Purchasing Power Parity: Granger Causality Tests for the Yen-Dollar Exchange Rate

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Abstract: The paper analyses the causality between the Japanese-US relative export prices and the yen-dollar exchange rate. It explains why the Japanese yen proved strong even during the economic slump of the 1990s. The paper suggests that the appreciation of the Japanese yen forced the Japanese enterprises into price reductions and productivity increases, which put a floor under the high level of the yen and thus initiated rounds of appreciation. This corresponds to the conjecture of a vicious (virtuous) circle of appreciation and price adaptation.

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1 Introduction

The 1990s have been a period of contradictory exchange rate development for the Japanese yen. Despite the deep and sustained recession in Japan, the yen proved extraordinarily strong. The combination of low interest rates, weak domestic activity and a strong currency has been regarded as puzzling.

While the impact of international capital flows on exchange rates has recently earned attention, the impact of prices on the yen exchange rate has been neglected. Although international capital flows doubtlessly drive exchange rates in the short run, a strong correlation between the yen-dollar exchange rate and relative Japan-US tradable prices can also be observed.

The fact that relative purchasing power parity holds true for the Japanese yen in the case of traded goods does not say anything about causation. Do capital market-driven exchange rate movements influence the pricing behaviour of export enterprises, or does the pricing behaviour on international markets influence the exchange rate?

This paper reconsiders the impact of prices on the exchange rate. It tests causality between the yen-dollar exchange rate and Japanese tradable prices on the basis of both aggregated and disaggregated Japanese export price data.

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The results provide evidence that the pricing of the Japanese export industry between 1973 and 2000 was influenced by the exchange rate. This corresponds to the pricing to the market behaviour of the Japanese export industry. International capital flows cause the yen to appreciate and the (export) industry to adapt prices and productivity.

Further, tests on the basis of disaggregated industry data show that certain industries have lowered their prices more than necessary to adapt to the appreciation and thus put additional appreciation pressure on the yen exchange rate. Both results together give evidence for a vicious (virtuous) circle of yen appreciation and price adaptation.

The paper is divided into six sections. Section 2 discusses the general causality between prices and exchange rate. Section 3 reviews the respective research on the determinants of the Japanese yen exchange rate. After data description in section 4, Granger tests estimate cause-and-effect-relationship between Japanese export prices and the yen-dollar exchange rate in section 5. Conclusions will be drawn in section 6.

2 Cause-and-Effect Relationships between Prices and Exchange Rate

The concept of purchasing power parity (PPP) is widely attributed to Cassel (1916: 62), who suggested that the exchange rate of two currencies is determined by the price levels of the two countries (absolute PPP). Due to problems in specifying comparable price indices in two countries, the majority of the empirical literature tries to verify the relative version of PPP. This version says that a decrease (increase) in the domestic price level in comparison to that abroad is accompanied by a proportionate appreciation (depreciation) of the home currency.

Although in their survey of PPP literature Froot and Rogoff (1995: 1648) conclude that "*[relative] PPP is not a short-run relationship*" and "*price level movements do not begin to offset exchange rate swings on a monthly or even annual basis*," there is evidence that relative PPP holds for the yen-dollar exchange rate on a quarterly basis if it is based on the price indices of exclusively traded goods (Schnabl 2001). Pigou (1920) and Viner (1937) had already made this proposition.

Even if PPP holds true for the prices of traded goods, there is no indication of causality. Does relative price stability (inflation) cause an appreciation (depreciation) or does appreciation (depreciation) trigger price adjustments? For empirical OLS investigations question arises as to whether the exchange rate should be defined as an exogenous or endogenous variable.

In his original formulation of PPP Cassel (1916: 62) saw the exchange rate as "*an expression for the value in the money of one country put upon the money of another country*." He defined the exchange rate as relative quantities of money and translated it via the quantity theory of money into a relationship between prices. "*The conclusion is that the exchanges are […] governed essentially by the degree of inflation of the different monetary systems*." (1916: 64).

Following the approach of Cassel, authors like Krugman (1978) and Giovannini (1988) used the prices as an exogenous variable in their regressions and estimated the influence on the exchange rate. Frenkel (1976) examined the relationship between money, prices and the exchange rate for the German hyperinflation. He came to the conclusion that money and prices have a significant impact on the exchange rate.

In "*contradiction to the popular purchasing power parity theory of exchange*" Einzig (1935: 40) argued that changes in exchange rates produce changes in relative prices. He based his assumption on the observation that during the First World War price levels in the neutral countries rose less than in the countries at war because of the firm tendency of their exchange rates.[1]

Einzig's observation corresponds to the notion that in a system of flexible exchange rates appreciation (depreciation) of a country's currency leads to a decrease (increase) in the general price level because of their impact on domestic activity. An appreciation (depreciation) dampens (stimulates) domestic activity, inflation is curbed (accelerated) and the central bank will adapt monetary policy by slowing (accelerating) monetary expansion.

Besides domestic activity, import prices can act as a transmission channel from the exchange rate to domestic (general) prices as outlined by Hafer (1989). Given constant export prices of the foreign exporter, an appreciation (depreciation) lowers (raises) the prices of imported goods in domestic currency. This puts a downward (upward) pressure on the domestic general price level for three reasons: First, imported goods make up part of the basket of consumer goods. Second, changed import prices trigger price reactions of domestic competitors because of substitution relationships. Third, prices of imported inputs for domestically sold products are altered.[2]

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1 The notion that causation goes from the exchange rate to prices is in accordance with Frenkel's (1981) view that exchange rates are determined on the asset markets and prices just adapt. As McKinnon and Ohno (1997: 181) attribute in this context, adverse causality is also possible. If the exchange rate is interpreted as a forward variable that anticipates future autonomous changes in the fundamentals, the true causality is again from prices to the exchange rate, although the exchange rate alteration precedes the alteration of prices.

2 In practice although generally assumed as true, most empirical studies only find weak support for this relationship (see Hafer (1989) as well as Parsley and Popper (1998)).

Finally, the exchange rate can affect domestic prices through export prices due to incomplete pass through and productivity adjustments. According to Menon (1995) exchange rate innovations are (at least partially) reflected in the selling prices of traded goods. In the case of appreciation, the enterprises are tempted to reduce export prices in domestic currency to stay competitive in the international market.

As attributed by Mann (1986), the imperfect shifting behaviour in reaction to exchange rate changes can be compensated by profit margins in the short-run. If profit margins are to be held constant in the long run however, productivity adjustments are necessary. Since such productivity increases are commonly not restricted to internationally traded goods, but also affect the prices of the same goods sold domestically, an appreciation would also put a downward pressure on domestic (wholesale) prices.

Taking into account that both directions of price-exchange rate causality have their own rationality per se, empirical testing of cause-and-effect relationships is of special interest. The relatively small number of empirical investigations come to differing results:

Pippenger's (1995) Granger causality tests for the Swiss franc exchange rate and Swiss wholesale prices for the flexible exchange rate period from 1973 to 1988 find evidence for a causation from prices to the exchange rate in the sense of Cassel. This finding is supported by Cheng (1999) who examines the causality between yen and dollar for the 1951-1994 period. He concludes that there is a long-run causality from relative US-Japan consumer prices to the yen-dollar exchange rate.

