Estimation of the Undervaluation of the Chinese Currency by a Non-linear Model

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Abstract

This paper conducts a quantitative estimation for the equilibrium value of the Chinese currency, the RMB, by a non-linear model. The model provides a better fit for the valuation of the Chinese currency, than the conventional linear or log linear specification models. Our regression reveals that the RMB was undervalued by 32% in 2004, and 25.3% in 2005. The estimates are more reasonable than the results from other results and are more consistent with general beliefs. The estimates provide important information about the likely change of the value of RMB in near future.

JEL classifications: F31, C31

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1. Introduction

The subject of the equilibrium value of the Chinese currency, the RMB, has become both an academic and political issue in the past several years. There have been different estimates. Goldstein and Lardy (2003) suggest that the RMB was undervalued by 15 to 25 percent. Chang and Shao (2004) estimate an undervaluation of 22.5% in 2003 by using a linear model with a control of heteroskedasticity. Frankel (2004) uses a double log linear model and find that the RMB is 36% undervalued in 2000. The U.S. Senate Bill by Charles Schumer (D., N.Y.) and Lindsey Graham (R., S.C.) implies that RMB is 27.5% undervalued, and called for a punitive duty of the same level of 27.5% on the Chinese imports.

There are some shortcomings with each of the above estimate. Goldstein and Lardy (2003) seem to give a rough estimate. They did not provide a model and did not offer a point value estimate. Chang and Shao (2004) use a linear model, but the actual relationship of the regression model seems to be nonlinear. Frankel (2004) uses a nonlinear model (the Rogoff specification), which regresses the log real exchange rate (RER) against log per capita income. However, the estimates from the Rogoff model could be even worse, as we will show, than those from the simple linear model.

In this paper I will suggest a new nonlinear specification for regression. It can be seen that this model fits the distribution of the observation better than either the linear or Rogoff models. In the following section I will discuss the data and set up the regression model. Section 3 provides the estimates and discusses the results. Section 4 is the conclusion.

2. Model and estimation

There are three basic approaches to estimate the equilibrium value of a currency. One is based on the supply and demand of the foreign exchange and current account balance. The result, at best, is the short-run equilibrium value. It is different from the long run equilibrium value of RMB, which is what the currency value supposed to converge. Another approach is estimating changes in the relative purchasing power parity (PPP). The problem with this approach is that the researcher has to start with a benchmark year, which is assumed to be the time period that the exchange rate is in equilibrium. This cannot be used for estimating the Chinese currency value, because, as commonly realized, that China had never been in a market system in the past, and there was not a reliable equilibrium bench mark year in the past for the exchange rate.

The third approach is using the absolute PPP. Fewer studies adopted this approach because the data were less available than those needed for calculating relative PPP. However, the data are available by calculating the difference between the GDP figures in exchange rate and in PPP, which are readily available from the World Development Indicator by the World Bank.

We let *e* stands for the nominal exchange rate, *p* for a country's domestic price, and *p** for the U.S. dollar price. The U.S. dollar is used as the international currency unit and thus the common denominator. The real exchange rate (RER) of the country's currency is $\mathrm{RER} = \frac{ep^*}{p}$. In a frictionless economic world, PPP with equal productivity across all sectors, the real exchange rates of all countries would be the same. However, because of the Balassa-Samuelson effect, the RER would be higher in poorer countries. [2] In other words, the currencies in the poorer countries tend to be undervalued at first glance without correcting the Balassa-Samuelson effect. The more reasonable equilibrium value of a currency should take into account the Balassa-Samuelson effect. The common approach is to regresses the RER across all countries on per capita GDP. Deviations form the regression line represent the currency's over or undervaluation. Figure 1 plots the RER against the income level of 160 countries in 2001, which are available in the World Development Indicator. Chang (2004) and Chang and Shao (2004) adopt a linear function specification, $\mathrm{RER}_i = a + b\,\mathrm{GDPpc}_i + \varepsilon_i$, where GDPpc stands for the GDP per capita, and ε_i the error term for country i. After a further control of the heteroskedasticity, they obtain the predicted RER at various per capita income level. Table 1 replicates their results.

