One good - two prices[1]

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Abstract

We examine deviations from the law of one price (LOP) with price data from duty-free outlets where each product, at a given location, has its price quoted in (at least) two currencies. Reluctance to adjust relative prices for "small" deviations from LOP allows prices to differ by up to 7-10 percent. Deviations below this level can be very persistent and last up to a decade. Even after accounting for costs of exchanging currency, there are periods with arbitrage opportunities. However, if exchange rates bring prices further out of line then the outlets adjust nominal prices to reduce the deviations from LOP.

Keywords: law of one price, market segmentation, price discrimination, purchasing power parity.

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Introduction

For a wide range of goods, national markets are not integrated in the sense that the law of one price does not hold (see e.g. Rogoff, 1996 and Goldberg and Knetter, 1997). Engel and Rogers (1996, 1999) show that the variability of relative prices, controlling for geographical distance, is far higher if the locations are in different countries. Trade barriers and differences in product specifications, service levels, warranties and costs of local inputs are factors that can explain why prices are different across the border. For other goods such factors appear to be relatively unimportant but large deviations from the law of one price remain.

The observed deviations from the law of one price (LOP henceforward) have also been attributed to price rigidities and fluctuations in exchange rates. However, when price differentials become large enough we expect arbitrage to exert an equalizing pressure on prices. There are two issues in this observation. First, how far (and for how long) can prices drift from LOP before adjustments of nominal prices reduce the deviations? Second, is LOP restored when nominal prices are adjusted, or are prices systematically different? We analyze these questions with nominal prices of goods sold at duty-free outlets, where each item at each outlet has its price quoted in (at least) two currencies. For any of these products, a set of physical characteristics is available at a given location at one point in time. For such truly identical goods one *a priori* expects that LOP holds, in contrast to cases where one or more of the mentioned criteria are violated.

Figure 1 shows the nominal prices of Marlboro cigarettes in Swedish kronor (SEK) and Finnish markka (FIM) together with the exchange rate in one of the duty-free shops (Birka Line) over the period 1975-1998. A key feature is that nominal prices are fixed for extended periods even though the exchange rate moves continuously. If LOP holds the relative price equals the exchange rate. Clearly, this is not what is observed in the figure and deviations from LOP are often quite persistent. In the long run, however, the relative price tracks the nominal exchange rate - relative price adjustment lowers the difference. We also note that nominal prices are at times adjusted in a way that preserves the relative price. Deviations from LOP are therefore not just a byproduct of sticky prices, even in this setting where there are no differences in costs and where arbitrage is frictionless in comparison with (m)any other goods markets. Finally, following the floating of the Swedish currency in late 1992 the exchange rate volatility increases sharply and Birka Line abandons dual currency price setting. In the following we explore how the above pattern relates to findings in studies of LOP that use more aggregate data, and to micro evidence of price rigidities.

Figure 1 about here.

That nominal prices are rigid is well established - for recent studies see Kashyap (1995) and Lach and Tsiddon (1996); Taylor (1998) provides a survey. Nominal price rigidities coupled with international markets relate our work to Knetter (1997) and Ghosh and 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 addition Knetter emphasizes price discrimination as a reason for the breakdown of LOP in geographically segmented national markets. In a recent study Haskel and Wolf (1999) examine catalogue prices from the furniture retailer IKEA and find median deviations from LOP of 20 to 50 percent. 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 costs of distribution (and printing) are likely to differ across countries. As regards arbitrage, in the duty free outlet the consumer can choose the currency of payment (either cash or by charging the credit card) whereas the scope for arbitrage of magazines or furniture is limited.

Also related to our study, but with no focus on pre-set prices, are studies on international price discrimination. A recent example is Goldberg and Verboven (1998) who examine car prices in five European countries between 1980 and 1993, attempting to control for differences in product characteristics and trade restrictions. They find substantial price differentials and attribute the local currency price stability mainly to local costs and, to a lesser extent, to price discrimination.[2] Will a common European currency diminish price differentials? The data from the duty-free shops allow us to examine the currency aspect of deviations from LOP in isolation.

[2] There are two, largely separate, literatures that relate to these findings but in a national perspective. First, given that consumers typically have search costs, identical products within a market may differ in price (see for instance the seminal article by Stigler, 1961, and references thereto). Second, given differences in demand, costs and competitive situation, price levels may differ across geographical regions within the same country (see for example Weiss, 1989).

We examine monthly price data from three duty-free retail outlets; two Finnish ferry operators connecting Finland and Sweden, Birka Line (over the period 1975-98) and Viking Line (1991-97), and Scandinavian Airlines Systems' inflight shop (1995-98).[3] 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 three duty-free outlets issue catalogs with prices in several currencies. 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.