Kholdy and Sohrabian (1990) test Granger causality between prices and US dollar exchange rates of DM, yen and Canadian dollar for the period from 1973 to 1988. They find a unidirectional causation from the exchange rate to Canadian wholesale prices as stressed by Einzig. For Germany and Japan the causation between wholesale prices and exchange rates is classified as bi-directional.

The differing results of the tests make two conclusions possible. First, many authors like Frenkel (1976: 203) and Krugman (1978) argue that it is difficult to regard neither prices nor exchange rates as properly exogenous. Instead it is assumed that exchange rates and prices affect each other and are contemporaneously determined.

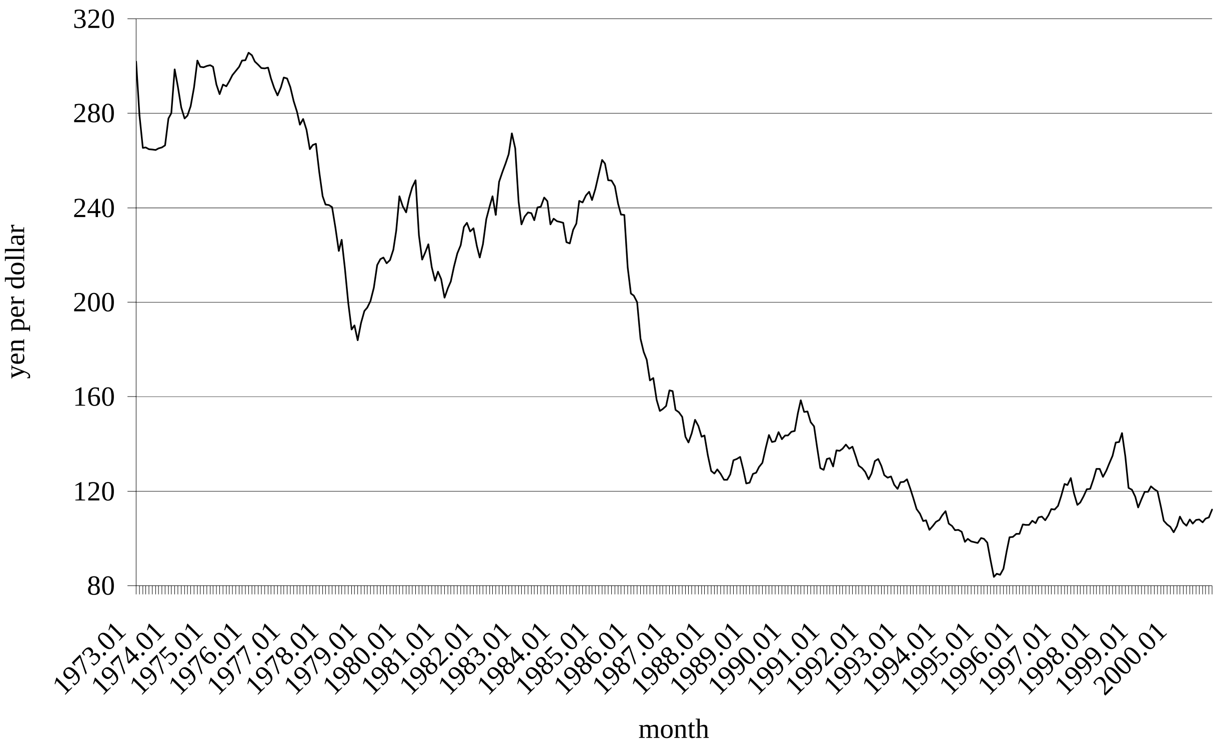
Second, the different results of the particular tests might indicate that the causation between prices and currency depends on the currency, the specific economic conditions and the respective time period. The influence of the exchange rate on the general price level might depend on the attitude of the central bank. While central bank A conducts its monetary policy only with regard to domestic economic conditions, central bank B might find it important to take the exchange rate into account.

To know how the specific economic environment in Japan has influenced the yen exchange rate, Japanese export enterprises and the attitude of the Bank of Japan has to be further scrutinised.

3 Empirical Evidence for the Japanese Yen

What was generally said about empirical tests of general PPP is also true for the explanation of the yen exchange rate. Most empirical tests based on GDP deflators, consumer prices or wholesale prices find little evidence that relative PPP holds for the yen exchange rate as a short-term relationship.[3]

Figure 1: Yen-Dollar Exchange Rate



Source: IMF: IFS.

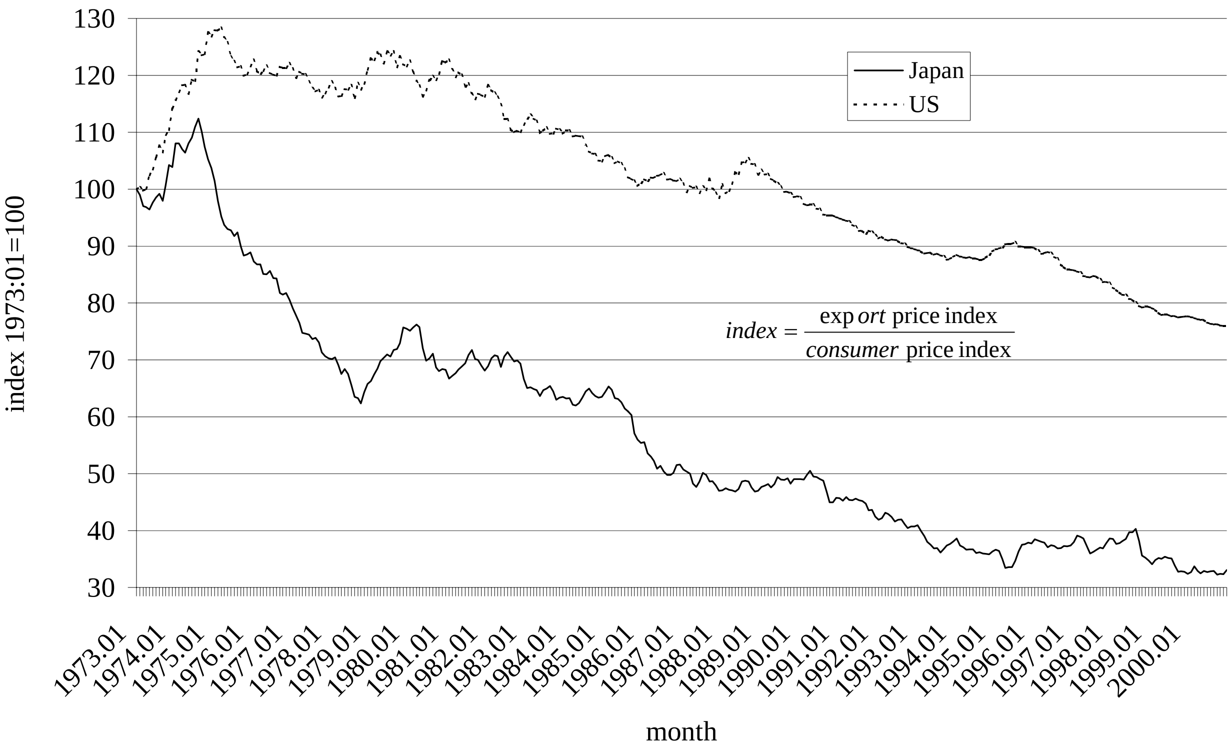
Since one of the striking particularities of the yen exchange rate is the continuous appreciation since the break down of the Bretton Woods System in 1973 (see Figure 1), most explanation approaches are based on Balassa's (1964) and Samuelson's (1964) productivity differen-

[3] Since Japanese external trade is mainly contracted in US dollars, most studies focus on the yen-dollar exchange rate.

tial model. Relative price reductions and productivity increases in the traded goods sector cause the departure of the exchange rate from PPP.

