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Exchange rate pass-through in deflation: The case of Taiwan

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**Abstract**

This paper incorporates deflation in an analysis of the relationship between the exchange rate pass-through and inflation. Using a nonlinear model based on monthly data of Taiwan's import prices from 1981 to 2008, we find that the degree of exchange rate pass-through is increasing in deflation. The increase becomes smaller when the price of oil is excluded. Evidence for pass-through increasing in deflation has not previously been found in the existing literature and presents a new understanding of the pricing behavior of firms. Poor profits in deflation cause firms to pass through most of the cost of exchange rate changes to their products to avoid exiting the market.

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1. Introduction

Differences in the degree of exchange rate pass-through were attributed to microeconomic factors until Taylor (2000) first suggested that inflation has a positive impact on the degree of pass-through exhibited by firms.¹ Additional studies have also found evidence of a positive relationship between these two variables (Bouakez & Rebei, 2008; Choudhri & Hakura, 2006; Gagnon & Ihrig, 2004; María-Dolores, 2010). A consensus emerges from the studies focused on this relationship; high inflation increases the degree of exchange rate pass-through, and conversely, low inflation decreases it. However, the data that these studies define as low inflation include both low positive and negative inflation rates. That is, there are some cases of deflation. Deflation in the importing country typically threatens foreign firms' profits through weak domestic demand and falling prices. Because their profits are severely reduced, foreign firms become more vulnerable to cost fluctuations. Any cost changes, including those due to exchange rate movements, are easily reflected in their products. Under the law of one price, the import price is also affected. Exchange rate pass-through, which describes the extent to which import prices respond to exchange rate changes, thus becomes higher. This obviously contradicts the results of existing studies. We infer that the increased exchange rate pass-through is likely to emerge when deflation occurs in the importing country. The initial assumption that there is a positive relationship between lower pass-through and lower inflation, including deflation, may not hold. Therefore, this paper is designed to draw out this particular effect, re-examining the relationship between the exchange rate pass-through and inflation by incorporating the case of deflation.

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¹ In Taylor (2000), higher exchange rate pass-through results from persistent cost changes under high inflation, based on a staggered price setting model. As firms set prices several periods in advance, their prices are more responsive to cost increases if cost changes are perceived to be more persistent. According to the US data provided in the paper, regimes with higher inflation tend to have more persistent costs such that higher inflation increases the degree of exchange rate pass-through.

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Existing papers exploring the impacts of an inflation environment on the degree of pass-through, to the best of our knowledge, usually compare the degrees of pass-through under low and high inflations, while few have included deflation as a separate macroeconomic factor. For example, Gagnon and Ihrig (2004) distinguish periods of high and low inflations for 20 industrial countries to test the hypothesis that decreased exchange rate pass-through is the result of an inflation-stabilizing policy; Choudhri and Hakura (2006) sort 71 countries into low to high inflation groups to explore the relationship between the pass-through to Consumer Price Index (CPI) and the inflation environment; Bouakez and Rebei (2008) estimate the pass-through in Canada for relatively low and high inflation levels. These studies all demonstrate that pass-through is lower when inflation decreases. This positive relationship is supported by the empirical analysis, which is typically performed for two regimes: low and high inflation. Because no specific attention is paid to the impact of deflation, pass-through in a deflation regime tends to be considered the same way as that of a low inflation regime. Therefore, this may lead to biased results. In view of the mixed impacts of low inflation, this paper intends to reinforce the role of deflation and clarify its influence on pass-through. Using data from Taiwan, a more detailed analysis of pass-through is provided by also considering the case of deflation. These pass-through estimates are discussed separately, not only in different inflation regimes but also in a deflation regime.

The Taiwanese data contains information that is useful for an investigation of pass-through in three regimes (including both inflation and deflation) because it exhibits the following features. From 1989 to 1997, Taiwan experienced rapid economic growth due to a thriving high-tech industry. The CPI inflation rates, as shown in Table 1 and Fig. 1, were above 3% during this prosperous period. After 1997, the Asian financial crisis caused a slowdown in domestic economic growth. In the years that followed, the burst of the internet bubble and the terrorist attacks in the U.S. also influenced Taiwan’s economy. The Severe Acute Respiratory Syndrome (SARS) epidemic in 2001 further dampened the domestic economy. During these years, Taiwan’s CPI inflation rate became negative and continued to decline. The core CPI also exhibited a negative growth rate of —0.61% in 2003. According to Rogoff et al. (2003), Taiwan was one of the countries at risk of worsening deflation. Weak domestic demand put the island’s economy on a path toward recession. Based on these characteristics in Taiwan’s economic data, we are able to examine the degree of exchange rate pass-through in a deflation environment and for different levels of inflation.

Because this study hypothesizes that there is a nonlinear relationship between the degree of exchange rate pass-through and inflation, the threshold model proposed by Tsay (1998) is applied in this paper. The data employed are from 1981 to 2008. In examining these data, we note that oil prices usually fluctuate much more than the prices of other imports. Marazzi and Sheets (2007), Sekine (2006), and Campa and Goldberg (2005) all find that oil prices impact estimations of the degree of pass-through. For this reason, we also apply a non-oil import price index to the model. To provide a basis for comparison, we first run the model and estimate the degrees of exchange rate pass-through only considering two regimes, in which the inflation rate is either above or below 3%. The results show that a positive relationship exists and that pass-through decreases with inflation, which is consistent with existing studies. Then we extend the model to clearly distinguish a deflation regime from a low inflation regime. The results from the two-regime model used in related papers. Instead of consistently finding lower pass-through for lower inflation rates, in Taiwan, the pass-through becomes inversely greater as the inflation rate falls into a deflation regime. That the pass-through appears to be less willing to bear the exchange rate costs, resulting in a higher degree of pass-through. The pass-through estimates are discussed in Section 3.