1. Price setting in duty-free outlets - some considerations

To introduce the issues involved we begin by a brief discussion of the factors underlying the duty-free outlets' decision to adjust prices, exemplifying with Birka Line. It sells an array of products imported from different countries and until 1992 prices each product in its catalogue in both SEK and FIM. 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 new prices are set at given frequency, whereas with a state dependent rule new prices are posted when costs or demand conditions have changed sufficiently to motivate taking the cost of adjusting price, see Taylor (1998) for a discussion. In its simplest form, where the state variable (for instance marginal cost) follows a random walk without drift, the price should be adjusted back to the short run optimum once the state variable crosses a lower or upper boundary.

What are the factors that motivate new catalogues under state-dependent pricing? First, inflation increases the desired nominal prices both via demand and cost channels. Second, the desired nominal prices change with the costs of imported inputs, to a large extent influenced by the exchange rates vis-à-vis producing countries. Thirdly, when excise taxes on shore are raised it increases demand in duty free outlets. Hence, we predict that new prices are posted when there has been significant inflation, large movements in

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

relevant exchange rates and following tax changes. If Birka strictly followed a time dependent rule, a new catalogue would appear only at specific times, for instance in January.

Focus now on the decision to set each product's price in two currencies. Given that products are available at the same location and time and that there are arbitrage opportunities one would expect LOP to hold when a new catalogue is printed. Thus, the relative price should be adjusted to restore LOP once the SEK/FIM exchange rate has moved sufficiently upward or downward or sufficient time has passed.[4] 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 is 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 adjustment of prices. The second rationale is price discrimination. Demand on duty free items is likely to differ due to 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 the mentioned rationales for dual pricing require that not all consumers engage in arbitrage. There are two potential arbitrage costs in the present setting - 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 determines the transactions cost. We return with a more thorough discussion of these costs, for now note that there is no fixed charge associated with exchanging currency on the boats or typically when using a credit card. And you get the same exchange rate regardless of if you exchange USD 7 or USD 700. 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 doing the price comparison. And it is not more difficult to compare USD 700 to GBP 400 than what it is to compare USD 7 to GBP 4. Since the potential gains are greater the more expensive the good is, we expect lower percentage deviations from LOP on

[4] 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 Dixit and Pindyck (1994).

big-ticket items. Under both costs of arbitrage we conjecture that the greater the deviation from LOP, the larger the share of customers who pay the lower price.

2 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 3 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 is

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

We focus the analysis on Birka Line, where our data cover more than two decades. After that we briefly discuss price setting at Viking Line and SAS.

Birka Line

During 1975-98 Birka issued 26 catalogues, of which the first 20 contained 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 with a new catalogue without new nominal prices). The first important observation is that Birka Line uses the *same* relative price on every product in a given catalogue (save for tick-size effects on the order 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. Secondly, the observed pattern of price adjustment is well in line with other micro studies of price rigidities. For instance the median length of time during which price is fixed - 11 months (min 0 months and max 22 months) - is within the range typically found (see Taylor, 1998). Using prices from US mail order catalogs for outdoor products (which are imported from various countries, as are the products in the duty-free outlets) Kashyap (1995) finds that on average prices change once a year. In his data, the average size of a price change is 8 percent, with the 25th percentile roughly at 3 percent and the 90th at roughly 15 percent; about 8 percent of his 261 price changes are negative. These figures are remarkably similar to those reported for Birka Line. Looking more closely at the 196 nominal price adjustments of 12 products (not all products are present in every catalogue) we find that the average change in the SEK price is 8.5 percent. There is substantial variation in the size of the price changes; the 10th, 25th, 50th, 75th, and 90th percentiles of the distribution are 2, 4, 7.5, 11, and 20 percent, respectively.[5] In 7 percent of the cases the nominal price in SEK was reduced.

From Figure 1 it is clear that LOP is a useful way to think about the adjustment of relative prices, even though prices are almost never equal when expressed in the same currency. Furthermore, it is seen that the adjustment of the relative price can not fully be 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. State dependent pricing implies that the price will be adjusted whenever the underlying variables have drifted far enough to motivate taking the fixed cost of adjustment. In columns 2-4 we examine the predictions outlined in Section 2 by comparing three types (T) of months; no new catalogue (T=1), a new catalogue but unchanged relative price (T=2) and finally months with a new catalogue and new relative price (T=3). The product we use is Smirnoff vodka, but the results are virtually identical for all other products.[6] To understand what preceded the decision to print a new catalogue (with or without new relative prices) we denote by $\Delta Z|T = x$ the percentage movement in variable Z since the last event T=x.[7] We also construct a contrafactual deviation from LOP as

$$CDLOP^i_{X/Y}[t] = 100(e_{X/Y}[t]P^i_Y[t-1] - P^i_X[t-1]) / P^i_X[t-1]$$

where t denotes the month. In words, CDLOP measures the percentage deviation from LOP that would have resulted with non-adjusted nominal prices.[8]

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[5] In any given new catalogue there is also some variation as to the percentage change of individual products, which is likely a reflection of different development in costs and/or demand.