As observed by DeGregorio, Giovannini and Wolf (1994), the discrepancy between traded and nontraded goods prices is particularly large in Japan. Since 1973 export prices have declined significantly while consumer prices have risen steadily (see Figure 2, Figure 4, Figure 6). Hsieh (1982), Marston (1987) and Ceglowski (1996) explain the price gap between traded and nontraded goods in Japan with an extraordinary productivity growth in the Japanese traded goods sector (particularly in comparison to the United States). Marston (1987: 92-93) concludes that this productivity gap between the traded and nontraded goods sector caused the need for real exchange rate appreciation.

Figure 2: Export Prices in Comparison to Consumer Prices, Japan and US



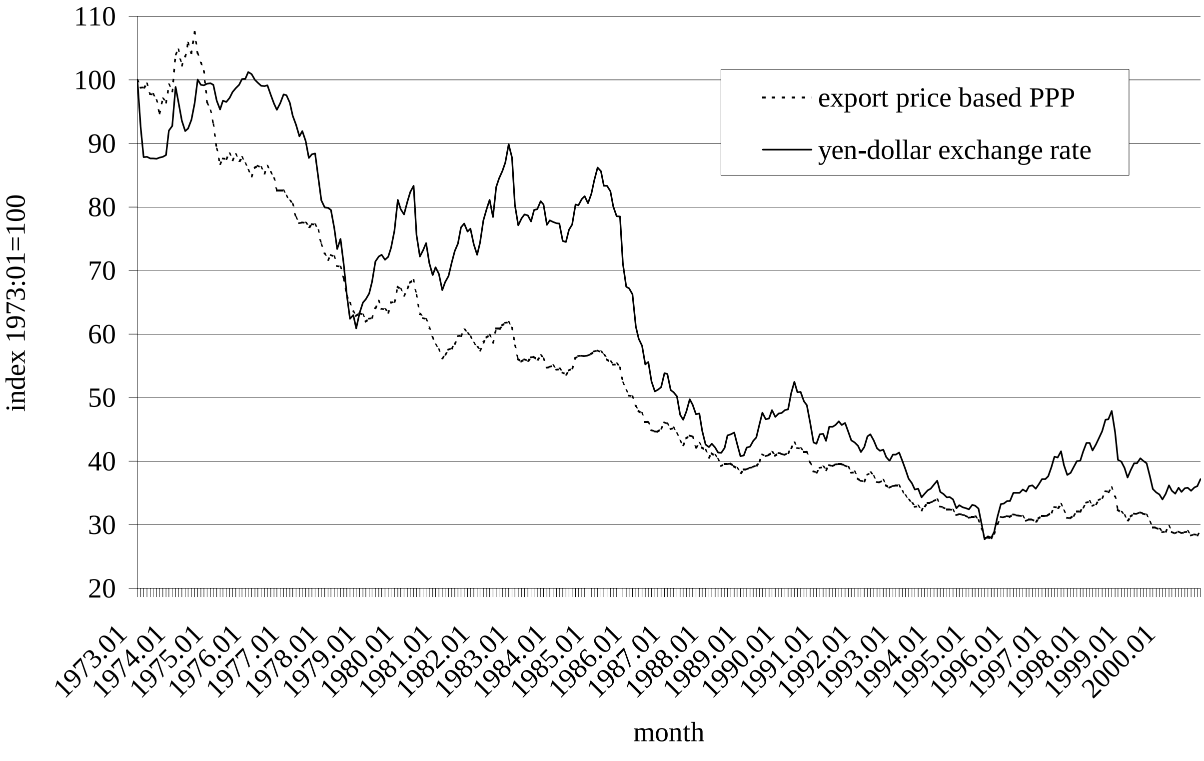
Source: IMF: IFS.

The notion that the exchange rate can be approximated by relative export prices is supported by Schnabl (2001), who finds that the difference of export price changes between Japan and the US is closely related to the yen-dollar exchange rate changes between 1980 and 1999. Export price-based relative PPP holds – in contrast to wholesale and consumer price based PPP – even on a quarterly and monthly basis (see Figure 3).

Cassel's conjecture that changes in relative prices alter the exchange rate would presume that the Bank of Japan determined Japanese monetary policy according to domestic economic conditions alone. The resulting changes of the general price level would be reflected in the exchange rate.

There is strong evidence that monetary policy has not been restricted to purely domestic objectives, however. As outlined by Hutchison (1988), Takagi (1991), and McKinnon and Ohno (1997: 177-200) the exchange rate has turned out to be an important parameter of Japanese monetary policy also under the regime of flexible exchange rates. Jinushi, Kuroki and Miyao (2000) prove by econometric tests and by anecdotal evidence that Japanese monetary policy has been influenced significantly by such external considerations as the exchange rate and the current account.

