Online Appendix

Consider the PPP relation when P^{US} and P^{M} refer to the prices of a market basket of goods in the US and Mexico, respectively, and S is the nominal exchange rate, the peso price of a US dollar. As is well known, purchasing power parity requires that the cost of the market basket is the same in both countries, $SP^{US} = P^{M}$, thus the real exchange rate is one. In empirical work, one must use price indices rather than the actual cost of a market basket. If, instead P^{US} and P^{M} are price indices, SP^{US} will be different from P^{M} except by coincidence. However, if the real exchange rate in terms of the price indices, $\frac{SP^{US}}{P^{M}}$, is a stationary series then PPP holds.[1]

An important structural change common to many exchange rate data series is the shift from a fixed to a floating nominal rate regime as occurred with the breakdown of the Bretton Woods system. Such a regime change affects the adjustment to PPP, S can now change freely in response to market forces, but does not alter the real exchange rate at which PPP holds. Thus it is incorrect to suggest that any structural change will cause a level shift of the type we observe in our empirical results for Mexico. Instead, only a structural shift that alters the traded/non-traded goods composition of the price indexes can account for level shifts in the real exchange rate. Such structural changes did occur in Mexico especially during the 1969-1994 period.

The empirical findings for the Mexico-US purchasing power parity relationship raise two issues that are addressed in detail in this appendix. First, the typical view of PPP is that any deviations from the PPP value of the real exchange rate lead to a return to the same PPP value. Since the empirical evidence suggests that PPP in Mexico holds, but with mean shifts in the equilibrium value of PPP, we must explain how these shifts in the PPP relationship can occur. Second, the dates of these mean shifts very often coincide with dates of nominal rate devaluation raising the question of the relationship between devaluation, trade liberalization, and the real exchange rate value of PPP.

[1]Strictly, mean reversion of the real rate is not a sufficient condition for PPP. Consider a real exchange rate $Q + b + \varepsilon$ where b is a constant and ε is a white noise error. If Q, the PPP value of the real exchange rate, is stationary, unit root tests will show that the mean real exchange rate is stationary, it reverts to Q + b even though PPP does not hold. Since it is hard to imagine conditions under which the real exchange rate might be stationary yet differ from its PPP value by a constant, most researchers, including ourselves, discount this possibility and regard evidence of mean reversion as support for PPP.

Our explanations are based on the use of price indexes composed of both traded and nontraded goods in the empirical work rather than the (unavailable) costs of market baskets of traded goods. Trade liberalization alters the traded/nontraded goods composition of the price indexes as well as changing the prices of newly traded goods. These two effects can, and likely will, cause a shift in the real exchange rate associated with PPP.

Consider a period t Laspeyres price index for country j where 0 refers to the base period, $P_t^j = \frac{\sum_{i=1}^{T} p_{it}^j q_{i0}^j}{\sum_{i=1}^{T} p_{i0}^j q_{i0}^j}$. Base period prices and quantities of individual goods in country are given by p_{i0}^j and q_{i0}^j respectively. For convenience, both Mexico and the United States are assumed to have the same goods in the index although the expenditure weights can differ. Goods are ordered so that goods 1… N<T are nontraded thus N+1…T are traded.[2] Second, suppose both countries use period 0 as the base so that $P_0^j = 100$. Purchasing power parity holds in any period *t* if $S_t p_{it}^{US} = p_{it}^M \; \forall i = N+1 \ldots T$ since each traded good has the same price in both countries in terms of a common currency. S_t is the period *t* nominal exchange rate, the peso price of one US dollar.

Clearly the nontraded goods components of the price indexes pose problems for uncovering PPP in empirical work since the prices of nontraded goods will generally differ between the two countries due to trade barriers or transportation costs. However, our empirical results indicate that purchasing power has held between the US and Mexico even for the period prior to 1976 when Mexico followed an import substitution strategy. To incorporate this empirical evidence, suppose that period 0, the base period, occurs before trade liberalization and that the empirical results show that the real exchange rate associated with PPP is equal to its value during the base period. Since both base period price indexes are 100, the nominal and real exchange rates are the same, S_0, and equivalent to the equilibrium value given by PPP.[3]

[2] Good b is treated as nontraded if there is no trade in the good between the two countries, although one of the countries might trade good b with a third country. For example, if Mexico has a trade barrier preventing the import of good b from the US, good b is treated as nontraded even if the US exchanges good b with a third country.