[6] 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 the relative price unchanged at 1.176.

[7] For instance $|\Delta e_{SEK/FIM}|T = 3|$ refers to the absolute percentage movement in the SEK/FIM exchange rate since the last time relative prices were adjusted.

[8] 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

Table 1 about here

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. More important is that the period contains both large negative and positive deviations from LOP. The average absolute value deviation, $|DLOP|$, is 4.28 which suggests that in most months there are considerable violations of the law of one price. At this stage, it would be easy to conclude that 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, Birka Line printed five new catalogues between 1982 and 1988, each time conserving the relative price.

Although LOP is rejected, it remains a useful guiding principle for understanding the development of the relative price. As suggested by Figure 1, Birka 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 month before an adjustment of the relative price, the average $|DLOP|$ was 7.2. The averages of $|CDLOP|$ give further indication of Birka's desire to reduce deviations from LOP. In particular, had it not adjusted relative prices when it did so, the deviation would have been 8.36.

It is common in the literature (see e.g., Rogoff, 1996) to test for a unit root in deviations from LOP (or PPP).[9] The presence of a unit root, such that the relative price follows a random walk, suggests that there is no equalizing pressure from arbitrage. The simplest test, in our setting, amounts to a 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

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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).

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

for unit roots, the simple AR(1) regression on our data will allow a comparison with other studies, where price data is usually far more aggregate. We thus estimate

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

where α=0 and β<1 if LOP is exerting influence on the relative price. Based on 214 monthly observations, the least squares estimates are α=-0.000570 (0.00124) and β=0.971 (0.0236), with standard errors in parentheses, and DW=2.14 and adjusted 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 follows a random walk.

Given that the estimated β is less than unity, it is interesting to calculate the implied half-life of a deviation from LOP (*n* months defined by β^n=0.5). The half-life is 24 months, which can be compared with the 3-5 years commonly found in studies that employ more aggregate data (for references, see Rogoff, 1996). A half-life of two years remains long, but can be related to Obstfeld and Taylor's (1997) explanation of the apparently weak equalizing pressure from arbitrage.[10] 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, LOP almost never holds exactly and there are only eight, out of 214, months when the firm acts to reduce deviations. Put differently, it keeps the relative price constant for an average of 28 months, but 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. The key point, however, is that when deviations become too large the firm adjusts relative prices.

SEK/FIM: The most important explanation to why relative prices are not adjusted in each new catalogue can be seen by comparing $\Delta e_{SEK/FIM} \left| T = 3 \right.$ in columns T=2 and T=3. When a new catalogue with unchanged relative price appears (T=2) the drift in

[10] Obstfeld and Taylor estimate a threshold autoregression. Given that there are only eight changes in relative price in our sample, estimation of thresholds is difficult.

$e_{SEK/FIM}$ has only been moderate (about 2.5 percent) compared to the rather dramatic change of 7.5 percent when the relative prices are renewed. Hence, small movements in the $e_{SEK/FIM}$ do not motivate any change in the relative price.

Y/USD: By comparing $\Delta e_{Y/USD}|T = 2 \text{ or } 3$ for Y=SEK,FIM in the last three columns we conclude that before a new catalogue appears there are quite large changes (around 8 percent) in the exchange rates against the USD (the results are similar for GBP and FRF) since the last new catalogue. Since the products sold by Birka are typically imports this is evidence of delayed pass-through into consumer prices. (The very large means in column T=3 are partly due to devaluations that also triggered adjustments of relative prices.)

Inflation: Inflation (*ΔCPI*) 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 (nine in January and five in June or July).[11] This may partly reflect a time dependent pattern in the apparition of new catalogues - partly it also reflects that taxes on cigarettes and alcohol, two important product groups, are often effective from January 1 and July 1.

