Asymmetric and Non-linear Exchange Rate Pass-Through:

An Empirical Analysis for Six Different Countries

Master Thesis

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Abstract

Due to downward price rigidities, market share objectives, binding quantity constraints and menu costs the responses of import prices to exchange rate changes can be asymmetric and non-linear. In this paper, regression equation augmented with interactive dummy variables is used on quarterly data from 1980 to 2014 for six different countries, Germany, Iceland, New Zealand, Sweden, the U.K. and the U.S., in an attempt to test whether the direction and the size of the exchange rate change matters for pass-through to import prices. The results indicate that asymmetry cannot be neglected. For the U.S. and Sweden, evidence of asymmetric behavior is found but the direction of asymmetry varies between the two countries. For no country can the restriction of linear pass-through be rejected, unless when also taking into account the direction of the change, suggesting that the direction effects overshadow the size effects.

Contents

1 Introduction

How import prices respond to changes in the exchange rate, commonly referred to as the exchange rate pass-through (ERPT), has long been of interest to economists. Following the great inflation of the 1970s and the collapse of the Bretton Woods system, interest in ERPT spiked. Due to the effects that import prices have on domestic inflation, understanding how and to what degree exchange rate changes are passed through to import prices is of key importance for the implementation of central bank´s monetary policy. Furthermore, the degree of ERPT determines the impact of exchange rate changes on the balance of payments. Other things equal, the higher degree of ERPT, the greater is the impact of exchange rate changes.

Since the 1970s, empirical literature focusing on ERPT has grown in abundance. The lion´s share of the literature assumes that the relationship between exchange rate and import prices is symmetric and linear, meaning that neither the direction nor the size of the exchange rate change matters: pass-through is the same either way. However, as several episodes in recent years have showed, these assumptions are not realistic. For instance, from 1999 to 2001 the euro depreciated by almost 20%, causing an increase in euro area import prices by roughly the same magnitude. However, by 2004 the euro had regained much of it former value but at the same time euro area import prices had only decreased by 5% (Bussière, 2007). This example suggests that import prices do not react in the same way to appreciations and depreciations.

There exist numerous factors that can justify asymmetric and non-linear ERPT. Downward price rigidities, binding quantity constraints and pricing-to-market strategies are all examples of such factors. In theory, appreciation of the importing country's currency (local currency) can lead to either higher or lower ERPT than depreciation. If prices are rigid downwards, as Peltzman (2000) notes, then exporters are less keen to decrease their export prices than increase them, implying a higher ERPT during depreciations of the local currency than appreciations. The same results arise when exporters are faced with binding quantity constraints. In contrast, if exporting firms operate under a market share objective, then an appreciation of the importing country's currency can cause larger ERPT than depreciations. Furthermore, menu costs can generate non-linear ERPT, as exporters only change their prices if the exchange rate change exceeds a certain threshold. Only a handful of studies consider, and test for, asymmetry and non-linearity. They have found mixed results, with some reporting evidence of asymmetric and non-linear responses while others do not. Furthermore, there seems to be no consistency in the direction of asymmetry.

This paper uses quarterly, aggregate data for six different countries, Germany, Iceland, New Zealand, Sweden, the United Kingdom and the United States, in order to answer two different questions. First, is the degree of pass-through affected by the direction of the exchange rate change? Second, does the size of the exchange rate change matter for pass-through?

The motivation for conducting this research stems from a price survey carried out by the Central Bank of Iceland in 2008. Approximately two-thirds of firms raised their prices in response to a 30% depreciation of the Icelandic krona in 2008, while only fifth lowered their prices following a 10% appreciation in 2007 (Ólafsson, Pétursdóttir and Vignisdóttir, 2011). In addition, studies have shown (see for example Campa and Goldberg, 2002, and Pétursson, 2008) that ERPT is more pronounced in Iceland than in other inflation-targeting countries, making it an interesting subject to study. New Zealand and Sweden are chosen for their similarities with Iceland, all countries being small open economies with their own currency, while Germany, the U.K. and the U.S. are chosen in order to make comparison with other studies possible.

The contribution of this study to the ERPT literature is twofold. First, it provides new up-to-date estimates of ERPT for the six countries included in the study, using a larger dataset than has previously been done for some of them. Second, it is the first, to my knowledge, to explore whether ERPT to import prices in Iceland, New Zealand and Sweden is asymmetric and non-linear.

The results indicate that asymmetry and non-linearity cannot be ignored when estimating ERPT. For two countries, the U.S. and Sweden, asymmetry cannot be rejected. The direction of asymmetry varies between the countries, with higher ERPT during appreciations of the US dollar but during depreciations of the Swedish krona. For Iceland, New Zealand and the U.K. symmetric ERPT cannot be rejected. However, the size of the difference between the estimated ERPT coefficients for appreciations and depreciations is considerable, suggesting caution when interpreting the estimates from the linear and symmetric model. For no country can the restriction of linear pass-through be rejected, unless when also taking into account the direction of the change, suggesting that the direction effects overshadow the size effects.

The paper is structured as follows. Section 2 presents the theoretical microeconomic assumptions that can generate asymmetric and non-linear ERPT and reviews the findings of previous empirical studies. Section 3 presents the empirical framework, its underlying foundations and describes the data. Section 4 discusses the results and several robustness tests and finally, section 5 concludes.

2 Literature review

2.1 Exchange rate pass-trough

To explain the concept of ERPT intuitively it is convenient to use a simple example. Suppose that there are two countries, for example the U.K. and Iceland, where the U.K. is the importing country, Iceland the exporting country and codfish the traded good. The export price of codfish is expressed in Icelandic kronas while the import price in British pounds. In this simple example, the difference between import and export price only depends on the exchange rate between the two currencies. Now, suppose that the pound appreciates against the krona. As a result, fewer pounds are needed to buy the same quantity of codfish as before. Therefore, the import price of codfish, in pounds, decreases. In other words, the appreciation of the pound is "passed through" to import prices, hence the term exchange rate pass-through.

More formally, ERPT can be defined as the impact of a one percent change in the exchange rate between the exporting and importing countries, on import prices in local currency. Generally speaking, ERPT is said to be "complete" if import prices respond one-for-one to changes in exchange rates. From the literature´s standpoint[1], this occurs if exporters keep prices in their home currency stable, so the whole exchange rate change is passed through to import prices. In contrast, ERPT is said to be zero if exporters adjust prices in their home currency, following a change in the exchange rate, so that import prices in local currency remain stable. However, if exporters only partially adjust prices in their home currency, ERPT is said to be "incomplete" (Goldberg and Knetter, 1997). For complete ERPT to be realized two conditions are required. First, mark-up of price over marginal cost must be constant. If this condition does not hold, exporters can adjust their mark-up in order to absorb exchange rate changes, limiting pass-through. Second,

[1] The existing literature models ERPT by considering how exporters change their prices when the exchange rate changes, see e.g. Bussière (2013).

marginal cost must be constant. For this condition to hold, exporters must only use domestically produced inputs in their production process. If imported inputs are used as well, then an appreciation of the foreign currency will reduce marginal cost, as imported inputs will be cheaper, resulting in a decrease in export prices and thus an incomplete, or in extreme cases zero, ERPT. These two conditions, however, are seldom satisfied in practice (Campa, Goldberg and González-Mínguez, 2005).

Interest in ERPT research steadily increased as the number of empirical studies who rejected the Purchasing Power Parity (PPP) grew. Unsurprisingly perhaps, as the two concepts are closely related: if PPP holds, ERPT is complete[2]. Take for example the absolute version of PPP:

$$P = EP^*$$

where P can be interpreted as import price in local currency, P* as export price in foreign currency and E is the exchange rate, defined as local currency per unit of foreign currency. Suppose the exchange rate increases by 10% (more units of local currency are needed in order to buy one unit of foreign currency) and export price remains stable. It is clear that for PPP to hold import price must also increase by 10%, indicating complete ERPT. Thus, complete ERPT only occurs if export price remains stable, that is, if both mark-up and marginal cost are constants (Herzberg, Kapetanios and Price, 2003).