[3] Of course there is no reason why the prices of nontraded goods would be the same in both countries, nor is there any statistical reason why the nontraded goods components of the two countries' price indexes might adjust in some way over time to show empirical evidence of PPP, but such are our results. Indeed empirical evidence of PPP despite the use of price indexes, perhaps, ought to be considered surprising.

Now consider the effects of an unexpected period t trade liberalization in Mexico, defined as a reduction in trade barriers leading to trade in at least one previously nontraded good. For concreteness and example clarity four additional assumptions are made, i)among the previously nontraded goods, only good 1 is traded after liberalization, ii) prior to liberalization the peso price of good 1is higher in Mexico than the US, hence trade barriers protected the Mexican producers of good 1 from US competitors or $S_t p_{1t}^{US} < p_{1t}^{M}$, iii) since Mexico is small compared to the US only the Mexican peso price adjusts with trade liberalization, and iv) there is no inflation nor relative price changes in either country other than those caused by the trade liberalization, thus for Mexico $p_{it+k}^{M} = p_{i0}^{M} \; \forall i = 2 \ldots T, \forall k > 0$. Thus the price index in both countries is 100 immediately prior to the liberalization. We first examine the effects of liberalization on the PPP relationship when the exchange rate, S, is fixed.

Case 1-The nominal exchange rate is fixed and does not change with liberalization, thus $S_0 = S_t = S$. When the nominal exchange rate does not change the immediate effect of trade liberalization is downward pressure on the Mexican price of good 1 until the law of one price is restored at some post liberalization time, t+k, so that $S p_{1t+k}^{US} = p_{1t+k}^{M}$. Since all components of the US price index are unchanged it remains $P_{t+k}^{US} = 100$. Since the price of good 1has fallen in Mexico with trade and no other prices have changed, the Mexican price index is less than 100. Splitting the index into two components as in equation (A1) illustrates the point more clearly.

$$P_{t+k}^{M} = \frac{p_{1t+k}^{M} q_{10}^{M}}{\sum_{i=1}^{T} p_{i0}^{j} q_{i0}^{j}} + \frac{\sum_{i=2}^{T} p_{it+k}^{M} q_{i0}^{M}}{\sum_{i=1}^{T} p_{i0}^{j} q_{i0}^{j}} < 100 \qquad \text{(A1)}$$

Given that $p_{it+k}^{M} = p_{i0}^{M} \; \forall i = 2 \ldots T, \forall k > 0$ the second term in Mexico's price index is identical to its value before liberalization and the first term is smaller, $\frac{p_{1t+k}^{M} q_{10}^{M}}{\sum_{i=1}^{T} p_{i0}^{j} q_{i0}^{j}} < \frac{p_{1t}^{M} q_{10}^{M}}{\sum_{i=1}^{T} p_{i0}^{j} q_{i0}^{j}}$, because the price of newly traded good 1 must fall in Mexico due to the law of one price. Purchasing power parity holds because each traded good has the same price in both countries, but the real exchange rate associated with purchasing power parity is different since the Mexican price index has declined, $\frac{S P_{t+k}^{US}}{P_{t+k}^{M}} > \frac{S P_{0}^{US}}{P_{0}^{M}} = S$. Allowing additional nontraded goods to be traded after liberalization would merely accentuate the

impact since the Mexican prices of these goods would fall as well to restore the law of one price in each case.[4] In order to capture this liberalization effect a mean shift in the PPP value of the real exchange rate should be allowed for in empirical work.