Estimating the pass-through for clearly defined deflation, low positive inflation and high inflation regimes, we find that the degree of pass-through does not always decrease with the inflation rate. There is a pattern of increasing pass-through in deflation regimes. This finding is very different from the general view of a positive relationship between pass-through and inflation that results from the two-regime model used in related papers. Instead of consistently finding lower pass-through for lower inflation rates, in Taiwan, the pass-through becomes inversely greater as the inflation rate falls into a deflation regime. That the pass-through is higher in a deflation regime is especially obvious after the 1997 financial crisis. Conversely, the lowest degree of pass-through are found in the clearly defined low positive inflation regime; that is, our analysis, contrary to what a positive relationship would predict, does not find an unlimited downward trend in the pass-through. There is a rebound in the degree of pass-through once deflation is clearly identified. In other words, as an inflation environment becomes one of deflation, firms are found to be less willing to bear the exchange rate costs, resulting in a higher degree of pass-through. The pass-through appears to be higher in a deflation regime. At the end of the empirical analysis, robustness checks are performed to examine these results.

The remainder of the paper is organized as follows. Section 2 presents the theoretical framework used in this paper. Section 3 discusses the methodology and presents and explains the results of the empirical analysis; robustness checks are provided in this section. Conclusions and general remarks are made in Section 4.

2. Theoretical framework

The exchange rate pass-through, according to Hooper and Mann (1989), can be broadly defined as the extent to which a change in the nominal exchange rate induces a change in the price of imports. In this paper, we follow a narrower definition

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2 Al-Abri and Goodwin (2009) re-examine the exchange rate pass-through into 16 OECD countries’ import prices using the threshold cointegration estimation technique. Tica and Poseidel (2009) apply a threshold model for investigating the exchange rate pass-through in Croatia.

3 Marazzi and Sheets (2007) suggest distinguishing the impacts of oil prices due to their volatility. Sekine (2006) also controls for the price of oil in the regression while studying the degree of pass-through. Campa and Goldberg (2005), however, do not distinguish the impact of oil prices, but they observe that energy prices “have the most anomalous behavior among all product categories, with country estimated pass-through varying considerably”.

4 The index of non-oil import price is neglected in most studies because it is not published by the government in Taiwan.

5 This assumption is later examined in the robustness checks.
that describes pass-through as the partial derivative of the import price with respect to the nominal exchange rate. To allow for interaction between domestic and foreign firms, we begin with the markup model adopted by many previous analyses. By operating through variations in the markup, foreign firms can, more or less, control their output prices.

Under the markup model, a foreign exporter’s price \( (PM^*) \) can be expressed as the product of their marginal cost of production \( (MC^*) \) and the markup \( (\theta) \):

\[
PM^* = \theta MC^*.
\]

By the law of one price, an import price can be expressed as the foreign export price multiplied by the exchange rate (domestic currency per unit of foreign currency):

\[
PM = PM^* ER = \theta MC^* ER.
\]

The markup, \( \theta \), is assumed to be variable, and it responds to both competitive pressures in the domestic market and demand pressures in foreign countries. That is, \( \theta = \frac{\beta^d}{(MC^*ER)Y} \), where \( \beta^d \) is the average competitors’ price level of the good in the domestic market and \( Y \) is the domestic demand. Substituting the expression for \( \theta \) into Eq. (2) and taking the logarithm of the result yields:

\[
\log(p_m) = (1-\alpha)\log(e) + \alpha p^d_Y + (1-\alpha)\log(MC^*) + \beta y_t.
\]

According to Hooper and Mann (1989), three versions of this model can be used to estimate the pass-through by relaxing the restrictions on the coefficients of \( p^d_Y \) and \( MC^* \). In line with numerous other studies, which generally adopt the least restrictive form for their estimations, this study also allows the coefficient on \( p^d_Y \) to differ from \( \alpha \) and the coefficient on \( MC^* \) to differ from \( (1-\alpha) \). Thus, we can rewrite Eq. (3) as:

\[
\log(p_m) = \beta_0 + \beta_1 e_t + \beta_2 p^d_Y + \beta_3 MC^* + \beta_4 y_t + \epsilon_t
\]

where \( \beta_1 = 1-\alpha \) is the exchange rate pass-through, and we expect \( 0<\alpha<1 \). If \( \alpha = 1 \), foreign firms are price takers in the market, absorbing all of the changes in exchange rates with the markup so that \( \beta_1 = 0 \); hence, the exchange rate pass-through is zero. This is called local-currency pricing (LCP); fluctuations in exchange rates have no effect on domestic import prices. If \( \alpha = 0 \), changes in exchange rates are completely reflected in import prices, and the pass-through coefficient \( \beta_1 = 1 \). Foreign firms set prices independently from domestic competitors, referred to as producer-currency pricing (PCP).

3. Empirical analysis

This section first describes the data and its characteristics and uses the threshold autocorrelation model (TAR) in Tsay (1998) to estimate the exchange rate pass-through in two (high inflation and low inflation) and three (high inflation, low positive inflation, and deflation) regimes. Under this framework, this study explores the difference in the degree of pass-through when deflation is clearly defined in the model. The influence on the degree of pass-through of potential structural changes resulting from the 1997 Asian financial crisis is also considered. Finally, robustness checks are provided to examine the results found in this study.

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6 See Athukorala (1991), Hooper and Mann (1989), Kim (1990), Knetter (1989, 1993, 1995), Campa and Goldberg (2005), and Gust, Leduc, and Vigfusson (2010).

7 The competitive pressures in the domestic market are measured by the gap between the domestic competitors’ prices and the cost of foreign products in the domestic currency. Demand pressure on foreign output, according to Hooper and Mann (1989), is measured by capacity utilization. However, data for foreign countries’ capacity utilization is difficult to obtain. Therefore, we replace it with domestic demand (\( Y \)) to represent the demand pressure on foreign output.