In line with the documented failure of PPP, researchers have in general found ERPT to be incomplete. According to Goldberg and Knetter (1997), ERPT to U.S. import prices is around 60%, though this number differs between industries. More recent studies on U.S. import prices report lower pass-through, with Ihrig, Marazzi and Rothenberg (2006) estimating a long-run pass-through as 32%, same as Bussière, Chiaie and Peltonen (2014). It should be noted, however, that ERPT into U.S. import prices is relatively low when compared to other advanced economies. For example Campa and Goldberg (2005) find that average pass-through to import prices for a sample of 23 OECD countries is 46% in the short-run and 64% in the long-run.

Majority of the existing ERPT literature seeks to answer two questions, why ERPT is incomplete, even in the long-run, and why it changes over time. Broadly speaking, the theoretical literature can be divided into two groups: the first being from a microeconomic perspective and the second from a macroeconomic perspective. The first group, which could be further divided into cost theories and competition theories, focuses

[2] This results applies to both absolute and relative PPP.

on the industrial structure of the economy. For example, in a seminal paper Dornbusch (1987) expounds how the structure of competition in an industry affects ERPT. He argues that a more active competition prompts exporters to adjust their mark-ups in response to changes in the exchange rate, rather than pass the change fully through to import prices, in order to maintain their competitiveness. He summarizes that ERPT depends on market structure, product substitutability and the number of foreign firms relative to local firms. Froot and Klemperer (1989), using a dynamic model where exporter´s profit tomorrow depends on market share today, show that exporter faces a trade-off between raising current or future profits when the local currency appreciates.

The second group of literature focuses on macroeconomic environment, especially the role of monetary policy. According to Taylor (2000), the low inflation rate in the developed countries, due to a tightening and more credible monetary policy, has led to a decline in the degree of ERPT. This hypothesis has been supported by several empirical studies, for instance Gagnon and Ihrig (2004) and Bailliu and Fujii (2004). Numerous other factors, which I will not expand on, have been put forward as determinants of incomplete and declining ERPT[3].

2.2 Asymmetric and non-linear exchange rate pass-through

The existing empirical literature on ERPT, generally assumes that the relationship between exchange rate and import prices is (i) symmetric and (ii) linear. In other words, it is presumed that appreciations and depreciations of the local currency have the same impact[4] on import prices and that the size of the exchange rate change does not matter for the degree of pass-through (Bussière, 2013). These assumptions are, however, not very realistic. In fact, there exist numerous theoretical microeconomic assumptions that can generate asymmetric and non-linear ERPT. In this section the key assumptions will be briefly summarized.

Market Share

Pricing-to-market (PMT), as labelled by Krugman (1986), is the most cited explanation for incomplete ERPT. In this context, PMT refers to the pricing behavior of an exporter when faced with local currency exchange rate changes. Suppose that an exporter has the objective of maintaining market share in his export market. By strategic pricing the

[3] See for example Mann (1986) and Gust, Leduc and Vigfusson (2010).
[4] With the opposite sign.

exporter may adjust his mark-up downwards[5] when the local currency depreciates in order to maintain his market share but retain his mark-up and allow the import price to fall when the local currency appreciates (Gil Pareja, 2000). Goldberg and Knetter (1997) provide an excellent example of actual pricing-to-market strategy, implemented by Toyota in the 1990s. In 1994 a Japanese made Toyota Celica cost $16,968 in the U.S. One year later, the price had increased by two percent. However, over the same time period, the yen appreciated by 34% against the dollar. Thus, in order to maintain their market share, Toyota decreased their mark-up, letting it absorb the yen appreciation, effectively decreasing their export price and limiting ERPT to U.S. import price. Generally, exporter raises his export price less when the local currency appreciates than he reduces his price when the local currency depreciates, making ERPT into import prices greater during appreciations than depreciations, as in Marston (1990).

Binding Quantity Constraints

Binding quantity constraints arise when exporter´s ability to increase sales in his export market when the local currency appreciates, is limited. As Knetter (1994) points out, there are several scenarios where quantity constraints might occur, for example when trade restrictions like quotas apply or when exporter is unable to expand his marketing capacity. For instance, in the 1980s, U.S. imports of Japanese made automobiles were restricted. As a result, Japanese automobiles manufacturers were faced with binding quantity constraints: as the dollar appreciated, Japanese exporters were unable to exploit their gain in price competitiveness by letting their dollar price fall, as the allowed quantity of Japanese automobiles sold in the U.S. had already been reached. Since passing the dollar appreciation to import prices was not possible, exporters increased their mark-ups instead and charged the market clearing dollar price (Knetter, 1994). Quantity constraints are only binding during appreciations of the local currency. Therefore, the degree of ERPT to import prices is higher for depreciations of the local currency than appreciations (Pollard and Coughlin, 2004).

Downward Price Rigidities

As Peltzman (2000) eloquently put, “prices rise faster than they fall”. This statement implies an asymmetric ERPT. To elaborate, suppose that there are two countries doing business, for example, the U.K. imports goods from Germany. Now, if the pound appreciates against the euro, German exporters might let their mark-ups absorb the pound

[5] Note that export prices are always given in the foreign currency unless otherwise stated.

appreciation, consequently raising their export prices in euros but keeping prices in pounds steady. On the other hand, if the pound depreciates against the euro, absorbing the depreciation and keeping prices in pounds steady would mean that German exporters would have to lower their export prices in euros. As prices are generally considered rigid downwards, one would expect German exporters to be more reluctant to decrease their export prices than increase them. Thus, depreciation of the pound will be passed through to U.K. import prices to a greater extent than appreciations.

Production Switching

Although not often cited, production switching can be an important reason for asymmetric ERPT. Following Webber (2000) and Pollard and Coughlin (2004), suppose that there are two countries trading with each other. Continuing with the example from above, now assume that German exporters can choose whether to import production inputs from the U.K. or use domestically produced inputs. Logically, German exporters will only use domestically produced inputs when the pound appreciates against the euro, as they have become relatively less expensive. Thus, as appreciation of the pound does not affect exporters marginal cost[6], it is assumed that export prices will remain stable, implying a high degree of pass-through, ceteris paribus. On the other hand, when the pound depreciates against the euro, German exporters will only use imported inputs. Therefore, depreciation of the pound will decrease exporters marginal cost, resulting in lower export prices, all other things being equal, indicating no or limited pass-through as the decrease in export prices offsets the depreciation of the pound.

Menu and Switching Costs

Of the key assumptions mentioned in this section, menu cost is the only one which refers to the size of the exchange rate change, not the direction of the change. In the presence of menu costs exporter may decide to let small fluctuations in the local currency exchange rate pass by without changing his export price, only adjusting his price if the change in the exchange rate exceeds a certain threshold. Thus, the degree of pass-through is higher for smaller changes than larger ones. As Pollard and Coughlin (2004) show, this result only applies if imports are invoiced in the exporter´s currency, otherwise the opposite holds true. To illustrate, suppose imports are invoiced in the local currency. In this framework exporter holds the local currency price stable when the exchange rate change is small, as changing it is costly, by letting his mark-up absorb the change. This implies

[6] As the marginal cost only depends on prices of domestically produced inputs and not the exchange rate.

zero, or very limited, ERPT. However, if the exchange rate change is large enough the exporter will change his price, resulting in a higher degree of pass-through. On the other hand, if imports are invoiced in the exporter´s currency, changes in the exchange rate will not affect the payment received by the exporter. Thus, for small changes in the exchange rate, he will not change his export price, implying complete ERPT, other things being equal. If the exchange rate change exceeds a certain threshold, the exporter will change his price, limiting ERPT.

On a similar note, switching costs can also generate asymmetric pass-through as Bussière (2013) points out. As long as the price in local currency does not exceed a certain threshold, after which local consumer would switch to a different product, exporter will not respond to exchange rate changes by adjusting his price.

2.3 Previous empirical literature

Despite the abundance of empirical literature on ERPT only a handful of studies consider, and test for, asymmetry and non-linearity. Most of these studies are micro-oriented and conducted at the industry level, while studies using aggregate data are scarcer. Very few studies focus on ERPT to consumer prices. Previous papers have found mixed results when testing for asymmetry and non-linearity. Furthermore, there seems to be no consistency in the direction of asymmetry, as some studies associate appreciations of local currency with higher degree of pass-through than depreciations, while other report the opposite.

