Exchange-Rate Risk Mitigation with Price-Level-Adjusting Mortgages: The Case of the Mexican UDI

Authors

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Abstract

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In 1995, Mexico introduced a price-level-adjusting unit of account called the Unidad de Inversion (UDI). Loans denominated in UDIs maintain their purchasing power and provide a real rate of return in pesos. This study examines the real rate of return earned by dollar investors in UDI mortgages and the extent to which the inflation-adjusting aspect of the UDI mitigates losses from currency devaluations. Exchange-rate patterns relative to purchasing power parity are also examined to find investment strategies that increase the real-dollar rate of return on investments in Mexico's UDI mortgages.

Introduction

There is a housing shortage in Mexico that continues to worsen.[1] A major contributing cause is insufficient capital flowing into the Mexican mortgage market. The reasons are many, including the fact that the level of income is low and sources of income are unreliable for much of the population. The infrastructure for the mortgage market is much improved in recent years but remains inadequate, which exacerbates default and liquidity risks.[2] Default and inflation risks associated with long-term lending have been high in the volatile Mexican economy, which suffered from bouts of very high inflation and unemployment, and declining real wages in the 1980s and 1990s. A separate risk, exchange-rate risk, awaits foreign investors who might supply capital to the Mexican mortgage market by investing in peso-denominated mortgages. Each of these forms of risk has been reduced somewhat in recent years. The government has made an effort to reduce liquidity risk by working toward the development of a secondary mortgage market. Similarly, both default and inflation risks were reduced in 1995 when the Mexican government introduced an inflation-adjusting unit of account called the Unidad de Inversion (UDI).[3]

''The UDI can be thought of as a parallel currency that tracks inflation and is converted to pesos at the time of payment. This unit adjusts (in terms of pesos/UDI) daily with inflation and can be used to price investments and loans,'' (Softec, 2001). Mortgage loans denominated in UDIs eliminate the risk of loss in purchasing power for lenders/investors that fund from peso sources of capital. The UDI interest rate is low relative to the peso interest rate because the UDI rate has no component for expected inflation and no risk premium for unexpected inflation. Compared to other inflation-coping mortgages available in Mexico in the recent past, UDIs lessen the likelihood of mortgage default.[4]

It is the purpose of this study to show that UDI mortgages also reduce exchange-rate risk for mortgage lenders/investors that have foreign capital as their source of funding. If UDI mortgages can be shown to mitigate much of the exchange-rate risk for dollar investors, the flow of capital into the Mexican mortgage market might increase and more housing will be built. The research question is to what extent does the UDI's inflation-adjusting aspect mitigate the exchange-rate risk for dollar investors and can investment strategies based on the peso's strength relative to purchasing-power-parity (PPP) lead to real-dollar returns that equal or exceed real-peso returns on UDIs? If exchange-rate mitigation is significant, there is less need to enter into hedging strategies to protect against exchange-rate losses. Moreover, if UDI mortgages provide a natural mitigation or hedge of peso risk for dollar investors, that is one less impediment to the flow of capital into the Mexican mortgage market.[5]

The next section describes the mechanics of UDI mortgages including an example of the UDI mortgage payment and amortization calculation. In the following section, UDI mortgages are simulated to obtain the nominal and real rates of return in both pesos and dollars using Mexico's economic data from 1982 to 1998. This is followed by an examination of changes in the real-dollar return relative to the real peso return over a 17-year period. The purchasing-power-parity between the peso and the dollar is examined in an effort to establish an investment strategy for dollar investors to further mitigate exchange-rate risk. The final section is the conclusion.

Mechanics of UDI Mortgages

The UDI mortgage calculation provides a real-rate of return for the mortgage lender/investor. As an example, assume a homebuyer borrows 250,000 pesos to purchase a house. The loan will be cast in UDIs with an interest rate of 12%, which is fixed for the 15-year term of the loan. The homebuyer contracts to borrow the UDI equivalent of 250,000 pesos. For the purposes of this example, say that one UDI is worth one peso on the day the loan is made. Thus, the borrower contracts to repay 250,000 UDIs plus 12% interest in 15 equal annual payments.[6] Each payment of principal and interest is for the peso equivalent of 36,706.06 UDIs. Also for the purposes of this example, assume that inflation is 20% per

year in each of the 15 years of the loan. Although the payment is fixed in terms of UDIs, the peso value of the payment changes each year with the peso/UDI conversion index that is growing at the rate of 20% per year.[7]

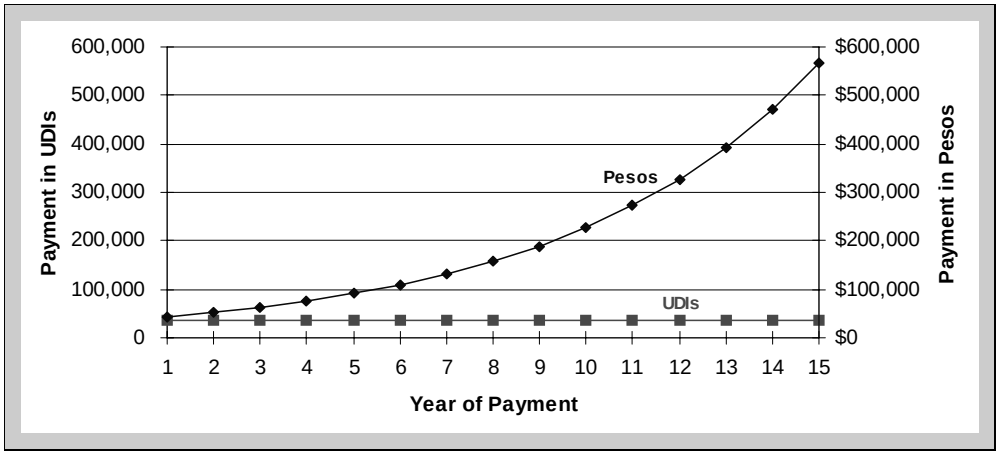
The first payment occurs one year after the loan is made. The borrower will consult the UDI conversion index to find the peso equivalent of an UDI on the day the payment is due. In the example, at the end of the first year, an UDI is worth 1.2 pesos, as indicated in Exhibit 1. Therefore the borrower will pay the lender 44,047.27 pesos (36,706.06 UDIs × 1.2 pesos per UDI). The second year, the borrower will pay 52,856.73 pesos (36,706.06 UDIs × 1.44 pesos per UDI). Following the first payment, the remaining balance of the loan is 243,293.94 UDIs. If the borrower wanted to prepay the balance at the end of the first year, he/she would pay 291,952.73 pesos (243,293.94 UDIs × 1.2 pesos per UDI). Exhibit 1