8 See, for example, Campa and Goldberg (2005), Sekine (2006), Al-Abri and Goodwin (2009), Ceglowski (2010).
3.1. Data description

We use monthly data from Taiwan during 1981–2008. The data begin in 1981 because of limitations that were placed on exchange rates. Taiwan adopted a floating exchange rate system in 1978, and the data for the first three years do not provide much information. Therefore, we use 1981 as the beginning of the sample period. To separate the impact of oil prices, except domestic price ($p_{m}^{d}$) and domestic demand ($y_t$), we construct non-oil indices for import prices ($pm_t$), exchange rates ($e_t$), and foreign costs ($mc_t^*$). Except for the non-oil indices, all of the data are from the IMF-IFS database or the Directorate General of Budget, Accounting and Statistics, Executive Yuan (DGBAS) in Taiwan. More details regarding the composition of these indices and the data sources are outlined in Appendix A.

When employing time-series data, performing tests for stationarity and cointegration is a priority. The standard tests for stationarity are the Augmented Dickey–Fuller and PP (Phillips & Perron, 1988) tests; both tests indicate that the series are non-stationary in logarithmic levels but stationary in first differences. Accordingly, a Johansen test for cointegration was performed on these series. At a 5% significance level, the null hypothesis of no cointegration cannot be rejected.10 These test results suggest that our estimation for the pass-through in Eq. (3) should be employed in a first-difference form.

3.2. Exchange rate pass-through in two regimes

As this study hypothesizes that there is a nonlinear relationship between exchange rate pass-through and inflation, the threshold autoregressive model (TAR) in Tsay (1998) is applied. If the pass-through differs as the inflation level changes, different degrees of pass-through should be observed in different inflation regimes. As most studies suggest a positive relationship between exchange rate pass-through and inflation, a higher pass-through should appear in a higher inflation regime. Therefore, before we focus on analyzing the pass-through in deflation, we first employ the TAR model only for higher and lower inflation regimes. In this two-regime TAR, we compare the pass-through when the inflation rate is above and below 3%. As described in the theoretical framework of Section 2, we adopt the least restrictive form of the markup model used in numerous other studies for the estimation, which relaxes the restrictions on the coefficients of $p_{m}^{d}$ and $mc_t^*$ presented in Eq. (4). Therefore, based on Eq. (4), the two-regime TAR is as follows:

$$
\Delta pm_t = \begin{cases} 
\mu + a_1 \Delta pm_{t-1} + b_1(L) \Delta e_t + c_1(L) \Delta p_{m}^{d} + d_1(L) \Delta mc_t^* + e_1(L) \Delta y_t + v_t, & \text{if } \pi_{t-i} > 3
\end{cases}
$$

(5)

\[ \begin{cases} 
\mu + a_2 \Delta pm_{t-1} + b_2(L) \Delta e_t + c_2(L) \Delta p_{m}^{d} + d_2(L) \Delta mc_t^* + e_2(L) \Delta y_t + v_t, & \text{if } \pi_{t-i} < 3
\end{cases} \]

where $\pi_t$ is the monthly inflation rate in Taiwan and $i$ denotes the lag number of threshold $\pi_t$.

Before running these regressions, we perform a nonlinearity test to check whether the specification of the model is appropriate. The test statistic $C(i)$ is used in Tsay (1998) to detect nonlinearity in the model. We assume that the influence of inflation on the exchange rate pass-through would not last more than a year. The test results for twelve threshold lags are provided in Table 2. Under the null hypothesis that the import price series is linear and hence model (5) reduces to a linear model, the test statistics significantly reject the null hypothesis for the lag numbers $i = 2, 3, 4, 6$, suggesting threshold nonlinearity when the inflation rate is given these lag periods. Among these statistics, the maximum value of $C(i)$ suggests that we use three lags of inflation rate as the threshold.

In model (5), the regressions are run using the Akaike Information Criterion (AIC) to determine the order of each lag polynomial on the estimates.10 The coefficient $b_i$ represents the effect of exchange rate pass-through. The sum of its current and lagged values is used as our estimate for the cumulative exchange rate pass-through.

Table 3 shows the long-run estimates of the exchange rate pass-through in the two-regime TAR. As displayed in the table, the pass-through are both greater when the inflation rate is over 3%. It is approximately 28% higher for all import goods and 16% higher for domestic demand term with ten lags.

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9 The test involved two lags, no trend, and an intercept in the model.
10 The regression is run in first differences with current and two lags of exchange rate, current and one lag of domestic price level, current foreign costs, and a domestic demand term with ten lags.
for non-oil import goods. This result is consistent with multiple other studies that find that higher inflation increases the pass-through. As presented in the above results, by employing this two-regime TAR, we find that similar evidence also exists in Taiwan.

3.3. Exchange rate pass-through in three regimes

We proceed to focus on the pass-through in deflation as well as in higher and lower inflation. In this section, we adopt the suggestion put forward in Rogoff et al. (2003) and assume that there is deflation when the inflation rate is below 1%. Based on model (5), we extend the two-regime TAR model to a three-regime one, where a deflation regime is different from a lower inflation regime. The three-regime TAR is modeled as follows:

$$
\Delta p_{mt} = \begin{cases} 
\mu_1 + \rho_1 \Delta p_{mt-1} + \beta_1(L) \Delta \epsilon_t + \gamma_1(L) \Delta p_{mt}^d + \delta_1(L) \Delta m_c^d + \phi_1(L) \Delta y_t + \nu_t, & \text{if } \pi_{t-3} > 3% \\
\mu_2 + \rho_2 \Delta p_{mt-1} + \beta_2(L) \Delta \epsilon_t + \gamma_2(L) \Delta p_{mt}^d + \delta_2(L) \Delta m_c^d + \phi_2(L) \Delta y_t + \nu_t, & \text{if } 1% < \pi_{t-3} < 3% \\
\mu_3 + \rho_3 \Delta p_{mt-1} + \beta_3(L) \Delta \epsilon_t + \gamma_3(L) \Delta p_{mt}^d + \delta_3(L) \Delta m_c^d + \phi_3(L) \Delta y_t + \nu_t, & \text{if } \pi_{t-3} < 1%.
\end{cases}
$$

Model (6) clearly describes the central theme of this paper. The degree of exchange rate pass-through is analyzed in three regimes. Here, the low positive inflation regime indicates low but positive inflation rates, which do not include deflation. High inflation, low positive inflation and deflation are defined as inflation rates of more than 3%, between 1 and 3%, and less than 1%, respectively. Through this three-regime TAR, we are able to obtain the pure effect that deflation has on exchange rate pass-through.

