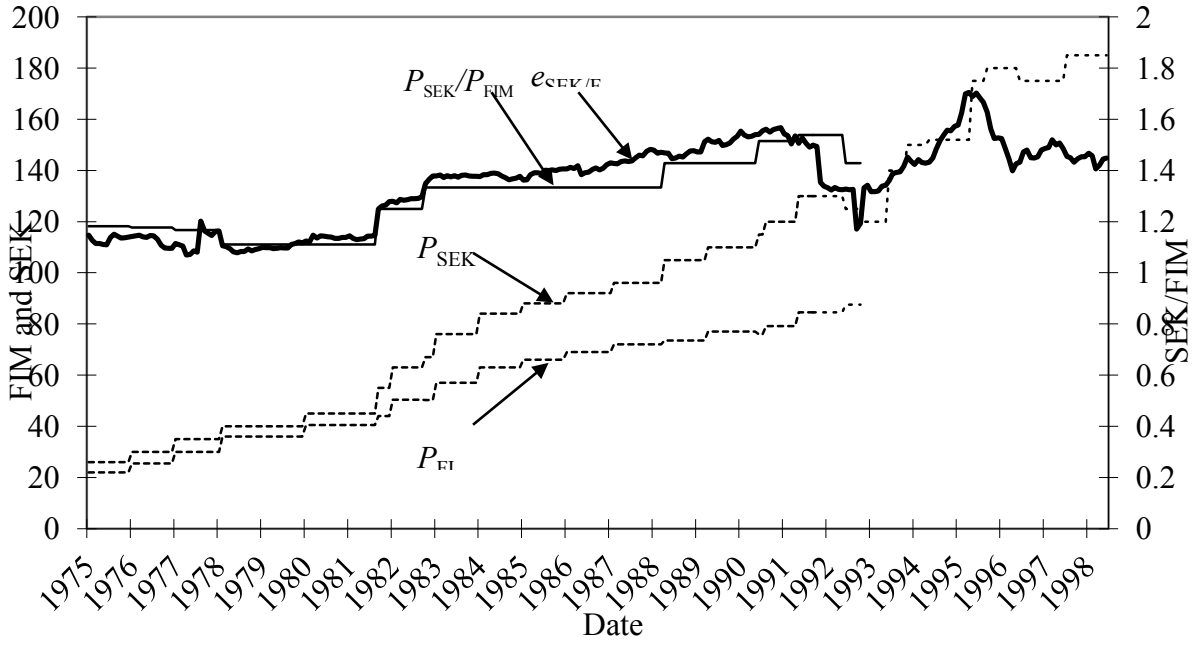
Let $P_X^i$ denote the nominal price of product *i* in currency *X*, and $P_X^i / P_Y^i$ its relative price in currencies *X* and *Y*. Further, let $e_{X/Y}$ be the nominal exchange rate, the currency *X* price of currency *Y*. Throughout, we employ end-of-month exchange rates from International Financial Statistics (IFS); in section III we discuss how these relate to the exchange rates that face customers. If LOP holds for product *i* then $P_X^i = e_{X/Y} P_Y^i$, consequently the percentage deviation from LOP, denoted *DLOP*, is

$$DLOP_{X/Y}^i = 100(e_{X/Y} P_Y^i - P_X^i) / P_X^i \quad (1)$$

We focus our analysis on Birka Line, where our data cover more than two decades (1975-1998). After that we briefly discuss price setting at the ferry operator Viking Line (1991-1997) and the airline SAS (1995-1998).[2] All three duty-free outlets issue catalogues with prices in several currencies. The prices of 18 products are used - primarily well known international brands such as Marlboro cigarettes, Smirnoff vodka, and Chanel No. 5 perfume (see Appendix A for a full list of products). The revenues from duty-free sales are very significant for the ferry lines (some 50 percent of total revenue for Viking Line) and many passengers use the ferries primarily to purchase products that are heavily taxed in the two countries.