Figure 3: Yen-Dollar Exchange Rate and Export Price Based PPP



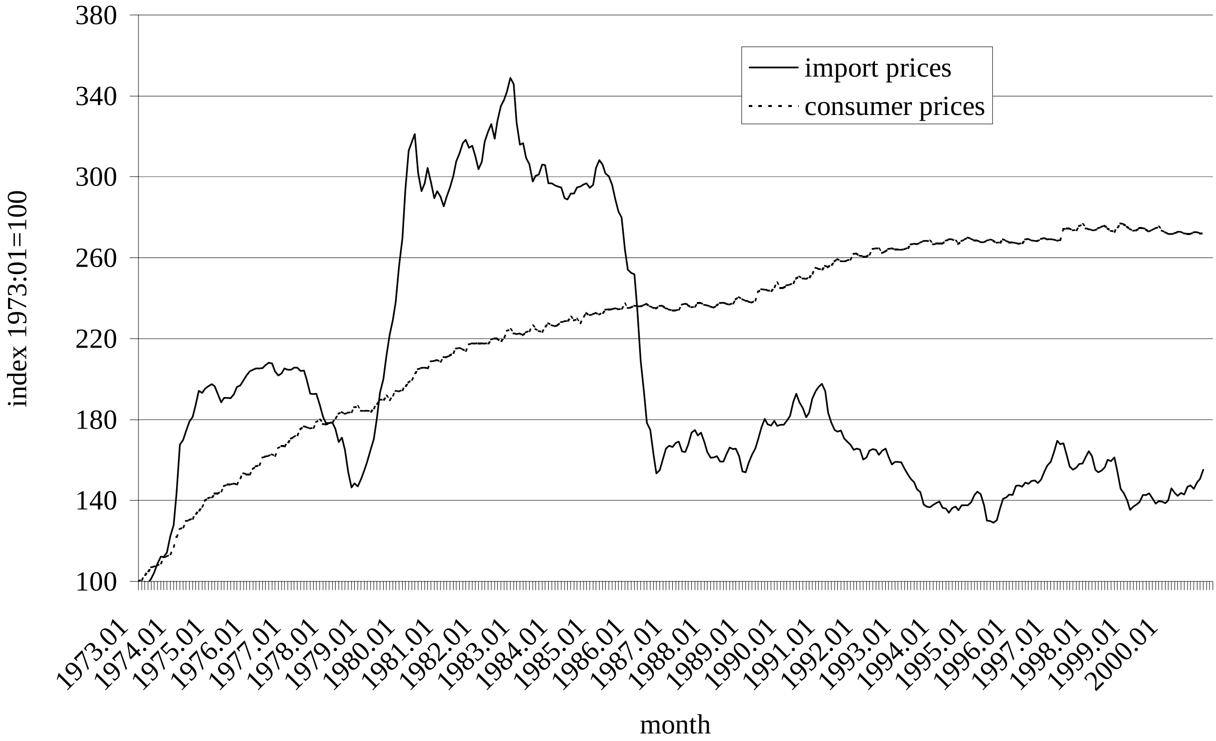
Source: IMF: IFS.

If the impact of the yen exchange rate on Japan's domestic prices and money supply is to be analysed, the function of transmission channels such as domestic activity, import and export prices have to be discussed. The level of the appreciation's impact on Japanese domestic activity has generally been regarded as high. The importance of exports for growth is symbolised by commonly used terms like "*export-led growth*" (*gaiju shudôgata seichô*) and "*high-*

yen-induced recession" (*endaka fukyô*).[4] The contribution of exports to economic growth in Japan has indeed been traditionally regarded as large and has dramatically increased during the economic slump of the 1990s.

In the import market it can be observed that Japanese import prices have fallen considerably, particularly since the Plaza-Agreement. This would imply a downward pressure on Japanese consumer prices. In practice, the influence of import prices and Japanese inflation cannot be traced empirically (McCarthy 2000). Klitgaard (1999: 43) stresses that the impact of the exchange rate on overall input costs is rather small. Further, the regulation in Japanese domestic markets and the distribution system is pervasive (McKinnon and Ohno 1997: 31-35), what postpones – but not necessarily excludes – the passthrough of import prices to consumer prices (see Figure 4).

Figure 4: Japanese Consumer and Import Prices (Yen Basis)



Source: IMF: IFS.

Nevertheless, as visible in Figure 5, movements in import prices are reflected in the movements of Japanese wholesale prices, which implies at least some impact of import prices on the domestic Japanese price level.

4 For further details on *endaka fukyô* see McKinnon and Ohno (1997: 68-71).

Figure 5: Japanese Wholesale and Import Prices (Yen Basis)

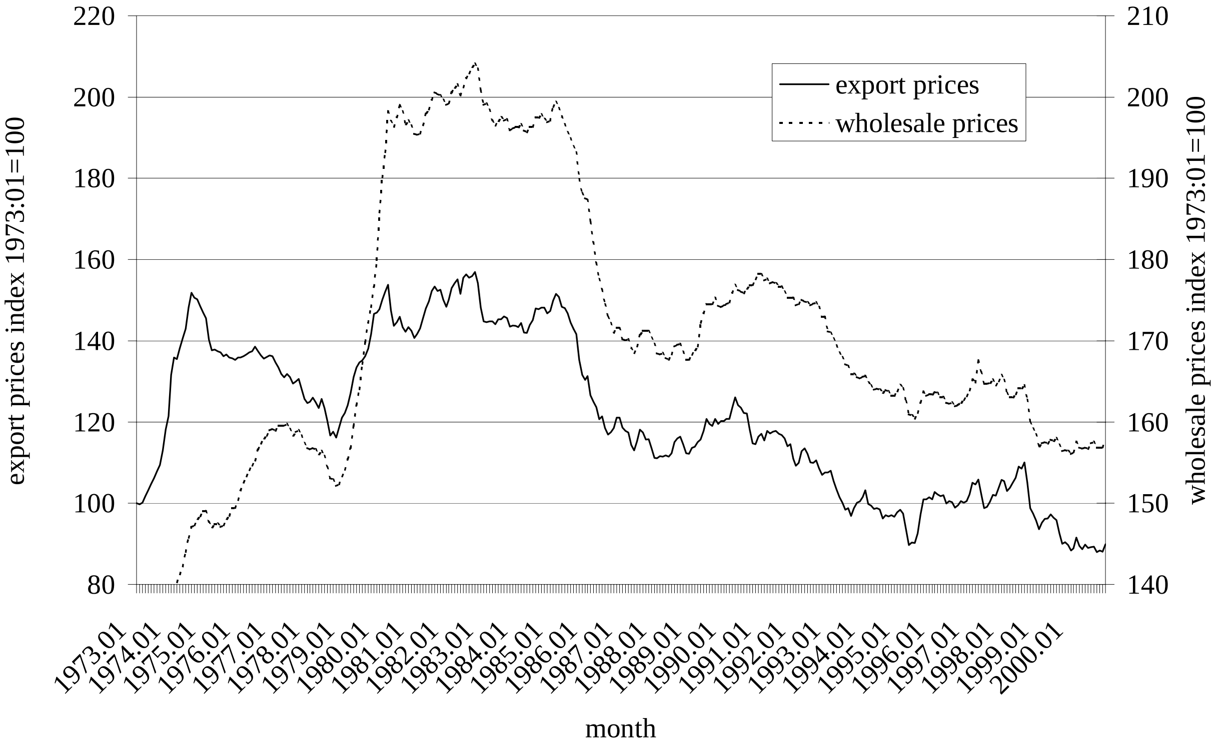
Source: IMF: IFS.

On the export side, the influence of the exchange rate on the pricing behaviour of the Japanese export industry has earned keen attention. According to Marston (1990) (1991) Japanese enterprises tend to reduce yen export prices in case of appreciation. Athukorola and Menon (1994: 280) identify this incomplete pass through as an "*in-built feature*" of Japanese export pricing. Hung, Kim and Ohno's (1993) cross-country study of export pricing comes to the conclusion that imperfect Japanese shifting behaviour is unique among industrial countries.

In the short run, the imperfect shifting in reaction to appreciation occurred at the expense of the Japanese exporters profit margins (Klitgaard 1999), which Ohno (1990: 296-298) explains with a long-term profit orientation of Japanese exporters. While US enterprises tend to pass through exchange rate changes in order to keep profit margins stable in the short run, Japanese enterprises prefer to stabilise prices in foreign currency to keep their market share.