Table 4 reports the OLS estimates from model (6). Two sets of coefficients are estimated, one for all import goods and another for non-oil import goods. Model characteristics, such as sample size, R-squared, F-tests and a test for the presence of autocorrelation in the residuals, are displayed at the bottom of the table. The long-term effects of these variables are consistent with the theoretical predictions.\(^{11}\) The cumulative exchange rate pass-through is measured by the sum of the coefficients \(\beta_3\).\(^{12}\)

Before discussing the model’s estimated results for the degree of exchange rate pass-through, the coefficients on the domestic price level changes (\(\Delta p_{mt}^d\)) in Table 4 provide related information and merit attention. Examining the estimated results for the deflation regime in Table 4, the coefficients on the domestic price changes (\(\Delta p_{mt}^d\)) in the short-run are smaller and not significant, indicating that foreign firms do not match changes in the importing countries’ prices. In the long-run, the coefficients become larger but are still not significant, suggesting that the price-taking behavior of foreign firms weakens in a deflation regime.

As deflation occurs, the importing market is less competitive because of its weak domestic demand. Foreign firms react less to their competitors’ price level in the importing market when setting their export prices. Smaller responses to the competitive price in the importing country are made by foreign firms. According to theory, a lower magnitude of the competitive price level implies that most of the costs from changes in the exchange rate would be passed through. Therefore, the coefficients on \(\Delta p_{mt}^d\) primarily predict that there would be a greater exchange rate pass-through in a deflation regime.

We now proceed to examine the results for the degree of exchange rate pass-through. Table 5 presents the long-run exchange rate pass-through from the OLS estimates presented in Table 4. This table provides the main results of this paper. Notably, the pass-through estimates show greater values in deflation and high inflation regimes. Approximately 60–70% of the change in the exchange rate is reflected in the import price for these two regimes, while only 20–50% is passed through in the low positive inflation regime. As the previous section shows, the finding that higher pass-through is correlated with higher inflation remains

\(^{11}\) We check the long-run effect of each variable through the sum of its contemporaneous and lagged coefficients.

\(^{12}\) Long-run effects are measured by \(\gamma(1)/(1-\rho)\), where \(\gamma(1)\) is the sum of current and lagged coefficients on the domestic price level changes (\(\Delta p_{mt}^d\)).
the same. The increasing pass-through in the deflation regime, however, sheds new light on the connection between exchange rate pass-through and the initial low inflation regime.

According to previous studies, the exchange rate pass-through is expected to decrease as inflation continues to fall due to the positive relationship that has been found for many countries. The results of our model, however, indicate that although the degree of pass-through is higher in high inflation regimes and decreases with a falling inflation rate, this pattern does not persist once the inflation rate has fallen enough to be considered deflation. From the results of the three-regime TAR, the decreasing trend stops and then reverses. The degree of the exchange rate pass-through is v-shaped. Higher degrees of pass-through are possible in a deflation regime.

Regarding firms' attitudes toward cost changes, the higher pass-through estimates of 0.67 and 0.60 in Table 5 imply that firms only absorb 33–40% of exchange rate changes in a deflation regime. This percentage is initially up to 45–49% when deflation is still included in low inflation (Table 3). This substantial decrease shows that firms are less willing to incur these exchange rate costs. The initial estimates obviously underestimate the degree of pass-through in this regime. The lower estimates found in low inflation regimes cannot explain the pricing behavior of firms in deflation regimes. In fact, the broadly defined low inflation regime includes the impacts of deflation and low but positive inflation. There is a huge difference between these two regimes.

In an economy that experiences low positive inflation, as long as the market demand remains strong, falling prices within this inflation range imply that firms are able to produce goods at lower prices. Profits would increase, and this would enhance firms' capabilities for dealing with cost shocks. Having a more flexible profit margin apparently enables firms to rely less on pass-through. Therefore, in a low positive inflation regime, import prices respond less to exchange rate fluctuations. In contrast, when an economy undergoes deflation, the implication is that the overall economic conditions are becoming worse, as is demand. Suffering from a continued decline in selling prices, the profit margin on sales to the importing country is severely reduced; this leaves little space for firms to accommodate any cost changes. Consequently, the costs resulting from exchange rate changes are largely reflected in the prices of imports; thus, a greater degree of exchange rate pass-through occurs in a deflation regime.

Therefore, based on these long-run pass-through estimates, we find a positive impact of deflation on the degree of exchange rate pass-through. As the initial two-regime model does not address deflation, the initial pass-through estimates underestimate the influence of deflation and also overestimate the influence of low positive inflation. The different impacts of these two regimes produce the biased results of previous studies. The evidence shows that firms actually exhibit greater degrees of exchange rate pass-through in deflation.

To ascertain the impact of oil prices, we can compare the estimates on the left and the right columns in Table 5. The degree of pass-through for non-oil import goods is higher in the low positive inflation regime and is considerably lower in the other two regimes. The sharp 43% increase in the pass-through previously found for the deflation regime drops to a mild 14% when the price of oil is excluded. With smaller changes in the point estimates, the changes in the degree of pass-through apparently become smoother for non-oil import goods. Fluctuations in the price of oil influence the measurement of the pass-through. However, the v-shape of the degree of exchange rate pass-through remains unchanged. Although the price of oil is dropped from the model, the pass-through is still found to be higher in deflation.

3.4. Possible structural change due to the 1997 Asian financial crisis

The Asian financial crisis of February 1997 influenced the economic performance of most Asian countries. Here, we examine the influence of this possible structural change in our data.

