Macroeconomics Determinants of Exchange Rate Pass-through: New Evidence from the Asia-Pacific Region

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Abstract

Some recent studies observe an increasing degree of exchange rate pass-through (ERPT) to domestic prices, which has raised questions about the nature of the incompleteness and decline in pass-through. This paper reexamines the degree of ERPT to the import, producer, and consumer price indices in Australia, New Zealand, Japan, and Korea in the Asia-Pacific region using up-to-date data, with several important findings. First, we reveal that ERPT to domestic prices follows the distribution chain, in that exchange rate movements alter import prices in the first stage and then producer and consumer prices in the second stage. Second, we offer valid evidence of an increase in ERPT to import prices after the global financial crisis in Japan, Korea, and New Zealand and of a relatively stable ERPT in Australia. Third, the changes in ERPT elasticities are most affected by macroeconomic determinants such as inflation volatility, interest rates, and trade openness, but this varies considerably across the surveyed countries and the three price indices. All our findings make a significant contribution to the empirical literature on ERPT and have policy implications.

Keywords: Asia-Pacific region, exchange rate pass-through (ERPT), inflation

JEL classification: E31, F31, F41

1 Introduction

One of the key concerns in international finance, which has attracted great attention among scholars all over the world, is the extent to which exchange rate changes affect domestic prices, known as exchange rate pass-through (ERPT). It refers to the mechanism of converting the movement of exchange rates into the import price index (IMP), called the first stage, and in turn into the producer price index (PPI), as well as the consumer price index (CPI), known as the second stage. The extent of ERPT into domestic prices can have both short-run and long-run effects.

Several studies, using various approaches, have documented that ERPT seems to be incomplete and decreasing in previous decades, especially before the 2008 global financial crisis. However, the findings related to ERPT seem to be different in recent studies. Some articles have been carried out in East Asian countries. Using a sample of nine Asian-Pacific countries, Webber (1999) finds evidence of partial, long-run pass-through to import prices in most cases from 1978Q1 to 1994Q4 on the basis of a single equation technique. Specifically, Pakistan has the highest long-run pass-through, at 109%, while the lowest is experienced in Australia, at 26%. The pass-through is about 50% in South Korea and Japan, and just over 30% in New Zealand. Ito and Sato (2008) focus on five Asia countries—Indonesia, Thailand, Malaysia, Singapore, and South Korea—as they suffered severely from the 1997 Asian financial crisis. Their results reveal that the pass-through of exchange rate shocks appears to be the largest on IMP, then on PPI, and the smallest on CPI and that the entire period from 1994 to 2006 has a higher degree of pass-through to the three indices than the sub-timeframe starting in 1997. Additionally, ERPT in Japan, Australia, and New Zealand is lower in Takhtamanova (2010), which analyzes 14 member countries of the Organization for Economic Cooperation and Development (OECD) in two different periods: the 1980s and 1990 to 2007. Hara, Kazuhiro, and Yoshitaka (2015) explore a rise in ERPT in Japan

since the late 2000s with the application of a time-varying parameter estimation as well as a decomposition approach. A sharply rising ERPT in 2010–2011 has been documented in Switzerland (Fleer, Rudolf, and Zurlinden 2016). Alvarez, Jaramillo, and Selaive (2012) reexamine the degree of ERPT to import prices and wholesale prices in Chile, using both aggregated and disaggregated data, and do not find incomplete and declining ERPT. The disaggregated import prices include consumption, intermediate uses, and capital, and the disaggregated wholesale prices cover agriculture, mining, and industry. Their findings indicate that (i) the degree of ERPT is complete and not declining in the long run, and (ii) wholesale price indices appear to be less sensitive to exchange rate movements, and evidence of an asymmetric ERPT is weak. It is likely that ERPT has changed its behavior in recent years since the global financial crisis.

It is equally imperative to identify what causes the implications of exchange rate changes. Some empirical studies use panel data to incorporate different factors, with the most emphasis on inflation. Soon, Baharumshah, and Wohar (2017) find that inflation volatility in Asia affects the degree of exchange rate changes that pass through to inflation. In Latin America, Ghosh (2013) reveals that trade openness, exchange rates, and inflation are likely to be significantly related to the degree of ERPT to domestic prices, both CPI and IMP. Ozkan and Erden (2015) also explore various macroeconomic factors using panel data on as many as 88 countries. Their results indicate that, although inflation, trade openness, output gaps, exchange rates as well as inflation targeting appear to play a central role in explaining the degree of ERPT, those factors react differently across a group of countries, including developed, less developed, and developing countries. Takhtamanova (2010) reveals that inflation has a significantly negative impact on long-run ERPT, and trade openness is positively correlated with short-run pass-through. Furthermore, some papers

offer direct insights into what influences the degree of ERPT within a single country. In addition to inflation, exchange rates, output gaps, and trade openness, Jiménez-Rodríguez and Morales-Zumaquero (2016) observe that the exchange rate regime is important in explaining changes in ERPT in G-7 countries. However, in New Zealand, Parker and Wong (2014) divide the causes of exchange rate movement into such two categories as (i) changes in international prices of the commodity exports and (ii) other factors. Similarly, Hara et al. (2015) confirm that rising ERPT in Japan since the 2008 global financial crisis is attributed to the import-intensiveness of manufacturing and to greater responsiveness of inflation to marginal costs, implying that firms may have changed their pricing behavior. Alvarez et al. (2012) believe that the monetary policy of inflation targeting plays a fundamental role in the absence of decline in ERPT in Chile.

The incomplete magnitude and changing nature of ERPT vary considerably across Asia-Pacific countries in different studies, which may result from studying different time spans and using different econometric techniques. Also, few studies have investigated the role of macroeconomic factors in explaining changes in ERPT. Therefore, it is important to reexamine those characteristics of ERPT on domestic prices in Asia-Pacific countries especially after the global financial crisis. A deep understanding of the extent and causes of ERPT in the Asia-Pacific region is essential for policy makers designing a prompt monetary response.

The study has three main objectives. First, we focus on the effect of ERPT on domestic prices (IMP, PPI, and CPI) in four developed countries: Australia, New Zealand, Japan, and South Korea in the Asia-Pacific region, arguably one of the most integrated and dynamic economic regions in the world. The region has developed considerable economic integration, which is expected to create a different pattern in ERPT behavior. The short- and long-run pass-through are based on an autoregressive distributed lag (ARDL) model with up-to-date data. We show that the degree of

ERPT is far greater to IMP than to PPI as well as CPI, and among the four countries, Korea experiences a much higher degree of ERPT to IMP than the others. Second, we consider the changing pattern in ERPT elasticities over time, as indicated in previous studies. Our results show that ERPT to domestic prices tends to be stable in Australia, whereas Japan, Korea, and New Zealand have an upward trend in import prices after the global financial crisis. Third, we explore which macroeconomic factors drive the changing patterns in ERPT. Changes in ERPT elasticities are affected most by macroeconomic determinants such as inflation volatility, interest rates, and trade openness, but this varies considerably across the surveyed countries and price indices. All our findings make a significant contribution to the empirical literature on ERPT and have policy implications.