Viking Line

Figure 2 shows the development of nominal prices and the deviation from LOP at Viking Line. As on Birka Line, Viking Line sets price in SEK and FIM and uses the same relative price for all goods. Throughout the period 1991-1998 some 70 percent of passengers are Finnish and the more even mix of Finns and Swedes made it attractive to Viking Line to keep its dual currency price setting also in the period of floating exchange rates. Again we observe infrequent price adjustment and therefore deviations from LOP; on average 1.82 (standard deviation 6.92 with 78 observations). A two-tailed t-test thus rejects LOP at the 5 percent level (t=2.31). The average |*DLOP*| is 5.78 (standard deviation is 4.29), which shows that deviations are somewhat larger on Viking than on Birka, reflecting the greater volatility of the exchange rate for the period covered by the Viking data (see Figure 1). When a new catalogue is issued it reduces the average |*DLOP*| to 3.71 from 10.6 the month before. When Viking issues a new catalogue it also adjusts the relative prices except on one occasion when *DLOP* was small. Relative prices are held constant for periods between nine and sixteen months. Summing up, much of the pattern of relative price adjustment is the same as on Birka Line. Some differences, such that Viking almost always adjusted the relative price when it issued a new catalogue, may be due to the higher exchange rate variability during the period covered by the Viking data.

Figure 2 about here

The airline SAS

Pricing behavior on SAS differs in some respects from that of the ferry lines. SAS sets prices in US dollars (USD) as well as in the Scandinavian currencies (DKK: Denmark, NOK: Norway, and SEK). The most important difference is, however, that it does not use the same implicit exchange rate on 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 about here

Clearly, in several cases the null hypothesis, that *DLOP=0*, is rejected. Prices are adjusted often, 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 Jan 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, as the other firms, acts to reduce large deviations from LOP. Also in accordance with the other firms *DLOP* is not zero after adjustment.

One expects rules-of-thumb (such as "pay in your own currency") to become less important as the nominal amounts increase. Buying a Mont Blanc pen for USD 138, many

[11] The rest of the catalogue dates are spread out across the year: three in May, two each in February, April, September and November and one in May.

travelers might find it worthwhile to consider the relative prices. On the other hand, a consumer buying a box of Marlboro cigarettes for USD 22 may assume that the difference is too small to motivate the effort. There is some evidence of this. Comparing the SEK price of the two 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 only up to 2 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 entire 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.

3. 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. This is a simplification as i) rates vary daily and ii) as soon as we allow for costs of doing arbitrage there will be a bound of inaction within which the deviation from LOP can fluctuate before arbitrage becomes profitable. These transactions costs will differ across consumers: many will exchange currency at home in preparation for a trip abroad, others are returning home and are holding foreign currency that they would like to spend and some choose to exchange on board. Further if you pay by credit card, the issuing bank will typically use the exchange rate a couple of days hence. It proved impossible to find historical information about these transactions costs. Nevertheless, some indication of the potential importance can be gained by examining the current spreads. Figure 3 illustrates the deviations from LOP on Viking Line, with the arbitrage costs implied by the spreads on the exchange rate from November 10, 1999, in the exchange booth on Viking Line and in the largest retail foreign exchange dealer in Stockholm, Forex. The rates for credit card are similar to those at Forex.[12]

[12] 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 boot were 1.34 and 1.56, implying a transaction cost of 7.58 percent.

Figure 3 about here

Figure 3 shows that deviations that were greater than implied by the bounds of the on board transactions costs on board were short-lived. The pattern is consistent with the notion that costs of exchanging money on board are an important barrier to arbitrage. This 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 transactions costs can not explain deviations since almost always is the deviation from LOP outside the bands implied by the on shore (credit card) transactions cost.[13] Catalogs are available on 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 transactions cost but also costs of optimizing play a role in allowing deviations from LOP. The tendency for prices on SAS to be closer to LOP on expensive goods, and that USD prices are higher, are also consistent with rule-of-thumb behavior. The lessons for other retail markets is that actual transactions costs create a bound of inaction, where arbitrage is not exerting any equalizing pressure, of a few percent. Costs in time and effort of optimizing make this band somewhat wider. Given that there are also transport costs associated with essentially any other goods arbitrage implies that bounds of inaction will be wider.[14]

What are the mechanisms that finally trigger the change in relative price? 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 the respective currency is quite stable. Swedes shop in SEK and Finns in FIM. Supportive evidence for 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 January 1 1994 one of the ferries (Kalypso) continued to operate under the Viking 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

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[13] On November 10 1999 P_{SEK}/ P_{FIM} equaled 1.50 on Viking Line, consequently it was 3.18 percent cheaper in FIM using the point exchange rate as in previous sections and 1.69 percent cheaper using the on shore rate.