Figure 1 plots the 160 observations in the sample with a linear fitted line. However, one can see from Figure 1 that the relationship between RER and income

[2] See Samuelson (1964).

apparently is not linear, but more of a nonlinear curve. Frankel adopts a double log form specification suggested by Rogoff: $\ln \text{RER}_i = a + b \ln \text{GDPpc}_i + \varepsilon_i$. The second last column from right shows the estimation results from this model. Figure 2 shows the curve from the regression and the observations. While the Rogoff specification is non-linear, it does not seem to be a better fit than the linear curve. The regression results appear to be out of line. For instance, it says that in 2003, China's currency RMB is 193% undervalued.

In this study I suggest a new specification for the relationship between RER and per capita income level as follows:

$$\text{RER}_i = c + (a + b\,\text{GDPpc}_i)^{-1} + \varepsilon_i$$

To estimate, we use the sample in Chang and Shao (2004), which includes only the country data from 2001 provided by the World Bank.[3] This sample still consists of 160 observations, enough for meaningful estimation. Because we use only the data of 2001, we avoid adding dummy variables for the possible structural shifts over time periods. Figure 3 plots the regression curve along with the original observations. The coefficient estimates of the regression are listed at the bottom of the table.

From a comparison among the three figures, one can see the new specification provides a better fit to the distribution of the observation. This is indeed the case as we compare the sum of squared errors (SSE) of the three regressions. The Rogoff double log model is the worst, with a value of SSE of 856.44. The straight linear model has the value of SSE of 539.86. The new nonlinear model reduces the SSE to 299.07. Apparently this specification offers a better description of the relationship between RER and the per capita income level.

We then obtain the predicted RER for each country by the estimated coefficients, which are shown in Table 2. The last column of Table 2 present the estimated overvaluation (+) or undervaluation (-) of RMB.

It can be seen that RMB had been overvalued prior to 1991, but became undervalued since that year. The undervaluation has become more substantial since the beginning of this century. In 2003, the undervaluation of RMB against dollar reached

[3] WDI online, Oct. 2003, the World Bank

its peak level of 35.3%. Note during the period of the past four years, the U.S. and many other countries pressed China to revalue its currency whenever there was a trade dispute with China. Our empirical test reveals that, regardless whether the revaluation would help to reduce their trade deficits with China, the argument that RMB was undervalued is valid.

An important change in the trend occurred in 2004, when the undervaluation of RMB started to diminish. In 2005, the undervaluation of RMB shrank by seven percentage points to 25.3%. The main reason is that there was a significant price increase (10.46%) in the GDP deflator. This can be easily derived from the difference in the nominal and real GDP growth index. What is interesting is that during the period the CPI grew by only 1.8 percent.[4] This may reflect the large gap in changes in the prices between GDP goods and the consumption goods of a household basket.

To make a comparison of the empirical results from different models, Table 3 presents the estimates for the undervaluation of RMB from four different models in one table. The Rogoff double log model does not provide convincing results, as it shows that the RMB has been undervalued more than 100% since 1987. The OLS linear model or the linear model with a control of heteroskedasticity yields similar results. The new non-linear model is also in line with the linear models in terms of the trend of the changes in the valuation of RMB, although the numerical values are quite different in some years.

3. Concluding Remarks

In this paper we suggest a nonlinear specification for estimate the long-run equilibrium value of RMB, after controlling the Balassa-Samuelson effect. Our model provides a much better fit for the data than the previous models including the linear models and the Rogoff double log model. The Rogoff model was rejected because it fails to provide a good fit for the data, and, it does not provide a convincing conclusion about the valuation of RMB against the international currencies. The estimates for the

[4] According to the State Statistical Bureau Annual Statement, the nominal GDP for 2004 and 2005 are 159878 yuans and 182321 yuans respectively. The real growth rate is 9.9. Hence the implicit GDP deflator is 10.46%. This seems to be a surprising jump, when the CPI is only 1.8%. According to the government, this may reflect the surge in GDP product prices such as finished houses as compared with a moderate increase in the prices of consumption goods.

valuation of RMB from the linear model are in general consistent with the general belief about the valuation of RMB. However, the relationship between per capital income level and RER is apparently nonlinear. Hence, the linear model does not fit the distribution of the data well, especially for those observations far away from the mean of the per capita income. The estimates for the undervaluation of RMB by our new nonlinear model is in general consistent with the results of the linear models, but the results are more accurate because that model describe the implied relationship better, and, has a much better fit for the world data.