Exhibit 1 | UDI Amortization Example

End of Year	Payment in UDIs	Conversion Index	Payments in Pesos ($)	Loan Balance in UDIs	Loan Balance in Pesos ($)
1	36,706.06	1.200	44,047.27	243,293.94	291,952.73
2	36,706.06	1.440	52,856.73	235,783.15	339,527.74
3	36,706.06	1.728	63,428.07	227,371.07	392,897.21
4	36,706.06	2.074	76,113.69	217,949.54	451,940.17
5	36,706.06	2.488	91,336.42	207,397.42	516,071.16
6	36,706.06	2.986	109,603.71	195,579.06	583,995.93
7	36,706.06	3.583	131,524.45	182,342.48	653,366.08
8	36,706.06	4.300	157,829.34	167,517.52	720,294.68
9	36,706.06	5.160	189,395.21	150,913.56	778,680.84
10	36,706.06	6.192	227,274.25	132,317.13	819,272.80
11	36,706.06	7.430	272,729.10	111,489.13	828,373.55
12	36,706.06	8.916	327,274.92	88,161.76	786,059.13
13	36,706.06	10.700	392,729.90	62,035.11	663,733.57
14	36,706.06	12.839	471,275.88	32,773.27	420,782.04
15	36,706.06	15.407	565,531.06	—	0.00

Notes:
Loan Amount in Pesos = $250,000
Real Interest Rate = 12%
Term of Loan in Years = 15
Number of UDIs Borrowed = 250,000
Annual Payments in UDIs = 36,706.06
Annual Inflation Rate = 20%

Exhibit 2 | Mortgage Payments

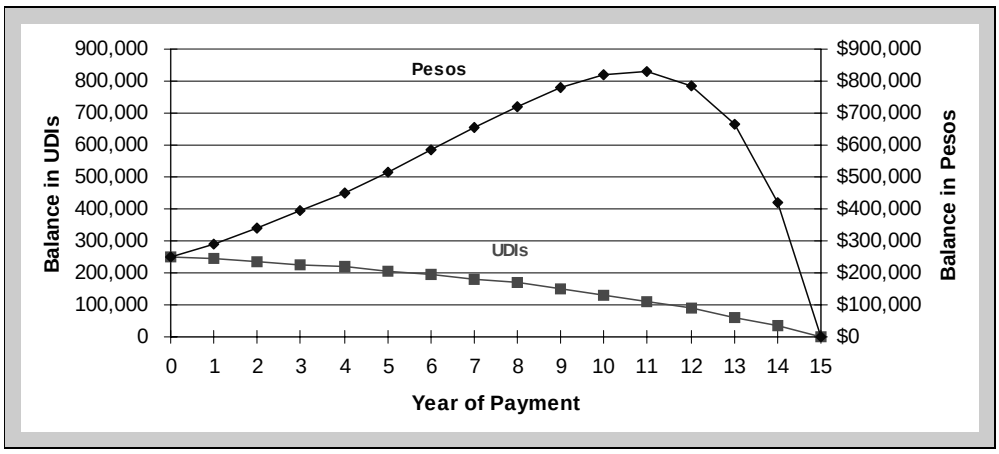


shows each of the 15 payments and their associated loan balances in terms of UDIs and in terms of peso equivalents.

Curves of the payments in UDIs and in pesos are shown in Exhibit 2. The payments are fixed at 36,706.06 UDIs over the life of the loan, but the peso value of the payments grows dramatically and peaks at the end of 15 years with a final payment of 565,531.06 pesos.

Exhibit 3 shows plots of the UDI and peso for the balances. The curve of UDI balances exhibits the typical appearance of an amortization pattern for constant-

Exhibit 3 | Loan Balance



payment fixed-rate loans. The decline in the UDI balance is continuous and accelerating. However, in terms of pesos, the balance increases initially until it peaks at 828,373.55 pesos following the payment in year 11. Then, the peso balance begins to decline and reaches zero following the 15th payment.

As a check to verify that the mechanics of the UDI mortgage result in a 12% real peso rate of return, the peso balance after the 14th payment, 420,782.04, can be multiplied by 1.20 to adjust for 20% inflation in the final year of the loan. Then, the inflation-adjusted balance can be increased by 12% to allow for interest that has accrued for the year. The result is \$565,531.06 (\$420,782.04 $\times$ 1.20 $\times$ 1.12), which is the same as the final peso payment that was originally calculated by multiplying the fixed UDI payment, 36,706.06, by the current UDI conversion index, 15.4070. This comparison illustrates that the inflation-adjusting mortgage-amortization scheme employed in the UDI system does in fact yield a real return in pesos at the specified interest rate. Thus, the lender has received a repayment of 250,000 real-pesos and a real-rate of return of 12%.

Simulation of Returns Using Mexico's Historical Inflation

The UDI system is modeled after the price-level adjusting mortgages (PLAMs) used in Brazil in the past, as described by Anderson and Lessard in Lessard and Modigliani (1975). The UDI mortgage loan process begins with the origination of the loan for a specified number of pesos. The loan originator establishes the term of the loan, the payment frequency and the real rate of interest, all of which are fixed for the life of the loan. The real rate is a combination of a real interest rate in the classic sense plus a risk premium appropriate to the particular mortgage loan. On the day the loan is originated, the peso value of the principal is translated into UDIs using the UDI Index. From that time forward, the principal balance of the loan is denominated in UDIs, and payments and the amortization schedule are calculated in UDIs. When payment is due, the number of UDIs owed is translated back into pesos, using the current value of the UDI Index. The UDI's value was initially set at one-to-one with the peso on April 4, 1995, and continues to increase over time with the Mexican Consumer Price Index. On the 10th and 26th of each month, the Bank of Mexico publishes the index of an UDI's value for the next 15 days. The value of an UDI changes daily. The UDI value as of October 25, 2002 was 3.18 pesos/UDI.