Since low or even negative profit margins in the export business cannot be tolerated in the long run, cost reductions become necessary in order to stay competitive. This is particularly true for Japan, where appreciation has been continuing over decades. In accordance with this assumption Fukuhara (1996) and Schnabl (2001) point out that rapid productivity gains in the export sector have been instrumental in mitigating the effect of the overall appreciation. This leads back to Samuelson's (1964) and Balassa's (1964) productivity differential model as stressed by Marston (1987).

Figure 6: Japanese Wholesale and Export Prices (Yen Basis)



Source: IMF: IFS.

As the interdependence of the yen exchange rate, export, import and wholesale prices already suggests, the cause-and-effect relationship between exchange rate and prices is unclear. Empirical testing of the cause-and-effect relationships between Japanese prices and the yen exchange rates has led to different results:

In accordance with the view of Cassel, the tests of Cheng (1999) suggest a long-run causality running from Japanese consumer prices to the yen exchange rate.

In contrast to Cassel, but in accordance with Einzig, Ohno's (1989) Granger causality test using a vector autoregression model concludes that producer (wholesale) prices react partially to the exchange rate, while consumer prices are mainly unaffected by the exchange rate (see also Figure 4). McKinnon and Ohno (1997: 178-200) find that after the Plaza-Agreement, exchange rate movements preceded changes in relative national price levels, and that any initial movement of the exchange rate not only anticipated the Bank of Japan's long-run policy but actually caused it.

Combining the views of Cassel und Einzig, Kholdy and Sohrabian (1990) find a bidirectional relationship between wholesale prices and the exchange rate for Japan between 1973 and 1988. They talk of a “vicious circle” of appreciation and low inflation.[5]

To add evidence to the cause-and-effect relationship between prices and the exchange rate, we use Granger causality tests for the yen-dollar exchange rate. In contrast to former studies aggregated as well as disaggregated export price data are used.

4 Data

To study the causality between Japanese prices and the yen-dollar exchange rate, we use monthly data from the Bank of Japan’s “Financial and Economic Statistics Monthly”. We use the yen-dollar exchange rate, since most Japanese trade is conducted in US-dollars. Period averages were selected instead of end-of-the-period figures, because exporters trade their goods throughout the period. We use export prices instead of consumer or wholesale prices to circumvent price distortions through all kind of trade impediments and pervasive regulation. The exchange rate and export price time series consist of 331 monthly observations from the post-Bretton Woods-period spanning from January 1973 to July 2000.

Export prices published by the Bank of Japan are Laspeyres indices with weights altered every five years. The export price index is a multilateral price index, which reflects the trade of Japan with the rest of the world. This index contrasts with the notion that the yen-dollar exchange rate is only bilateral. Since bilateral export price indices are not available, the multilateral indices are used instead.

The overall export price index is disaggregated into the following sectors (numbers in brackets indicate the number of items represented in the basket and the weight in the overall export price index in percent): textiles (10/2.13), chemicals (36/7.68), metals and related products (30/7.30), general machinery (38/21.22), electrical machinery (51/35.48), transportation equipment (8/17.80), precision instruments (12/2.69) and other manufacturing industry products (24/5.70). The disaggregation of data by industry allows a distinction between the reactions of specific industries to exchange rate movements.

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5 This also could be seen as virtuous circle, because appreciation contributed to productivity increases and lower inflation.

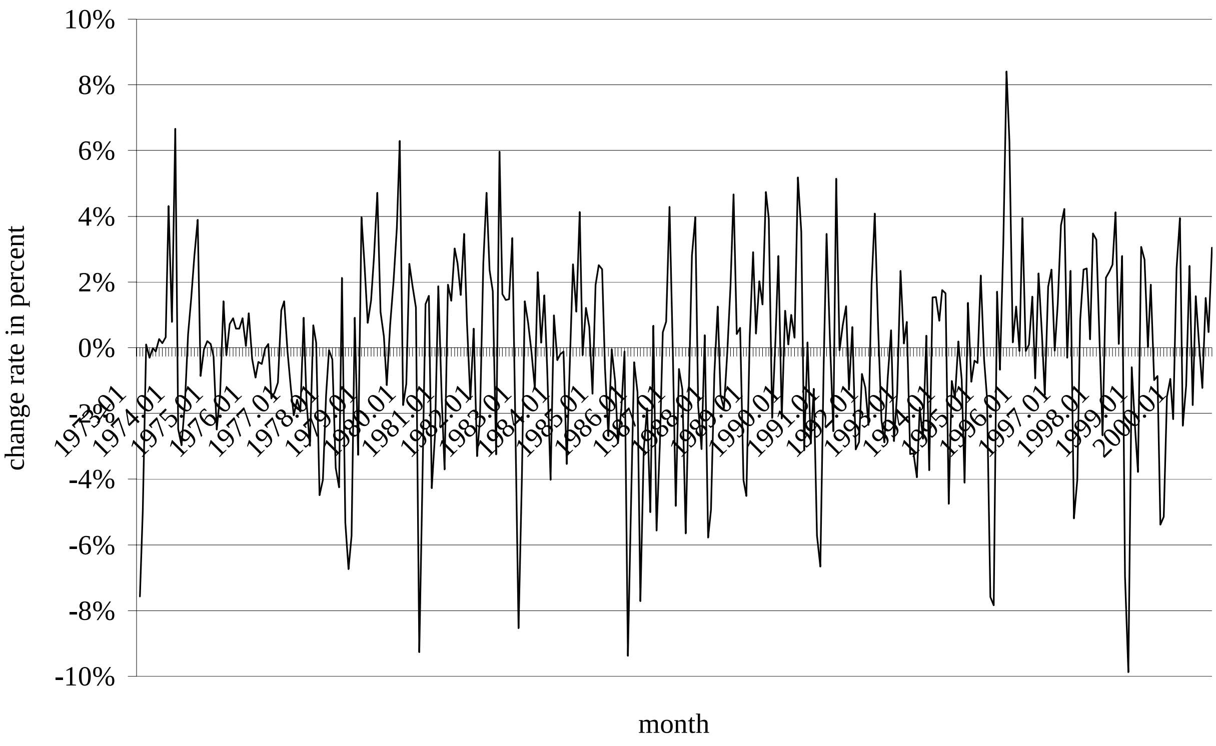
5 Granger Causality Tests

We base the causality tests between the exchange rate (x_t) and export prices (y_t) on the relative PPP. Thus, we use relative changes of the exchange rate and export prices denoted by X_t and Y_t, respectively. Taking logarithms, we get the relative changes:

$$X_t = \log(x_t) - \log(x_{t-1})$$
$$Y_t = \log(y_t) - \log(y_{t-1})$$

Figure 7 plots the relative changes of the exchange rate and shows that these series can be assumed to be stationary since there is no trend and an immanent tendency to return to zero. The same is true for Japanese export prices.[6] The stationarity of the data avoids the potential problems that can occur when non-stationary data are used (see Hamilton (1994), Chapter 11 for a summary).

Figure 7: Relative Changes of the Yen-Dollar Exchange Rate (Versus Previous Month)



Source: IMF: IFS.