Industry level

While most micro-oriented studies focus on several industries at a time, Goldberg (1995) and Kadiyali (1997) only look at one industry each. Goldberg studies ERPT in the U.S. automobile industry. Specifically, she examines U.S. imports of Japanese and German cars using a discrete choice model. Kadiyali, however, studies ERPT in the U.S. photographic print film industry by focusing on pricing by Fuji Photo Film of Japan. Both find that ERPT is greater when the dollar depreciates.

Focusing on import prices in 30 U.S. industries, Pollard and Coughlin (2004) utilize a profit maximization model to test whether the direction or the size of the exchange rate change matters for pass-through. They find evidence of asymmetric responses to appreciations and depreciations of the dollar in half of the industries but the direction of asymmetry varies. In addition, evidence of non-linearity is found in more than half of the industries. In all cases, there is a positive relationship between the size of the exchange rate change and the degree of pass-through, indicating invoicing in dollars. Finally, they conclude that the direction effects are overshadowed by the size effects. Similarly, Yang (2007) tests whether ERPT to US import prices is asymmetric using disaggregated U.S. industry data. Unlike Pollard and Coughlin, Yang specifies an interactive dummy variable which takes the value one after March 1985, when the dollar peaked, and zero before that time. The author finds evidence of asymmetric ERPT in few industries but the direction of asymmetry varies.

Kanas (1997) also finds evidence of asymmetric pass-through when examining export prices of eight commodities exported from the U.K. to the U.S. On the other hand, Olivei (2002) finds little evidence of asymmetric ERPT to U.S. import prices while Feinberg (1989) finds no evidence at all.

Wickremasinghe and Silvapulle (2004) use asymmetric models to show that in the long-run Japanese import prices of manufacturing respond asymmetrically to appreciations and depreciations of the yen. Meanwhile, Ohno (1989) examines the price setting of Japanese export manufacturers in a mark-up over cost framework. He finds evidence of asymmetric ERPT in three machinery and equipment industries, where exporters are keener to raise their prices when the yen depreciates than lower them when it appreciates. In addition, Ohno tests for non-linearity in the ERPT. He obtains mixed results: in some industries large changes in the yen exchange rate result in large price adjustments whereas the same exchange rate change causes small adjustments in others. Marston (1990) investigates export pricing by Japanese manufacturing firms and finds significant evidence of PTM behavior. For five industries, out of seventeen under observation, adjustment of mark-ups is greater when the yen appreciates. This indicates a higher degree of pass-through when the yen depreciates. In contrast, Athukorala and Menon (1994) reject that Japanese exporters employ PTM strategies in times of yen appreciations. In fact, they find no evidence of asymmetric ERPT. Similarly, Knetter (1994) seldom rejects the symmetric hypothesis for Japanese and German export prices.

Gil-Pareja (2000) tests for asymmetry in ERPT while focusing on a range of industries across a sample of European Union countries. In most cases the author cannot reject symmetric responses of import prices. However, analysis of coefficient estimates shows that the direction of asymmetry varies across industries as well as countries. More recently Campa, Mínguez and Barriel (2008) find significant evidence of non-linear

ERPT in EU15 countries while examining the adjustment of import prices towards their long-run equilibrium following an exchange rate change.

Aggregate level

Using aggregate trade data for eight countries across the Asia-Pacific, Webber (2000) investigates asymmetry in ERPT to import prices. Webber´s results strongly support asymmetric pass-through: in five countries the hypothesis of asymmetry could not be rejected. Bussière (2013) examines whether ERPT to export and import prices in the G7 countries is non-linear and asymmetric. Using a standard linear model, which is later augmented with polynomial functions of the exchange rate, Bussière´s findings indicate that non-linear effects are of importance and should be considered when estimating ERPT. However, the findings show a great deal of cross-country variation as both the direction of asymmetry and the magnitude of non-linearities are different for each country. Stronger evidence of asymmetry and non-linearity are found in export prices than import prices. In contrast, Herzberg et. al. (2003) find no evidence of non-linear ERPT to U.K. import prices.

El bejaoui (2013) uses an Asymmetric Cointegrating Autoregressive Distributed Lag (ARDL) model to investigate the possibility of asymmetric ERPT to export and import prices in the U.S., Germany, France and Japan. He finds evidence of asymmetric responses in the long-run, for both import and export prices.

Delatte and López-Villavicencio (2012) also use an ARDL model while focusing on ERPT to consumer price indexes in the U.S., U.K., Germany and Japan. They find that depreciations of the local currency are associated with higher degree of pass-through than appreciations. They argue that their findings indicate a weak market competition. Similarly, Przystupa and Wróbel (2011) find evidence of asymmetric responses of consumer prices to exchange rate changes in Poland, while Correa and Minella (2006) find higher degree of pass-through to consumer prices in Brazil when the local currency depreciates sufficiently.

3 Methodology

3.1 Analytical framework

Before introducing the empirical specification it is useful to first acquaint oneself with its underlying foundations. The most straightforward way of testing the relationship between exchange rate and import prices is by estimating a simple reduced form equation:

$$\Delta p_t^{MP} = \beta \Delta er_t + \varepsilon_t \quad (1)$$

where p_t is the natural logarithm of import price, er_t is the natural logarithm of nominal exchange rate, defined as local currency per unit of foreign currency, ε_t is an error term and β is the ERPT coefficient. If $\beta = 1$ then ERPT is complete. This simple specification has not, however, established itself in the literature as it lacks economically meaningful specifications[7]. Instead, researchers have adopted a micro-oriented approach, focusing on the pricing behavior of exporters.

The model presented in this paper follows Goldberg and Knetter (1997), Bailliu and Fujii (2004) and Bahroumi (2006), to name a few, and is common in the ERPT literature. A representative foreign firm, which exports its product to a home country, is assumed to enjoy market power in its exporting market. The foreign firm maximizes its profit in its own currency (foreign currency henceforth) by solving the following profit maximization problem:

$$\max_{P^*} \pi = P^* Q(P^*) - C^*(Q) \quad (2)$$

where π is the profit in foreign currency, P^* is the price of the good in foreign currency, Q is the quantity produced and C^* is the cost function in foreign currency units. The first-order condition of the profit maximization can be written as:

$$P^* = c^* \mu \quad (3)$$

where μ is the mark-up over marginal cost, defined as $\mu = \eta/(\eta - 1)$, where η is the elasticity of demand[8]. In the home country, import price is expressed in the local currency:

$$P^{MP} = EP^* = Ec^* \mu \quad (4)$$

[7] See Campa and Goldberg (2002).

[8] The formula for the price elasticity of demand is: $\frac{dQ}{dP}\frac{P}{Q}$

where P^{MP} is the import price expressed in the local currency and E is the nominal exchange rate. It is clear from equation (4) that exchange rate changes and changes in the foreign firm´s marginal cost and mark-up can alter the local currency import price. Note that changes in marginal cost and mark-up do not necessarily occur as results of changes in the exchange rate. For instance, the foreign firm´s marginal cost can shift because of changes in factor prices. As an example, wage increase in the foreign country can result in increased marginal cost for the foreign firm. Demand conditions and demand shocks in the home country can also shift the foreign firm´s marginal cost, as marginal cost is increasing in quantity[9]. Furthermore, the firm´s mark-up depends on the elasticity of demand. The elasticity does not only depend on pricing decisions of the foreign firm but also on the pricing decisions of firms in the home country. If the foreign firm is engaged in a competition with firms in the home country it will face more elastic demand, causing the mark-up to decrease.

To finalize the model, the log-linear form of equation (4) may be expressed as follows:

$$p_t^{MP} = \alpha + \beta er_t + \gamma w_t^* + \delta y_t + \varepsilon_t \qquad (5)$$

where w_t^* denotes foreign marginal cost of production and y_t is demand conditions in the home country. Equation (5), and different variations of it, has entrenched itself in the ERPT literature, as noted by Goldberg and Knetter (1997).