Mexican UDIs did not exist until April of 1995. However, in order to simulate the peso return that UDI mortgages would have earned had they existed as far back as January 1983, the actual inflation data is used to create a representative UDI Index. The inflation data used in this study begins in December 1982 with the Mexican Consumer Price Index (CPI) at 1.13 and ends in January 2001 with the CPI at 338.42.[8] Thus, a representative UDI Index that would have existed had Mexico initiated the UDI system in January 1983 can be created. Therefore, the representative UDI Index begins at 1.00 peso per UDI at the end of December

1982 and ends at 298.62 pesos per UDI on January 31, 2001. The representative UDI Index is plotted in Exhibit 4.

In each month of the study, an origination of a new UDI loan is simulated. The loan could be for any amount. The study assumes that there are no defaults. The loan has a real interest rate of 12% and a term of 15 years with monthly payments.[9] The origination of a new UDI loan is simulated at the beginning of each month between January 1983 and February 1997, a period of 170 months. Thus, there are 170 loans, each beginning in a different month.

The loan that is originated in January 1983 matures 15-years later, in December 1997. The loan originated at the end of January 1985 and all subsequent loans do not reach maturity, but prepay the remaining balance in December 2000. The last loan is originated at the end of January 1997, which allows 48 months of amortization before paying off the balance at the end of December 2000. All unpaid balances were accelerated at the end of December 2000 because that was the end of the data set. Calculating the IRR in UDIs confirms that the rate of return in UDIs, and therefore the real rate of return in pesos, is indeed 12%. Barring default, an UDI loan will always yield the intended real rate of return to peso lenders/investors.

Nominal payments are determined by multiplying the payment amount in UDIs by the number of pesos per UDI prescribed by the current value of the UDI Index. The nominal rate of return for each loan is calculated as the IRR of the peso cash flows. The nominal rate of return changes with each loan because it is a function of the changing rate of inflation. Exhibit 5 plots the nominal IRR for each of the 170 loans above the corresponding origination date.

The highest nominal-peso rate of return over the life of a loan, 65.36%, is a loan that originated in January 1983. The lowest peso rate of return was 25.18% on a

Exhibit 4 | UDI Index

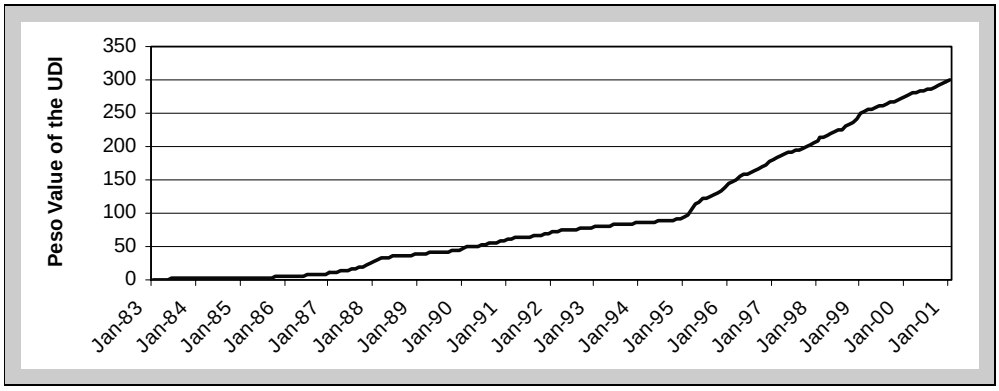
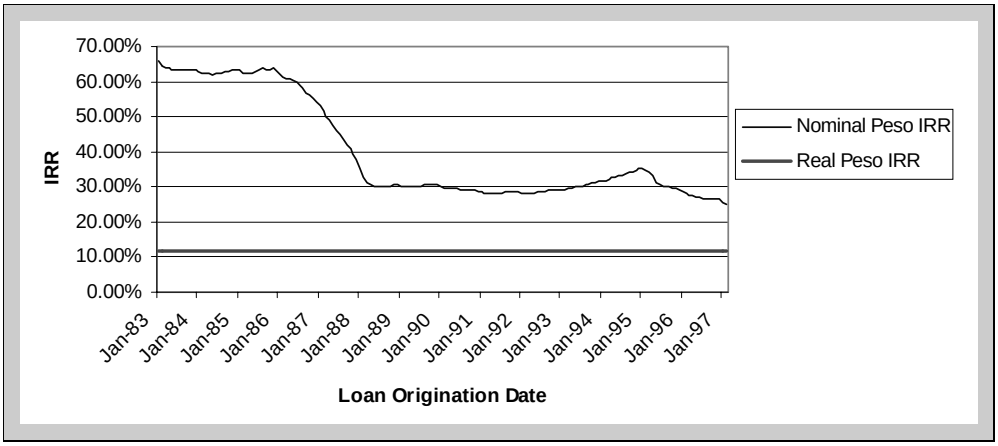


Exhibit 5 | Nominal and Real Peso Return



loan that was originated in February 1997. The nominal-peso return for 170 loans had a mean of 40.08% and a standard deviation of 14.56%. Between January 1983 and January 1986 the average nominal peso rate of return was 63.11%. During that same 3-year period, annual inflation in Mexico was 54.37%.

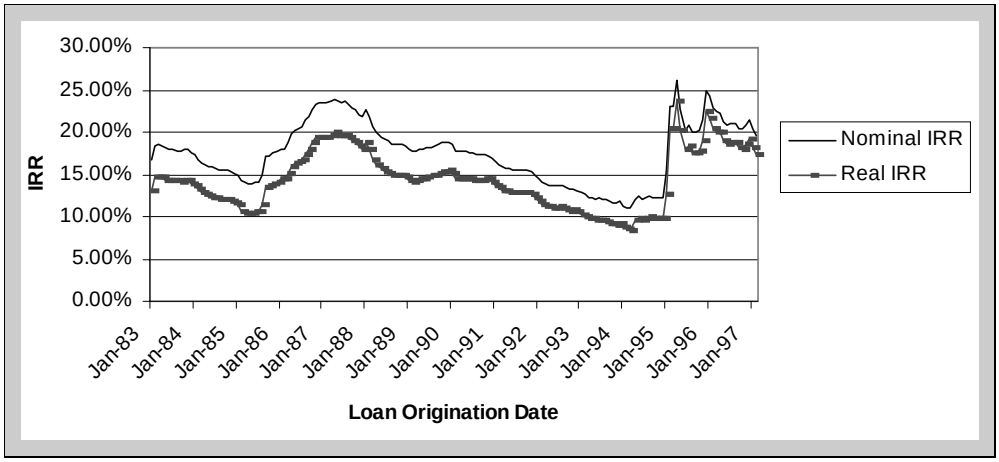
Dollar Returns

The exchange rate between the peso and the U.S. dollar was 0.02 pesos per dollar at the end of January 1983 and peaked at 10.21 pesos per dollar in September 1998.[10] It declined to 9.28 in August of 2000 and rose again to 9.77 by January 2001. With respect to the dollar, the value of the peso declined 99.01% in 18 years.