### A. *Birka Line*

The first important observation is that Birka Line uses the same relative price for every product in a given catalogue (save for tick-size effects of 1-2 percent on products with low nominal prices). Hence, the persistence and magnitude of the deviation from LOP is independent of product characteristics. Figure 1 shows the nominal prices of Marlboro cigarettes in SEK and FIM, the relative price ($P_{SEK}/P_{FIM}$), and the exchange rate. If LOP holds, the relative price equals the exchange rate. This is not what is observed in the figure, and deviations from LOP are often quite persistent. During 1975-1998 Birka Line issued 26 catalogues, of which the first 20 listed prices in both SEK and FIM, and the last 6 only in SEK. The timing of the catalogues can be inferred from the nominal price adjustments in Figure 1 (there is no instance of a new catalogue without new nominal prices). The pattern of price adjustment (e.g., the time between price adjustments and the size distribution of price adjustments) at Birka Line is well in line with what is typically found in micro-data studies of price rigidities (see Taylor, 1999).[3]




From Figure 1 it is clear that LOP is a useful way to think about the adjustment of relative prices since over time the relative price tracks the exchange rate. Furthermore, it is clear that the adjustment of the relative price can't be fully described by a time dependent rule, sometimes a relative price lasts long, sometimes it doesn't. Table 1 presents some descriptive statistics on the price adjustments on Birka Line. In columns 2-4 we examine the predictions outlined in Section I by comparing three types of months: no new catalogue (M=1), a new

catalogue but unchanged relative price (M=2), and finally months with a new catalogue and new relative price (M=3). The product we use is Smirnoff vodka, but the results are virtually identical for all other products.[4] To understand what preceded the decision to print a new catalogue (with or without new relative prices), we denote by $\Delta Z|M = x$ the percentage movement in variable Z since the last event M=x. We also construct a contrafactual deviation from LOP, denoted *CDLOP*, as the percentage deviation from LOP that would result in month t if nominal prices were held constant from month t-1.[5] Formally, we define *CDLOP* as

$$CDLOP^{i}_{X/Y}[t] = 100(e_{X/Y}[t]P^{i}_{Y}[t-1] - P^{i}_{X}[t-1]) / P^{i}_{X}[t-1]. \quad (2)$$

**Table 1.** Descriptive statistics for Birka Line.

| | Full sample. | Months when no new catalogue appeared, (M=1). | Months when new catalogue without new relative prices appeared, (M=2). | Months when new catalogue with new relative prices appeared,(M=3). |
|---|---|---|---|---|
| | Mean(Standard Deviation)<br>Min, Median, Max | Mean (Standard Deviation)<br>Min, Median, Max | Mean (Standard Deviation)<br>Min, Median, Max | Mean (Standard Deviation)<br>Min, Median, Max |
| *Percentage deviation from law of one price (DLOP)* | 1.01 (5.22)<br>-18.04, 2.36, 11.15 | 1.01 (5.35)<br>-18.04, 2.49, 11.15 | 2.37 (3.73)<br>-5.27, 3.06, 7.01 | -0.83 (3.10)<br>-7.08, -0.28, 2.77 |
| *Absolute value of percentage deviation from law of one price* (\|*DLOP*\|) | 4.29 (3.14)<br>0.00, 3.23, 18.04 | 4.39 (3.20)<br>0.00, 3.28, 18.04 | 3.87 (1.90)<br>1.16, 3.23, 7.01 | 2.22 (2.18)<br>0.08, 1.89, 7.08 |
| *Absolute value of percentage deviation from law of one price if prices are unchanged from the previous month* (\|*CDLOP*\|) | 4.50 (3.26)<br>0.00, 3.31, 18.04 | 4.39 (3.20)<br>0.00, 3.28, 18.04 | 3.87 (1.90)<br>1.16, 3.23, 7.01 | 8.36 (4.37)<br>0.59, 7.85, 13.72 |

| | | | | |
|---|---|---|---|---|
| *Absolute value of percentage change in SEK/FIM exchange rate since the last catalogue with new relative price was issued* (*$|\Delta e_{SEK/FIM}|$*M=3|). | 3.23 (2.84)<br>0.01, 2.61, 12.95 | 3.12 (2.73)<br>0.01, 2.60, 12.10 | 2.55 (1.55)<br>0.52, 2.23, 5.85 | 7.49 (4.09)<br>2.24, 7.92, 12.95 |
| *Absolute value of percentage change in SEK/USD exchange rate since the last catalogue was issued* (*$|\Delta e_{SEK/USD}|$*M=2 or M=3|) | 5.71 (5.27)<br>0.03, 4.60, 34.31 | 5.24 (4.53)<br>0.03, 4.16, 25.45 | 7.95 (5.28)<br>0.24, 9.30, 16.90 | 15.25 (12.23)<br>5.17, 9.41, 34.31 |
| *Absolute value of percentage change in FIM/USD exchange rate since the last catalogue was issued* (*$|\Delta e_{SEK/USD}|$*M=2 or M=3|) | 5.88 (4.91)<br>0.10, 4.88, 24.83 | 5.51 (4.53)<br>0.10, 4.62, 23.35 | 8.34 (6.05)<br>0.26, 9.87, 19.44 | 12.20 (8.19)<br>1.17, 11.34, 24.83 |
| *Percentage change in Swedish CPI since last catalogue* (*$\Delta CPI$*|M=2 or M=3) | 4.39 (4.17)<br>0.00, 3.23, 19.57 | 4.06 (3.92)<br>0.00, 2.94, 19.57 | 7.23 (4.50)<br>2.02, 7.14, 17.95 | 9.37 (6.02)<br>1.83, 7.92, 19.57 |