3.2 Empirical specification

3.2.1 Linear specification

In this paper, a variation of equation (5) is used to estimate ERPT. The following basic regression equation is estimated separately for each country, in log differences and with quarterly data:

$$\Delta p_t^{MP} = \alpha + \underset{(+)}{\beta \Delta er_t} + \underset{(+)}{\gamma \Delta w_t^*} + \delta Z_t + \varepsilon_t \qquad (6)$$

where p_t^{MP} is the natural logarithm of aggregate import price, er_t is the natural logarithm of nominal effective exchange rate, w_t^* is the natural logarithm of foreign marginal cost

[9] If the law of diminishing returns holds then marginal cost will eventually increase when quantity increases.

of production, defined in foreign currency, and Z_t is a vector of other controls. In order to estimate the long-run ERPT, dynamics are introduced to equation (6):

$$\Delta p_t^{MP} = \alpha + \underset{(+)}{\sum_{j=0}^{k} \beta_j} \Delta er_{t-j} + \underset{(+)}{\sum_{j=0}^{k} \gamma_j} \Delta w_{t-j}^{*} + \delta Z_t + \varepsilon_t \qquad (7)$$

Following Campa and Goldberg (2002), short-run ERPT is given by the coefficient β_0 while long-run ERPT is given by the sum of the coefficients on the contemporaneous and lagged changes in the exchange rate. In order to keep the analysis uniform across the observed countries, only one lag[10] of each explanatory variable is included, so that k=1. The models are estimated using Ordinary Least Squares (OLS). Furthermore, to account for possible heteroskedasticity, robust standard errors are employed.

The expected signs for the coefficients β and γ are given in brackets under the equations. In this specification the exchange rate is defined as local currency per unit of foreign currency. Therefore, an increase in er_t, which in this case means a depreciation of the local currency, should increase the aggregate import price. As measuring foreign marginal cost of production, the primary control variable, on an aggregate level is particularly difficult, foreign producer price index for all commodities is used as a proxy[11]. It is expected that a cost increase, represented as an increase in $\mathrm{w}_{\mathrm{t}}^{*}$, should raise import price.

The vector of control variables Z_t is defined as $Z_t = [PPI_t,\ oil_t,\ S1,\ S2,\ S3]$ where PPI_t denotes domestic producer price index, oil_t stands for oil prices in local currency and $S1,\ S2,\ S3$ are quarterly dummy variables to capture seasonal effects, as the data is not seasonally adjusted. Similar to Olivei (2002), the variable PPI_t is included as a proxy for competitor's prices in the home country, capturing the tendencies of pricing to market. As prices of competitive goods change, exporters will change their prices accordingly in order to maintain their market share. Thus, one can expect a positive relationship between import price and PPI. In addition, although not specifically considered here, including PPI as a proxy for domestic cost can account for exporter´s local distribution cost, as discussed by Aron, Macdonald and Muellbauer (2014). No

[10] I start by including up to four lags of the explanatory variables in the regression. To determine the appropriate value of k, I use an F-test to evaluate the joint significance of the same lag lengths of each variable (for example the fourth lag of each variable). If they are not jointly significant, those lags are dropped from the model. For the majority of the observed countries, only one lag of each variable is significant. Thus, to keep the analysis uniform across countries, k=1.

[11] Preferably, I would have liked to use foreign unit labor cost as a proxy for foreign marginal cost of production, as it gives a clearer picture of the production cost firms encounter. However, due to data limitations, this was not an option.

direct demand terms, like gross domestic product (GDP) or output gap, are included in the specification, even though theory would suggest otherwise, mainly because in practice they often prove to be insignificant[12]. The reasoning behind this is that PPI already captures the shift in domestic demand, as prices tend to rise as demand increases.

Following Marazzi et al. (2005), I include oil prices in local currency as a measure of commodity prices. By doing so, I control for the direct effects that oil prices have on import prices. As Bussière (2013) points out, the pass-through to oil prices, and commodity prices in general, is usually very high. Therefore, failing to take them into account could result in overestimating the ERPT. In addition, it is advisable to account for the volatile nature of oil prices by including them as an explanatory variable when dealing with aggregate import price.

Finally, to test for the presence of unit root in the series, an Augmented Dicky Fuller (ADF) test is conducted. The test results are reported in Table A1 in the Appendix. The results indicate that all variables are stationary in first difference, or integrated of order one, I(1). Given the non-stationarity of the series in log levels and integration of the same order, I perform an Engle-Granger (1987) two-step method to determine whether the three key variables are cointegrated. That is, I test whether a linear combination of import price, exchange rate and foreign marginal cost of production produces a stationary process. The results, also reported in Table A1, do not support the cointegration hypothesis, as the residuals are non-stationary for all countries except New Zealand. Consequently, I estimate the models in log differences, instead of applying an error correction model.

3.2.2 Allowing for asymmetry and non-linearity

In equations (6) and (7) ERPT is assumed to be symmetric and linear, meaning that neither the direction nor the size of the exchange rate change matters, the degree of pass-through is the same either way. However, as previously noted, these assumptions are not very realistic. Thus, the possibility of asymmetric and non-linear responses has to be taken into account. Following Pollard and Coughlin (2004), two dummy variables are created[13], one representing appreciations of the local currency and the other

[12] This is formally tested below using real GDP as a proxy for demand condition in the home country.

[13] It is also possible to estimate ERPT for appreciations and depreciations by creating only one dummy variable, generating the same results. However, as using two dummy variables generates results that are easily interpreted, and is in fact more common in the literature, I choose that method.

depreciations, in order to determine whether the direction of the exchange rate change matters for the degree of ERPT. More specifically:

$$A_t = \begin{cases} 1\ if\ \Delta er_t < 0 \\ 0\ otherwise \end{cases} \qquad and \qquad D_t = \begin{cases} 1\ if\ \Delta er_t > 0 \\ 0\ otherwise \end{cases}$$

These dummy variables are then interacted with the exchange rate and plugged into equation (6), generating an equation that provides two different estimates of the ERPT, one for appreciations and the other for depreciations of the local currency:

$$\Delta p_t^{MP} = \alpha + \beta_A(A_t\Delta er_t) + \beta_D(D_t\Delta er_t) + \gamma\Delta w_t^* + \delta Z_t + \varepsilon_t \qquad (8)$$

The inclusion of two dummy variables allows for formally testing whether the degree of ERPT is significantly different for appreciations and depreciations. This is done by testing the coefficient restriction $\beta_A = \beta_D$. Rejection of this restriction indicates that asymmetry is present.

To determine whether the size of the exchange rate change matters for the degree of ERPT, two dummy variables are created, one representing large exchange rate changes and the other small exchange rate changes. When deciding what constitutes as a large exchange rate change I follow Bussière (2013) and define the threshold value for each country[14] as being equal to one standard deviation of the quarterly exchange rate change. More specifically:

$$L_t = \begin{cases} 1\ if\ |\Delta er_t| \geq st.dev \\ 0\ otherwise \end{cases} \qquad and \qquad S_t = \begin{cases} 1\ if\ |\Delta er_t| < st.dev \\ 0\ otherwise \end{cases}$$

Like before, these dummy variables are interacted with the exchange rate and plugged into equation (6), generating an equation that provides two different estimates of ERPT, one for large exchange rate changes and the other for small exchange rate changes:

$$\Delta p_t^{MP} = \alpha + \beta_L(L_t\Delta er_t) + \beta_S(S_t\Delta er_t) + \gamma\Delta w_t^* + \delta Z_t + \varepsilon_t \qquad (9)$$

Rejection of the restriction $\beta_L = \beta_S$ indicates that the size of the exchange rate change matters for the degree of ERPT. As discussed in Pollard and Coughlin (2004), it depends on the currency of invoice whether or not one would expect the degree of ERPT and the size of the exchange rate to be positively correlated. For example, as imports of larger economies are usually invoiced in their own currencies, one can assume that the degree of pass-through is higher for larger exchange rate changes. The opposite might be

[14] Pollard and Coughlin (2004) choose the same threshold value for all sectors in their study. However, doing so in this study could generate misleading results, as the exchange rate changes in the countries under observation are vastly different. What constitutes as a large change in Germany for example would be unremarkable in Iceland.

assumed to hold for smaller economies, where the home market is small and the exchange rate often more volatile.