In the past, dollar investors have viewed exchange-rate risk as among the most serious impediments to investing in loans denominated in Mexican pesos.[11] To determine if such fears are warranted with respect to UDI investments, the peso cash flows for UDI mortgages are recalculated based on the dollar equivalent. Peso cash flows are translated into dollars at the prevailing exchange rate and the IRR is calculated to provide a nominal-dollar rate of return.[12] The real-dollar return for each loan was also calculated. The real rate is determined using the U.S. Consumer Price Index to adjust each dollar received to the value of a dollar on the day the loan was originated. Exhibit 6 shows the nominal rate of return and the real rate of return for dollar investors.

Clearly the nominal-dollar return is less than the nominal-peso return. On the other hand, the average real-dollar rate of return, 14.39%, is higher than the real-peso return of 12%. Exhibit 7 summarizes the rates of return in pesos and dollars and the inflation rates in both countries from 1983 through 2000.

Exhibit 6 | Nominal and Real Dollar Returns



Improving the Real-Dollar Rate of Return

No dollar investments in the simulated UDI mortgages lost money. The real-dollar return was 14.39% on average, which is higher than the 12% real-peso return. However, the standard deviation of the distribution of real-dollar returns was 3.45%, which is clearly less desirable than the zero standard deviation of the real-peso return. The wide variation in real-dollar returns is obviously a function of the changing exchange rate and inflation in the two countries. However, changes among those three variables (*i.e.*, the currency price and the two rates of inflation) may follow a predictable pattern, possibly creating an investment rule that can not only raise the average real-dollar return but lower the standard deviation of the distribution as well.

Exhibit 7 | Rates of Return and Inflation Rates

	Mexican Inflation	Peso IRR	Real Peso IRR	U.S. Inflation	Dollar IRR	Real-Dollar IRR
Average	41.41	40.08	12.00	3.70	17.52	14.39
Std. Dev.	43.41	14.56	0.00[a]	1.18	3.62	3.45
Max. Value	176.83	65.86	12.00	15.66	26.21	23.75
Min. Value	7.50	25.18	12.00	1.43	11.08	8.45

Note: All values are percentages.
[a]The standard deviation of the real peso IRR is zero because it never deviates from 12%.

In economic theory, purchasing power parity (PPP) suggests that exchange rates are a function of relative prices, so that (using the U.S. and Mexico as examples):

$$MP/USD = P_{mx}/P_{us} \quad (1)$$

where *MP* is Mexican Pesos, *USD* is U.S. dollars, P_{mx} is the Mexican price level and P_{us} is the U.S. price level. In the event that $MP/USD \neq P_{mx}/P_{us}$, this means that the average price (in terms of a common currency) of goods and services in one country is relatively lower than that in the other. This creates arbitrage opportunities that drive the system back to equality. PPP can be expressed both as levels (absolute PPP) and rates of change (relative PPP).

Despite its intuitive appeal, the empirical record of PPP is mixed at best. That said however, it has proved relatively more useful when at least one of the two economies examined has experienced high rates of inflation (Frenkel, 1978; Edison, 1985; Taylor and McMahon, 1988; McNown and Wallace 1989; Liu, 1992; and Zhou, 1997). Clearly, that is the case with Mexico, and, in fact, numerous studies have found support for PPP with respect to the specific case of the USD-MP exchange rate (*e.g.*, Ghoshroy-Saha and Van Den Berg, 1996).

The sample period in this study was from January 1983 through February 1997. The start date coincides with a prolonged period of market liberalization and an increasing international focus on the part of Mexican business leaders and policy makers (Cockcroft, 1998). Any conclusions drawn from an earlier period would be of questionable value to those wishing to invest in the future.

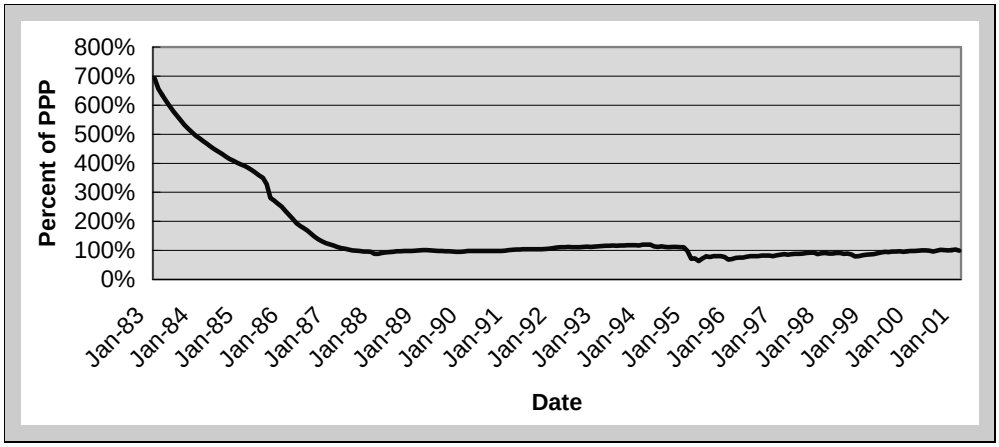
The following regression was estimated:

$$MP/USD = \underset{(0.746)}{0.608 + 14.08\,(P_{mx}/P_{us})} \quad (2)$$

where the parenthetical value is the asymptotic standard error.[13] If the values for P_{mx}/P_{us} are taken and the equation used to generate PPP values for the exchange rate, the peso is found to be overvalued (relative to PPP) from the beginning of the sample period (January 1983) through June 1987, undervalued from July 1987 through November 1990 (with a brief period of overvaluation from December 1988 to February 1989), overvalued again from December 1990 through November 1994 and undervalued from December 1994 through the March 2000 (see Exhibits 8 and 9).[14] From April 2000 the peso value vacillates only slightly above and below PPP until the end of the sample period in January 2001.