The paper is organized as follows. Following this Introduction, Section 2 reveals relevant theories and empirical studies related to ERPT to domestic prices. The methodology is presented in Section 3 while Section 4 presents data description and empirical results. Our final remarks are in Section 5.

2 Literature Review

In recent decades, the degree of ERPT is reported to be incomplete and declining in a large number of countries, especially the industrialized countries. Both theoretical and empirical literature has attempted to explain this phenomenon from micro- and macroeconomic perspectives. On the one hand, the microeconomics-based works discuss theoretically the prevalence of local currency pricing over producer-currency pricing. Devereux and Engel (2003) argue that if producer-currency pricing (PCP) dominates, the ERPT to domestic prices will be immediate, and exchange rate flexibility plays a central role in an optimal monetary policy. In contrast, if local currency pricing (LCP) dominates, exporters will keep their prices fixed in the foreign currency

and accept the resultant domestic price at the prevailing exchange rate. They would be willing to reduce their profit margin on condition that a nominal exchange rate appreciation prevents a pass-through to import and consumer prices. On the other hand, a macroeconomics-based theory has emerged to explain EPRT based on the new open-economy model by Obstfeld (2002). Additionally, Taylor (2000) posits a well-known hypothesis that an environment of low inflation leads to low ERPT to domestic prices. Studies using a model of firm behavior based on staggered price setting and monopolistic competition show that the degree of ERPT is regime specific, and in low-inflation scenarios the effectiveness of monetary policy could be severely impaired. This theoretical literature offers a strong catalyst for empirical studies on the ERPT. It should be noted that there is a reconciliation between macro and micro aspects, as foreign producers' pricing strategy is also related to macroeconomic conditions in the importing country. Exporters may follow an LCP setting if they perceive a stable macroeconomic environment in the destination country, and ERPT will be lower. However, in instable economic conditions, the PCP strategy will be perfect, and hence ERPT will be larger (Ben Cheikh and Rault 2016).

In parallel with theory building, substantial empirical papers have contributed to the ERPT literature. However, they vary considerably in terms of data, econometric techniques, and countries under analysis. In their survey, Aron, Macdonald, and Muellbauer (2014) offer a complete overview of the ERPT literature on the concepts, methodologies, and policy implications in the context of developing and emerging economies. Their survey provides a comparison and categories of methodologies that have been adopted to measure the degree of ERPT in contemporary research, highlighting some controls and restrictions that policy makers consider in ERPT measures.

Concerning econometric techniques, a large number of estimation alternatives can be identified and roughly divided into two main categories. The first type of research relies on multi-equation models to investigate whether ERPT follows the distribution chain. Vector autoregressions (VAR) are widely applied in empirical studies, such as Cazorzi et al. (2007), Ito and Sato (2008), An and Wang (2012), and McCarthy (2007). The other category uses a single equation with ordinary least squares (OLS) estimation to examine the incompleteness of ERPT (Barhoumi 2006; Campa and Goldberg 2005). Additionally, some scholars have employed co-integration tests and error correction models (Toh and Ho 2001).

In recent years, numerous studies have emerged on the issue of asymmetries and nonlinearities in ERPT. A recent study by Bussiere (2013) attempts to find evidence on this issue by adopting methods such as polynomial terms, interactive dummy variables, and nonlinear tests for G7 countries. The nonlinear effect should not be neglected although it is less evident than asymmetry. Also, the author shows that large exchange rate appreciation affects export prices disproportionately, and there is considerable variation in the direction of asymmetry and the magnitude of nonlinearity across countries. In microeconomic assumptions, the difference is attributed mainly to price rigidity and demand elasticities. Shintani, Terada-Hagiwara, and Yabu (2013) apply an exponential smooth transition autoregressive model to validate the dynamic of ERPT, with the transition variable being lagged inflation. Their result supports nonlinearity in ERPT in the US. Based on a logistic smooth transition pass-through estimation, Kilic (2015) confirms the nonlinearity in low and high pass-through regimes. The author also find evidence of asymmetric ERPT on import prices in developed countries, providing that a 1% currency depreciation is not followed by the same degree of ERPT. Baharumshah, Soon, and Wohar (2017) show evidence of nonlinear pass-through in six Asian countries—Indonesia, South Korea, the

Philippines, Thailand, Japan, and China—with the application of a Markov-switching model. The pass-through from exchange rates to domestic inflation is estimated on the basis of two regimes, stable or unstable, defined as higher inflation uncertainty. The pass-through is incomplete and varies across the surveyed countries and the two regimes, and the stable regime has significantly lower pass-through than the unstable one.

Regarding samples in empirical analysis, many studies are in favor of a group of countries with different economic policies, such as exchange rate regime and inflation targeting. For example, Ghosh (2013) documents decreasing and incomplete ERPT to both consumer and import prices since the 2000s and confirms that ERPT declines over time in nine Latin American countries with a history of high inflation. In their analysis, Ben Cheikh and Louhichi (2014) emphasize the role of inflation regimes in examining the effect of ERPT on import prices using panel data on 63 countries from 1992 to 2012. The countries were divided into three subsamples according to their inflation threshold level. The finding provides convincing evidence of dependence between ERPT and inflation regimes; the high inflation countries have a higher degree of ERPT. This finding highly supports the research by Barhoumi (2006), in which the effect of exchange rate movement on import prices was documented using a sample of 24 developing countries.

Panel data are widely used in studies. For instance, Ozkan and Erden (2015) use an approach that combines dynamic conditional correlation-generalized autoregressive conditional heteroskedasticity (DCC-GARCH) and panel threshold regression to analyze the time-varying nature of ERPT in a large group of countries from 1980 to 2013. The ERPT values reached peaks in the mid-1980s, the early 1990s, and the late 1990s, gradually declined until the 2008 global crisis, and then remained stable for the rest of the period. Adopting another time-varying parameter method with stochastic volatility models, Sekine (2006) investigates changes in the ERPT to IMP

at the first stage and then to CPI at the second stage. The evidence supports a decline in ERPT at both stages. Like Sekine (2006), Jiménez-Rodriguez and Morales-Zumaquero (2016) find that the ERPT elasticities remain relatively stable from 1970 to 2014 in the G-7 countries (Canada, France, Germany, Japan, Italy, the United Kingdom, and the United States), except for Germany and the UK, in that a declining ERPT is recorded during the 1980s. Similarly, Jasova, Moessner, and Taka (2016) reveal that developed countries have a relatively low and stable ERPT over time while developing countries have decreasing ERPT since the 2008 global financial crisis. The finding of declining ERPT appears to be consistent with Taylor's (2000) hypothesis, emphasizing that the low inflation environment is statistically related to lower ERPT. He argues that the declining ERPT in recent decades results from a decrease in inflation in developed countries.