[14] The costs of exchanging currency are, of course, of relatively less importance for large commercial transactions where the bounds are much narrower. For instance, on November 11 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 bound of inaction of 0.4 percent.

in SEK using the IFS exchange rate. Nevertheless, cash revenue from on board sales denominated in FIM amounted to FIM 9.5 million (SEK 13.6 million) whereas sales in SEK were some SEK 10 million. Hence, even though it was cheaper to buy in SEK more than half of revenue was in FIM during this month. This is perhaps not very surprising as a traveler who buys a USD 100 bundle (which can be thought of as a representative consumer) would save no more than USD 6 with the on shore exchange rate. At times of large deviations the gains become more apparent, with more customers exchanging currency in advance and word of mouth spreading that the credit card should be charged in the favorable currency.

Some indirect evidence that consumers do take advantage of arbitrage opportunities when deviations from LOP become large comes from the fact that Birka Line stops the practice of dual currency price setting in 1992, when 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 dual currency pricing. As of today, it is still possible to pay in FIM but prices are only quoted in SEK and translated by the current exchange rate. Another indication of arbitrage at work is that both ferry lines mentioned that some customers, in particular frequent travelers, tended to shop in the currently favorable currency. Nevertheless, both ferry lines mentioned as a major motivation for limiting the deviations from LOP, that customers from one nation 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. The lesson being that it may be reasonable to put less weight on consumer arbitrage and more weight on other mechanisms (such as reputation), than is commonly done when examining deviations from LOP.

4 Conclusions

Different countries typically have different currencies, and most prices remain rigid for considerable periods. We explore if this can contribute to our understanding of deviations from the law of one price. To this end we have examined data from duty-free outlets where each good (at the same location) has price tags in multiple currencies. Since exchange rates move daily, whereas nominal prices are adjusted only infrequently, it will almost always be cheaper in one of the currencies. The law of one price is rejected at all the outlets. The nature of the data imply that the reasons for potential failure that commonly plague studies of LOP and PPP are controlled for (product characteristics, local costs components,…). Given that LOP is rejected in this ideal setting, it is unsurprising that studies using more aggregate data from different locations often reject LOP. Further, we found that deviations from LOP were not only a result of pre-set prices in the respective currencies. There is thus something to the argument that costs of exchanging currency and costs of comparing prices allow for some degree of price discrimination when prices are expressed in different currencies. On the issue of price equalization resulting from a common currency it is however likely that these costs are small in relation to transport and other information costs for most other consumer goods.

Finally, the main lesson from the paper is that in this "natural experiment", LOP is a faithful guide to the behavior of relative prices - even though nominal rigidities and a band of inaction leads to non-negligible and often persistent deviations from LOP. As deviations become large, prices are adjusted to reduce the deviation from LOP, and thereby limit arbitrage possibilities. At the two ferry lines, where we had the longest data series, the average deviation the month before adjustment of the relative price was 7 and 10 percent, respectively, but only 2 and 4 percent the month after. The patterns at the duty free outlets suggest 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.

References

Dixit, Avinash K and Robert Pindyck, 1994, Investment under uncertainty, MIT Press, Cambridge MA.

Engel, Charles and John Rogers, 1996, How wide is the border?, The American Economic Review 86, 1112-1126.

Engel, Charles and John Rogers, 1999, Deviations from the law of one price: Sources and welfare costs, manuscript, University of Washington.

Engel, Charles, 1999, Accounting for U.S. real exchange rate changes, Journal of Political Economy 107, 507-539.

Goldberg, Penelopi K. and Michael M. Knetter, 1997, Goods prices and exchange rates: What have we learned?, Journal of Economic Literature XXXV, 1243-1272.

Goldberg, Penelopi K. and Frank Verboven, 1998, The evolution of price dispersion in the European car market, NBER Working Paper No 6818.

Ghosh, Atish and Holger C.Wolf, 1994, Pricing in international markets: Lessons from *The Economist*, NBER Working Paper No 4806.

Haskel, Johnathan and Holger Wolf, 1999, Why does the "law of one price" fail? A case study, CEPR working paper no 2187.

Kashyap Anil K, 1995, Sticky prices: New evidence from retail catalogs, The Quarterly Journal of Economics CX, 245-274.

Knetter, Michael M., 1997, The segmentation of international markets: Evidence from *The Economist*, NBER Working Paper No 5878.

Lach, Saul and Daniel Tsiddon, 1996, Staggering and synchronization in price-setting: Evidence from multiproduct firms, The American Economic Review 86, 1175-1196.

Obstfeld, Maurice and Alan M. Taylor, 1997, Nonlinear aspects of goods-market arbitrage and adjustment: Heckscher's commodity points revisited, Journal of the Japanese and International Economies 11, 441-79.

Rogoff, Kenneth, 1996, The purchasing power parity puzzle?, Journal of Economic Literature, 34, 647-668.