The final specification in this section combines the former two, i.e. it takes into account both the direction and size of the exchange rate change. Thus, four new dummy variables are created:

$$LA_t = \begin{cases} 1 \; when \; L_t = 1 \; and \; A_t = 1 \\ 0 \; otherwise \end{cases} \quad and \quad SA_t = \begin{cases} 1 \; when \; S_t = 1 \; and \; A_t = 1 \\ 0 \; otherwise \end{cases}$$

$$LD_t = \begin{cases} 1 \; when \; L_t = 1 \; and \; D_t = 1 \\ 0 \; otherwise \end{cases} \quad and \quad SD_t = \begin{cases} 1 \; when \; S_t = 1 \; and \; D_t = 1 \\ 0 \; otherwise \end{cases}$$

Interacting the dummy variables with the exchange rate and substituting into equation (6) gives an equation that provides different estimates of ERPT, for large appreciations, for small appreciations, for large depreciations and the final for small depreciations:

$$\Delta p_t^{MP} = \alpha + \beta_{LA}(LA_t \Delta er_t) + \beta_{SA}(SA_t \Delta er_t) + \beta_{LD}(LD_t \Delta er_t) + \beta_{SD}(SD_t \Delta er_t) + \gamma \Delta w_t^* + \delta Z_t + \varepsilon_t \qquad (10)$$

As before, the threshold is defined as being equal to one standard deviation of the quarterly exchange rate change.

3.4 Data

The dataset is composed of quarterly, aggregate data for six different countries: Germany, Iceland, New Zealand, Sweden, the United Kingdom and the United States. The sample period is from 1980:Q1 through 2014:Q4 for each country. All series are in index form, with 2010:Q3 = 100, and are not seasonally adjusted. For most variables, data is collected from the International Monetary Fund´s (IMF) International Financial Statistics (IFS) database.

The quarterly series for import prices come from the IFS, for all countries except Iceland. From the IFS, I use import price for all commodities as the dependent variable. The IFS does not report import price for Iceland so instead I use the import price deflator calculated by the Central Bank of Iceland as dependent variable. Series for nominal effective exchange rates (NEER) for all countries under observation come from the IFS. NEER is a trade weighted series, calculated by using consumer price index (CPI) of the home country and of its trading partners. As in my specification the exchange rate is defined as domestic currency per unit of foreign currency, I divide one with the NEER series (1/NEER).

Measuring foreign marginal cost of production is hard, as it is not directly observable. In the literature it is common, see for example Campa and Goldberg (2002), to construct a proxy for foreign marginal cost of production by computing $ULC_t^* = NEER_t ULC_t / REER$ where ULC_t^* is foreign unit labor cost, ULC_t is the local unit labor cost and NEER and REER are the nominal and real effective exchange rate, respectively, calculated by using unit labor cost. This gives a proxy for foreign marginal cost of production, where the cost of each trading partner is weighted by its importance in the home country´s trade. Because of insufficient data[15], I choose a slightly different method. Instead of using foreign ULC as a proxy for marginal cost of production I use foreign PPI. For each country under observation I calculate $w_t^* = \sum_{j=1}^{5} \omega_{j,t} PPI_{j,t}^*$ where $\omega_{j,t}$ is a weight, assigned to each of the top five trading partners of the home country, depending on their importance in the home country´s trade. The weights are changed every five years, to account for changes in trading patterns during the observed time period[16]. The necessary data to calculate the weights come from statistical offices of each country while the PPI series come from the IFS.

Data for domestic PPI comes from the IFS for all countries, except Iceland. As Statistics Iceland has only compiled data on Icelandic producer prices from 2006, no older data is available. Thus, for Iceland, I include real GDP instead of domestic PPI. Oil prices are from the U.S. Energy Information Administration (EIA), where spot prices per barrel of WTI are used for the U.S. and New Zealand and spot prices per barrel of Brent for the European countries. The spot prices are converted into domestic currencies. Finally, I exploit that the IFS reports both NEER and REER, calculated from CPI, to create a variable for foreign prices by computing $CPI_t^* = NEER_t CPI_t / REER$ where CPI_t is the price level in the home country while CPI_t^* is the trade-weighted price level of home´s trading partners.

[15] Time series for ULC were too short so including them meant shortening my sample by ten years. In addition, REER is not calculated for Iceland by using ULC.
[16] For example, after 2000, imports from China increased in all observed countries.

4 Results

4.1 Results from the linear specification

The results from the linear specification are summarized in Table 1. I start by estimating the simple reduced form equation $\Delta p_t^{MP} = \beta \Delta er_t + \varepsilon_t$. As there are no variables included to control for certain factors and to isolate the effects of the exchange rate on import price, the pass-through coefficient reported in Panel A of Table 1 can be interpreted as a combination of direct and indirect effects of the exchange rate on import price. Because of the inclusion of indirect responses, the pass-through coefficients reported in Panel A should be considerably higher than the ones in Panels B and C, as is the case for most countries.

The estimated pass-through coefficients reported in Panel B are obtained by estimating equation (6), which in addition to the exchange rate includes a set of explanatory variables. By controlling for indirect effects of the exchange rate on import price, operating through changes in different factors, the pass-through coefficients should only reflect direct effects of the exchange rate. Finally, I estimate equation (7). As the equation includes dynamics I can calculate both the short- and long-run pass-through. The results are reported in Panel C. The full results of equations (6) and (7) are reported in Tables A2 and A3 in the Appendix. Overall, the models perform are satisfactorily: most key variables are statistically significant with the expected signs, the goodness-of-fit seems to be high and the residuals show low or no serial correlation.

Table 1: Summary results for the linear specification

	DE	IS	NZ	SE	UK	US
Panel A: Import price on exchange rate						
ERPT	0.688 ***	0.965***	0.678***	0.391***	0.331***	0.401***
Panel B: Import price on exchange rate and controls, static						
ERPT	0.498***	0.962***	0.586***	0.208***	0.351***	0.164***
Panel C: Import price on exchange rate and controls, dynamic						
Short-run ERPT	0.531***	0.909***	0.562***	0.215***	0.312***	0.120***
Long-run ERPT	0.556***	0.940***	0.719***	0.275***	0.482***	0.195***

*Note: The full results are reported in Tables A2 and A3 in the Appendix. A positive coefficient indicates that a depreciation of the home currency results in an increase in import price. ***, ** and * indicates significance at 1%, 5% and 10% level respectively.*

On the whole, the results are in line with the literature. The pass-through coefficients reported in Panels B and C can be compared with existing results for most of the countries included in this study. Starting with the U.S., the pass-through coefficients reported here are slightly lower compared to Campa and Goldberg (2005, henceforth CG), Choudhri and Hakura (2012, henceforth CH) and Bussière (2013, henceforth MB) who estimate short-run ERPT coefficient as 23%, 38% and 23%, respectively. The difference between the long-run estimates is slightly greater, perhaps unsurprisingly considering I only use one lagged term of the exchange rate to calculate the long-run pass-through while other studies use up to three or four lagged terms. For the U.K., the present estimates are close to CG (36% and 46%)[17] and MB (39% and 48%) but slightly lower than Ihrig et al. (2006, henceforth IMR), who estimate a long-run pass-through coefficient as 59%. For Germany, the estimates presented in Panel C are similar to CG (55% and 80%) but higher than MB (33% and 36%). The present estimates for Sweden are lower than CG (48% and 38%) and CH (39% in the short-run). For New Zealand the estimates reported here are closer to CH (65% in the short-run) than CG (22% and 22%).

Estimated ERPT coefficients for Iceland stand out as they are much higher than those for other countries. The results, however, are consistent with a recent report from the Central Bank of Iceland (2011) who claims that ERPT is more prominent in Iceland than in most other developed countries. As far as I know, only Campa and Goldberg (2002) have estimated ERPT to aggregate import prices in Iceland. They report a short-run pass-through coefficient of 118%, which seems unrealistic, and a long-run pass-through coefficient of 76%. Pétursson (2008) estimates that ERPT to consumer prices in Iceland is 43%, which is considerably higher than estimates for most other countries in his study.