| | | | | |
|---|---|---|---|---|
| *Percentage change in Finnish CPI since last catalogue (ΔCPI* \|M=2 or M=3) | 4.88 (4.53)<br>-0.50, 3.40, 22.09 | 4.63 (4.32)<br>-0.50, 3.24, 20.45 | 7.33 (5.49)<br>0.00, 6.40, 17.24 | 8.19 (6.72)<br>2.59, 5.37, 22.09 |
| Number of observations | 214 | 195 | 11 | 8 |

*Deviation from LOP:* For the full sample (214 observations), the average *DLOP* is 1.01 with a standard deviation of 5.22 such that a two-tailed t-test rejects the null hypothesis of zero deviation (t=2.83, which is significant at the 1 percent level). An average deviation from LOP of one percent can not, however, be taken as evidence of systematic price discrimination over the entire period, in particular since the period contains both large negative and positive deviations from LOP. The average absolute value deviation, |*DLOP*|, is 4.29, which suggests that in most months there are considerable violations of LOP. At this stage, it would be easy to conclude that the fixed costs of printing new catalogues and adjusting nominal prices are alone responsible for the deviations from LOP. This, however, is not the complete story as, for example, five new catalogues were printed between 1982 and 1988, each time conserving the relative price.

Although LOP is statistically rejected it remains a useful guiding principle for understanding the development of the relative price: Birka Line adjusts its relative price when the deviation from LOP becomes too large. This is evidenced in the last three columns in Table 1. Conditioning on the type of month, we find that when relative prices are adjusted the average |*DLOP*| is 2.22 - lower than the other columns. The average |*DLOP*| the month prior to an adjustment of the relative price is 7.21 (not shown in Table 1). The averages of |*CDLOP*| give further indication of Birka Line's desire to reduce deviations from LOP. In particular, had it not adjusted relative prices when it did, the deviation would have been 8.36. In contrast when new catalogues were issued in which the relative price was unchanged the average |*CDLOP*| was only 3.87.

It is common in the literature (see, e.g., Kenneth Rogoff, 1996) to test for a unit root in deviations from LOP (or purchasing power parity, PPP).[6] The presence of a unit root, such that the relative price follows a random walk, would suggest that there is no equalizing pressure from arbitrage. The simplest test, in our setting, amounts to an AR(1) specification with the deviation, $q$, defined as $\ln(e_{SEK/FIM}) - \ln(P_{SEK}) + \ln(P_{FIM})$. While keeping in mind all the potential problems in tests for unit roots, the simple AR(1) regression on our data will allow a comparison with studies that employ aggregate data. We thus estimate

$$q_t = \alpha + \beta q_{t-1} + \varepsilon_t, \tag{3}$$

where $\alpha$=0 and $\beta$<1 if LOP is exerting an influence on the relative price. Based on 214 monthly observations, the least squares estimates are $\alpha$=-0.000570 (0.00124) and $\beta$=0.971 (0.0236), with standard errors in parentheses (D-W=2.14 and adj.$R^2$=0.88). With a test statistic of -1.43, against a critical Dickey-Fuller value of -2.57 at the 10 percent level, it cannot be rejected that deviations from LOP follow a random walk.

Given that the estimated $\beta$ is less than unity, it is interesting to calculate the implied half-life of a deviation from LOP ($n$ months defined by $\beta^n = 0.5$). The half-life is 24 months, compared to the 3-5 years commonly found in studies that employ aggregate data (for references, see Rogoff, 1996).[7] A half-life of two years remains long, but can be related to Maurice Obstfeld and Alan M. Taylor's (1997) explanation of the apparently weak equalizing pressure from arbitrage. Their argument is that arbitrage only occurs when deviations from LOP are sufficiently large, and, consequently, there is a 'band of inaction' where small deviations can persist. In terms of the results from the AR(1) model above, there are many periods where deviations are too small to induce arbitrage, which explains the long half-life, but when deviations occasionally move outside the band of inaction the adjustment is rapid. At Birka Line, LOP almost never holds exactly and there are only eight, out of 214, months when the firm acts to reduce deviations. To put it another way, Birka Line keeps the relative price constant for an average of 28 months (the duration differs between one and 64 months). Corresponding to this are long periods when the deviation stays either positive or negative, on average 24 months but lasting up to 112 months between October 1981 and February 1991. However, when deviations become too large the firm adjusts relative prices.