Our results, reported in Table 2, show that the RMB was overvalued in 1970s and 1980s but become undervalued in 1990s and 2000s. Admittedly, the predicted figures in 1970s and 1980s are less accurate, because the economic structure in those periods may be different from that in 2001, the year from which we obtained the estimated parameters. However, these predicted figures still seem to fit the conventional beliefs about the dynamic changes in the RMB values. We see the RMB was substantially overvalued prior to 1986. In 1986 China introduced the dual exchange rate regime, and at the beginning of 1994, China unified the exchange rates. This explains why the RER abruptly changed in those two years. After 1998, the under-valuation has tended to increase. Two forces are behind this trend. First, the RER grows due to low inflation or even deflation during this period in China. Secondly, the predicted RER declines because of rapid economic growth.

Our results further confirm that the RMB has been undervalued in the range of 25% to 35% in the past four years. In July, 2005, China announced to abandon the *ad hoc* dollar-peg exchange rate system, and since then China allows RMB to adjust within a moderate range to respond to the market. What is the future of RMB? On one hand, we can anticipate two forces that will push a real revaluation of RMB, or, to reduce the extent of undervaluation of RMB. The first force is the nominal revaluation. For instance, since July 2005, the RMB exchange rate has already cumulatively revalued by 3.2 % from the previous 8.27 yuans to one dollar to 8.01 yuans to one dollar. The second force is the difference in the inflation rates between China and U.S. The undervaluation of RMB will cause a foreign capital inflow, thus causing the monetary base to increase, and adding pressure to the price level. The surge in the prices of new houses and construction material in China during the period of 2003 and 2004 is one example. For instance, in 2005, the inflation rate measured by the GDP deflator is much higher in China than that in the U.S., which has effectively revalued the RMB in the real term. On the other hand, we also anticipate a counter force against a real revaluation of RMB. As the Chinese economy grows and GDP per capita increases, the Balassa-Samuelson effect diminishes. Hence, *ceteris perabus*, the estimated undervaluation by our model will intensify. The net result of the change in the valuation of RMB will depend on the the relative magnitudes of these positive and negative forces. However, one can expect that the market force will prevail once the RMB is moving to a more flexible regime; hence, we can be confident to predict that the revaluation that will correct the current undervaluation of RMB is the trend in near future. The reduction of the undervaluation of RMB in 2005 has supported this prediction.