We estimate the pass-through for two sub-sample periods. The first sub-sample period is the monthly data from before February 1997, and the second sub-sample period begins with the outbreak of the crisis in February 1997. The degree of pass-through is estimated using models (5) and (6) based on these two sub-samples. The results are presented in Table 6.

The pass-through estimates in Table 6 show that a positive relationship between the exchange rate pass-through and inflation existed before the financial crisis. The pass-through for the period of 1981–1997.1 (before financial crisis) is approximately 0.4 in the low inflation regime and rises to 0.9 and 0.76 in the high inflation regime under model (5). After the financial crisis, the pass-through rates for the period of 1997.2–2008 in the low inflation regime are 0.78 and 0.81 under model (5) and 0.93 and 0.81 in the deflation regime under model (6). According to these estimates, in the two-regime analysis, the pass-through in low inflation became higher after the financial crisis. For three regimes, the pass-through in deflation were also higher after the financial crisis.

Table 3
Long-run exchange rate pass-through for two regimes.

| Regimes         | All goods | Non-oil goods |
|-----------------|-----------|---------------|
| High inflation  | $\pi > 3\%$ | 0.79          | 0.71          |
| Low inflation   | $\pi < 3\%$ | 0.51          | 0.55          |

Note: The long-run exchange rate pass-through is computed as $b(1)/(1 - \rho)$, where $b(1)$ is the sum of contemporaneous and lagged $b$ coefficients.

# Footnotes

13 In Gagnon and Ihrig (2004), 20 industrial countries exhibit lower pass-through rates by adopting inflation stabilizing policies. Choudhri and Hakura (2006) find strong evidence for a positive relationship between the pass-through and inflation in 71 countries. Bouakez and Rebei (2008) report a result of low pass-through at low inflation for Canada.

14 In the markup model, the profit margin can be measured by the difference between import prices and the sum of the exchange rate and foreign costs.
Compared with the results obtained for the whole period of 1981–2008 in Table 5, the pass-through rates after the crisis show an increase of over 20% in deflation. The evidence indicates that the impact of deflation on the pass-through is greater after the financial crisis.

However, some estimates in Table 6 are not persuasive due to an insufficient number of sub-samples. Therefore, we cannot conclude that the pass-through rates are definitively higher in deflation than in low positive inflation if the data are split according to the financial crisis.

3.5. Robustness checks

In this section, some robustness checks regarding the definition of deflation and the threshold values are performed to examine the results in this paper.

As noted above, this study essentially adopts Rogoff's suggestion in 2003 that deflation occurs when the inflation rate is less than 0%. However, some estimates in Table 6 are not persuasive due to an insufficient number of sub-samples. Therefore, we cannot conclude that the pass-through rates are definitively higher in deflation than in low positive inflation if the data are split according to the financial crisis.

Table 7 shows the results of pass-through in model (6) with deflation defined as inflation less than 0%. The first panel is the pass-through rates after the crisis show an increase of over 20% in deflation. The evidence indicates that the impact of deflation on the pass-through is greater after the financial crisis.

In this section, some robustness checks regarding the definition of deflation and the threshold values are performed to examine the results in this paper.

As noted above, this study essentially adopts Rogoff's suggestion in 2003 that deflation occurs when the inflation rate is less than 0% and observes a higher pass-through rate in deflation. To check the robustness of this result, we estimate the degree of pass-through if deflation is defined as an inflation rate less than 0%.

Table 4 OLS estimated results for three regimes.

|                      | All goods | Non-oil goods |
|----------------------|-----------|---------------|
|                      | High inflation$^a$ | Low positive inflation$^a$ | Deflation$^a$ | High inflation | Low positive inflation | Deflation |
| Constant             | −0.0022   | 0.0064        | 0.0025        | 0.0000        | 0.0004          | 0.0028       |
| (−0.488$^b$)         | (1.3471)  | (0.5625)      | (2.6736)      | (0.0063)      | (0.1211)        | (0.7857)     |
| Δpt−1                | 0.3022$^{**}$ | 0.0212        | 0.25$^{***}$  | 0.2016$^*$    | 0.2951$^{***}$  | 0.1314       |
| (2.2624)             | (0.2113)  | (2.6736)      | (1.8)         | (2.8622)      | (1.3296)        | (7.4607)     |
| Δpt−1$^{nonoil}$     | 0.7474$^{***}$ | 0.5683$^{***}$ | 0.5918$^{***}$ | 0.6481$^{***}$ | 0.5532$^{***}$  | 0.5059$^{***}$ |
| (7.3442)             | (5.4298)  | (5.6323)      | (10.778)      | (7.8170)      | (7.4607)        | (7.4607)     |
| Δet                  | −0.3361$^{**}$ | −0.2665$^{**}$ | −0.1345       | −0.1573       | −0.1705$^*$     | 0.0063        |
| (−2.3395)            | (−2.1286) | (−1.765)      | (−1.637)      | (−1.8)        | (0.065)         | (0.065)      |
| Δet−2                | 0.1397    | −0.076        | 0.03675       | 0.0778        | −0.0642         | −0.0858       |
| (1.3849)             | (−0.7896) | (0.3299)      | (1.3156)      | (0.9843)      | (0.0984)        | (0.9843)     |
| Δpt                  | 0.6915$^{***}$ | 0.6538$^{***}$ | 0.1858        | 0.3058$^{***}$ | 0.4766$^{***}$  | 0.2121        |
| (3.8162)             | (3.5943)  | (0.8012)      | (2.5872)      | (3.84)        | (1.158)         | (1.158)      |
| Δpt−1                | −0.1891   | 0.0807        | 0.2706        | 0.1378        | −0.0436         | 0.3169$^*$    |
| (−0.9728)            | (−0.4728) | (1.2368)      | (1.3053)      | (−0.3193)     | (1.8506)        | (1.8506)     |
| Δmc$^c$              | 0.4189$^{**}$ | 0.8108$^{**}$ | 1.0825$^{***}$ | 0.1884        | −0.0904         | 0.5059$^{**}$ |
| (2.0223)             | (2.4093)  | (3.8697)      | (0.7926)      | (−0.2977)     | (2.2785)        | (2.2785)     |
| Δmc$^c$, nonoil       | 0.0252    | −0.0083       | 0.0191        | 0.0209        | 0.0013          | 0.0281$^*$    |
| (1.2253)             | (0.7282)  | (0.8893)      | (1.6309)      | (0.078)       | (1.677)         | (1.677)      |
| Sample size          | 95        | 95            | 124           | 95            | 95              | 124           |
| SSR                  | 0.01      | 0.0076        | 0.0249        | 0.0039        | 0.0037          | 0.0152        |
| F statistic          | 5.1186$^{**}$ | 0.0446        | 7.1481$^{***}$ | 3.2417$^*$    | 8.1919$^{***}$  | 1.7679        |
| $R^2$                | 0.6243    | 0.4644        | 0.3144        | 0.6668        | 0.6236          | 0.3518        |
| Breusch–Godfrey statistic | 1.5388   | 0.1065        | 1.7052        | 1.0117        | 0.2587          | 1.4071        |
| (p-values)           | (0.2148$^d$) | (0.7441)      | (0.1916)      | (0.3145)      | (0.611)         | (0.2355)      |