*SEK/FIM*: The most important explanation of why relative prices are not adjusted in each new catalogue can be seen by comparing $|\Delta e_{SEK/FIM}|M=3|$, i.e. the absolute value of the percentage movement in $e_{SEK/FIM}$ since the last catalogue with new relative prices, in columns M=2 and M=3. When a new catalogue with unchanged relative price appears (M=2), the drift in $e_{SEK/FIM}$ has been a moderate 2.5 percent, compared to the rather dramatic 7.5 percent when the relative prices are revised. Hence, small movements in the $e_{SEK/FIM}$ do not motivate any change in the relative price.

*Y/USD:* By comparing $|\Delta e_{Y/USD}|M=2 \text{ or } M=3|$ for Y=SEK,FIM in the last three columns we conclude that before a new catalogue is issued there have been large changes (between 8 and 15 percent) in the exchange rates against the US dollar (USD) (the results are similar for British pounds and French francs) since the last new catalogue. Since the products sold by Birka Line are typically imports, this is evidence of delayed pass-through

into consumer prices. (The very large means in column M=3 are partly due to devaluations that also triggered adjustments of relative prices.)

*Inflation:* Inflation ($\Delta CPI$) in Sweden and Finland makes the nominal prices outdated and induces the firm to print a new catalogue. Still, despite annual inflation averaging 8 percent in both countries over the period, the firm only issues 26 catalogues. Before a new catalogue (with or without new relative prices) is issued, inflation has eroded prices by an average of more than seven percent - evidence of substantial nominal rigidities.

*Taxes:* More than half of the catalogues are published in January, June and July. This may partly reflect a time dependent pattern in the appearance of new catalogues – but also the fact that new taxes on cigarettes and alcohol, two important product groups, are often effective from 1 January and 1 July.

B. *Viking Line*

The ferry operator Viking Line also sets prices in SEK and FIM and uses the same relative price for all goods. Again, there are infrequent price adjustments and therefore deviations from LOP - on average 1.82 (standard deviation 6.92 with 78 observations). A two-tailed t-test rejects LOP at the 5 percent level (t=2.31). The average $|DLOP|$ is 5.78 (standard deviation 4.29); when a new catalogue is issued it reduces the average $|DLOP|$ to 3.71 from 10.6 the month before. Relative prices are held constant for periods between nine and sixteen months. Some differences between Viking Line and Birka Line, such as larger deviations on the former and that Viking Line always adjusts relative prices when new catalogues are printed (except on one occasion when *DLOP* is small), may be attributed to the higher exchange rate variability during the period covered by the Viking Line data. Nevertheless, much of the pattern of relative price adjustment is the same as on Birka Line.

C. *SAS*

The airline SAS sets prices in USD as well as in the Scandinavian currencies (DKK: Denmark, NOK: Norway, and SEK). Pricing behavior on SAS differs in some respects from that of the ferry lines. The most important difference is that it does not use the same relative price for all products. Hence, deviations from LOP will differ across products. In Table 2 we summarize average *DLOP* for some products in different price ranges.

**Table 2.** Deviations from the Law of One Price at the SAS inflight shop.
The measure is average percentage deviation from LOP with standard deviation in parenthesis.[a]

| Product | Average USD price | SEK/DKK | SEK/NOK | SEK/USD |
|---|---|---|---|---|
| Marlboro | 23.7 | -7.8*** (7.1) | 1.3 (5.3) | 6.2*** (7.6) |
| Mont Blanc Ballpoint Pen | 138 | -0.4 (3.7) | 1.4 (5.1) | 6.2*** (7.4) |
| Eurosleeper | 551 | 1.1* (3.7) | 2.2*** (4.2) | 9.3*** (8.6) |
| Renault Carte Noir | 24.5 | -6.7*** (5.4) | -2.7*** (4.0) | 1.9* (6.3) |
| Absolut Airborn 2*20cl | 14.4 | -0.3 (3.3) | 4.7*** (4.5) | 13.2*** (7.3) |
| Arden, Visible Difference | 48.7 | -2.8*** (4.6) | -2.5*** (4.5) | 1.5 (7.5) |

***, **, and *, denote statistical significance at the 1, 5, and 10, percent level, respectively.

a) The number of observations vary with product and column: Marlboro, Eurosleeper, Renault Carte Noir and Arden Visible Difference: 39 observations in the second column, 39 in the third column and 32 in the last column. For Mont Blanc ballpoint pen the corresponding number of observations are 33, 33, and 32. For Absolut Airborn the number of observations are 29 in all the columns.