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6 Augmented Dickey Fuller tests confirm this hypothesis but are not reported here.

To investigate the causal relationship between Japanese export prices and the yen-dollar exchange rate, we use the causality test introduced by Granger (1969). Formally, a time series A_t *(t=1, ... T)* does not Granger-cause a time series B_t (t=1,...,T), if the prediction error of a forecast of B_t based on all the lagged information of B_t is the same as the prediction error of a forecast of B_t based on all lagged information of B_t *and* all lagged values of A_t. The reason for that definition of causality is that if an event A_t (at $t=t_1$) is the cause of another event B_t (at $t=t_2$) then the event A_t must precede the event B_t, i.e. $0 < t_1 < t_2$ (< T).

Our econometric test method builds upon the following autoregressive specification, which can be derived from a bivariate VAR model and is estimated by OLS:

$$Y_t = c + a_1 Y_{t-1} + a_2 Y_{t-2} + ... + a_p Y_{t-p} + b_1 X_{t-1} + b_2 X_{t-2} + ... + b_p X_{t-p} + u_t \qquad (1)$$

where X_t is the change of the exchange rate and Y_t the specific export price change under investigation. The lag length p is assumed to be the same for X_t and Y_t.

This specification is the basis for a test of the null hypothesis that the exchange rate does not Granger cause the export prices. Thus, the null hypothesis is $H_0 : b_1 = b_2 = ... = b_p = 0$ and the test statistic is $S = \frac{(RSS_0 - RSS_1) * p}{RSS_1 * (T - 2p - 1)}$ which follows a F-distribution with p and T-2p-1 degrees of freedom, while T is the number of observations. RSS_1 denotes the sum of squared residuals for a regression of equation (1) and RSS_0 is the sum of squared residuals for a regression under the null hypothesis. If the test statistic is larger than a critical value for a given significance level, we reject the null hypothesis, i.e. there is evidence that the exchange rate causes export price changes.

A second test investigates whether there is a causal relationship for the opposite direction, i.e. whether export price changes cause exchange rate changes. The relevant regression is based on the following equation:

$$X_t = c + a_1 X_{t-1} + a_2 X_{t-2} + ... + a_p X_{t-p} + b_1 Y_{t-1} + b_2 Y_{t-2} + ... + b_p Y_{t-p} + u_t \qquad (2)$$

If the causality tests of equations (1) and (2) both point to causality there is bidirectional causality or feedback between the variables. Otherwise there is a unidirectional causality or none. Whenever there is evidence of bidirectional causality the question arises as to whether one direction dominates the other. We will try to answer such questions by weigthing the F-statistics resulting from the causality tests. A similar procedure is suggested by Gourieroux and Monfort (1997, Chapter 10).

We are aware of the possibility to choose the lag length by the final prediction error criterion (FPE) or the Schwarz information criterion (SIC). We suspect, however, that information is lost if only one particular lag length is analysed. We account for this by not choosing any lag length a priori but compute causality tests for every lag length between one and twelve.

The F-statistics of our tests are tabulated in Table 1 to Table 3. Stars denote the significance level for which the null hypothesis can be rejected. First, we report results for the whole sample period (Table 1) and second for two sub-samples that consist of a pre-Plaza-Agreement period (Table 2) and a post-Plaza-Agreement period (Table 3). The sub-samples are built to identify different pricing behaviour before and after the Plaza-Agreement.

The causality tests for the whole sample (Table 1) support the pricing to the market and pass through approaches to the yen exchange rate. The results give clear evidence that changes in the exchange rate cause changes in all export prices at all lags, since all F-statistics are larger than the critical values at a 1%-level. This implies that the Japanese export industries have directly changed export prices in reaction to exchange rate movements. The prevailing yen appreciation has caused major reductions in export prices in all Japanese industries. In combination with the stylized fact of falling wholesale prices and low inflation, this finding supports Einzig's notion that the exchange rate affects domestic prices.

On the other hand, there is limited evidence for Cassel's PPP interpretation that export price changes cause changes in the exchange rate. The smaller F-values indicate a weaker causality compared to the opposite direction. Only general machinery and electrical machinery cause exchange rate changes with a lag of four to five periods. The lagged reaction of the exchange rate to prices might be due to a slower transmission process. Nevertheless, considering the fact that general and electrical machinery sum up to more than 56 percent of the Japanese export sector (see data), this means that the pricing behaviour of these two industries had a major impact on the exchange rate.

As depicted in Figure 1 and Figure 8 following the Plaza-Accord in September 1985 the yen appreciated very quickly, subsequently triggering extreme price adaptations. To avoid any bias by extreme price movements before and after the Plaza-Agreement we excluded the years 1985 and 1986 from the sample getting two new samples from January 1973 until December

1984 and from January 1987 until July 2000. The two sub-samples also allow the identification of potential changes in the pricing of particular industries following the Plaza-Accord.

The causality test results mainly support the conclusion drawn from the overall sample. Table 2 shows the results of causality tests for the sample before the Plaza-Agreement. There is again clear evidence that exchange rate changes cause export price changes for all series except precision instruments. For the opposite direction, the evidence is mixed. Only general machinery has a significant F-value at lag 2, transportation equipment has highly significant F-values for lags 1 to 4 and precision instruments has a peak at lag 5, indicating significance at the 10 % level.

Table 3 shows the results of causality tests for the sample after the Plaza-Agreement. Again, there is strong evidence that exchange rate changes cause export price changes for all lags according to the high F-statistics. Causality tests for the opposite direction show that almost all export prices exhibit peaks of F-values at lag 4 but only four export prices have a significant causal impact on the exchange rate: chemicals, general machinery, electrical machinery and precision instruments. Metals do have a significant F-value at the 10 % level at lag 7.

The different causalities among the export prices is potentially due to the different competitive pricing behaviors and the size of the sectors. As suggested by Marston (1990) and outlined in Figure 8, the price reaction to appreciation differs significantly from industry to industry. Since 1985 industries such as electrical machinery have reduced their export prices even more than was necessary to cope with the appreciation. Considering that electrical machinery makes up a significant part of the Japanese export industry, this has put additional appreciation pressure on the yen exchange rate.

Other industries like textiles or general machinery have reduced their export prices much less. There may be two reasons for this: First, a low price elasticity of the industries' products as can be assumed for general machinery. Second, the inability to reduce costs in reaction to appreciation as it is probable for the textile industry. Indeed the textile industry's pricing had no influence on the yen exchange rate. This indicates that it had to adapt fully to exchange rate movements.

If the appreciation, which is enforced by highly competitive industries, lowers the competitiveness of other industries such as textiles and metals products, the structural change within the Japanese export industry is accelerated.