$^a$ High inflation, low positive inflation, and deflation regimes denote the monthly inflation rate ($\pi$) of $\pi>3\%, 1\%<\pi<3\%$ and $\pi<1\%$.

$^b$ The figures in parentheses below the coefficients are t-statistics, with significance levels denoted as: $^*=10\%, ^{**}=5\%, ^{***}=1\%$.

$^c$ Adjusted $R^2$.

$^d$ The figures in parentheses are p-values for the Breusch–Godfrey statistic; the null hypothesis of no autocorrelation in residuals is not rejected at the significance level of 5%.

In Table 6, the pass-through estimates in the deflation regime during the period of 1981–2007.1 (after the financial crisis) are 0.93 and 0.81, which are 20% higher than those of 0.67 and 0.60 obtained from the whole sample period of 1981–2008 in Table 5.
According to Tsay (1998), the grid search method determines the appropriate threshold values in a TAR model. Based on this approach, the threshold values endogenously generated from the data for the lower bound of a high inflation regime and the upper bound of a deflation regime in model (6) are, respectively, 2.83% and 0.8% (for the whole period); 2.85% and 0.8% (before the financial crisis); 2.8% and 0.8% (after the financial crisis). By using these values as the threshold values for the regimes in model (6), the pass-through rates are estimated for these three redefined inflation regimes. The estimated long-run pass-through are presented in Table 8.

In the first panel for the whole period, although the pass-through for non-oil goods in deflation (0.56) is slightly lower than that in low positive inflation (0.58), the pass-through for all goods in deflation is 0.60 and is obviously higher than that of 0.36 in low positive inflation, indicating that the result of higher pass-through in deflation is consistent with the result in this study. In the second and the third panels of the sub-samples, the estimates also show a higher degree of pass-through in deflation than in low positive inflation, except for the non-oil goods after the crisis. Nonetheless, with endogenous threshold values, the increase in the degree of pass-through in deflation holds in the sub-samples. In addition, the pass-through of 0.98 and 0.86 in deflation for the period of 1997.1–2008 (after the financial crisis), which are higher than the 0.60 and 0.56 values obtained for the whole sample period of 1981–2008, indicates that, after the financial crisis, the pass-through increase more in deflation than they do over the whole period. This also implies that a higher degree of pass-through can be found in deflation, whether the threshold values are exogenous or endogenous to the model.

The above results of Tables 7 and 8 show the increasing pass-through in deflation that are reported in this study. Although some of the estimated pass-through rates for the sub-samples are not empirically persuasive due to the limited sample size, the robustness checks performed on the data for the whole period all show higher pass-through rates in deflation. Therefore, we conclude that the observed results are robust under these checks.

4. Conclusion and general remarks

Based on Taiwan’s import price data, this paper separates the impact that deflation has on the degree of exchange rate pass-through that is generally included in a low inflation regime. Using a nonlinear threshold model, we find that the degree of

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**Table 5**
Long-run exchange rate pass-through for three regimes.

|                                | All goods | Non-oil goods |
|--------------------------------|-----------|---------------|
| High inflation                 | $\pi > 3\%$ | 0.79          | 0.71          |
| Low positive inflation         | $1\% < \pi < 3\%$ | 0.24          | 0.46          |
| Deflation                      | $\pi < 1\%$ | 0.67          | 0.60          |

Note: The long-run exchange rate pass-through is computed as $\beta(1)/(1 - \rho)$, where $\beta(1)$ is the sum of contemporaneous and lagged $\beta_i$ coefficients.

**Table 6**
Long-run exchange rate pass-through, sub-samples.

|                                | All goods | Non-oil goods |
|--------------------------------|-----------|---------------|
| I. 1981–1997.1 (before the financial crisis) |          |               |
| Two regimes                     |           |               |
| High inflation                  | $\pi > 3\%$ | 0.90          | 0.76          |
| Low inflation                   | $\pi < 3\%$ | 0.43          | 0.40          |
| Three regimes                   |           |               |
| High inflation                  | $\pi > 3\%$ | 0.90          | 0.76          |
| Low positive inflation          | $1\% < \pi < 3\%$ | 0.09*         | 0.20*         |
| Deflation                       | $\pi < 1\%$ | 0.72*         | 0.53*         |
| II. 1997.2–2008 (after the financial crisis) |          |               |
| Two regimes                     |           |               |
| High inflation                  | $\pi > 3\%$ | $-3.04_{ab}$  | 0.57_{ab}     |
| Low inflation                   | $\pi < 3\%$ | 0.78          | 0.81          |
| Three regimes                   |           |               |
| High inflation                  | $\pi > 3\%$ | $-3.04_{ab}$  | 0.57_{ab}     |
| Low positive inflation          | $1\% < \pi < 3\%$ | 0.99*         | 1.08*         |
| Deflation                       | $\pi < 1\%$ | 0.93          | 0.81          |

Note: a. The degree of freedom of the estimation result is less than 30. b. The adjusted $R^2$ is negative for the estimation result.