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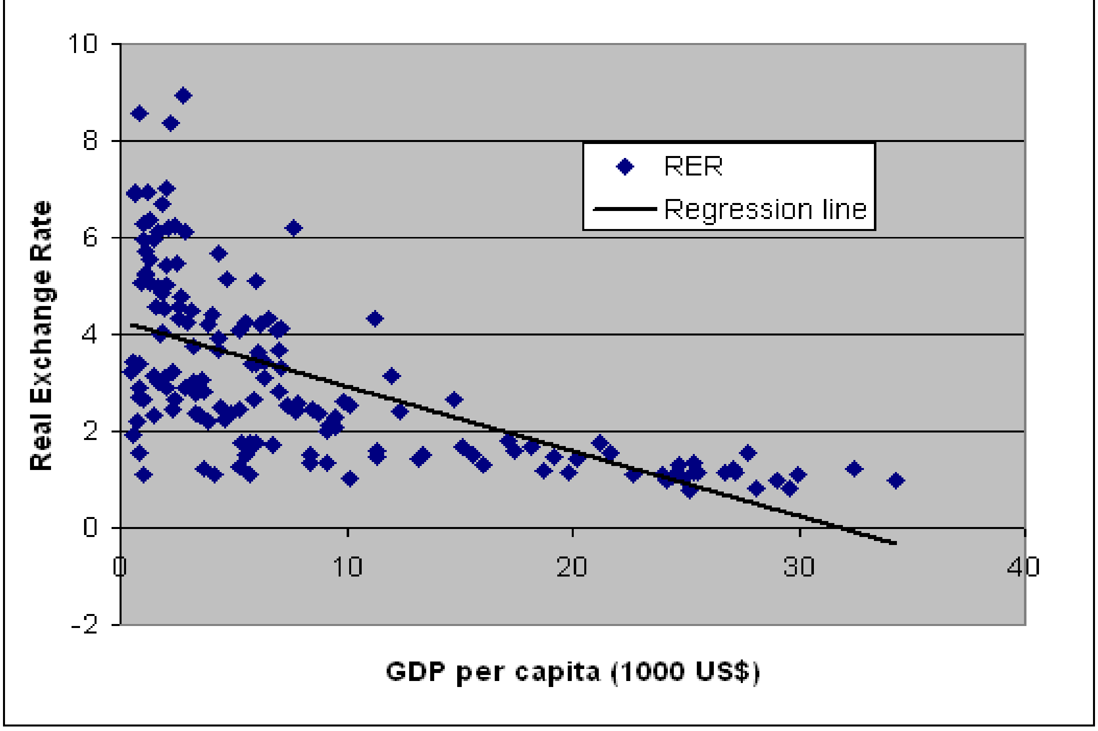
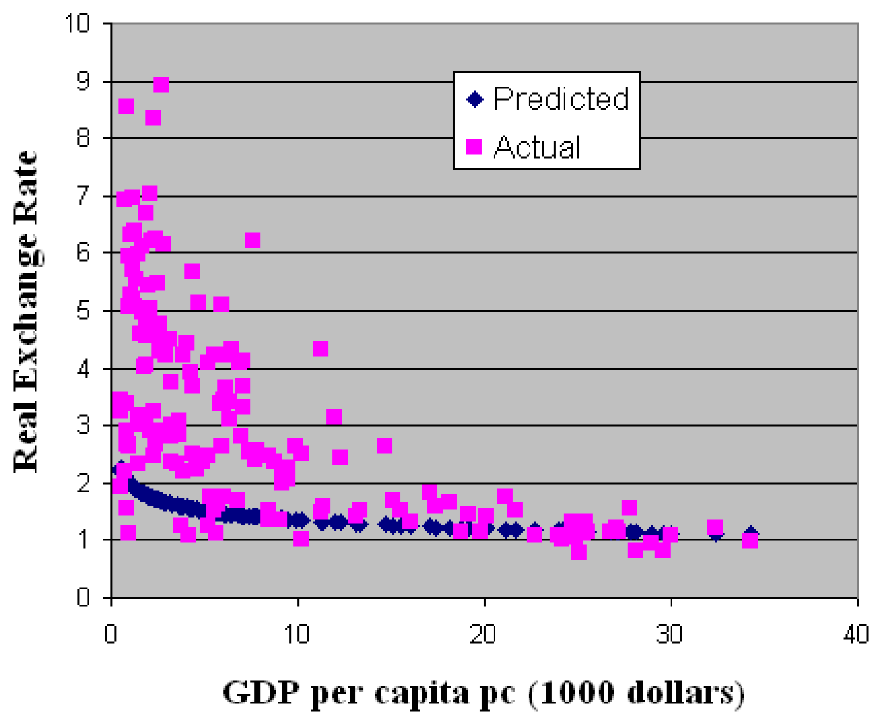
Fig 1. Real Exchange Rate (RER) of Various Countries



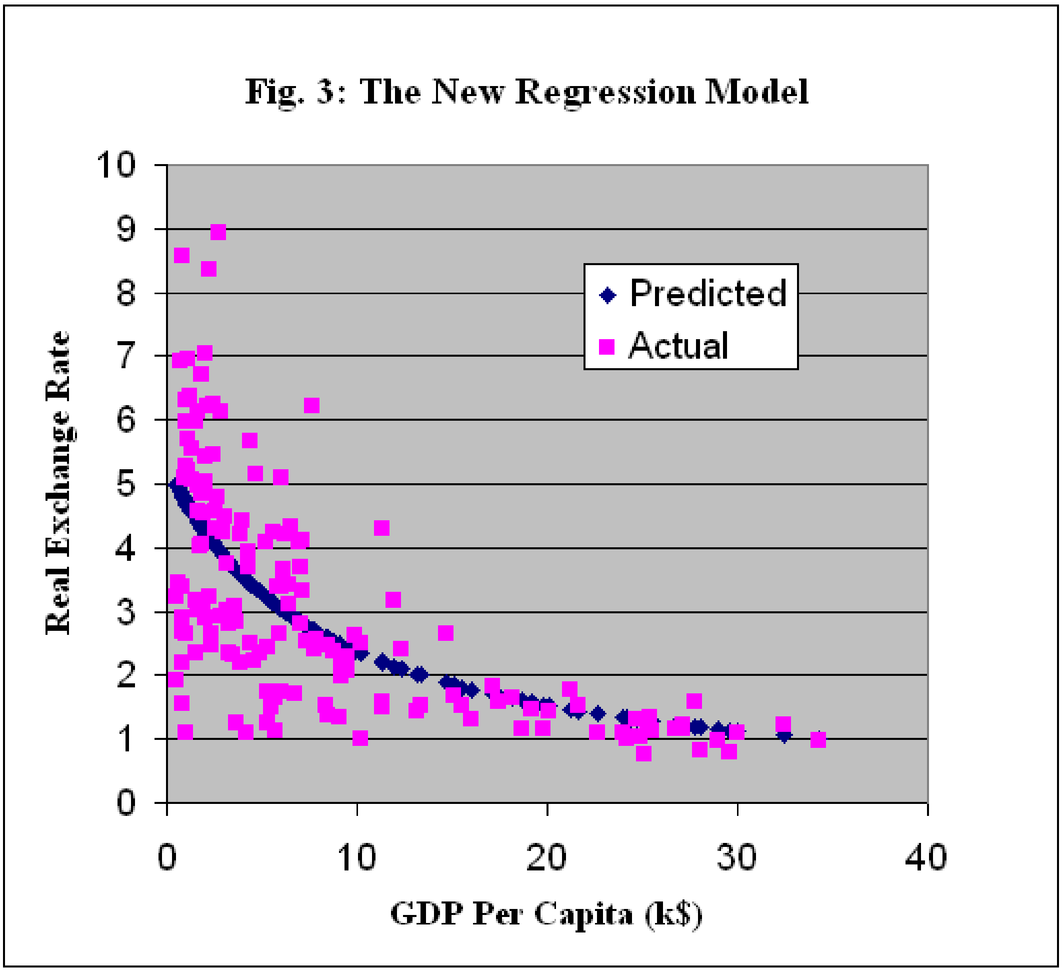
			OLS	Coefficients	Standard Error	t Stat
Observations	160		Intercept	4.28039	0.15922	26.88387
Sum of Square Errors	539.8581		GDPpc/1000	-0.13386	0.01320	-10.14495