Some empirical evidence on ERPT had been found on particular countries, both industrialized and developing. Jiang and Kim (2013) investigate the extent of ERPT to PPI and CPI with the application of a VAR model in China. ERPT is higher to PPI than to CPI. Also, they found incomplete pass-through and rapid pass-through from exchange rates to two types of prices. Using a single equation, some authors consider ERPT to domestic prices in East Asian countries, examine whether ERPT changes over time, and try to explain which determinants drive the movement (Ghosh and Rajan 2009; Prasertnukul, Kim, and Kakinaka 2010). Their main results indicate the downward trend of ERPT over time and that the key factors in ERPT movements are money growth volatility, inflation and inflation volatility, and trade openness.

3 Methodology

To quantify the degree of ERPT to price indices, we rely on the Campa and Goldberg (2005) model, which is based on the micro-foundation of exporter price behavior regarding foreign firms'

marginal cost and markup. The specification is also widely used in previous studies (Ghosh and Rajan 2009; Kilic 2015; Yanamandra 2015). Our specification is as follows:

$$\ln(P_t^i) = \alpha_0 + \beta \ln(NEER_t^i) + \delta \ln(MC_t^i) + \gamma \ln(GDP_t^i) + \varepsilon_t \quad (1)$$

where *i* and *t* represent observations in country *i* at time *t. P* represents the price indices: IMP, PPI, and CPI. *NEER* is the nominal exchange rate for each country *i,* and an increase in a country's *NEER* indicates depreciation in that country's currency. The marginal cost (*MC*) of exports in a foreign country is difficult to measure. Different proxies have been used in the literature to capture changes in foreign costs. Following Bailliu and Fujii (2004) and Campa and Goldberg (2005), we use the conventional index by multiplying the domestic unit labor cost (ULC) by the ratio of the ULC-based real effective exchange rate to the nominal effective exchange rate. The real gross domestic product (*GDP*) is demand in the importing country *i* with respect to the foreign firm's markup. Another proxy for demand is the output gap, the difference between actual and potential GDP, to measure changes in demand conditions.[1]

It is important to check whether the variables in equation (1) are cointegrated, as that would suggest a long-run relationship among them. In this study, we use two-step cointegration tests proposed by Engle and Granger (1987). The time frame is so long that data series can show structural breaks due to, for example, the Asian financial crisis. Thus, the residual-based test for cointegration in models with regime shifts by Gregory and Hansen (1996) is applied. Empirically, some scholars find supporting evidence on a long-run relationship between exchange rates and the

[1] In our robustness check, the output gap and the US PPI are used as proxies for domestic demand and foreign marginal cost. Additionally, exchange rate movements may indirectly affect import prices, and thus other domestic prices, via the impact on commodity prices, so we add the world oil price in equation (2) for a further check. The results are in Table A1.

price index based on the cointegration tests. Thus, it would be more appropriate to investigate the long-run ERPT using an error correction model or an dynamic OLS (Ghosh and Rajan, 2009; Yanamandra, 2015). However, several scholars fail to document the long-run link (Ben Cheikh and Rault 2016; Campa and Goldberg 2005; Kilic 2015). In cases of a relationship with no cointegration, to consider the long-run impact of exchange rate movements on the price level, it is possible to apply the ADRL to the analysis. We rely on this model in our case.

Equation (1) is transformed into a partial adjustment model using the ADRL model as follows.

$$\Delta \ln\left(P_t^i\right) = \alpha_0 + \sum_1^m \alpha_m \Delta \ln\left(P_t^i\right) + \sum_0^n \beta_n . \Delta \ln\left(NEER_t^i\right) + \sum_0^p \delta_p \Delta \ln\left(MC_t^i\right) + \sum_0^q \gamma_q \Delta \ln(GDP_t) + Dcrisis + Dquarterly + \varepsilon_t \quad (2)$$

We take into account the impact of the Asian financial crisis in 1997 and the global crisis in 2008 by adding a dummy variable. Also, the data are not seasonally adjusted, so the quarterly dummy is added to take seasonal characteristics into account. Like previous studies (Campa and Goldberg 2005; Ceglowski 2010), our model includes four lags due to the quarterly data, although this significantly reduces the degrees of freedom in the ADRL estimation.[2] The coefficients of NEER show the degree of pass-through. The short-run pass-through is β_0, whereas the long-run one is measured as follows:

$$ERPT_{LR} = \sum_0^n \beta_n / (1 - \sum_1^m \alpha_m) \quad (3)$$

The long-run ERPT is calculated based on equation (3) on condition that the coefficients of the nominal exchange rate as well as the price index and those of the lagged terms are statistically

[2] We reestimate equation (2) with one lag as a robustness check. The results are presented in Table A1.

significant. This calculation is the same as those in studies by Edwards (2006) and Prasertnukul et al. (2010).

The next step in our analysis is to consider whether the degree of ERPT changes over time in the four countries surveyed. To capture the time-varying nature of ERPT over time, earlier studies have used a wide range of methods, such as rolling windows, Kalman filtering, recursive methods (Beckmann et al. 2014; Ghosh and Rajan 2009; Gust et al. 2010), and time-varying parameter estimations (Sekine 2006). No clear consensus has been reached on the best method to apply. Thus, like several other studies, we rely on a recursive estimation.

Finally, we explore which macroeconomic factors drive changes in ERPT in the short run. The impact of macroeconomic factors on short-run ERPT is specified as follows.

$$ERPT_{SR} = \beta_0 = f(inf, v\_inf, ir, v\_ir, v\_neer, oilpg, ygap, openness) \quad (4)$$

where *inf* is inflation and *v_inf* is inflation volatility, while *ir* is interest rates and *v_ir* is interest rate volatility. The variable *v_neer* is the volatility of the nominal exchange rate. Finally, *oilpg* is growth in world oil prices, *ygap* is output gaps, and *openness* is trade openness. The volatility of a variable is measured by the standard error of the four lagged periods of the series. Output gaps are calculated using the HP filter, implying the difference between real GDP and its potential level, while trade openness is the ratio of total exports and imports to GDP.

In the literature, the indispensable factor in response to changes in ERPT is inflation. Taylor (2000) indicates a positive relationship between inflation and ERPT, meaning that when a country has higher inflation, it has a higher pass-through from exchange rate movements to domestic prices. Several authors have attempted to test this relation, even using non-linear models (Ben Cheikh and Rault 2016; Shintani et al. 2013). Additionally, inflation volatility is significantly

related to a lower ERPT to consumer prices (Gagnon and Ihrig 2004; Lopez-Villavicencio and Mignon 2017). Exchange rate volatility also has an impact on ERPT, based on exporters' reactions to their markup (Brun-Aguerre, Fuertes, and Phylaktis 2012).