According to Tsay (1998), the grid search method determines the appropriate threshold values in a TAR model. Based on this approach, the threshold values endogenously generated from the data for the lower bound of a high inflation regime and the upper bound of a deflation regime in model (6) are, respectively, 2.83% and 0.8% (for the whole period); 2.85% and 0.8% (before the financial crisis); 2.8% and 0.8% (after the financial crisis). By using these values as the threshold values for the regimes in model (6), the pass-through rates are estimated for these three redefined inflation regimes. The estimated long-run pass-through are presented in Table 8.

In the first panel for the whole period, although the pass-through for non-oil goods in deflation (0.56) is slightly lower than that in low positive inflation (0.58), the pass-through for all goods in deflation is 0.60 and is obviously higher than that of 0.36 in low positive inflation, indicating that the result of higher pass-through in deflation is consistent with the result in this study. In the second and the third panels of the sub-samples, the estimates also show a higher degree of pass-through in deflation than in low positive inflation, except for the non-oil goods after the crisis. Nonetheless, with endogenous threshold values, the increase in the degree of pass-through in deflation holds in the sub-samples. In addition, the pass-through of 0.98 and 0.86 in deflation for the period of 1997.1–2008 (after the financial crisis), which are higher than the 0.60 and 0.56 values obtained for the whole sample period of 1981–2008, indicates that, after the financial crisis, the pass-through increase more in deflation than they do over the whole period. This also implies that a higher degree of pass-through can be found in deflation, whether the threshold values are exogenous or endogenous to the model.

The above results of Tables 7 and 8 show the increasing pass-through in deflation that are reported in this study. Although some of the estimated pass-through rates for the sub-samples are not empirically persuasive due to the limited sample size, the robustness checks performed on the data for the whole period all show higher pass-through rates in deflation. Therefore, we conclude that the observed results are robust under these checks.

4. Conclusion and general remarks

Based on Taiwan’s import price data, this paper separates the impact that deflation has on the degree of exchange rate pass-through that is generally included in a low inflation regime. Using a nonlinear threshold model, we find that the degree of
exchange rate pass-through increases as the inflation environment becomes one of deflation. In contrast to the existing literature, our results indicate that the degree of exchange rate pass-through is v-shaped across regimes. The pass-through not only increases with positive inflation but also with deflation. The increasing trend for the latter is observed once deflation is clearly identified. If deflation is not separated from the broadly defined low inflation regime, a biased result may arise, and the degree of pass-through will be inaccurate.

The results also indicate that the price of oil influences the measurement of the degree of pass-through. Changes in the degree of pass-through are less variable once the price of oil is excluded. However, the pattern of increasing degrees of pass-through in a deflation regime is unchanged. The evidence shows that higher pass-through rates still exist for non-oil import goods in deflation.

Regarding policy implications, our results suggest that while keeping inflation as low as possible is beneficial, as it lowers the impact exchange rates have on import prices, this no longer works in periods of deflation. As this effect only operates while inflation is maintained above a certain level, the differing impacts that inflation has on the degree of pass-through should be considered carefully in policymaking.

In our view, the results may differ if other countries’ data or empirical models are applied. However, in an investigation of the relationship between the exchange rate pass-through and inflation, our results suggest that the separate impacts of deflation should be considered carefully.

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We thank two anonymous referees for their very helpful comments and suggestions.

Table 8

| All goods | Non-oil goods |
|-----------|---------------|
| **Whole period (1981–2008)** | | |
| High inflation | π > 2.83% | 0.79 | 0.71 |
| Low positive inflation | 0% < π ≤ 2.83% | 0.47 | 0.48 |
| Deflation | π ≤ 0% | 0.85 | 0.64 |
| **II. 1981–1997.1 (before the financial crisis)** | | |
| High inflation | π > 3% | 0.90 | 0.76 |
| Low positive inflation | 0% < π ≤ 3% | 0.31 | 0.30 |
| Deflation | π ≤ 0% | 1.64* | 0.17* |
| **III. 1997.2–2008 (after the financial crisis)** | | |
| High inflation | π > 3% | −3.04ab | 0.57ab |
| Low positive inflation | 0% < π ≤ 3% | 0.86 | 0.90 |
| Deflation | π ≤ 0% | 0.90a | 0.72a |

Note:
a. The degree of freedom of the estimation result is less than 30.
b. The adjusted R² is negative for the estimation result.
Appendix A

A.1. Taiwan import prices

Import price: The data are a monthly index of the weighted import price for ten product categories published by the Directorate General of Budget, Accounting and Statistics, Executive Yuan (DGBAS) in Taiwan. The list of products is: Animal and Vegetable Products and Prepared Foods; Mineral Products and Nonmetallic Mineral Products; Textiles and Textile Articles; Wood, Paper, Pulp and Articles Thereof; Chemicals, Plastics, Rubber and Articles Thereof; Primary Metals and Articles Thereof; Machinery, Optical and Precision Instruments; Electronic Machinery; Transportation Equipment and Panels; and Miscellaneous Products.

Non-oil import price: We compute the non-oil import price index by excluding the mineral products item from the import price.

A.2. Exchange rates

Nominal effective exchange rate: We construct the nominal effective exchange rate (NEER) based on the prevailing method used in the related studies of Kohlscheen (2010), Ito and Sato (2008), Campa and Gonzalez (2006), Gagnon and Ihrig (2004), Knetter (1995), and Steel and King (2004). This variable is an import-weighted average exchange rate index for 14 countries exporting to Taiwan. These countries are Australia, China, France, Germany, Hong Kong, Indonesia, Japan, Korea, Kuwait, Malaysia, Singapore, Saudi Arabia, the UK and the US. Purchases from these countries typically account for over 70% of the total imports. Among these 14 countries, except for major currencies, such as the Japanese Yen, Euro, UK Pound and the US Dollar, the bilateral exchange rates between the Taiwan NT-Dollar and the other currencies are replaced by the exchange rates with respect to the US-Dollar.