Fig. 2: Fitted Regression Line by the Rogoff Specification



Regression Function:	log RER = a + b log GDPpc/1000		
Observation: 160			
Coefficients	a	b	
	0.68742	-0.38561	
Sum of Squared Errors of the log RER values:			11.105
Sum of Squared Errors of the true values*:			856.44

*Note: To obtain this value, we first recover the predicted true value of RER, then obtain the sum of squared errors between the actual and true predicted values of RER.



Regression function:	RER = c + (a + b GDPpc/1000)^(-1) + ε			
Observations 160			Sum of squared errors:	299.0869
Estimated coefficients	a	b	c	
	0.18903852	0.023503552	0.010	

Table 1: Real Exchange Rate (RER) of Selected Currencies (2001) by a Linear Regression with a Control of Heteroskedasticity

Parameters	a	b	c	d	
Estimates	4.15608	-0.12034	1.53060	-0.02244	

	Per capita	Real Exchange Rate		Over(+) Under(-)	
Country	**GDP 2001**	**Actual**	**Predicted**	**valued**	**P-value**
Kyrgyz Republic	2750	8.92	3.83	-133.2%	0.000
Belarus	7620	6.22	3.24	-91.9%	0.014
Cambodia	1860	6.70	3.93	-70.3%	0.032
Congo, Dem. Rep.	680	6.91	4.07	-69.6%	0.031
India	2840	6.14	3.81	-60.9%	0.057
Ukraine	4350	5.68	3.63	-56.3%	0.077
South Africa	11290	4.31	2.80	-54.1%	0.118
Vietnam	2070	5.03	3.91	-28.6%	0.225
Bulgaria	6890	4.08	3.33	-22.6%	0.293
China	**4020**	**4.41**	**3.67**	**-20.1%**	**0.304**
Bangladesh	1610	4.58	3.96	-15.7%	0.339
Philippines	3840	4.21	3.69	-14.1%	0.359
Indonesia	2940	4.23	3.80	-11.3%	0.384
Italy	24670	1.31	1.19	-10.6%	0.449
Thailand	6400	3.42	3.39	-0.9%	0.491
Russian Federation	7100	3.32	3.30	-0.4%	0.496
Hungary	12340	2.42	2.67	9.4%	0.421
Hong Kong, China	24850	1.03	1.17	11.5%	0.445
Finland	24430	1.05	1.22	13.8%	0.432
France	23990	1.08	1.27	14.6%	0.426
Sweden	24180	1.03	1.25	17.8%	0.411
United Kingdom	24160	1.00	1.25	20.1%	0.400
Korea, Rep.	15090	1.69	2.34	27.7%	0.293
Japan	25130	0.77	1.13	31.9%	0.354
Kuwait	18700	1.17	1.91	38.9%	0.253
Saudi Arabia	13330	1.53	2.55	40.1%	0.203
Zambia	780	2.19	4.06	46.0%	0.109
Venezuela, RB	5670	1.12	3.47	67.9%	0.047
Congo, Rep.	970	1.10	4.04	72.8%	0.026

Note: This table replicates Table 1 of Chang and Shao (2004). Note the data was from WDI online 2003, hence the actual RER for China is slightly different from the other tables which are based on the WDI online 2006.