We also add interest rates and their volatility to take into account the reaction of the central bank to monetary policy. As suggested by Lopez-Villavicencio and Mignon (2017), the central bank may play a crucial role in quantitative monetary policy, using inflation, exchange rates, and growth of the money supply. The level and volatility of interest rates are closely related to the growth rate of money. Jimborean (2013) asserts that it is essential for the central bank in an inflation-targeting regime to adjust the interest rate regularly in order to counteract inflation deviations triggered by exchange rate changes. Thus, we expect these types of variables to have an impact on ERPT.

Another macroeconomic determinant is trade openness, which can be measured by the trade-to-GDP ratio or imports as a share of total trade. In theory, its impact on ERPT is ambiguous. On the one hand, a higher degree of openness could imply that domestic prices are more likely to be significantly influenced by global shocks, causing larger ERPT. On the other hand, greater openness leads to an increase in domestic competition for market share, implying a lower ERPT. Finally, the output gap affects ERPT through domestic demand. If an increasing gap is due to the demand side, meaning that increased demand leads to a rise in imports, thus resulting in higher ERPT. Also, increased costs due to, for example, currency depreciation, are more likely to shift to final prices in the case of an expansionary phase than a contractionary phase (Ozkan and Erden 2015). In contrast, if growth in domestic production widens the output gap, imports will decline, leading to lower ERPT (Ghosh and Rajan 2009).

4 Data and Empirical Results

4.1 Data Description

The study used up-to-date quarterly data in four countries, but the sample period began at different times due to data availability. Specifically, Australia, Japan, and New Zealand begin in 1995:1, while Korea starts in 1996:1. The price indices (IMP, PPI, and CPI) were collected from the International Monetary Fund's *International Financial Statistics,* the Australian Bureau of Statistics, and Statistics New Zealand, with a base year of 2010. The data for NEER vis-à-vis 138 partners come from Darvas's (2012) database. Table 1 shows the data descriptions. Among the countries surveyed, Australia has the highest mean and the lowest variance in IMP, while Japan has the highest mean and the lowest variance in both PPI and CPI. GDP is far higher in Japan than the other countries, with the mean of about USD 1.2 trillion.

[Table 1]

4.2 Empirical Results of Exchange Rate Pass-Through

Before we consider the pass-through from the exchange rate to the three price indices, the first step is to check whether the variables of interest are stationary, based on the Dickey-Fuller generalized least squares (DF-GLS) test proposed by Elliot, Rothenberg, and Stock (1996). It is perceived to be more robust and significantly more powerful than the traditional augmented Dickey-Fuller test. Also, because of the long sample period, data series can exhibit structural breaks—for example, the 1997 Asian financial crisis. We conduct unit-root tests following Zivot and Andrews (1992) to take into account the existence of shifts in the series. Table 2 depicts the results for the two unit-root tests. Most variables are generally stationary at I(1). A few I(0)

variables appear in some cases, such as import prices in Australia and the nominal exchange rate in Japan and Korea.

[Table 2]

We check whether there is a cointegrated relation among variables in equation (2). The results of two-step cointegration tests by Engle and Granger (1987) are presented in Table 3, together with the Gregory-Hansen test for cointegration with regime shifts proposed by Gregory and Hansen (1996). The null hypothesis of no cointegration cannot be rejected for any cases in both tests. Thus, the ARDL is appropriate for examining the long-run impact of exchange rate movements on domestic prices.

[Table 3]

Equation (2) is regressed on the basis of the ARDL model and the OLS technique to investigate the degree of ERPT in the Asia-Pacific region. Table 4 shows the estimation results of equation (2), and Table 5 provides a summary of the short- and long-run pass-through from exchange rates to three price indices in Australia, New Zealand, Japan, and Korea. The results indicate that ERPT is higher to IMP than to PPI and CPI, in both the short and long run. Interestingly, the findings support the theory that the degree of EPRT among the four countries is in the first stage to import prices, while a lower ERPT is documented in the second stage to producer and consumer prices.

[Table 4]

[Table 5]

It is evident that, of the four countries, Korea experiences the highest ERPT to IMP, with short- and long-run ERPT of 1.09 and 1.07, respectively. Short-run ERPT to IMP in Japan is

approximately 0.9, followed by New Zealand, with about 0.6, and these two countries have a relatively similar value in the long run, around 0.4. Korea, Japan and New Zealand's pass-through to IMP is higher in the short run than in the long run, as the lagged nominal exchange rate has significantly negative coefficients. However, the phenomenon of a lower long-run pass-through is found in several previous studies, such as Sweden (Campa and Goldberg 2005) and Australia (Kilic 2015). Australia has the lowest level of ERPT to IMP. As for the degree of ERPT to PPI, nearly similar patterns are observed, with the highest and lowest pass-through in Korea and Australia. Unexpectedly, ERPT to PPI is negative in Australia in both the short and long run. Furthermore, Japan and New Zealand have relatively low pass-through from exchange rates to CPI inflation, with low values in the short and long run. In Korea, pass-through is more than double those rates, just under 10%, with almost no gap between short-run and long-run ERPT to CPI.

The degree of ERPT to price indices follows the distribution chain in three of the countries (except Australia) in that pass-through is higher to IMP than to PPI and CPI. Although the three indices are separately estimated in the same model, our finding supports the view in previous studies. McCarthy (2007), using the VAR model and the Cholesky impulse-response function, tracks pass-through in the distribution chain in industrialized countries. Supporting evidence is also found in Ito and Sato (2008) for the East Asian region. Several explanations have been put forward in the ERPT literature. For example, this decline results because a smaller proportion of goods are affected by external factors in CPI. The share of tradables, which are likely to be more prone to external shocks than non-tradables (services), tends to decrease in price indices along the distribution chain. Another line of argumentation used in pass-through literature to explain the observed smaller pass-through to consumer prices is the presence of local distribution costs, the extent of imported inputs used in domestic production (Burstein, Eichenbaum, and Rebelo 2005),

and the optimal pricing strategies of foreign producers and domestic wholesalers/retailers (Bacchetta and van Wincoop 2003).

4.3 Changes in Exchange Rate Pass-Through over Time

Next, we consider ERPT over time to three price indices. In doing so, we adopted recursive methods on equation (2), using a rolling window of 10 years, or 40 quarters. Figure 1 illustrates short-run pass-through from exchange rate changes to IMP, PPI, and CPI, respectively. The ending points in the figure are estimated on the basis of the entire sample, indicating that they are the same as those in Table 5 for the short-run estimation.