Stigler, George J, 1961, The economics of information, The Journal of Political Economy LXIX, 213-225.

Taylor, John B., 1998, Staggered Price and Wage Setting in Macroeconomics, NBER Working Paper 6754, forthcoming in Handbook of Macroeconomics.

Weiss, Leonard, 1989, Concentration and price, The MIT Press, Cambridge, MA.

Table 1. Descriptive statistics for Birka Line.

	Full sample.	No new catalogue. T=1	New catalogue. No new relative prices. T=2	New catalogue. New relative prices. T=3
	Mean (Std.Dev.) Min,Median,Max	Mean (Std.Dev.) Min,Median,Max	Mean (Std.Dev.) Min,Median,Max	Mean (Std.Dev.) Min,Median,Max
DLOP	1.01 (5.22)	1.01 (5.35)	2.37 (3.73)	-0.83 (3.10)
	-18.04,2.36,11.15	-18.04,2.49,11.15	-5.27,3.06,7.01	-7.08,-0.28,2.77
|*DLOP*|	4.29 (3.14)	4.39 (3.20)	3.87 (1.90)	2.22 (2.18)
	0.00,3.23,18.04	0.00,3.28,18.04	1.16,3.23,7.01	0.08,1.89,7.08
|*CDLOP*|	4.50 (3.26)	4.39 (3.20)	3.87 (1.90)	8.36 (4.37)
	0.00,3.31,18.04	0.00,3.28,18.04	1.16,3.23,7.01	0.59,7.85,13.72
$\|\Delta e_{SEK/FIM}\|$T=2|	1.90 (2.53)	1.78 (2.42)	1.81 (1.08)	5.26 (4.52)
	0.00,1.03,12.10	0.00,0.97,12.10	0.11,1.65,3.66	0.78,3.54,11.87
$\|\Delta e_{SEK/FIM}\|$T=3|	3.23 (2.84)	3.12 (2.73)	2.55 (1.55)	7.49 (4.09)
	0.01,2.61,12.95	0.01,2.60,12.10	0.52,2.23,5.85	2.24,7.92,12.95
$\|\Delta e_{SEK/USD}\|$ T=2 or 3|	5.71 (5.27)	5.24 (4.53)	7.95 (5.28)	15.25 (12.23)
	0.03,4.60,34.31	0.03,4.16,25.45	0.24,9.30,16.90	5.17,9.41,34.31
$\|\Delta e_{FIM/USD}\|$ T=2 or 3|	5.88 (4.91)	5.51 (4.53)	8.34 (6.05)	12.20 (8.19)
	0.10,4.88,24.83	0.10,4.62,23.35	0.26,9.87,19.44	1.17,11.34,24.83
ΔCPI SWEDEN| T=2 or 3	4.39 (4.17)	4.06 (3.92)	7.23 (4.50)	9.37 (6.02)
	0.00,3.23,19.57	0.00,2.94,19.57	2.02,7.14,17.95	1.83,7.92,19.57
ΔCPI FINLAND| T=2 or 3	4.88 (4.53)	4.63 (4.32)	7.33 (5.49)	8.19 (6.72)
	-0.50,3.40,22.09	-0.50,3.24,20.45	0.00,6.40,17.24	2.59,5.37,22.09
NOBS	214	195	11	8

Table 2. Deviations from the Law of One Price at the SAS inflight shop.
The measure is average DLOP with standard deviation in parenthesis.[1]

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.
1) The number of observations vary with product and column:
Marlboro, Eurosleeper, Renault and Arden: 39, 39, and 32.
Mont Blanc: 33, 33, and 32.
Absolut: 29, 29, and 29.

Figure 1. Nominal prices in SEK (P_{SEK}) and FIM (P_{FIM}) of Marlboro cigarettes at Birka Line, together with relative price (P_{SEK}/P_{FIM}) and nominal exchange rate ($e_{SEK/FIM}$), 1975-1998.