4.2 Robustness tests

In order to check the robustness of the results four tests are conducted. First, I estimate equation (6) using instrumental variable techniques in order to account for the possibility of domestic prices being endogenous. If domestic firms are engaged in a competition with foreign firms, they take import prices into account when pricing their goods. Therefore it might be inaccurate to treat producer prices, which are used as a proxy for domestic competitive prices, as an exogenous regressor. However, the results obtained by using instrumental variable techniques, with lagged producer prices as instrument, are similar to the OLS estimators, see Table A4 in the Appendix.

[17] The first number represents short-run ERPT while the second number represents long-run ERPT. This applies for all numbers in parenthesis in this section.

Second, I add real GDP as an additional explanatory variable in order to test the chosen specification, which does not include direct demand terms even though theory suggests otherwise. Real GDP is chosen as a proxy to capture shifts in domestic demand, primarily because of data availability. The demand term is insignificant for all countries,[18] see results in Table A5 in the Appendix, indicating that shifts in domestic demand are already captured through producer prices.

Third, different proxy is used to capture domestic competitive prices. The literature is divided when it comes to choosing appropriate proxy: some use ULC, others PPI and a few CPI. As mentioned above, data for ULC is not available for all countries included in the study and not for the whole sample period. Therefore I only replace PPI with CPI in order to see if using different proxy yields different findings. The results, see Table A6 in the Appendix, are by and large not that different from the benchmark case. However, they indicate that using PPI is more appropriate, as the CPI coefficient is not significant for all countries and noticeably lower than the PPI coefficient in most cases. In addition, the goodness-of-fit falls slightly.

Finally, one may question the validity of the proxy for foreign marginal cost of production and its construction. Therefore, a different proxy is tested, specifically foreign consumer prices, whose construction is perhaps more solid considering that the CPI of each trading partner is weighted by its importance in the home country´s trade instead of just the top five trading partners. However, based on the estimation results, see Table A7 in the Appendix, CPI does not work as well as a proxy for foreign marginal cost of production as PPI: the coefficient is only statistically significant for four countries, and of those four coefficients, only two have the expected sign.

4.3 Results when allowing for asymmetry and non-linearity

Estimated ERPT coefficients, when allowing for asymmetry and non-linearity, are presented in Table 2. Estimation results in Panel A correspond to the coefficients of interest in equation (8), Panel B corresponds to equation (9) and Panel C to equation (10). Full results can be found in the Appendix.

[18] Iceland is not included in this robustness test.

Table 2: Summary results when allowing for asymmetry

	DE	IS	NZ	SE	UK	US
Panel A						
Appreciations	0.503 ***	1.173***	0.517***	0.099*	0.267**	0.169***
Depreciations	0.492 ***	0.925***	0.628***	0.245***	0.407***	0.152
Wald test statistic	0.076	1.343	-0.878	-2.377**	-1.085	0.149
Panel B						
Large changes	0.501***	0.961***	0.563***	0.219***	0.345***	0.159***
Small changes	0.486***	0.970***	0.722***	0.153***	0.374***	0.181***
Wald test statistic	0.154	-0.121	-1.158	1.447	-0.252	-0.364
Panel C						
Large appreciations	0.494***	1.441***	0.487***	0.115**	0.260*	0.176***
Small appreciations	0.412**	0.976***	0.761***	-0.038	0.429***	0.246**
Large depreciations	0.503***	0.934***	0.603***	0.247***	0.391***	0.129
Small depreciations	0.546***	0.962***	0.668***	0.330***	0.303**	0.120

*Note: The full results are reported in Tables A8, A9 and A10 in the Appendix. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. Significant Wald test statistic, indicated by ***, ** and * at 1%, 5% and 10% respectively, indicates that the coefficients are statistically different.*

Starting with the results in Panel A, the estimated ERPT coefficients are statistically significant at conventional levels, both for appreciations and depreciations, in all countries except the U.S., where the coefficient for depreciation is not significant. Of those countries, Sweden is the only one where the restriction $\beta_A = \beta_D$, meaning symmetric pass-through, can be rejected. In the case of Sweden, ERPT is significantly higher for depreciations of the Swedish krona than appreciations. These findings could indicate downward price rigidities in Sweden´s import prices. In contrast, the estimated ERPT coefficients for Germany are nearly identical, irrespective of the direction of the exchange rate change, suggesting that the ERPT estimates in Table 1 could be considered accurate. For Iceland, New Zealand and the U.K. however, the size of the difference between the estimated ERPT coefficients for appreciations and depreciations is considerable, even though the difference is not statistically significant. Therefore, I conclude that for those three countries the symmetric estimates in Table 1 should be taken with a grain of salt.

Ignoring for the time being that symmetric pass-through cannot be rejected, the estimates for New Zealand and the U.K could indicate that import prices are rigid downwards. On the other hand, for Iceland, appreciations appear to be passed through to import prices to a greater extent than depreciations. However, the estimated ERPT coefficient for appreciations is unrealistically high, suggesting caution when interpreting the results. Pass-through to U.S. import prices is only significant when the US dollar is appreciating, consistent with the market share theory. Thus, for the U.S., ERPT estimates in Table 1 provide a misleading picture.

Turning to the results in Panel B, estimated ERPT coefficients are statistically significant for all countries, irrespective of the size of the exchange rate change. For no country can the restriction of $\beta_L = \beta_S$, or linear pass-through, be rejected. For Germany, Iceland, U.K. and the U.S. the estimated ERPT coefficients for large and small exchange rate changes are extremely similar. In contrast, for Sweden and New Zealand the size of the difference between ERPT coefficients is larger, though not statistically significant. In the case of New Zealand, where the difference is most noticeable, ERPT is greater when the exchange rate changes are small. This is consistent with the menu cost assumption when imports are priced in the exporter´s currency. Even though I am unable to discriminate statistically between the coefficient estimates for large and small exchange rate changes, the size of the difference suggests that menu costs should not be ignored.

There are no guidelines or rules that dictate how large and small exchange rate changes should be defined. Thus, I apply alternative threshold values to test the robustness of the results in Panel B. First, I define the value of the threshold for each country as being equal to one and a half standard deviation of the quarterly exchange rate change and second, as being equal to two standard deviations of the quarterly exchange rate change. Overall, the basic results hold when the threshold value is increased, see Table A11 in the Appendix. Estimated ERPT coefficients are fairly similar to the estimates reported in Panel B and as before, linearity cannot be rejected.

Finally, looking at the results in Panel C, the estimated ERPT coefficients are statistically significant at conventional levels for large appreciations, small appreciations, large depreciations and small depreciations in Germany, Iceland, New Zealand and the U.K. For those countries, four different restrictions are tested, $\beta_{LA} = \beta_{LD}$, $\beta_{SA} = \beta_{SD}$, $\beta_{LA} = \beta_{SA}$ and $\beta_{LD} = \beta_{SD}$. Iceland is the only country where one or more of those restrictions can be rejected. To elaborate, $\beta_{LA} = \beta_{LD}$ and $\beta_{LA} = \beta_{SA}$ are rejected at five percent significance level. However, the estimated ERTP coefficient for large appreciations is unrealistically high, questioning the validity of this result. For New Zealand and the U.K. there is a considerable variation among the estimated pass-through coefficients, albeit not significant. For both countries small appreciations appear to be passed through to import prices to a greater extent than other exchange rate changes, which is interesting seeing as a higher degree of ERPT is associated with depreciations, see Panel A.

For Sweden, the estimated ERPT coefficient for small appreciations is not statistically significant. The restriction of $\beta_{LA} = \beta_{LD}$ is rejected at five percent significance level while the restriction $\beta_{LD} = \beta_{SD}$ is not. Thus, one might tentatively conclude that in Sweden the direction of the exchange rate change matters more for ERPT than the size of the change. Finally, for the U.S., only estimated ERPT coefficients for appreciations of the US dollar are statistically significant, both for large and small changes. However the restriction of $\beta_{LA} = \beta_{SA}$ cannot be rejected. Therefore, as for Sweden, one might cautiously interpret the results as such that the direction of the exchange rate is the key determinant for ERPT.