Clearly, in several cases the null hypothesis, that *DLOP=0*, is rejected. Prices are frequently adjusted, so that the rejection can not be ascribed to fixed nominal prices in the respective currencies. Take Marlboro cigarettes as an example. The average deviation from LOP in SEK and DKK is -7.8 percent (the average absolute deviation, |*DLOP*|, is 9.5). The nominal SEK and DKK prices were adjusted 8 and 7 times, respectively, which led to 11 adjustments of the relative price during the 39 months between January 1995 and March 1998. After the relative price was adjusted the average *DLOP* was -4.6 percent (with an average |*DLOP*| of 6.9). Since deviations were lower after adjustment than the average deviation, SAS like the other firms, acts to reduce large deviations from LOP.

One expects rules of thumb (such as "pay in your own currency") to become less important as amounts increase. When buying a Mont Blanc pen for USD 138, many travelers might find it worthwhile to consider the relative prices. On the other hand, a consumer buying a carton of Marlboro cigarettes for USD 22 may assume that the difference is too small to motivate the effort. There is some evidence of this. A comparison of the SEK price of the two

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most expensive items - the Eurosleeper (an upgrade to a reclining seat) and the Mont Blanc pen - with the DKK and NOK prices reveals average deviations of less than 2.5 percent. The cheaper products tend to have greater deviations.

It is worth noting that paying in USD is more expensive for all the products in Table 2. The average deviation from LOP over the period was almost 10 percent for the Eurosleeper. One could conjecture that customers paying in USD are less informed about the current exchange rates for Scandinavian currencies and that this implies less equalizing pressure on prices.

## III. Arbitrage

Following the tradition of previous work on deviations from LOP and purchasing power parity, we have measured deviations from LOP using a monthly financial exchange rate. Given that rates fluctuate daily, our measure may understate the arbitrage opportunities that arise within a month. However, except for months with currency devaluations, the variation within a month is quite modest. More important is that as soon as there are costs of arbitrage there will be a band of inaction within which the deviation from LOP can fluctuate before arbitrage becomes profitable. These transaction costs will differ across consumers: many will exchange currency at home in preparation for a trip abroad, some choose to exchange on board, while others are returning home and are holding foreign currency that they would like to spend. Further, if payment is by credit card, the issuing bank will typically use the exchange rate a couple of days hence. It proved impossible to acquire historical information about these transaction costs. Nevertheless, some indication of the potential importance can be gained by examining the current spreads. Figure 2 illustrates the deviations from LOP on Viking Line with the arbitrage costs implied by the spreads on the exchange rate from 10 November 1999, in the exchange booth on Viking Line and at the largest retail foreign exchange dealer in Stockholm, Forex. The rates for credit cards are similar to those at Forex.[8]