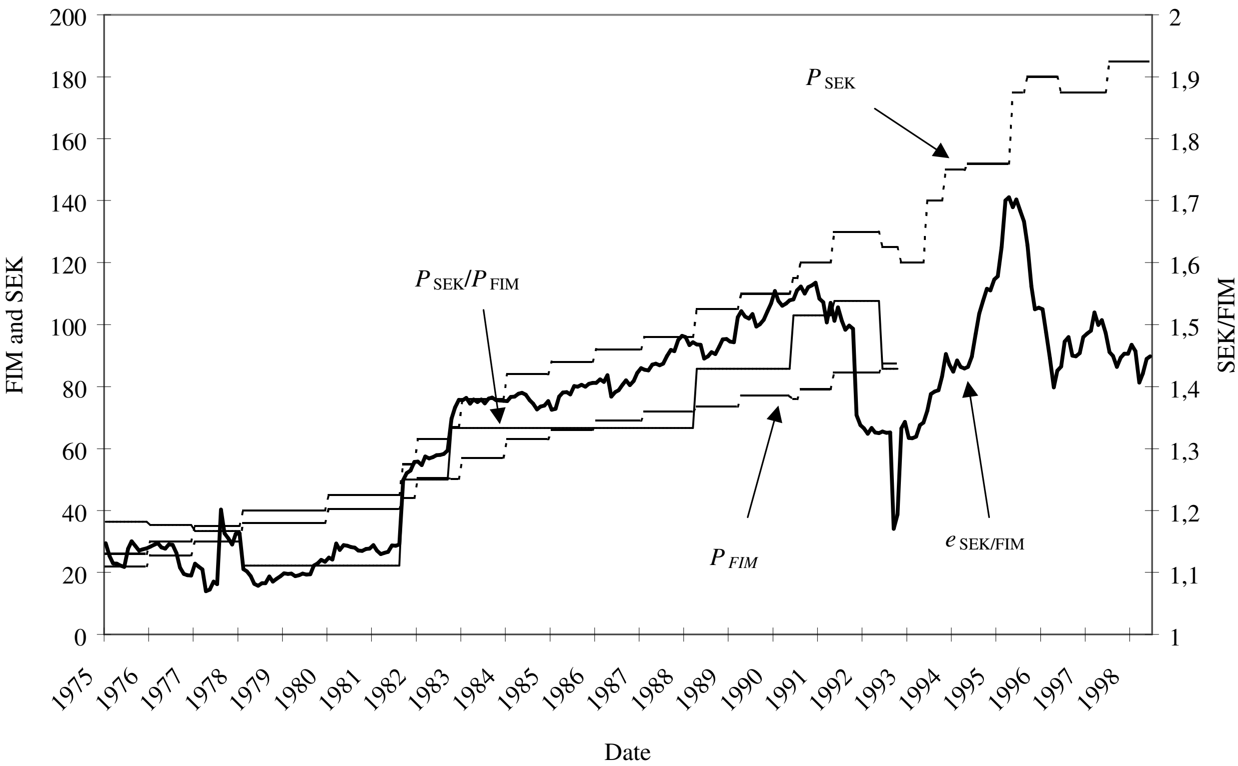


Figure 2. Nominal prices in SEK and FIM of Marlboro cigarettes at Viking Line, together with nominal exchange rate, 1991-1997.