Table 2: Real Exchange Rate (RER) of China

Year	Per capita GDP 2001	Real Exchange Rate Actual	Real Exchange Rate Predicted	Over(+) Under(-) valued
1975	585	1.28	4.94	74.0%
1976	567	1.42	4.95	71.3%
1977	601	1.43	4.93	71.0%
1978	662	2.00	4.90	59.2%
1979	704	1.96	4.87	59.8%
1980	749	2.15	4.85	55.8%
1981	779	2.41	4.83	50.1%
1982	835	2.66	4.80	44.6%
1983	911	2.72	4.76	42.9%
1984	1035	2.88	4.70	38.7%
1985	1161	2.84	4.63	38.8%
1986	1248	3.26	4.59	28.9%
1987	1371	4.13	4.53	8.9%
1988	1502	4.15	4.47	7.2%
1989	1538	4.02	4.45	9.7%
1990	1570	4.17	4.44	6.0%
1991	1692	4.44	4.38	-1.4%
1992	1912	4.68	4.28	-9.3%
1993	2151	5.28	4.18	-26.1%
1994	2394	4.83	4.09	-18.1%
1995	2656	4.28	3.99	-7.4%
1996	2876	4.09	3.91	-4.8%
1997	3088	4.10	3.83	-7.1%
1998	3315	4.27	3.76	-13.7%
1999	3506	4.41	3.69	-19.5%
2000	3756	4.46	3.62	-23.5%
2001	4020	4.53	3.54	-28.0%
2002	4305	4.59	3.46	-32.7%
2003	4647	4.55	3.36	-35.3%
2004	4999	4.32	3.27	-32.0%
2005*	5462	3.96	3.16	-25.3%

* estimates

Sources of data: For period from 1975-2003, from WDI on line, April 2006
Data after 2003 are adjusted by using the updated information from Chinese
Statistical Bureau Website Database.

Table 3: Comparison of the Estimates of Undervaluation from Various Models

Year	Linear OLS	Linear control of heteroskedasticity	Rogoff Log model	New non-linear model
1975	69.4%	66.7%	41.0%	74.0%
1976	66.2%	64.8%	35.0%	71.3%
1977	66.0%	65.5%	34.0%	71.0%
1978	52.3%	51.3%	6.2%	59.2%
1979	53.2%	50.8%	7.2%	59.8%
1980	48.7%	44.9%	-2.8%	55.8%
1981	42.3%	40.2%	-16.2%	50.1%
1982	36.2%	36.8%	-29.7%	44.6%
1983	34.7%	38.5%	-34.5%	42.9%
1984	30.5%	33.8%	-45.6%	38.7%
1985	31.3%	33.3%	-46.2%	38.8%
1986	20.7%	19.7%	-70.2%	28.9%
1987	-0.7%	-8.9%	-118.8%	8.9%
1988	-1.6%	-13.6%	-123.2%	7.2%
1989	1.4%	-4.4%	-117.1%	9.7%
1990	-2.5%	-5.0%	-126.2%	6.0%
1991	-9.6%	-11.2%	-143.9%	-1.4%
1992	-16.3%	-19.7%	-162.4%	-9.3%
1993	-32.2%	-35.2%	-201.7%	-26.1%
1994	-21.9%	-24.3%	-181.0%	-18.1%
1995	-9.1%	-12.6%	-153.6%	-7.4%
1996	-5.1%	-7.4%	-145.8%	-4.8%
1997	-6.1%	-6.1%	-149.3%	-7.1%
1998	-11.3%	-8.9%	-162.4%	-13.7%
1999	-15.8%	-14.3%	-173.9%	-19.5%
2000	-18.2%	-18.4%	-180.2%	-23.5%
2001	-21.0%	-20.1%	-187.5%	-28.0%
2002	-23.8%	-23.2%	-194.6%	-32.7%
2003	-24.4%	-22.5%	-196.0%	-35.3%
2004	-19.6%	-19.2%	-184.4%	-32.0%
2005*	-11.5%		-164.6%	-25.3%