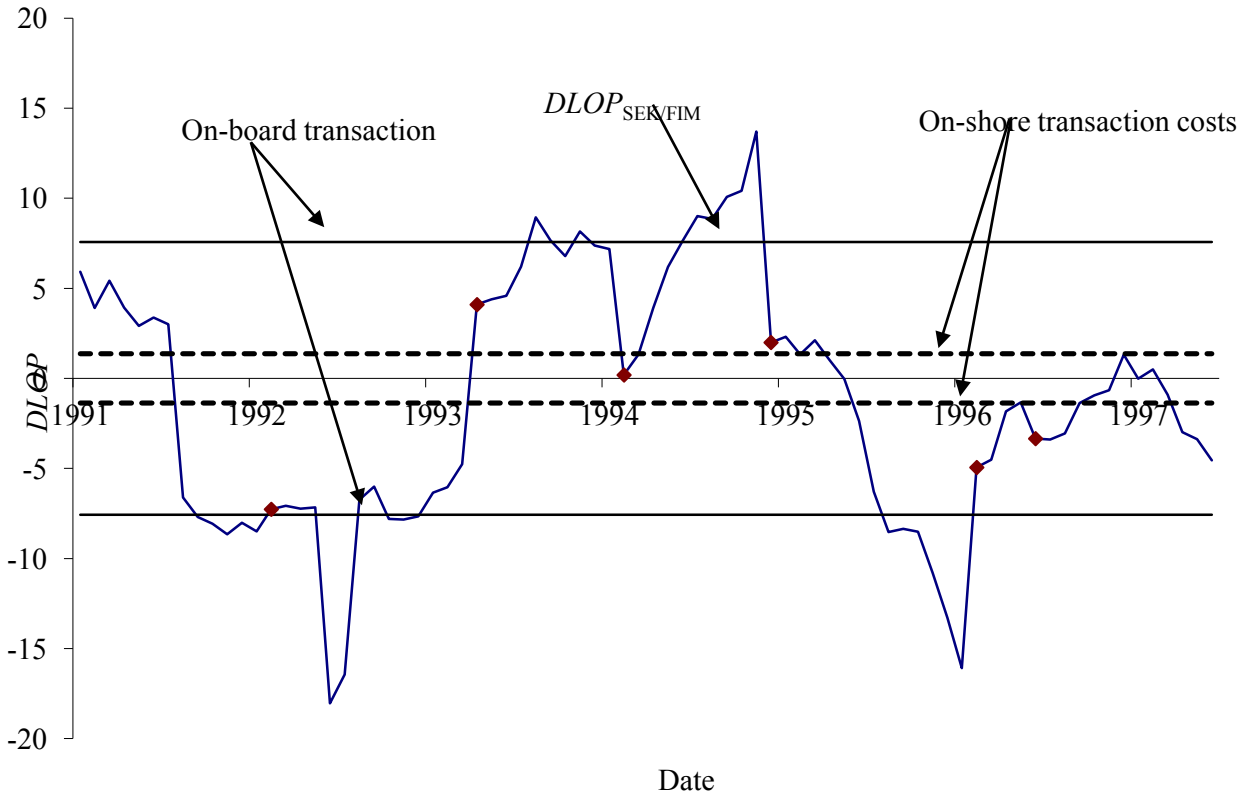


Figure 2 shows that deviations greater than the bands implied by of the on-board transaction costs were short-lived. This pattern is consistent with the notion that costs of exchanging money on board are an important barrier to arbitrage. It is also consistent with the fact that the ferry lines use the same relative price for all goods, since if costs of exchange are the main friction, the equalizing pressure should be independent of the price of the good.

However, actual transaction costs can not explain the pattern since the deviation from LOP is almost always outside the bands implied by the on-shore (credit card) transaction cost. Catalogues are available at several locations on shore (for example, at the Viking Line ticket office at the Stockholm central railway station, where there is also a Forex exchange booth), so, theoretically, price comparisons can be made and arbitrage is often possible with the on-shore exchange rates. One interpretation is that not only actual transaction costs but also costs of optimizing play a role in allowing deviations from LOP. The tendencies for prices on SAS to be closer to LOP for expensive goods, and for USD prices to be higher, are also consistent with rule of thumb behavior. Transaction costs and costs of optimizing thus create a band of inaction, where arbitrage does not exert any equalizing pressure, in the range of 5-10 percent. Since there are also transport costs associated with essentially any other arbitrage of goods by consumers, the bands of inaction should be wider for other goods in this price range.[9]

Are consumers taking advantage of the deviations from LOP? Unfortunately, no firm was willing to provide detailed statistics on the currency distribution of revenue, but in interviews both ferry lines clearly stated that the share of customers shopping in each currency is quite stable. Swedes shop in SEK and Finns in FIM. Evidence to support this comes from the 1993 bankruptcy of Rederi AB Slite, one of the owners of Viking Line. Slite filed for bankruptcy in April but until 1 January 1994 one of the ferries (Kalypso) continued to operate under the Viking Line flag. The bankruptcy files include accounting information from this ferry for the last month. In this month it was 7.6 percent cheaper to buy in SEK using the IFS exchange rate. Nevertheless, cash revenue from on-board sales denominated in FIM amounted to FIM 9.5 million (or about SEK 13.6 million) whereas sales in SEK were some SEK 10 million. Hence, even though it was cheaper to buy in SEK, 73 percent of the revenue was in FIM during this month. In fact, this number corresponds closely to the approximately 70 percent of travelers that Viking Line said were Finnish. This is perhaps not very surprising as a traveler who buys a USD 100 bundle (who can be thought of as a representative consumer) would save no more than USD 6 with the on-shore exchange rate.