[Figure 1]

In most of the countries, the degree of ERPT is highest to import prices, followed by producer prices, and the least to consumer prices, with the exception of Australia. In Australia, the elasticity of ERPT to IMP and CPI is relatively stable, while the ERPT to PPI decreases in terms of absolute values throughout the period. In Korea and New Zealand, the degree of ERPT to PPI and CPI remains unchanged. The elasticity of the pass-through to IMP in Korea is quite stable but suddenly increases in 2008, the year of the global financial crisis, before experiencing upward fluctuation to end at more than 1, while in New Zealand it significantly decreases until 2008 and gradually recovers to its initial value of approximately 0.7 in the last quarter of 2016. In Japan, ERPT to IMP and PPI fluctuates until 2008 but then increases in the second period, with a dramatic rise in ERPT to IMP.

The global financial crisis has a considerable impact on the ERPT trend in Japan, Korea, and New Zealand, where it increases in some cases. This conclusion is supported by Hara et al. (2015), which provides evidence of an increase in the rate of ERPT since the late 2000s. Recent changes

in ERPT behavior in Japan are attributed mainly to increased co-movement between the currency and the price index as well as the changes in firm pricing behavior (Hara et al. 2015). Additionally, although Ozkan and Erden (2015) find a decline in ERPT over time and even more dramatically since the mid-1990s, the ERPT structure in developed countries is stable. This is fairly consistent in our study, especially in Australia.

4.4 Macroeconomics Determinants of Exchange Rate Pass-Through

Next, we investigate what triggers changing patterns in ERPT by incorporating macroeconomic factors such as inflation, inflation volatility, interest rate volatility, exchange rate volatility, the output gap, oil price growth, and the degree of trade openness. Table 6 shows our estimation results. Generally, the degree of ERPT is sensitive to various macroeconomics factors across the different countries under study. The short-run ERPT elasticities are most affected by inflation volatility, interest rates and trade oppeness, while other macroeconomic factors play a smaller role.

[Table 6]

Our study shows that the inflation rate reveals few effects on the ERPT elasticities, as no significant cases are recorded. The result offers a different insight on the role of inflation in a single open country. As suggested by Taylor (2000), higher inflation results in a higher degree of ERPT to import prices. This hypothesis is proved by Ben Cheikh and Louhichi (2014) using a panel threshold approach. In contrast, inflation volatility has a negative impact on ERPT elasticities in eight out of twelve estimations, although five of them are significant. The degree of effects is much higher for import inflation. The coefficients for the impact of inflation volatility on the short-run pass-through to IMP and PPI in Japan are positively significant. Our findings are consistent with Beckmann, Belke, and Verheyen (2014), who examine Germany. Our results show a positive

impact of exchange rate volatility on ERPT elasticities, whereas earlier empirical findings are ambiguous; some are positive (Campa and Goldberg 2005; Choudhri and Hakura 2006), but others are negative (An and Wang 2012; McCarthy 2007).

Interest rates are the most determining factor driving changes in ERPT behavior in the four countries studied here, and most of their coefficients are negatively significant. This variable often has a strong correlation with monetary policy in a country. Several papers have discussed the relationship between monetary policy and ERPT. Openness is another important determinant of short-run pass-through, especially in Japan and Korea.

Other macroeconomic factors, namely, interest rate volatility, exchange rate volatility, the output gap, and oil price growth, play a less important role in explaining changes in ERPT, as only 12 estimations are significant, either positively or negatively, and these significant coefficients vary across the four countries as well as the price indices. In summary, changes in ERPT elasticities vary considerably according to the country, the type of prices, and the macroeconomic determinants.

5 Conclusion

Some recent studies appear to observe an increasing ERPT to domestic price indices, which raises questions about the nature of incompleteness and decline in pass-through. This paper reexamined the degree of ERPT to three price indices in four countries in the Asia-Pacific region: Australia, New Zealand, Japan, and Korea. We use up-to-date data until 2016, together with an ARDL model in a single equation in our analysis. We also consider how the degree of ERPT changes over time, using a recursive estimation, and identify the macroeconomic determinants of changes in ERPT behavior.

We have several important findings. First, we reveal that ERPT to domestic prices follows the distribution chain, in that the degree of pass-through alters import prices in the first stage and producer and consumer prices in the second stage. The EPRT to IMP appears to be most significant among the price indices, and the impact is felt mostly within a quarter. Additionally, the ERPT to PPI is moderate in the short run and gradually transfers to the long run, while the ERPT to CPI changes little between the short run and the long run, at a relatively low degree, around 10%. Our estimated findings provide the government in those countries with some insights about the degree of ERPT to domestic prices in the short and long run. Second, we document valid evidence of an increase in ERPT to IMP since the global financial crisis in Japan, Korea, and New Zealand, and a relatively stable pass-through in Australia. Third, changes in ERPT elasticities vary considerably according to the country, the type of prices, and macroeconomic determinants, of which the most prevalent are inflation volatility, interest rates, and trade openness. These variables are closely related to a country's monetary and trade policy. Thus, policy makers should be cautious about implementing policies intended to achieve price stability and export competitiveness and address trade imbalances.

One limitation of our paper is that our sample of four countries yields approximately 80 observations, and the application of ADRL required time lags for some variables, significantly reducing the degrees of freedom. As a consequence, a concern is raised about biased coefficients in the estimation. This concern appears to be ignored in previous empirical studies because of greater concern over the small sample size of the study (Ghosh 2013; Ito and Sato 2008; and others). Given our focus on the Asia-Pacific region, which has very limited data, we consider that it is best to sort out the small sample issue and then to handle the small bias problem. In our future

studies, we include a more comprehensive sample of regions and countries to ensure that empirical findings are more robust.

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Table 1. Descriptive statistics

	Australia			Japan			Korea			New Zealand		
	μ	δ	η	μ	δ	η	μ	δ	η	μ	δ	η
IMP	102.75	6.12	88	96.33	17.11	88	77.80	19.18	84	98.26	8.00	87
PPI	89.39	13.63	88	100.18	3.01	88	89.43	12.26	84	85.68	15.27	88
CPI	89.02	15.22	88	101.51	1.39	88	88.94	15.34	84	89.83	12.93	88
GDP	212.32	108.16	88	1,204.90	159.52	88	226.51	82.93	83	28.49	12.41	88
NEER	113.74	13.73	88	117.02	12.40	88	87.98	11.37	84	101.19	11.44	88
MC	77.51	24.22	88	130.98	36.56	88	102.05	16.15	84	87.24	16.37	88

Notes: μ, δ, η denote the mean value, the variance, and the number of observations of the variables, respectively.