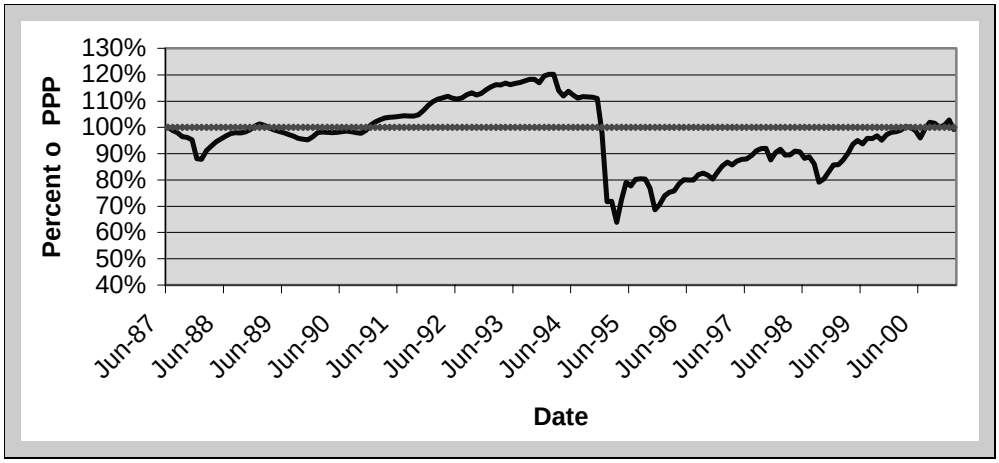
Returning to the goal of increasing dollar returns and reducing variability, if PPP holds in Mexico, then periods of undervaluation (again, relative to the predicted

Exhibit 8 | Actual Value of the Peso as a Percentage of PPP from January 1983 to January 2001



PPP value) should forecast peso appreciations and periods of overvaluation should anticipate peso depreciations. Hence a simple rule can be created using the ratio of the U.S. and Mexican price levels in combination with Equation (2) and the actual prevailing exchange rate. At its most basic level, that rule is to buy mortgages only when the prevailing MP/USD is greater than the PPP MP/USD. Take January 1993 as an example, a period during which economists were arguing that the peso was overvalued (just over a year after this Mexico would experience a major financial crisis partly because of that overvaluation). For that month, $MP/USD = 3.11$ and $P_{mx}/P_{us} = 0.212$. Inserting the latter into Equation (2) gives $(MP/USD)_{PPP} = 3.59$ (where $(MP/USD)_{PPP}$ is the exchange rate that would

Exhibit 9 | Actual Value of the Peso as a Percentage of PPP Beginning in June 1987



prevail if PPP held), implying that the peso was overvalued by some 15%. This would suggest **not** buying mortgages, as the anticipated peso depreciation will reduce the profitability of the investment in dollar terms. Indeed, a mortgage purchased that month would have earned 10.25%, markedly below the sample-period average of 14.39%. The same calculations for June 1996, however, yield $MP/USD = 7.54$ and $(MP/USD)_{PPP} = 6.03$, or a peso undervalued by 20%. Mortgages purchased that month would have earned 18.55%.

Exhibit 10 shows the inverse relationship between the value of the peso relative to the PPP and the real-dollar return relative to the real-peso return. Clearly the return on the dollar is greater when the peso is undervalued.

One can make the rule more or less restrictive, as tastes for risk warrant. Exhibit 11 shows the effect of setting a filter that requires the peso to be undervalued by particular levels before mortgages are purchased (in each case comparing those numbers to the alternative). Filter rules that dictated investing if the peso was undervalued by 3%, 5% and 10% were tested. As is evident from the exhibit regardless of which specific rule is adopted, the goal of increasing returns and lowering volatility is achieved an estimate of PPP is used as a guideline.

Recall that the original estimate of the PPP equation (the one used in the calculations for Exhibit 11) was based on data from January 1983 to January 2001. In reality, investors could not have made decisions in 1985, for example,

Exhibit 10 | Price of the Peso Relative to PPP and Real Dollar Return Relative to the Real Peso Return

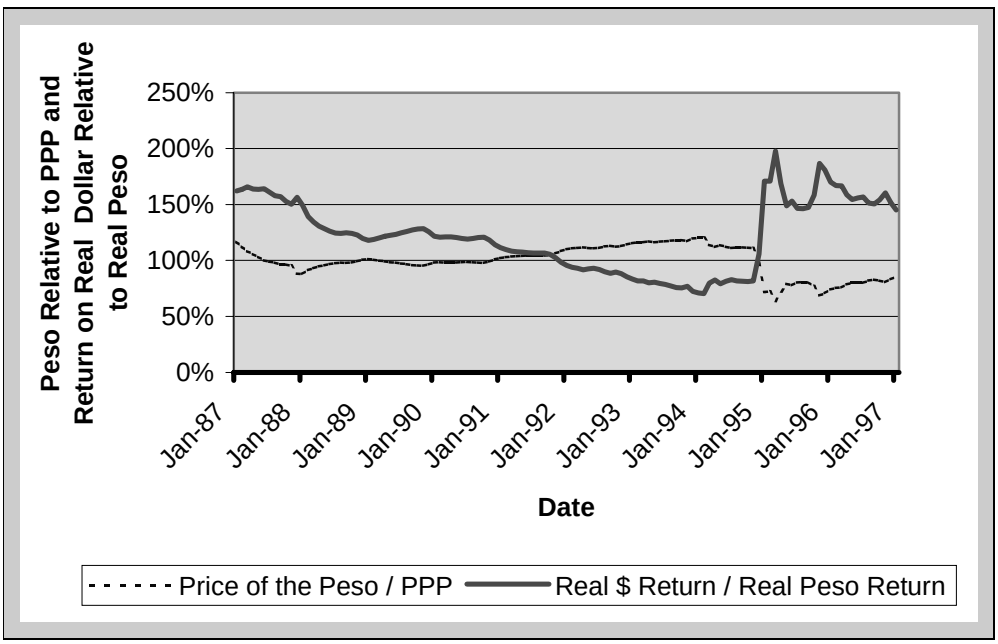


Exhibit 11 | Investment Rules and Related Returns, Using Whole-Period Estimate of PPP