Table 1: F-values of Granger causality tests (1973.01 – 2000.07, 331 observations)

Exchange rate causes export prices (All F-values are significant at the 1 % level)

	Lag length											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
All Commodities	87,8669	52,2254	35,7663	35,3493	28,8425	23,8100	20,8261	17,4516	15,4081	14,0787	12,9572	13,1120
Textiles	53,6051	32,3466	23,1780	17,7908	13,9548	11,6991	9,9647	8,9387	8,2037	7,4349	7,4947	7,3533
Chemicals	38,9553	34,2872	24,7766	19,5737	15,5516	13,1644	11,8645	10,3181	9,4658	9,1006	8,8548	9,7312
Metals	41,4476	40,7349	27,2286	27,1746	21,7630	17,9741	15,6014	12,9324	11,5502	10,3869	9,5160	9,4607
General Machinery	104,0248	58,8080	39,7831	39,3158	31,8477	26,3600	22,9384	19,5296	17,6093	15,7753	14,1225	14,4273
Electrical Machinery	139,0297	67,9347	45,0155	37,0694	29,4459	24,2542	21,7730	19,2161	17,2298	16,7981	14,9494	13,8010
Transportation	93,0409	46,6290	31,1095	25,0508	20,7573	16,8988	14,5872	12,5504	11,0670	10,0459	9,4955	9,1348
Precision Instruments	13,0927	7,6948	6,2985	7,0691	5,7363	4,7611	4,3466	4,4180	4,0278	3,9852	3,4471	3,1219
Other Manufactures	106,2785	55,5903	36,4296	33,2730	26,7388	21,8667	18,6202	16,2042	14,4451	13,2384	11,9366	12,5217

Export prices cause exchange rate

	Lag length											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
All Commodities	0,1893	0,8770	0,3959	0,9802	1,2591	0,6785	1,1008	0,9873	0,8103	0,8319	0,7559	0,8686
Textiles	0,3275	0,0289	0,4788	0,8334	0,5287	0,5447	1,0181	0,6265	0,5355	0,4952	0,5074	0,4195
Chemicals	0,5856	0,2212	0,9848	1,2573	1,2932	1,0437	1,3212	0,8874	0,7781	1,0358	0,6735	0,7255
Metals	0,0005	0,3513	0,8217	1,1884	1,1243	1,0573	1,5971	1,3470	1,1023	1,0214	0,9992	0,8464
General Machinery	0,3280	1,6404	1,3841	2,1624 *	2,5149 **	1,6704	1,5779	1,2974	1,0659	1,1577	0,8502	1,0647
Electrical Machinery	1,2119	1,4955	0,6919	1,8903	2,5759 **	1,6003	1,7386	1,3245	1,1220	1,4659	1,1696	1,2032
Transportation	0,0008	1,2431	0,2980	0,3461	1,2100	0,6029	0,6159	0,7752	0,6013	0,5721	0,6367	0,6692
Precision Instruments	0,0026	0,0816	0,1644	0,4150	0,3376	0,6103	0,5542	0,6399	0,5605	0,4796	0,3768	0,5906
Other Manufactures	0,1504	0,5926	0,2502	0,6002	0,8309	0,3994	0,8641	0,8202	0,6887	0,7031	0,6521	0,9490

*, **, *** denotes significance at the 10 %, 5 % and 1 % level, respectively

Table 2: F-values of Granger causality tests (1973.01 – 1984.12, 144 observations)

Exchange rate causes export prices (All F-values are significant at the 1 % level, except Precision Instruments, denoted with +)

	Lag length											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
All Commodities	20,2762	21,8750	16,5493	15,1664	12,0512	10,1148	9,5998	8,3473	7,4071	7,0395	6,5718	7,2118
Textiles	11,6138	10,3754	8,0706	6,3708	5,5815	4,5568	4,1456	4,0246	3,8298	3,4389	3,0345	3,1570
Chemicals	12,1449	11,7397	10,1835	7,1285	5,6876	5,1589	5,3999	5,3001	4,7837	4,6617	5,3954	6,4057
Metals	9,5182	14,8792	9,3664	9,4682	8,4011	6,9106	6,6419	5,5260	4,6476	4,2748	3,9136	5,2433
General Machinery	29,6047	20,2944	14,5652	12,8855	10,2494	8,7025	8,3840	7,3711	6,8707	6,0870	5,7940	7,3542
Electrical Machinery	74,2260	35,2292	21,8913	19,9266	15,8759	13,0968	12,1418	10,3505	9,3542	11,5323	10,4745	8,8617
Transportation	39,9429	24,2852	17,9099	13,7705	10,6626	9,1950	7,8105	6,7428	5,9179	5,8255	5,4399	5,7302
Precision Instruments	0,2399 +	0,4835 +	1,4819 +	1,6624 +	1,1286 +	1,0389 +	1,0070 +	1,9184 +	2,1796 +	1,9895 +	1,8613 +	1,7282 +
Other Manufactures	32,1345	19,7378	13,1735	11,4495	9,3535	7,5024	6,4468	5,8076	5,2603	4,7873	4,6574	5,9470

Export prices cause exchange rate

	Lag length											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
All Commodities	0,5945	1,6287	0,4617	0,3684	0,4402	0,6456	1,0389	0,8811	0,7721	0,7325	0,7438	1,0371
Textiles	0,0439	0,0570	0,6552	0,4629	0,3691	0,5366	0,6334	0,6141	0,5208	0,4963	0,4598	0,3972
Chemicals	0,4661	0,9921	0,4224	0,4412	0,3183	1,0681	1,3196	1,4314	1,3548	1,1283	0,9788	0,8114
Metals	0,5805	0,7484	0,4897	0,3665	0,4893	0,5264	0,5584	0,4808	0,6348	0,5632	0,7512	0,8236
General Machinery	0,6152	2,8094 **	1,1221	0,8600	0,8988	0,7383	0,7816	0,6669	0,5731	0,5404	0,4749	0,7705
Electrical Machinery	0,0803	1,2781	0,6036	0,9894	1,7357	1,4195	1,2826	1,1329	1,3315	1,4251	1,2480	1,4174
Transportation	3,3115	3,4520 **	2,8946 **	3,2960	2,7863 **	2,2946 **	2,0688 *	1,7914	1,5601	1,4307	1,4257	1,5193
Precision Instruments	1,7102	1,1130	0,7661	1,3616	2,3795 *	1,9018	1,6598	1,5982	1,3915	1,2106	1,1794	1,1440
Other Manufactures	0,7968	0,8376	0,2156	0,2706	0,2661	0,2775	0,3931	0,3039	0,4022	0,3679	0,4101	0,8886

*, **, *** denotes significance at the 10 %, 5 % and 1 % level, respectively

Table 3: F-values of Granger causality tests (1987.01 – 2000.07, 187 observations)

Exchange rate causes export prices (All F-values are significant at the 1 % level, except Precision Instruments, denoted with +)