Some indirect evidence that consumers do take advantage of arbitrage opportunities when deviations from LOP become large comes from the fact that Birka Line stopped the practice of dual currency price setting in 1992, when the floating of the SEK led to increased volatility of $e_{SEK/FIM}$. The service motive for dual currency pricing had also gradually lost importance, as the fraction of Finnish customers dwindled from almost 50 percent in 1975 to only 5-10 percent in 1992. Higher volatility increased arbitrage opportunities and Birka Line deemed that it was not in their best interest to continue the policy. As of today, it is still possible to pay in FIM but prices are quoted only in SEK and converted at the current exchange rate. At Viking Line, however, the more even mix of Finns and Swedes throughout the period 1991-1998 made it attractive to keep the dual currency price setting also in the period of floating exchange rates. Another indication of arbitrage at work is that both ferry lines mentioned that frequent travelers tended to shop in the currently favorable currency. Presumably, these travelers hold both currencies and are able to quickly compare the relative prices with the current exchange rate. Interestingly, both ferry lines claimed that a major motivation for limiting the deviations from LOP was that customers from one country complain that prices are lower in the other currency. The risk of damaging customer relations by not treating each one “fairly” was seen as a significant risk. This suggests that, in addition to opportunities for consumer arbitrage, there are other factors (such

as reputational concerns) that should be taken into account when discussing why LOP holds, or why it does not.[10]

## IV Conclusions

It is well established that for a wide range of goods, national markets are not integrated in the sense that LOP does not hold (see e.g. Rogoff, 1996 and Goldberg and Knetter, 1997). This is starkly illustrated in Charles Engel and John Rogers (1996) who show that the variability of relative prices, controlling for geographical distance, is far higher if the locations are in different countries. While often difficult to control for empirically, factors such as trade barriers and differences in product specifications, service levels, warranties and costs of local inputs can explain why some prices are different across the border. The evidence from Scandinavian duty-free outlets shows that LOP may fail even when the same product is available at the same location only because it is priced in different currencies.

One reason for the violations of LOP is that, because of differences in demand or costs across markets, optimal prices differ between locations. Costs of arbitrage give firms a certain degree of freedom to allow prices to differ across markets. For example, a recent study by Goldberg and Verboven (1998) of international price discrimination in European car markets shows that, after controlling for differences in product specifications, the substantial price differentials can be attributed to local costs and, to a lesser extent, to price discrimination. A number of transport and information costs are typically associated with conducting arbitrage. Although the consumers in the duty-free stores know the nominal prices in several currencies and face no transport costs, there are still some costs of arbitrage that prevent them from fully taking advantage of the deviations. There is thus some substance to the argument that costs of exchanging currency and costs of comparing prices make possible some degree of price discrimination when prices are expressed in different currencies. It is, however, likely that these costs are small in relation to transport and other information costs for most consumer goods.

Another explanation for the observed deviations from LOP is that they are a byproduct of price rigidities and fluctuations in exchange rates. That nominal prices are rigid is well established - for recent studies see Kashyap (1995) and Saul Lach and Daniel Tsiddon (1996); Taylor (1999) provides a survey. Nominal price rigidities coupled with international markets relate our work to Michael M. Knetter (1997) and Atish Ghosh and Holger C. Wolf

(1994). They examine the cover prices of the magazine *The Economist* and attribute a significant portion of deviations from LOP to the fact that nominal prices are adjusted infrequently. In a recent study, Johnathan Haskel and Holger C. Wolf (1999) examine catalogue prices from the furniture retailer IKEA and also find substantial deviations from LOP. What distinguishes our study from these is the local cost component of products and the potential for arbitrage. The cost of the product to the duty-free outlet is independent of the currency in which the consumer chooses to pay, but for magazines and furniture the local costs are likely to differ across countries. As regards arbitrage, in the duty-free outlet the consumer can choose the currency of payment, subject to some transaction costs, whereas arbitrage of magazines or furniture is hindered by several additional factors. The rejection of LOP at the duty-free outlets suggest that nominal rigidities are important for deviations from LOP.

We also showed that, even in this simple setting, the estimated half-lifes of deviations from LOP are of similar length as in the previous studies of deviations from LOP and purchasing power parity surveyed by Rogoff (1996). One reason for why long half-lifes can be compatible with relatively low costs of arbitrage has been proposed by Obstfeld and Taylor (1997). Their argument is that arbitrage costs create a band of inaction within which relative prices can move without any equalizing pressure from arbitrage. Our data showed if the deviation from LOP was small, the relative price was indeed kept constant. During these, sometimes long, periods deviations followed a random walk. To larger deviations, however, firms responded by adjusting relative prices to restore LOP. Thus, the band of inaction was found to account for both long half-lifes and rapid adjustment to large exchange rate movements.

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[1] This is under the assumption that the SEK/FIM exchange rate follows a random walk with no drift. In practice, however, the exchange rate might well exhibit a mean reverting element as the two economies are closely linked. For more on decision rules for such more complex processes (e.g. with drift and mean reversion) see Avinash K. Dixit and Robert Pindyck (1994).