Period	Min. (%)	Max. (%)	Average (%)	Std. Dev. (%)	Months
Total	8.45	23.75	14.39	3.44	170
Undervaluation	9.80	23.75	16.95	2.58	65
Overvaluation	8.45	19.91	12.81	2.92	105
Undervaluation ≥3.0% of PPP	12.70	23.75	18.19	2.15	41
Otherwise	8.45	19.91	13.18	2.85	129
Undervaluation ≥5.0% of PPP	12.70	23.75	18.79	2.00	31
Otherwise	8.45	19.91	13.41	2.89	139
Undervaluation ≥10.0% of PPP	12.70	23.75	19.00	1.94	28
Otherwise	8.45	19.91	13.48	2.91	142

Notes: Values are real-dollar rates of return.

based on future data (February 1985 through January 2001). In practice, investors are forced to work with PPP estimates derived only from data available at the time the decision is being made. Therefore Equation (2) was re-estimated with that in mind. For investment decisions made starting in January 1985, for example, an estimate of the equation was used based on the previous twenty-three months that were *available at that date*: January 1983 through November 1984. Exchange rate data are available without a lag, but CPI numbers in both countries are released during the following month, which means that January's CPI is not available until sometime in February.

One's first inclination is to update the PPP equation every month as new price and exchange rate data become available. However, economic theory would suggest otherwise. As PPP is considered to be a very long-term phenomenon, it is unwise to re-estimate the relationship with great frequency. Currencies **will** stray from PPP levels, and may do so for many years at a time; sample periods must be large enough to allow for corrections to have occurred. Thus, this study updated the estimates only after five additional years of data were available (still being careful not to include observations that would have been unavailable at the time).

Exhibit 12 shows the regressions as calculated at various points in the sample period. Recall that these numbers are used by investors to create the PPP exchange rate, against which the actual exchange rate is compared. The row of coefficients in the exhibit simply repeats Equation (2), included for comparison purposes. The next line shows an estimate for the January 1983 through November 1984 sub-period (as mentioned above). This would be employed by investors making decisions from January 1985 through December 1989. A new regression would then be run including data up to November 1989 (shown in the next line).

Exhibit 12 | PPP Estimates Using Past-Data Only: $MP/USD = \alpha + \beta (P_{mx}/P_{us})$

Period	α	β	Std. Error	Used to Forecast
1/83–2/97	0.608	14.080	0.746	NA
1/83–11/84	0.041	14.364	0.053	1/85–12/89
1/83–11/89	0.229	16.224	1.791	1/90–12/94
1/83–11/94	0.476	12.749	1.302	1/95–2/97

These numbers are used to create the PPP exchange rate from January 1990 to December 1994. Finally, the data are updated again to go through November 1994. The new estimate is used to guide investors from January 1995 to the end of the time period (February 1997).

Exhibit 13 is identical to Exhibit 11 except that determinations of the degree by which the peso is over or undervalued are based on PPP regressions that could have been run by agents of the investors at that time (the coefficients shown in Exhibit 12), using data for ''current'' currency prices and inflation indices. Nevertheless, Exhibit 13 shows that a significant improvement in both return and the variability thereof is had by choosing to buy Mexican mortgages only when the peso is undervalued.[15] The rule can, therefore, be employed by investors even under more realistic restrictions regarding the availability of data at the time that decisions must be made.

Exhibit 13 | Investment Rules and Related Returns, Using Pre-Investment Data Only

Period	Min. (%)	Max. (%)	Average (%)	Std. Dev. (%)	Months
Total	8.45	23.75	14.57	3.66	146
Undervaluation	11.35	23.75	16.85	2.48	92
Overvaluation	8.45	13.38	10.68	1.33	54
Undervaluation ≥3.0% of PPP	13.53	23.75	16.99	2.38	89
Otherwise	8.45	13.67	10.78	1.38	57
Undervaluation ≥5.0% of PPP	13.53	23.75	17.28	2.34	80
Otherwise	8.45	14.51	11.27	1.78	66
Undervaluation ≥10.0% of PPP	13.65	23.75	17.44	2.30	76
Otherwise	8.45	15.10	11.45	1.89	70

Notes: Values are real-dollar rates of return.

Conclusion

Enabling markets to function more efficiently, thus, providing the capital needed to better house the country's population, is an important goal of the Mexican government. The risks associated with investing in Mexican mortgages have been excessive, as evidenced by the country's historically high mortgage interest rates. Today, the few Mexicans who can access the formal mortgage market still pay an exceptionally high real rate of interest. This extreme cost of mortgage financing continues to reduce the quantity and quality of housing that Mexicans can afford. Thus, the solution is to reduce lenders' risk and uncertainty, which should in turn reduce mortgage interest rates, attract more capital and improve housing affordability.

Mexico could benefit greatly from an influx of foreign capital seeking to take advantage of the country's high real mortgage rates. However, international investors tend to fear exchange rate risks associated with peso investments. Between January 1983 and January 2001, the peso lost 99.01% of its value with respect to the U.S. dollar. This history of a near total loss in peso value raises concerns that the value of dollar investments in peso-denominated securities will be eroded, possibly to negative rates of return. This study demonstrates that the UDI mortgage has the potential to mitigate that risk, thus allaying some of the apprehension harbored by international investors considering investing in Mexican mortgages. The salient question is, does Mexico's price-level-adjusting UDI mortgage provide adequate exchange-rate risk mitigation or is the risk of exchange-rate loss too great for dollar investors?

To answer that question, the origination of UDI mortgages was simulated each month between January 1983 and January 1997 and they were treated as though the lender/investor was purchasing them with dollars. No external exchange-rate protection was provided. Only the implicit protection of inflation adjustments was in effect. The results indicated that the real-dollar rate of return was slightly greater on average than the peso return (14.39% compared to 12% per year). The difference was a net profit in the currency translations in and out of the peso. Although the dollar return may be high (depending on total risk), the standard deviation is also high, 3.45% per year, given that the real peso return exhibited a standard deviation of zero.