	Lag length											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
All Commodities	61,3063	29,5352	19,1192	16,7994	12,8386	10,3931	9,6498	8,3096	7,5987	6,6792	5,7216	5,7452
Textiles	46,9306	23,4959	15,1565	11,5822	9,1613	7,4166	6,6683	5,7468	4,7944	4,4457	4,4557	4,2217
Chemicals	29,8706	18,2702	11,7075	10,2847	7,4760	6,1902	6,0193	4,8715	4,1381	3,9004	3,0305	2,7257
Metals	39,1212	22,6547	15,1504	14,4993	11,6208	9,6477	9,8493	9,4738	8,4412	7,9421	6,8675	6,4152
General Machinery	67,5383	32,6173	20,3300	20,4798	15,4416	12,3444	11,4033	9,2425	8,1369	6,8000	5,9866	5,9953
Electrical Machinery	52,1320	24,7740	16,6138	13,4956	9,9750	8,3197	7,4232	6,3791	5,7749	4,9164	4,0906	4,0009
Transportation	43,5565	21,0576	13,0668	12,2260	9,7147	7,8267	6,8851	5,6588	5,1115	4,3344	4,1203	4,2878
Precision Instruments	14,3581	7,2988	5,0456	5,7586	4,4858	4,3505	4,0505	3,5047	3,1649	2,7901 +	2,5651 +	2,2890 +
Other Manufactures	70,9409	34,8699	22,0023	17,8273	13,5687	10,7853	9,8837	8,7127	7,8381	6,7163	5,6368	5,4957

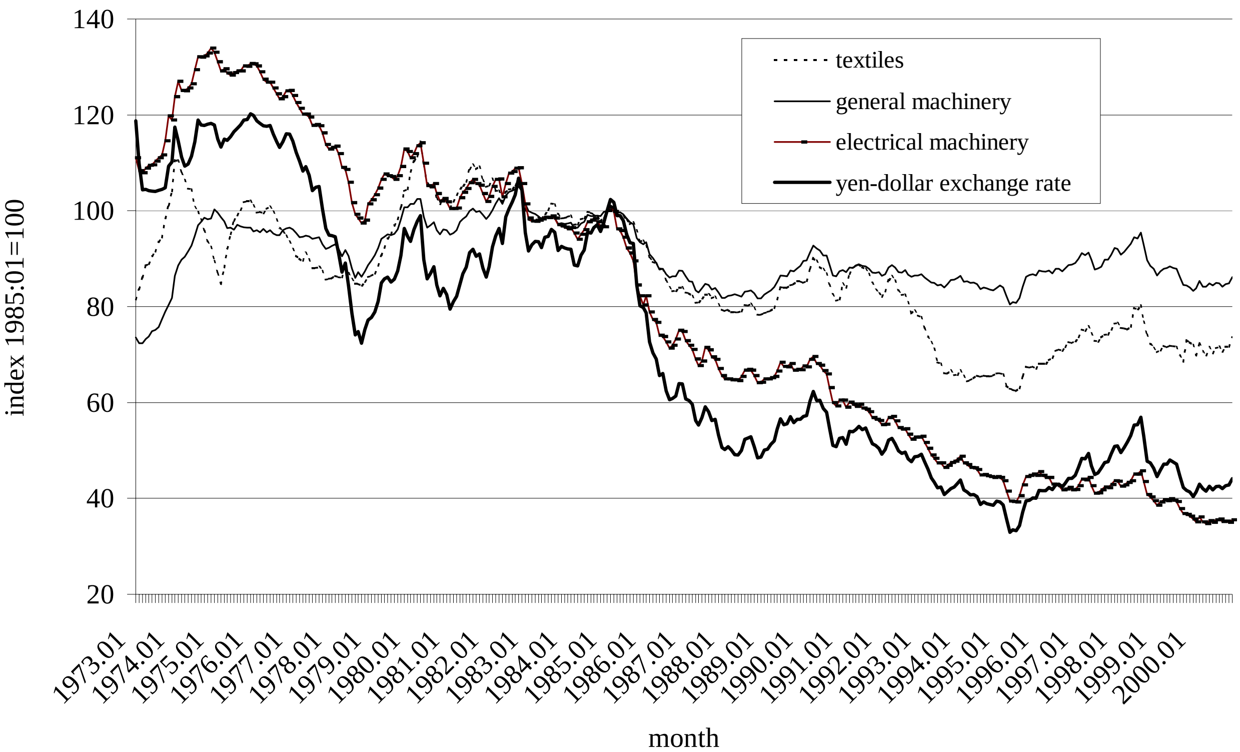
Export prices cause exchange rate

	Lag length											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
All Commodities	0,2491	0,0814	0,2786	1,9240	1,4004	0,9976	1,0431	0,8038	0,7847	0,8662	0,6716	0,8583
Textiles	0,5248	0,2064	0,1497	0,9537	0,3086	0,2818	0,7865	0,5607	0,4785	0,5406	0,5628	0,6061
Chemicals	0,2557	0,5330	0,6178	2,4174 **	1,9802	1,6994	1,3828	1,2423	1,1720	1,8078	1,3698	1,2043
Metals	0,0000	0,2228	0,3221	1,4279	0,6286	0,8836	2,2090 *	1,9150	1,7100	2,1955	1,7858	1,9397
General Machinery	0,5849	0,2281	1,1201	3,4702	2,5203 **	1,7963	1,8987	1,4993	1,4754	1,3897	1,2258	1,5833
Electrical Machinery	0,5448	0,2932	0,2418	2,8722 **	2,2256 *	1,6291	1,7418	1,1733	1,0201	0,9200	0,6560	0,6041
Transportation	0,5052	0,2826	0,7381	1,4560	1,0241	0,6759	0,5793	0,4584	0,4682	0,4388	0,6186	0,8496
Precision Instruments	0,6666	0,2781	1,1088	2,8256 **	1,5664	1,5051	1,2376	1,3886	1,1573	1,2319	1,8417	2,2110
Other Manufactures	0,3258	0,2189	0,4009	1,6049	1,1118	0,7439	1,2570	1,3004	1,3519	1,5310	1,2655	1,3094

*, **, *** denotes significance at the 10 %, 5 % and 1 % level, respectively

In summary, the Granger causality tests lead to three main results. First, the tests strongly support the thesis of imperfect pass through and thus price adjustments of the Japanese export industry in reaction to appreciation,. Second, there is evidence that certain industries such as electrical machinery and chemicals reinforced the ongoing trend in the exchange rate by their pricing behaviour and thus have put a floor under the ongoing appreciation. Both results combined correspond with Kholdy and Sohrabian's finding of the (vicious) circle of appreciation and price adaptation.

Figure 8: Sectoral Export Prices



Source: Bank of Japan: Financial and Economics Statistics Monthly.

Third, since the ability to influence the exchange rate differs from industry to industry there is strong evidence that appreciation not only enforced the structural change in the Japanese industry, but also that structural change was driven by highly competitive industries such as electrical machinery and chemicals.

6 Conclusion

The high yen has forced Japanese export enterprises to adapt by price reductions and productivity increases. This reaction pattern has reinforced the appreciation of the yen and thus initiated new rounds of appreciation. This corresponds to the conjecture of a vicious (virtuous) circle of appreciation and price adaptations.

Within this competition in the adaptation to the high yen certain industries such as electrical machinery and chemicals have performed better than others; a fact that has accelerated the structural change in the Japanese export sector.

As regards the strong yen during the 1990s, it can be concluded that the decision to repatriate international assets has put significant pressure on the yen, which has in turn forced the export industry to restructure. The respective price adjustments and productivity increases have contributed to the deflation and to the strong yen during the 1990s.

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