IMP = import price index; PPI = producer price index; CPI = consumer price index; GDP = gross domestic product; NEER = nominal exchange rate; MC = marginal cost

Table 2. Stationary tests

	Australia		Japan		Korea		New Zealand	
	ERS	*ZA*	*ERS*	*ZA*	*ERS*	*ZA*	*ERS*	*ZA*
imp	-3.29**	-4.56	-2.77	-3.97	-1.90	-3.26	-2.18	-3.01
ppi	-1.88	-4.36	-1.67	-3.12	-1.83	-2.38	-1.68	-3.55
cpi	-1.96	-2.53	-2.41	-3.61	-1.13	-2.95	-1.21	-2.35
gdp	-1.54	-2.45	-2.26	-4.12	-2.60	-3.71	-2.12	-3.30
neer	-2.23	-3.15	-2.90*	-3.89	-2.98	-4.82***	-2.39	-2.95
mc	-1.96	-2.77	-1.35	-4.52	-1.98	-2.86	-2.51	-4.47
Δ *imp*	4.57***	-7.93***	-3.50	-5.38***	-4.95	-5.85***	-3.73**	-8.17***
Δ *ppi*	-4.59***	-8.08***	-4.32	-7.65***	6.36	-6.92***	-3.84	-4.83**
Δ *cpi*	-4.69***	-8.80***	-3.44	-3.80	3.91	-9.08***	-3.06	-8.51***
Δ *gdp*	-3.46**	-7.28***	-2.93	-4.87**	-3.94	-4.05	-2.94	-6.35***
Δ *neer*	-3.00*	-8.06***	-2.63	-4.38	-4.36	-5.32**	-4.59	-7.50***
Δ *mc*	-3.29**	-5.25**	-4.37	-6.73***	-3.32	-8.02***	-5.57	-8.23***

Notes: ***, **, and * indicate the null hypothesis of the unit root is rejected at 1%, 5%, and 10%, respectively. The first column reports Elliot, Rothenberg, and Stock (ERS; 1996) tests while the second shows Zivot and Andrews (ZA; 1992).

Table 3. Cointegration tests

	Australia			Japan		
	IMP	PPI	CPI	IMP	PPI	CPI
Engle and Granger	-3.07	-3.32	-1.18	-3.12	-3.05	-2.25
GH in constant	-4.99	-4.03	-3.86	-4.18	-4.86	-3.83
GH in constant and slope	-5.38	-4.74	-4.21	-5.55	-5.44	-5.36
	Korea			New Zealand		
Engle and Granger	-3.45	-3.36	-3.22	-3.66	-2.70	-1.76
GH in constant	-4.01	-3.81	-3.78	-3.92	-4.48	-4.25
GH in constant and slope	-4.08	-4.26	-4.73	-4.99	-4.71	-4.78

Notes: ***, **, and * show the null hypothesis of no cointegration at 1%, 5%, and 10%, respectively. The first row reports the Engle and Granger (1987) tests. The second and third show the Gregory and Hansen (GH; 1996) test, with the former indicating in constant and the latter in constant and slope. IMP, PPI, CPI denotes the test on the basis of the import price index, producer price index, and consumer price index, respectively.

Table 4. Results from equation (2) for Asia-Pacific countries

	Australia			Japan		
Variable	Δimp	Δppi	Δcpi	Δimp	Δppi	Δcpi
Δp_{t-1}	-0.07	0.03	0.15	0.58***	0.51***	0.04
	(0.125)	(0.123)	(0.126)	(0.123)	(0.123)	(0.135)
Δp_{t-2}	0.10	-0.18	-0.03	-0.32**	-0.09	0.09
	(0.130)	(0.136)	(0.129)	(0.149)	(0.145)	(0.135)
Δp_{t-3}	-0.08	-0.04	-0.11	0.19	0.11	0.18
	(0.129)	(0.133)	(0.127)	(0.139)	(0.146)	(0.133)
Δp_{t-4}	0.08	0.04	-0.05	-0.05	-0.06	0.05
	(0.126)	(0.127)	(0.119)	(0.118)	(0.133)	(0.137)
$\Delta neer_{t}$	0.35***	-0.03	0.05	0.89***	0.18**	0.05
	(0.128)	(0.114)	(0.039)	(0.249)	(0.072)	(0.041)
$\Delta neer_{t-1}$	0.049	-0.035	0.034*	-0.60***	-0.027	0.016
	(0.090)	(0.053)	(0.017)	(0.149)	(0.028)	(0.015)
$\Delta neer_{t-2}$	-0.07	0.03	-0.00	0.13	0.00	0.01
	(0.091)	(0.051)	(0.018)	(0.175)	(0.029)	(0.015)
$\Delta neer_{t-3}$	-0.04	-0.03	0.00	-0.16	-0.02	0.01
	(0.091)	(0.050)	(0.017)	(0.157)	(0.027)	(0.014)
$\Delta nerer_{t-4}$	-0.09	-0.01	0.02	0.05	0.02	0.01
	(0.092)	(0.048)	(0.017)	(0.124)	(0.023)	(0.013)
Δmc_{t}	0.17	0.19	0.07*	-0.24	0.07	0.05

	(0.146)	(0.127)	(0.044)	(0.235)	(0.066)	(0.038)
Δmc_{t-1}	0.06	0.11	-0.07	-0.34*	-0.08	-0.02
	(0.147)	(0.130)	(0.044)	(0.196)	(0.054)	(0.030)
Δmc_{t-2}	-0.09	0.12	0.04	0.02	-0.03	-0.02
	(0.145)	(0.132)	(0.045)	(0.206)	(0.056)	(0.030)
Δmc_{t-3}	0.16	0.11	0.06	0.00	-0.01	-0.01
	(0.140)	(0.134)	(0.044)	(0.208)	(0.055)	(0.031)
Δmc_{t-4}	0.18	0.04	0.00	0.26	0.09*	0.03
	(0.134)	(0.130)	(0.040)	(0.188)	(0.049)	(0.027)
Δgdp_t	-0.17*	-0.05	0.06**	-0.02	0.10	0.04
	(0.088)	(0.081)	(0.027)	(0.246)	(0.069)	(0.040)
Constant	-0.00	0.00	0.00	-0.00	-0.01**	0.00
	(0.005)	(0.004)	(0.002)	(0.008)	(0.002)	(0.001)
Crisis Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Quarterly Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	83	83	83	83	83	83
R-squared	0.737	0.364	0.340	0.774	0.514	0.460