An examination of individual mortgages revealed the following: the real-dollar return ranged from a maximum of 23.75% to a low of 8.45%, even though the real-peso return was fixed at 12%. Noting that all of the deviation above and below 12% was attributable to exchange rate fluctuations, the study examined the consequences of investing only when the peso was weak with respect to the dollar. Mortgages were not purchased in any month in which the peso was strong.

To gauge the strength of the peso, its value was estimated based on purchasing power parity theory. Cointegration regression methodology was employed to estimate the theoretical exchange rate as indicated by PPP. A simple rule was

established that said to invest dollars in UDIs only when the peso was undervalued with respect to PPP. Following that simple rule, the average real-dollar return increased from 14.57% to 16.85%. At the same time, the standard deviation of returns fell from 3.66% to 2.48%.

Three times this rule was modified, investing when the peso was undervalued by at least 3%, then 5%, and finally, 10%. In each case, the average return increased and standard deviation decreased even more. As an example, if mortgages were purchased only when the peso was at least 10% undervalued, the return increased to 17.44% and the standard deviation reduced to 2.30%. The least restrictive rule, to invest whenever the peso is undervalued by any amount, limited investment opportunities to 92 of 146 months, or 63% of the time. The most restrictive rule, to invest only if the peso is undervalue by 10% or more, still allowed the investor to participate in the market in 76 out of 146 months.

The macroeconomic impact of numerous foreign investors following the strategy of buying UDI mortgages when the peso is undervalued should push the peso toward its PPP value. This in turn lowers the exchange rate profits that produce real-dollar returns that exceed real-peso returns. The real-dollar return would be driven closer to the real-peso return while simultaneously reducing the standard deviation. Similarly, a sizeable increase in the amount of foreign capital flowing into Mexico's UDI mortgages should drive down the real rate on UDI mortgages, thus making housing more affordable and mortgage financing more available.

The findings indicate that had they existed prior to 1983, UDI mortgages would have mitigated most of the exchange-rate risk between 1983 and 2000. Although UDI mortgages were not available in 1983, they are now and have been since the government introduced them in 1995. In future transactions the price-level-adjusting feature of UDI mortgages will mitigate much of the exchange-rate risk. However, there is no guarantee that the exchange-rate patterns of the past will repeat themselves. In the past fifteen years, the peso/dollar exchange rate has deviated from its theoretical value, eventually returning to PPP. As long as the relationship between PPP and the peso value continues to hold, dollar investments in UDI mortgages will not suffer significant exchange-rate losses.

Appendix

Many researchers have found that the time series used for modeling PPP are non-stationary. This means that data have trends, seasonal patterns or variances that change over time. When that is the case, a basic assumption regarding the asymptotic properties of the phenomenon in question is being violated. This can lead to serious errors, such as spurious regression.

As a consequence, the first step was to test the price levels and exchange rate for unit roots (*e.g.*, Dutton and Strauss, 1997; and Flores, Jorion, Preumont and Szafarz, 1999). This is shown in Exhibit 1A. The fact that the levels exhibit unit roots but the differences do not (regardless of how the equation is specified)

Exhibit 1A | Unit Root Tests (assuming an intercept)

Test	*MSN/USD*	P_{us}	P_{mx}	P_{mx}/P_{us}	10% Critical Value
Without Trend Levels ADF	−0.033	0.090	1.599	1.238	−2.88
1st Differences ADF	**−3.127 [8]**	**−2.994**	**−3.298 [3]**	**−3.540 [3]**	−2.88
With Trend Levels ADF	−2.469	−2.347	−0.427	−1.453	−3.44
1st Differences ADF	**−3.814 [7]**	**−3.598 [9]**	**−4.617 [3]**	**−4.365 [3]**	−3.44

Notes: ADF is Augmented Dickey-Fuller test statistic. Bolded entries reject the null hypothesis of a unit root (*i.e.*, non-stationarity) at the 5% level or better (if an entry below the variable name shows a value less than the critical one listed on the right then the null hypothesis is rejected). The number of lagged differences is twelve unless a bracketed number appears beside the test statistic, in which case that value is the lagged differences employed. These were selected using the criterion suggested by Campbell and Perron (1991) whereby a maximum value for the lagged differences was selected (twelve is the standard choice in monthly studies and thus served as the max) and then reduced by one until stationarity was achieved. As the ADF tests on levels never achieved stationarity, the results are reported using twelve lagged differences.

indicates that *USD/MP*, P_{us} and P_{mx} are I(1), or integrated of order one (note that the last proves to be integrated of order one only when trend is assumed).

This is, in one sense, bad news since it means that testing PPP using standard methods runs the risk of spurious regression. On the other hand, it is possible to test to see if a linear combination of such integrated series is stationary (meaning

Exhibit 2A | Johansen Cointegration Test: Exchange Rate and Price Ratio

Null	Likelihood Ratio Test	5% Critical Value
$r = 0$	**18.54**	15.41
$r \neq 1$	2.45	3.76

Notes: Data assume an intercept and trend. Bolded entries reject the null hypothesis of no cointegration at the 5% level or better (if an entry below the variable name shows a value greater than the critical one listed then the null hypothesis is rejected). Lagged intervals (pairs): 1, 10. Drawing again on Campbell and Peron (1991; see the documentation accompanying Exhibit 1), the test started with twelve and the number was reduced until the null hypothesis was rejected. There was, in any event, only a minor difference in the parameter estimates reported in Equation (2) regardless of the assumption we made with respect to lagged intervals. $r = n$ indicates null hypothesis of n cointegrating vectors.

that they are caused by a common process, a process that cancels out if estimated properly). If so, then statistical support **is** had for PPP, and an estimate of the relationship can be made. This is accomplished with a Johansen cointegration test (see Exhibit 2A).

Note that regardless of the particular assumptions made with respect to trend or the intercept, the exchange rate and price ratio series are cointegrated (*i.e.*, their non-stationarity is caused by a common process). This implies that at least a weak form of absolute PPP does hold for the USD-MP exchange rate. All estimates of the PPP relationship in the study employed the Johansen cointegration technique.