Source: International Financial Statistics.

Non-oil nominal effective exchange rate: This variable is computed by excluding the countries from which Taiwan imports oil. These countries are Saudi Arabia, Kuwait and Indonesia.

A.3. Foreign costs

Foreign costs: It is an import-weighted average of producer price indices (PPI’s) or the consumer price index (CPI) for 14 countries that export to Taiwan. Data on PPIs for China, France, Hong Kong, Kuwait, Malaysia and Saudi Arabia are difficult to obtain, so we use the CPIs as a proxy for production costs in these countries.

Source: International Financial Statistics.

Non-oil foreign costs: This variable is computed by excluding the countries from which Taiwan imports its oil (i.e., Saudi Arabia, Kuwait and Indonesia) from foreign costs.

A.4. Domestic price

This is a monthly series of the wholesale price index for domestic products and sales in Taiwan. Instead of a general PPI or WPI, we select the wholesale price index of domestic products and sales to represent the domestic competitive price pressure to avoid endogeneity with import prices. As the products in this index are produced and consumed domestically, prices for these domestic products are not intercorrelated with import prices.

Source: DGBAS Taiwan.

A.5. Domestic demand

This variable is a monthly index computed by the total value of private consumption, government consumption and gross fixed capital formation.

Source: DGBAS Taiwan.

A.6. Inflation rates

This is a monthly series of the annual percentage changes in Taiwan’s Consumer Price Indices (CPI).

Source: DGBAS Taiwan.

References

Al-Abri, A., & Goodwin, B. (2009). Re-examining the exchange rate pass-through into import prices using non-linear estimation techniques: threshold cointegration. *International Review of Economics and Finance*, 18(1), 142–161.

Athukorala, P. (1991). Exchange rate pass-through: the case of Korean exports of manufactures. *Economic Letters*, 35, 79–84.

Bouakez, H., & Rebei, N. (2008). Has exchange rate pass-through really declined? Evidence from Canada. *Journal of International Economics*, 75, 249–267.

Campa, J., & Goldberg, L. (2005). Exchange rate pass-through into import prices. *The Review of Economics and Statistics*, 87(4), 679–690.

Campa, J., & Gonzalez, J. (2006). Differences in exchange rate pass-through in the euro area. *European Economic Review*, 50(1), 121–145.

Ceglowski, J. (2010). Exchange rate pass-through to bilateral import prices. *Journal of International Money and Finance*, 29(8), 1637–1651.

Choudhri, E., & Hakura, D. (2006). Exchange rate pass-through to domestic prices: does the inflationary environment matter? *Journal of International Money and Finance*, 25, 614–639.
Gagnon, J., & Ihrig, J. (2004). Monetary policy and exchange rate pass-through. *International Journal of Finance and Economics*, 9(4), 315–338.

Gust, C., Leduc, S., & Vigfusson, R. (2010). Trade integration, competition, and the decline in exchange rate pass-through. *Journal of Monetary Economics*, 57(3), 309–324.

Hooper, P., & Mann, C. (1989). Exchange rate pass-through in the 1980s: the case of U.S. imports of manufactures. *Brookings Papers on Economic Activity*, 1, 297–337.

Ito, T., & Sato, K. (2008). Exchange rate changes and inflation in post-crisis Asian economies: vector autoregression analysis of the exchange rate pass-through. *Journal of Money, Credit, and Banking*, 40(7), 1407–1438.

Kim, Y. (1990). Exchange rates and imports prices in the U.S.: a varying-parameter estimation of exchange rate pass-through. *Journal of Business and Economic Statistics*, 8(3), 169–210.

Knetter, M. (1989). Price discrimination by U.S. and German exporters. *American Economic Review*, 79(1), 198–210.

Knetter, M. (1993). International comparisons of pricing-to-market behavior. *American Economic Review*, 83(3), 473–486.

Knetter, M. (1995). Pricing to market in response to unobservable and observable shocks. *International Economic Journal*, 9(2), 1–25.

Kohlscheen, E. (2010). Emerging floaters: Pass-throughs and (some) new commodity currencies. *Journal of International Money and Finance*, 29(8), 1580–1595.

Marazzi, M., & Sheets, N. (2007). Declining exchange rate pass-through to U.S. import prices: the potential role of global factors. *Journal of International Money and Finance*, 26, 924–947.

Maria-Dolores, R. (2010). Exchange rate pass-through in new member states and candidate countries of the EU. *International Review of Economics and Finance*, 19(1), 23–35.

Phillips, P. C. B., & Perron, P. (1988). Testing for a Unit Root in Time Series Regressions. *Biometrika*, 75, 335–346.

Rogoff, K., et al. (2001). Deflation: determinants, risks, and policy options—findings of an interdepartmental task force. *IMF Occasional Papers Series [Date: June 30, 2003]*.

Sekine, T. (2006). Time-varying exchange rate pass-through: experiences of some industrial countries. *Bank for International Settlements, Working Paper*, 202.

Steel, D., & King, A. (2004). Exchange rate pass-through: the role of regime changes. *International Review of Applied Economics*, 18(3), 301–322.

Taylor, J. (2000). Low inflation, pass-through, and the pricing power of firms. *European Economic Review*, 44(7), 1389–1408.

Tica, J., & Posedel, P. (2009). Threshold autoregressive model of exchange rate pass-through effect: the case of Croatia. *Eastern European Economies*, 47(6), 43–59.

Tsay, R. S. (1998). Testing and modeling multivariate threshold models. *Journal of the American Statistical Association*, 93, 1188–1198.