Case 2-To protect the Mexican producer of good 1 assume that the trade liberalization is accompanied by a devaluation of the peso so that the peso price of good 1 does not fall with the time t liberalization, thus $p_{1t}^M = p_{10}^M$ and $S_t p_{1t}^{US} = p_{1t}^M$. The peso is devalued, $S_t > S_0$, to protect the Mexican producer of good 1 so that the peso price of good 1 in the US is the same as in Mexico. But the time t peso devaluation now means that all goods traded before liberalization now cost more in pesos in the US than they do in Mexico, $S_t p_{it}^{US} > p_{it}^M \quad \forall i = N+1 \ldots T$. Again, assuming that price adjustment occurs only in the small country, Mexico, and that the law of one price is restored for all goods by period t+k, the prices of the previously traded goods rise in Mexico, $S_t p_{it+k}^{US} = p_{it+k}^M > p_{it}^M = p_{it}^0 \quad \forall i = N+1 \ldots T$. To see this point clearly, the price index for Mexico is divided into three parts $P_{t+k}^M = \frac{p_{1t+k}^M q_{10}^M}{\sum_{i=1}^{T} p_{i0}^M q_{i0}^M} + \frac{\sum_{i=2}^{N} p_{it+k}^M q_{i0}^M}{\sum_{i=1}^{T} p_{i0}^M q_{i0}^M} + \frac{\sum_{i=N+1}^{T} p_{it+k}^M q_{i0}^M}{\sum_{i=1}^{T} p_{i0}^M q_{i0}^M}$. Since the nominal rate is devalued to maintain the peso price of the newly traded good 1, $p_{1t+k}^M = p_{1t}^M = p_{10}^M$ the first term in the index is unchanged from period 0. The third term in the index increases as the domestic prices of traded goods rise with the devaluation of the peso. Given our assumptions that the law of one price holds for each traded good N+1… T prior to devaluation and only Mexican prices adjust, the percentage increase of the third term is the same as the percentage devaluation after restoration of the law of one price. Notice that the price index in Mexico jumps with devaluation.[5] How the prices of nontraded goods, captured in the second term of the index, adjust is more complicated since it will depend on how traded and nontraded are related in the consumer's market basket. It is

[4] Again we assume that the peso prices of the newly traded goods are higher in Mexico than the US prior to liberalization.

[5] An anonymous referee noted that peso devaluations have often been accompanied by banking/financial crises and inflation that will affect the PPP dynamics. Although addressing a financial crisis is beyond the scope of this paper, this case demonstrates how political considerations may lead to devaluation and an increase in the Mexican price index after trade liberalization.

possible, however, to determine the two extremes of adjustment and draw some conclusions from the extreme situations.

At one extreme, suppose the peso price of each nontraded good rises by the same percentage as the devaluation in order to restore the relative prices prevailing before liberalization between nontraded goods (excluding good 1) and traded goods. If so then the second component of the index will increase by the same percentage as the devaluation. In this instance, the overall price level in Mexico rises by slightly less than the percentage of the devaluation (since the price of good 1 is unchanged) so that $\frac{S_t P_{t+k}^{US}}{P_{t+k}^{M}} > \frac{S_0 P_0^{US}}{P_0^{M}}$. Since the law of one price holds for each traded good, PPP holds although the real exchange rate associated with PPP differs from its pre-liberalization value.

At the other extreme, suppose the peso price of each nontraded good remains unchanged, so that nontraded goods are relatively cheaper compared to previously traded goods. If so then the second component of the index will not change from its period 0 value. In this instance, the overall price level in Mexico rises by less than the percentage of the devaluation since the price of good 1 and the prices of all nontraded goods are unchanged so that $\frac{S_t P_{t+j}^{US}}{P_{t+j}^{M}} > \frac{S_0 P_0^{US}}{P_0^{M}}$. Since the law of one price holds for each traded good, PPP holds but again the real exchange rate associated with PPP differs from its pre-liberalization value.

Case 3-Under a flexible nominal exchange rate regime, the adjustments are more complicated and impossible to specify since they involve joint movements in prices and the nominal rate. However, if we retain the assumptions that only Mexican prices adjust to restore the law of one price for each good and that the peso prices of nontraded goods are lower in the US than in Mexico prior to liberalization then by time t+k when all adjustments have occurred to restore PPP for traded goods, then the likely outcome is $\frac{S_{t+j} P_{t+j}^{US}}{P_{t+j}^{M}} > \frac{S_0 P_0^{US}}{P_0^{M}}$. We base this assertion on the likely decline of the overall price level in Mexico (denominator), as the peso prices of some newly traded goods fall to restore the law of one price and the peso is devalued thus raising the peso prices of goods in the US

(numerator). Once again, it can be seen that the real exchange rate associated with PPP almost certainly changes from its pre-liberalization level.

Thus a devaluation of the nominal exchange rate along with the reduction in trade barriers can account for the observed shifting mean of the real exchange rate over our sample. Clearly, any other change in the composition of the price index could also produce the described effects. Periodic revisions of the index that change the traded/non-traded goods proportions of the index or the imposition of trade barriers are two obvious examples.