Endnotes

[1] In the 2000 Census, there were 97.3 million Mexican citizens living in 21.5 million households. The occupancy level is 4.5 persons in Mexico. That can be compared to 2.3 in the United States. The average size of houses in Mexico is 700 square feet, compared to an average of 1900 square feet in the United States. Moreover, of the 21.5 million houses in Mexico, approximately one-half are believed to be substandard due to age or inferior construction. Fewer than half the houses in Mexico are built in the formal market by developers or builders. Over half the housing in Mexico is self-built, meaning no developers or building companies were involved. The land on which self-built houses are built may or may not be owned by or titled to the persons building the house and not all, if any, utilities are available. Most of these units are not eligible for mortgage financing. The housing consulting firm, Softec, estimates that the potential market for housing will average approximately 1.6 million new units per year until 2010, but the actual production is likely to be 800,000 units, half built in the formal market and half self-built. The source of this information is Mexican Housing Overview 2002, published by Softec, S.C., 2001, Mexico City.

[2] Mortgage markets are underdeveloped because of deficiencies in infrastructure such as little or no credit reporting for individuals, no title insurance, no mortgage insurance, and problems with laws pertaining to foreclosure and assignment of liens. Moreover, there are economic problems that have affected the capital markets, particularly the market for long-term debt, especially home mortgages. A complete description of Mexico's mortgage market and its deficiencies as they existed in 1994 can be found in the Barry, Castañeda and Lipscomb (1994).

[3] Unidad de Inversion is Spanish for Unit of Investment. The acronym UDI is pronounced ''oo-dee.'' A clarifying example of the UDI mortgage with payment and amortization calculations is provided in the next section.

[4] The Lipscomb and Hunt (1999) study conducted a historical simulation of UDI mortgages using Mexico's economic data from 1982 to 1998. The study showed that had UDI mortgages been used in Mexico between 1982 and 1998, mortgage defaults would have been limited to a manageable level.

[5] Economic theory tells us that an inflation differential between two countries is one of the drivers of exchange rate changes, particularly when one country has significantly higher inflation. It stands to reason that an inflation adjusting investment would have the effect of offsetting some of the exchange rate losses. Similarly, exchange rate changes also reflect interest rate differentials between two countries. It is also well

recognized that exchange rate losses tend to be compensated for by higher interest rates, which has clearly been the case in Mexico.

[6] UDI mortgages normally require monthly payments. Annual payments were used in this example to keep it simple and to permit an observation of the character of each payment throughout the term of the loan.

[7] The actual UDI Index is tied to Mexico's inflation rate. The term ''conversion index'' is used instead of UDI Index in this example to avoid confusion later when an UDI Index is created for the simulation.

[8] A 29,862% increase in the CPI in just 18 years.

[9] At the time of this analysis, 12% per year was the real rate charged by GMAC Financiera. As of December 2002, that rate had dropped to 9.75% per year.

[10] The 1983 peso price is stated in terms of new pesos. In 1993, Mexico issued the new peso to replace the old peso. One new peso was worth 1000 old pesos.

[11] This information was gained from personal conversations with New York investment bankers operating in Mexico in 1993 and 1994.

[12] Exchange rate data from Banco de Mexico was used.

[13] Because the study discovered that USD/MP, P_{us} and P_{mx} were integrated of order one, it was necessary to use a Johansen cointegration test to estimate Equation 2. This is discussed in the Appendix.

[14] Because of scale issues in Exhibit 8, which is influenced by the extreme overvaluation of the peso from 1983 to 1986, Exhibit 9 is included, which begins in June 1987 when the peso is equal to PPP.

[15] The returns and standard deviations are not as favorable as those of Exhibit 11, but the number of months that the dollar investor is in the market is far greater.

References

Barry, C., G. Castañeda and J. Lipscomb, The Structure of Mortgage Markets in Mexico and Prospects for their Securitization, *Journal of Housing Research*, 1994, 5:2:173–204.

Campbell, J. Y. and P. Perron, Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots, *NBER Macroeconomics Annual*, 1991, 141–201.

Cockcroft, J. D., *Mexico's Hope: An Encounter with Politics and History*, New York: Monthly Review Press, 1998.

Dutton, M. and J. Strauss, Cointegration Tests of Purchasing Power Parity: The Impact of Non-Traded Goods, *Journal of International Money and Finance*, 1997, 16:3, 433–44.

Edison, H. J., Purchasing Power Parity: A Quantitative Reassessment of the Evidence from the 1920's, *Journal of International Money and Finance*, 1985, 4, 361–72.

Flores, R., P. Jorion, P-Y. Preumont and A. Szafarz, Multivariate Unit Root Tests of the PPP Hypothesis, *Journal of Empirical Finance*, 1999, 6, 335–53.

Frenkel, J. A., Purchasing Power Parity: Doctrinal Perspectives and Evidence from the 1920's, *Journal of International Economics*, 1978, 8, 169–91.

Ghoshroy-Saha, A. and H. Van Den Berg, Mexico's Futile Attempt to Defy Purchasing Power Parity, *Applied Economics Letters*, 1996, 3, 395–99.

Lessard, D. and F. Modigliani, Inflation and the Housing Market: Problems and Potential Solutions, In *New Mortgage Designs for an Inflationary Environment*, D. Lessard and F. Modigliani (Eds.), Federal Reserve Bank of Boston Conference, 1975.

Lipscomb, J. B. and H. Hunt, Mexican Mortgages: Structure and Default Incentives, Historical Simulation, 1982 to 1998, *Journal of Housing Research*, 1999, 10:2: 235–65.

Liu, P. C., Purchasing Power Parity in Latin America: A Cointegration Analysis, *Weltwirtschaftliches Archiv*, 1992, 128:4, 66–79.

Mexican Housing Overview 2002, published by Softec, S.C., Mexico City, 2001.

McNown, R and M. S. Wallace, National Price Levels, Purchasing Power Parity, and Cointegration: A Test of Four High Inflation Economies, *Journal of International Money and Finance*, 1989, 8, 533–45.

Taylor, M. P. and P. C. McMahon, Long-run Purchasing Power Parity in the 1920's, *European Economic Review*, 1988, 32, 179–97.

Zhou, S., Purchasing Power Parity in High-inflation Countries: A Cointegration Analysis of Integrated Variables with Trend Breaks, *Southern Economic Journal*, 1997, 64, 450–67.

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