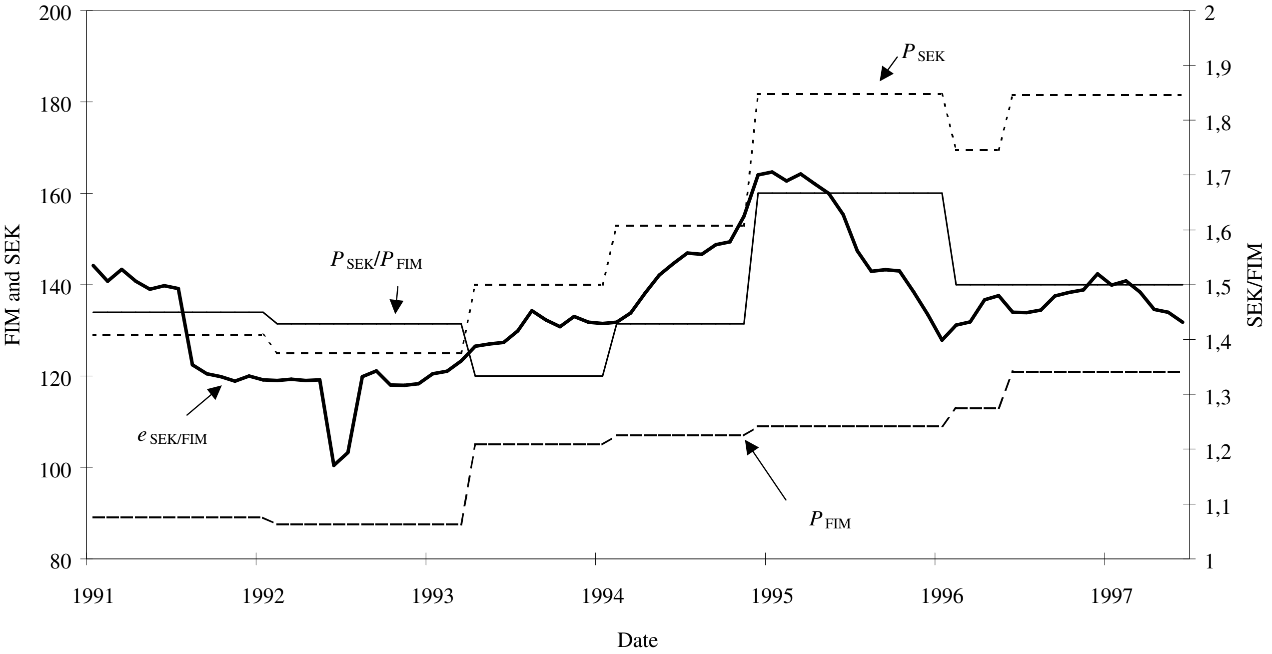
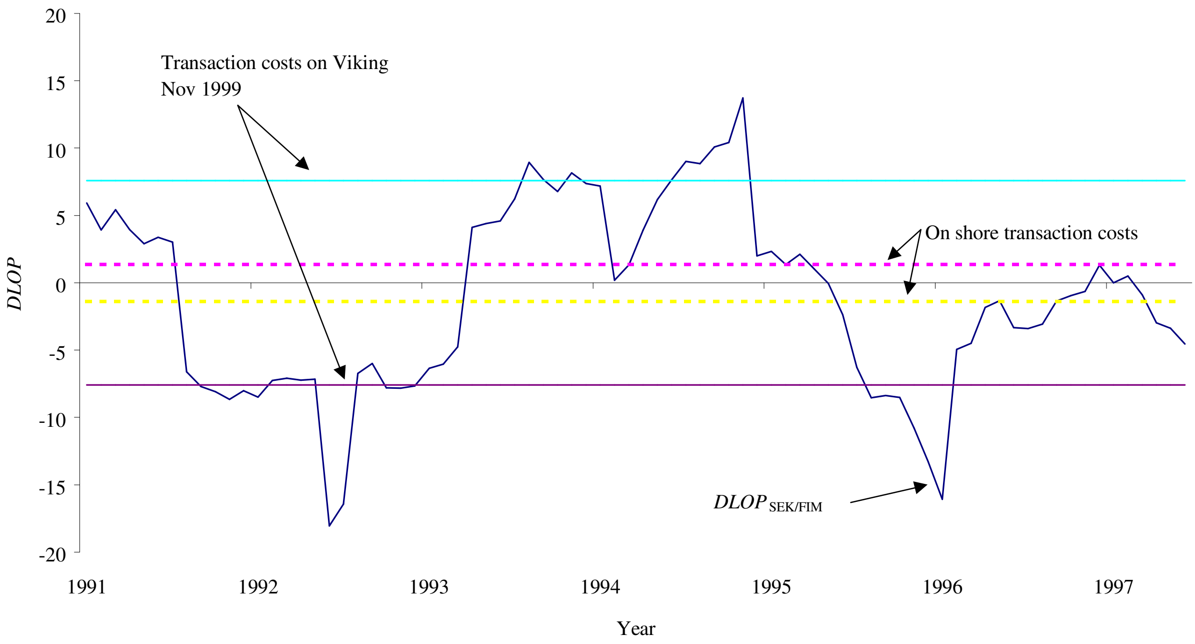


Figure 3. Deviations from LOP and no arbitrage bounds implied by costs of currency exchange Viking Line 1991-1997.



Appendix A: List of products.

Product name	Specification	Duty free shop(s)
Alcohol		
Absolut	Vodka, 1 liter 50% a)	B,V,S
Finlandia	Vodka, 1 liter 50% a)	B,V
Smirnoff	Vodka, 1 liter 50 %	B,V
J&B	Whisky, 1 liter	B,V
Ballentines	Whisky, 1 liter	B
Johnnie Walker Red Label	Whisky, 1 liter	B
Renault Carte Noire	Conjac, 1 liter	S
Le Cardinal	Red Bordeux, 1liter	B
Carlsberg Elephant	Beer, 6*0.33 liter	B
Heineken	Beer, 6*0.33 liter	V
Tobacco		
Marlboro Filter	Cigarettes, 200 psc	B,V,S
Ettan	Snuff, 50 gram	B,V
Cosmetics		
Chanel No. 5	Perfume, 7.5ml	B
Tabac Orginal	After Shave, 175ml	B
Arden Visible Difference	Lotion	S
Boss Elements Duopack	Aftershave+Deodorant	S
Other		
Eurosleeper	Seat upgrade	S
Mont Blanc	Ballpoint Pen	S

a) At Viking Line the product contains 40% alcohol. At SAS Absolut is 2*20 cl