[2] We are grateful to Nils-Ole Isakas, Viking Line, Agnetha Wigren and Stig Wilhelmson, SAS, and Bengt Carlström, Birka Line, for providing the data (available from the authors upon request). Parts of the current price lists are available on the Internet: http://www.scandinavian.net, http://www.vikingline.se (prices in SEK) and http://www.vikingline.fi (prices in FIM).

[3] In fact, a more detailed examination of the distribution of price adjustments reveals striking similarities with what Anil K. Kashyap (1995) reported for US mail order catalogues for outdoor products (which are imported from various countries, as are the products in the duty-free outlets). For instance, Kashyap finds that a price, on average, is kept fixed for 12 months and the average adjustment is 8 percent; about 8 percent of price changes are negative. At Birka, for the 12 products in our sample, prices are fixed on average 11 months and the average adjustment in SEK is 8.5 percent; in 7 percent of the cases the SEK price is reduced.

[4] Due to tick-size effects, there are a few more relative price changes on products with low nominal prices. The impact on results is minor. With Marlboro cigarettes, for example, there are two more changes in relative price than for Smirnoff. First prices change from SEK 26 and FIM 22 ($P_{SEK}/P_{FIM}$=1.182) to SEK 30 and FIM 25.5

($P_{SEK}/P_{FIM}$=1.176), and from this to SEK 35 and FIM 30 ($P_{SEK}/P_{FIM}$=1.167). More expensive products, such as Smirnoff vodka, had their relative price unchanged at 1.176.

[5] We use this measure since we employ end-of-the month exchange rates and we know only the month (not the date) when a new catalogue is issued. For example, at the end of August 1981 the SEK/FIM exchange rate was 1.145 and $P_{SEK}/P_{FIM}$ =1.11. Sweden devalued the following month, which resulted in an exchange rate of 1.249 in late September. Birka immediately responded to this with a new catalogue with $P_{SEK}/P_{FIM}$ =1.25. Hence, *DLOP*[August]=3.06 and *DLOP*[September]=-0.09, respectively. Had Birka not issued a new catalogue it would have had *DLOP* of 12.4 in September (i.e. *CDLOP*[September]=12.4).

[6] The high correlation between real and nominal exchange rates has been the subject of much research. Using price indexes, Charles Engel (1999) concludes that a very large share of real exchange rate variability can be explained by the failure of LOP for traded goods. However, prices of traded goods may contain significant non-traded inputs. The Birka line data are clearly consistent with the notion that deviations from LOP for traded goods are important for PPP deviations. The correlation between the SEK/FIM real exchange rate using CPIs and the "real exchange rate" using Birka prices instead of CPIs is 0.71.

[7] One could argue that LOP should be tested and half-lifes calculated using Augmented Dickey-Fuller tests (including more lags of $q$ in Equation 3). LOP is rejected also with this test. Using an Augmented Dickey-Fuller test (with lag length 4 months) yields a half-life of 44 months when using the first order coefficient. Estimating half-lifes using impulse response functions, as discussed in Christian J. Murray and David H. Papell (2000), yields lower half-lifes than the simple AR(1) specification.

[8] Forex bought FIM 1 for SEK 1.4301 and sold for SEK 1.4746. This implies arbitrage costs of 1.4746-(1.4301+1.4706)/2 = 0.02225 SEK in each direction, or 1.53 percent. The rates offered by the banks on sales of currency are similar to those offered by Forex. For instance, MeritaNordbanken, one of the largest banks bought FIM for 1.431218 and sold for 1.47446 both for cash and for credit card purchases that were booked on this date. The corresponding rates in the on-board exchange booth were 1.34 and 1.56, implying a transaction cost of 7.58 percent.

[9] The costs of exchanging currency are, of course, of relatively less importance for large commercial transactions where the bands are much narrower. For instance, on 11 November 1999, SEB (a major Swedish bank) quoted 1.431218 and 1.476446 for "tourists" but 1.452218 (buy) and 1.458946 (sell) for commercial transactions, corresponding to a band of 0.4 percent.

[10] A case in point comes from prices of cars in the UK - large and persistent price differentials between UK and continental Europe are well established (see Penelopi K. Goldberg and Frank Verboven, 1998, or the bi-annual price comparisons made by the European Commission). Parallel imports remain comparatively small but calls for consumer boycott and investigations by competitive authorities are highly visible responses to the deviations from LOP (see for instance The Financial Times, 3 December 1999, UK pricing review: Facing the flak from inquiry).