Table 4 (cont): Results from equation (2) for Asia-Pacific countries

	Korea			New Zealand		
Variable	Δimp	Δppi	Δcpi	Δimp	Δppi	Δcpi
Δp_{t-1}	0.26**	0.38***	0.11	0.01	0.41***	0.13
	(0.119)	(0.118)	(0.118)	(0.125)	(0.121)	(0.122)
Δp_{t-2}	-0.10	-0.16	0.01	-0.17	-0.21	0.09
	(0.123)	(0.127)	(0.116)	(0.121)	(0.133)	(0.126)
Δp_{t-3}	0.15	0.22*	0.38***	0.10	0.22	0.09
	(0.122)	(0.128)	(0.121)	(0.120)	(0.137)	(0.123)
Δp_{t-4}	-0.08	0.01	-0.00	0.03	-0.05	-0.05
	(0.110)	(0.112)	(0.114)	(0.120)	(0.129)	(0.115)
$\Delta neer_t$	1.09***	0.30***	0.13***	0.62***	0.16**	0.05**
	(0.188)	(0.068)	(0.026)	(0.162)	(0.067)	(0.027)
$\Delta neer_{t-1}$	-0.08	0.05	0.02	0.06	-0.05	0.00
	(0.112)	(0.033)	(0.014)	(0.107)	(0.043)	(0.016)
$\Delta neer_{t-2}$	-0.03	0.02	0.01	0.09	-0.04	-0.01
	(0.113)	(0.033)	(0.014)	(0.109)	(0.043)	(0.016)
$\Delta neer_{t-3}$	-0.22*	-0.05	-0.03**	-0.20*	-0.04	-0.00
	(0.116)	(0.034)	(0.015)	(0.109)	(0.042)	(0.016)
$\Delta nerer_{t-4}$	-0.16	-0.08**	-0.03**	0.07	0.07*	-0.01
	(0.122)	(0.037)	(0.016)	(0.106)	(0.040)	(0.016)
Δmc_t	-0.03	0.05	0.04	-0.00	0.02	0.01

	(0.156)	(0.057)	(0.022)	(0.154)	(0.078)	(0.032)
Δmc_{t-1}	-0.56***	-0.19***	-0.05**	-0.05	0.13	0.05*
	(0.154)	(0.056)	(0.022)	(0.156)	(0.077)	(0.031)
Δmc_{t-2}	0.09	0.02	-0.00	0.12	0.02	0.06*
	(0.163)	(0.059)	(0.022)	(0.157)	(0.077)	(0.031)
Δmc_{t-3}	-0.14	-0.03	0.01	0.18	-0.01	-0.02
	(0.154)	(0.056)	(0.021)	(0.157)	(0.078)	(0.033)
Δmc_{t-4}	0.12	0.10*	0.05**	-0.24	-0.14*	-0.03
	(0.147)	(0.053)	(0.020)	(0.155)	(0.078)	(0.034)
Δgdp_t	0.47***	0.18***	0.07***	-0.02	0.03	0.03**
	(0.169)	(0.061)	(0.024)	(0.110)	(0.041)	(0.017)
Constant	-0.03**	-0.01**	-0.01***	0.01	0.00	0.00
	(0.012)	(0.004)	(0.003)	(0.006)	(0.003)	(0.001)
Crisis Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Quarterly	Yes	Yes	Yes	Yes	Yes	Yes
Observations	78	78	78	82	83	83
R-squared	0.765	0.631	0.713	0.649	0.497	0.362

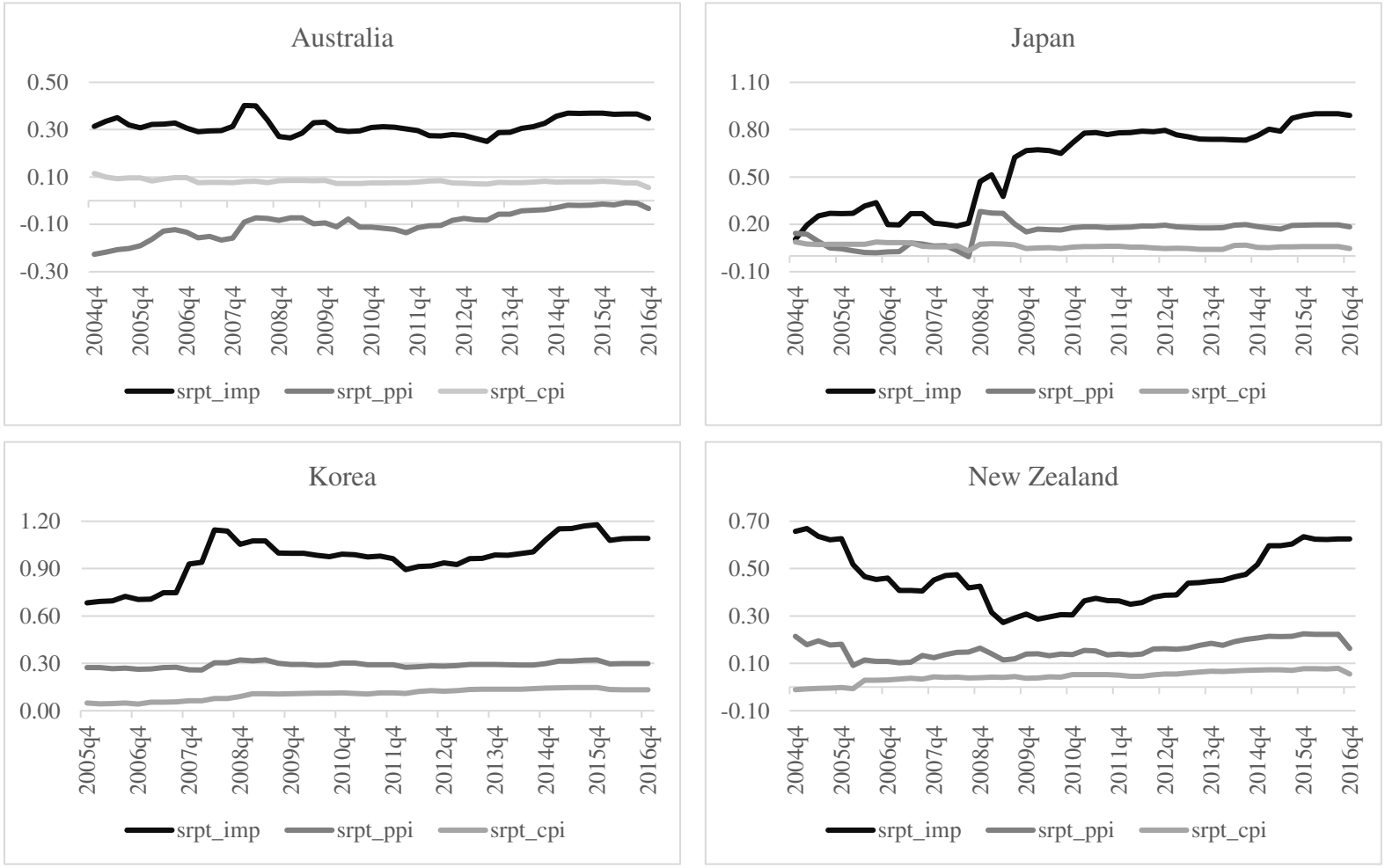
Notes: ***, **, and * indicate the significance level of 1%, 5%, and 10%, respectively. IMP, PPI, CPI denotes the test on the basis of the import price index, producer price index, and consumer price index, respectively. Δ denotes the first difference of the variables.