5 Conclusion

This paper investigates the possibility of asymmetric and non-linear responses of import prices to exchange rate changes, using quarterly data from 1980 to 2014. The study is conducted with aggregate import prices for six countries, Germany, Iceland, New Zealand, Sweden, the United Kingdom and the United States and by estimating a simple regression equation separately for each country, in log differences, which is later augmented with interactive dummy variables to account for possible asymmetries and non-linearities.

The results indicate that asymmetry and non-linearity cannot be neglected when estimating ERPT. For the U.S. and Sweden, evidence of asymmetric behavior is found but the direction of asymmetry varies between the two countries. Pass-through to U.S. import prices is only significant during appreciations of the dollar, consistent with the market share theory, while pass-through to Swedish import prices is significantly higher during depreciations of the Swedish krona, indicating downward price rigidities in Sweden’s import prices. For Iceland, New Zealand and the U.K. symmetric ERPT cannot be rejected. However, the size of the difference between the estimated ERPT coefficients for appreciations and depreciations is considerable, suggesting caution when interpreting the estimates from the linear and symmetric model.

For no country can the restriction of linear pass-through be rejected. Furthermore, in most cases the difference between estimated pass-through for large and small exchange rate changes is miniscule. However, in some cases, for instance New Zealand, the difference in pass-through is quite substantial, indicating that non-linearity cannot be ignored. In the case of New Zealand, ERPT to import prices is greater when the exchange rate changes are small, consistent with the menu cost assumption when imports are priced in the exporter´s currency. When combining the direction and the size of the exchange rate change, the results indicate that the direction effects overshadow the size effects.

While the aim of this paper is to investigate the possibility of asymmetric and non-linear responses of import prices to exchange rate changes, future research might examine the characteristics that explain cross-country differences. Another interesting area is to test for asymmetries and non-linearities using disaggregate, industry level import prices. Furthermore, focusing on asymmetries and non-linearities in the second-stage ERPT, or the pass-through of exchange rate changes to consumer prices, is of key importance for policy makers with the objective of price stability.

There remains a lot of work to do when it comes to the issue of asymmetries and non-linearities in ERPT. With the literature still relatively scarce, and mostly restricted to a small group of countries, it seems like the surface has barely been scratched.

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Appendix

Table A1: Stationarity test for key series

	DE	IS	NZ	SE	UK	US
A. Variables in first differences (ADF test statistic):						
p^{MP}	-6.577***	-8.212***	-9.433***	-8.388***	-7.811***	-8.657***
$er\ (NEER)$	-8.988***	-4.564***	-9.524***	-9.049***	-9.389***	-7.871***
w^*	-6.126***	-9.852***	-7.082***	-8.080***	-6.541***	-7.029***
PPI	-5.683***	*NA*	-6.532***	-8.091***	-6.239***	-8.408***
$Oil\ prices$	-10.47***	-9.969***	-10.637***	-10.330***	-12.372***	-10.493***
B. Cointegration test (ADF test statistic):						
	-2.548	-2.474	-4.199**	-1.924	-3.406	-2.102

*Notes: ***, ** and * denotes rejection of the null hypothesis of a unit root at the 1% level, 5% level and 10% level respectively. Different critical values apply for section A and B of this table. Section B relies upon critical values provided by MacKinnon (2010).*

Table A2: Full model, linear specification equation (6)

	DE	IS	NZ	SE	UK	US
Δer	0.498***	0.962***	0.586***	0.208***	0.351***	0.164***
	(0.060)	*(0.021)*	*(0.044)*	*(0.024)*	*(0.054)*	*(0.032)*
Δw^*	0.927***	0.269	0.645***	0.141**	0.448***	0.228
	(0.163)	*(0.198)*	*(0.142)*	*(0.056)*	*(0.170)*	*(0.260)*
ΔPPI	0.536***	0.034	0.735***	1.089***	1.392***	1.064***
	(0.179)	*(0.044)*	*(0.086)*	*(0.082)*	*(0.415)*	*(0.112)*
$\Delta Oil\ prices$	0.016***	0.002	-0.013	0.018***	0.016***	0.013***
	(0.005)	*(0.009)*	*(0.009)*	*(0.003)*	*(0.005)*	*(0.005)*
R-squared	0.831	0.881	0.731	0.915	0.681	0.837
Durbin-Watson stat	1.586	2.051	2.349	1.581	1.558	1.885

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A3: Full model, linear specification equation (7)

	DE	IS	NZ	SE	UK	US
Δer	0.556***	0.940***	0.719***	0.275***	0.482***	0.195***
	(0.068)	*(0.038)*	*(0.067)*	*(0.041)*	*(0.042)*	*(0.042)*
Δw^*	0.478***	0.462***	0.792***	0.143***	0.628***	0.365
	(0.136)	*(0.178)*	*(0.217)*	*(0.065)*	*(0.177)*	*(0.258)*
ΔPPI	0.662***	-0.090	0.446***	0.863***	1.074***	0.769***
	(0.137)	*(0.045)*	*(0.140)*	*(0.072)*	*(0.301)*	*(0.121)*
$\Delta Oil\ prices$	0.044***	0.047***	0.022***	0.042***	0.018	0.048***
	(0.005)	*(0.020)*	*(0.011)*	*(0.017)*	*(0.013)*	*(0.008)*
R-squared	0.886	0.911	0.773	0.946	0.738	0.862
Durbin-Watson stat	1.742	2.081	2.486	1.813	1.571	1.863

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% leve respectively. All regressions include quarterly seasonal dummies. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A4: Robustness test, instrumental variable estimator

	DE	IS	NZ	SE	UK	US
Δer	0.528***	0.976***	0.590***	0.276***	0.368***	0.197***
	(0.056)	*(0.025)*	*(0.059)*	*(0.043)*	*(0.049)*	*(0.068)*
Δw^*	1.166***	0.281	0.661***	0.301***	0.702***	0.507
	(0.178)	*(0.194)*	*(0.242)*	*(0.091)*	*(0.261)*	*(0.589)*
ΔPPI	0.149	0.153**	0.714***	0.797***	0.947***	0.821*
	(0.214)	*(0.065)*	*(0.216)*	*(0.164)*	*(0.254)*	*(0.450)*
$\Delta Oil\ prices$	0.014***	-0.002	-0.013	0.022***	0.015***	0.017*
	(0.005)	*(0.010)*	*(0.009)*	*(0.004)*	*(0.005)*	*(0.010)*
R-squared	0.818	0.874	0.731	0.895	0.665	0.826
Durbin-Watson stat	1.568	2.097	2.357	1.965	1.526	1.943

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A5: Robustness test, additional explanatory variables

	DE	IS	NZ	SE	UK	US
Δer	0.499***	*NA*	0.585***	0.208***	0.350***	0.163***
	(0.062)		*(0.046)*	*(0.024)*	*(0.053)*	*(0.032)*
Δw^*	0.932***	*NA*	0.643***	0.141**	0.436***	0.224
	(0.171)		*(0.142)*	*(0.056)*	*(0.155)*	*(0.261)*
$\Delta Real\ GDP$	-0.028	*NA*	-0.022	0.001	0.055	-0.027
	(0.052)		*(0.104)*	*(0.023)*	*(0.171)*	*(0.110)*
ΔPPI	0.537***	*NA*	0.735***	1.089***	1.412***	1.067***
	(0.180)		*(0.086)*	*(0.084)*	*(0.400)*	*(0.117)*
$\Delta Oil\ prices$	0.016***	*NA*	-0.013	0.018***	0.016***	0.013***
	(0.006)		*(0.010)*	*(0.003)*	*(0.005)*	*(0.005)*
R-squared	0.831	*NA*	0.731	0.915	0.682	0.838
Durbin-Watson stat	1.563	*NA*	2.345	1.581	1.546	1.885

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies.*
Iceland is not included in this robustness test as real GDP is already used in the estimated equation instead of PPI.