Table 5. Short- and long-run ERPT elasticities in Asia-Pacific countries

	IMP		PPI		CPI	
	Short run	Long run	Short run	Long run	Short run	Long run
Australia	0.35	0.35	-0.03	-0.03	0.06	0.09
Japan	0.89	0.40	0.18	0.32	0.05	0.05
Korea	1.09	1.07	0.30	0.54	0.11	0.13
New Zealand	0.62	0.43	0.16	0.39	0.06	0.06

Notes: IMP = import price index; PPI = producer price index; CPI = consumer price index

Figure 1. Trend in ERPT over time in Asia-Pacific countries from recursive regressions



Notes: *srpt_imp, srpt_ppi,* and *srpt_cpi* are the short-run ERPT elasticities.

Table 6. Effects of macroeconoics determinants on the short-run ERPT elasticities for three price indices

Variables	Australia			Japan			Korea			New Zealand		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	pt_imp	*pt_ppi*	*pt_cpi*	*pt_imp*	*pt_ppi*	*pt_cpi*	*pt_imp*	*pt_ppi*	*pt_cpi*	*pt_imp*	*pt_ppi*	*pt_cpi*
Inflation	1.76	1.40	-0.13	-0.77	1.55	0.39	5.52	0.47	-0.25	-1.33	0.08	-0.03
	(1.476)	(1.535)	(0.312)	(3.388)	(1.373)	(0.287)	(3.548)	(0.447)	(0.315)	(1.952)	(0.733)	(0.452)
Inflation volatility	-6.28**	2.43	-1.20*	9.03*	4.05*	-0.35	-23.45**	-1.64	-0.76	-36.82***	-7.66***	1.68
	(2.428)	(3.916)	(0.708)	(4.851)	(2.323)	(0.521)	(9.423)	(1.155)	(0.917)	(5.252)	(1.670)	(1.356)
Interest rate	0.00	-0.04***	0.01***	-0.81***	-0.11***	0.01	-0.07***	-0.01***	-0.03***	0.00	-0.01***	-0.01***
	(0.008)	(0.009)	(0.002)	(0.085)	(0.032)	(0.010)	(0.018)	(0.003)	(0.002)	(0.011)	(0.004)	(0.003)
Interest rate Volatility	-0.05	0.06	-0.03**	4.49**	0.51	-0.13	0.06	0.01	0.03***	-0.04	0.02	-0.03
	(0.043)	(0.059)	(0.015)	(1.696)	(0.636)	(0.211)	(0.073)	(0.011)	(0.006)	(0.071)	(0.026)	(0.016)
NEER Volatility	0.38	-0.82	0.40**	2.13***	1.14***	-0.20***	2.10**	0.22	0.00	0.32	-0.20	0.00

	(0.462)	(0.676)	(0.185)	(0.520)	(0.295)	(0.062)	(0.908)	(0.137)	(0.074)	(0.885)	(0.383)	(0.234)
Output gap	-0.08	0.04	-0.04**	1.38***	0.36**	-0.09***	0.11	-0.03	-0.00	-0.04	-0.01	0.00
	(0.077)	(0.085)	(0.019)	(0.286)	(0.134)	(0.026)	(0.246)	(0.036)	(0.024)	(0.036)	(0.012)	(0.010)
Oil price growth	0.02	-0.04	0.01	-0.28***	-0.16**	-0.01	-0.13	-0.02	-0.01	0.03	-0.04	-0.02
	(0.040)	(0.061)	(0.009)	(0.103)	(0.070)	(0.009)	(0.095)	(0.012)	(0.006)	(0.065)	(0.023)	(0.016)
Openness	-0.23	0.76*	-0.08	0.99*	-0.49*	-0.30***	0.59***	0.05**	0.19***	-0.75	-0.17	0.04
	(0.252)	(0.396)	(0.059)	(0.574)	(0.261)	(0.083)	(0.156)	(0.019)	(0.018)	(0.483)	(0.178)	(0.118)
Constant	0.40***	-0.05	0.07***	1.26***	0.37***	0.14***	0.95***	0.30***	0.10***	0.99***	0.38***	0.11**
	(0.090)	(0.128)	(0.022)	(0.222)	(0.097)	(0.034)	(0.124)	(0.018)	(0.010)	(0.169)	(0.065)	(0.046)
No	49	49	49	49	49	49	44	44	44	49	49	49
R-squared	0.274	0.491	0.357	0.856	0.644	0.567	0.638	0.651	0.939	0.691	0.621	0.500

Notes: ***, **, and * indicate the significance level of 1%, 5%, and 10%, respectively.

Table A1. ERPT to domestic prices using different robustness tests.

	IMP		PPI		CPI	
	Short run	Long run	Short run	Long run	Short run	Long run
Panel A: Output gap						
Australia	0.60	0.60	0.07	0.07	-0.02	-0.02
Japan	0.92	0.49	0.08	0.16	0.01	0.01
Korea	0.66	0.87	0.12	0.14	0.06	0.09
New Zealand	0.67	0.55	0.13	0.24	0.01	0.01
Panel B: Using US PPI as foreign marginal costs						
Australia	0.28	0.40	-0.04	-0.04	0.04	0.04
Japan	0.41	0.31	-0.01	0.03	-0.02	0.01
Korea	0.69	0.69	0.12	0.19	0.07	0.08
New Zealand	0.41	0.61	0.10	0.17	0.03	0.03
Panel C: Oil price						
Australia	0.35	0.27	-0.02	-0.03	0.06	0.09

Japan	0.49	0.17	0.10	0.19	0.02	0.07
Korea	0.66	0.79	0.16	0.31	0.09	0.09
New Zealand	0.45	0.29	0.14	0.31	0.04	0.04
Panel D: Using 1 lag						
Australia	0.33	0.33	-0.01	-0.01	0.05	0.08
Japan	0.91	0.89	0.16	0.30	0.03	0.03
Korea	1.02	1.44	0.25	0.38	0.11	0.11
New Zealand	0.54	0.54	0.17	0.25	0.06	0.08

Notes: Table A1 presents the short- and long-run ERPT to the import price index (IMP), the producer price index (PPI), and the consumer price index (CPI). Panel A shows the results of using output gap as a proxy for the change in domestic demand while panel B reports the use of the US PPI as a foreign marginal cost. Panel C add the growth rate in the world oil price for a further explanation of marginal costs. Panel D reports the results of a 1 lagged adoption in the ADRL model to estimate equation (2).