Table A6: Robustness test, alternative proxy for competitor´s prices

	DE	IS	NZ	SE	UK	US
Δer	0.540***	0.887***	0.686***	0.441***	0.421***	0.340***
	(0.058)	*(0.044)*	*(0.047)*	*(0.038)*	*(0.046)*	*(0.049)*
Δw^*	1.266***	0.226	1.136***	0.639***	0.862***	0.777***
	(0.127)	*(0.192)*	*(0.137)*	*(0.159)*	*(0.214)*	*(0.159)*
ΔCPI	0.150	0.157**	0.299***	0.343***	0.738	1.570***
	(0.113)	*(0.063)*	*(0.104)*	*(0.106)*	*(0.453)*	*(0.396)*
$\Delta Oil\ prices$	0.013***	0.002	-0.015	0.034***	0.019***	0.025***
	(0.005)	*(0.009)*	*(0.009)*	*(0.007)*	*(0.007)*	*(0.007)*
R-squared	0.808	0.886	0.685	0.655	0.567	0.722
Durbin-Watson stat	1.517	2.051	2.361	1.981	1.440	1.922

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies.*

Table A7: Robustness test, alternative proxy for foreign marginal cost of production

	DE	IS	NZ	SE	UK	US
Δer	0.477***	0.931***	0.524***	0.170***	0.372***	0.192***
	(0.095)	*(0.026)*	*(0.048)*	*(0.030)*	*(0.029)*	*(0.034)*
ΔCPI^*	0.220	1.007***	-0.185	-0.244*	-0.581***	0.150**
	(0.152)	*(0.324)*	*(0.228)*	*(0.134)*	*(0.033)*	*(0.064)*
ΔPPI	1.230***	0.059	1.084***	1.253***	1.557***	1.080***
	(0.140)	*(0.046)*	*(0.122)*	*(0.114)*	*(0.091)*	*(0.058)*
$\Delta Oil\ prices$	0.029***	0.002	-0.008	0.017***	0.021***	0.012***
	(0.009)	*(0.009)*	*(0.009)*	*(0.003)*	*(0.005)*	*(0.004)*
R-squared	0.732	0.884	0.705	0.914	0.826	0.847
Durbin-Watson stat	1.658	2.043	2.179	1.567	1.796	2.112

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A8: Full model, allowing for asymmetry, equation (8)

	DE	IS	NZ	SE	UK	US
$A\Delta er$	0.503 ***	1.173***	0.517***	0.099*	0.267**	0.169***
	(0.093)	*(0.155)*	*(0.093)*	*(0.057)*	*(0.118)*	*(0.046)*
$D\Delta er$	0.492 ***	0.925***	0.628***	0.245***	0.407***	0.152
	(0.087)	*(0.037)*	*(0.061)*	*(0.022)*	*(0.046)*	*(0.094)*
Δw^*	0.927***	0.255	0.659***	0.139***	0.504***	0.227
	(0.164)	*(0.192)*	*(0.144)*	*(0.053)*	*(0.148)*	*(0.261)*
ΔPPI	0.537***	0.034	0.739***	1.103***	1.334***	1.065***
	(0.179)	*(0.045)*	*(0.088)*	*(0.080)*	*(0.375)*	*(0.113)*
$\Delta Oil\ prices$	0.016***	0.002	-0.013	0.017***	0.015**	0.012***
	(0.005)	*(0.010)*	*(0.009)*	*(0.003)*	*(0.006)*	*(0.005)*
R squared	0.831	0.884	0.732	0.919	0.684	0.837
Durbin Watson stat	1.589	2.075	2.307	1.622	1.544	1.883

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% respectively. All regressions include quarterly seasonal dummies. A denotes appreciations of the home currency while D denotes depreciations. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A9: Full model, allowing for non-linearity, equation (9)

	DE	IS	NZ	SE	UK	US
$L\Delta er$	0.501***	0.961***	0.563***	0.219***	0.345***	0.159***
	(0.066)	*(0.024)*	*(0.051)*	*(0.023)*	*(0.073)*	*(0.035)*
$S\Delta er$	0.486***	0.970***	0.722***	0.153***	0.374***	0.181***
	(0.093)	*(0.072)*	*(0.120)*	*(0.048)*	*(0.069)*	*(0.056)*
Δw^*	0.926***	0.269	0.631***	0.146***	0.442**	0.227
	(0.172)	*(0.200)*	*(0.136)*	*(0.055)*	*(0.181)*	*(0.263)*
ΔPPI	0.539***	0.034	0.722***	1.088***	1.394***	1.065***
	(0.189)	*(0.044)*	*(0.086)*	*(0.081)*	*(0.421)*	*(0.112)*
$\Delta Oil\ prices$	0.016***	0.002	-0.013	0.017***	0.016***	0.013***
	(0.005)	*(0.010)*	*(0.010)*	*(0.003)*	*(0.005)*	*(0.005)*
R squared	0.831	0.881	0.735	0.916	0.682	0.838
Durbin Watson stat	1.587	2.049	2.333	1.575	1.550	1.882

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies. L denotes large exchange rate changes while S denotes small exchange rate changes. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A10: Allowing for asymmetry, equation (10)

	DE	IS	NZ	SE	UK	US
$LA\Delta er$	0.494***	1.441***	0.487***	0.115**	0.260*	0.176***
	(0.098)	*(0.232)*	*(0.092)*	*(0.057)*	*(0.147)*	*(0.052)*
$SA\Delta er$	0.412*	0.976***	0.761***	-0.038	0.429***	0.246**
	(0.216)	*(0.118)*	*(0.260)*	*(0.089)*	*(0.149)*	*(0.121)*
$LD\Delta er$	0.503***	0.934***	0.603***	0.247***	0.391***	0.129
	(0.101)	*(0.035)*	*(0.074)*	*(0.022)*	*(0.058)*	*(0.111)*
$SD\Delta er$	0.546***	0.962***	0.668***	0.330***	0.303**	0.120
	(0.172)	*(0.125)*	*(0.212)*	*(0.070)*	*(0.141)*	*(0.157)*
Δw^*	0.926***	0.233	0.656***	0.130**	0.513***	0.233
	(0.173)	*(0.177)*	*(0.143)*	*(0.052)*	*(0.151)*	*(0.270)*
ΔPPI	0.537***	0.029	0.717***	1.116***	1.327***	1.063***
	(0.192)	*(0.043)*	*(0.088)*	*(0.080)*	*(0.371)*	*(0.113)*
$\Delta Oil\ prices$	0.016***	0.003	-0.013	0.017***	0.015**	0.012**
	(0.005)	*(0.009)*	*(0.010)*	*(0.003)*	*(0.006)*	*(0.005)*
R squared	0.831	0.888	0.737	0.921	0.687	0.838
Durbin Watson stat	1.586	2.121	2.271	1.682	1.515	1.877

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies. LA denotes large appreciations, SA small appreciations, LD large depreciations and SD small depreciations. Because of data limitations I use GDP instead of PPI in the regression for Iceland.*

Table A11: Different thresholds

	DE	IS	NZ	SE	UK	US
Panel A: Threshold equal to one and a half standard deviation						
Large changes	0.560 ***	0.936***	0.574***	0.224***	0.329***	0.186***
	(0.060)	*(0.034)*	*(0.056)*	*(0.023)*	*(0.086)*	*(0.040)*
Small changes	0.435 ***	1.038***	0.610***	0.174***	0.384***	0.139***
	(0.088)	*(0.065)*	*(0.083)*	*(0.033)*	*(0.037)*	*(0.051)*
Wald test statistic	1.312	-1.170	-0.341	1.670*	-0.597	0.698
Panel B: Threshold equal to two standard deviations						
Large changes	0.588***	0.964***	0.571***	0.221***	0.421***	0.235***
	(0.093)	*(0.030)*	*(0.071)*	*(0.028)*	*(0.053)*	*(0.056)*
Small changes	0.467***	0.958***	0.599***	0.189***	0.290***	0.123***
	(0.064)	*(0.039)*	*(0.062)*	*(0.028)*	*(0.083)*	*(0.043)*
Wald test statistic	1.271	0.107	-0.287	1.047	1.330	1.469

*Notes: Standard errors in parenthesis. ***, ** and * indicates significance at 1%, 5% and 10% level respectively. All regressions include quarterly seasonal dummies.*