Heterogeneity in Exchange Rate Pass-Through to Import Prices in Thailand: Evidence from Micro Data*

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Abstract

We use transaction-level customs data and show that there is significant heterogeneity in exchange rate pass-through (ERPT) to import prices at the Thai border. Our findings uncover significant variations in ERPT across time as well as across disaggregated sectors. By studying several structural determinants of ERPT, we find that (i) prices of homogenous goods are more sensitive to exchange rate changes compared to differentiated goods; (ii) firms with a higher degree of market power face lower ERPT; and (iii) ERPT crucially hinges upon the currency of invoice in the trade transaction. For goods invoiced in a foreign currency, the effect of ERPT is significantly higher than those priced in Thai baht. We also find that for the large majority of Thai imports that are invoiced in the US dollar under the dominant currency pricing (DCP) paradigm, price responses to the US dollar are much higher than those associated with the bilateral exchange rate vis-à-vis the exporters' currency, but only in the short run. In the medium run, both exchange rates become equally relevant. Finally, by investigating state-dependent properties of ERPT, we find that while Thai import prices are equally sensitive to small versus large exchange rate changes, the degree of pass-through is stronger during episodes of depreciations rather than appreciations, particularly for goods that practice DCP.

Keywords: invoice currency, exchange rate pass-through, directional asymmetry, differentiated products, firm market power, dominant currency pricing.

JEL Classifications: E31, F14, F31, L11.

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1 Introduction

Exchange rates play a key role in the transmission of international shocks and have important implications for overall inflation, trade activities, and the determination of appropriate monetary policy. Understanding the nature of exchange rate pass-through (ERPT) thus becomes a core concern for policymakers, particularly in emerging economies such as Thailand that is typically exposed to large nominal exchange rate swings and is one of the most open economies in the world given a trade-to-GDP ratio well exceeding 100 percent.

Traditional analyses of ERPT at the macroeconomic level for many countries including Thailand mostly report low pass-through rates into consumer prices (see Ca' Zorzi et al., 2007; Ito and Sato, 2008; Forbes et al., 2017; Nookhwun, 2019).[1] Policymakers typically rely on these rough aggregate 'rules of thumb' to predict how currency movements will affect future inflation. However, as highlighted by Forbes et al. (2017) and Forbes et al. (2018), among others, these 'rules of thumb' could be misleading, as they ignore the possibility that aggregate results may be masking substantial heterogeneity in ERPT within a country as well as time variation in the price-exchange rate nexus that could arise from a range of structural, cyclical and policy factors (Ortega and Osbat, 2020).

In light of this issue, this paper aims to exploit the richness of transaction-level customs data to investigate heterogeneity in ERPT to import prices for an emerging economy, namely Thailand. We aim to analyze the nature of ERPT in Thailand and uncover its underlying key determinants. In doing so, we first ask whether there are any significant variations in pass-through across time as well as across disaggregated sectors. We then examine heterogeneity in ERPT on the basis of structural determinants of the economy such as the composition of products within sectors, market power of firms, as well as the currency of invoice. Finally, we investigate whether there is any evidence of nonlinearities or asymmetries in ERPT, that is, whether price responses differ during episodes of small versus large exchange rate changes or appreciations versus depreciations.

[1] ERPT is defined as the percentage change in local currency prices resulting from a 1 percentage change in the exchange rate between the exporting and importing country's currencies. It is generally undisputed that this sensitivity to the exchange rate declines along the price distribution chain, with ERPT being highest and fastest for import prices at the border but significantly smaller and relatively slower for final consumer prices.

Our work contributes to at least three different strands of the literature. First, a number of empirical studies examine how price sensitivities to exchange rate changes may vary across time (Campa and Goldberg, 2008; Jašová et al., 2019), sectors (Campa et al., 2005; Campa and Goldberg, 2008), and according to the direction or size of exchange rate changes (Delatte and López-Villavicencio, 2012; Bussiere, 2013; Colavecchio and Rubene, 2020). However, the vast majority of this research relies on aggregate data, thus it is not possible to identify why, for example, pass-through may be heterogeneous across sectors based on the individual characteristics of the products or firms that make up those sectors. Furthermore, any evidence of asymmetries or non-linearities in ERPT in relation to the direction or size of exchange rate changes are likely to be washed out by aggregate data, thus an empirical assessment of such issues from the lens of micro-level data should prove fruitful towards providing fresh evidence and a more in-depth understanding of ERPT.

Second, our work is closely aligned with a recent growing strand of literature that adopts micro-level price data to help uncover various underlying structural determinants of ERPT within a single country setting. Most studies find a prominent role for the currency of invoicing in ERPT to import prices (Gillitzer and Moore, 2016; Giuliano and Luttini, 2020; Gopinath et al., 2020; Chen et al., 2021), which has also been shown to generate different pass-through effects during particular events such as the large and sudden Swiss Franc appreciation in January 2015 (Bonadio et al., 2020; Auer et al., 2021). Meanwhile, a separate literature investigates whether pass-through depends on product types, differentiated by the use of imported inputs (Kasahara and Lapham, 2013; Amiti et al., 2014; Bas and Strauss-Kahn, 2014), product quality (Auer and Chaney, 2009; Basile et al., 2012; Chen and Juvenal, 2016; Bernini and Tomasi, 2015), or whether it differs by firm characteristics such as market power (Devereux et al., 2017; Auer and Schoenle, 2016; Garetto, 2016). However, the bulk of these studies often focus on studying the determinants of pass-through along one or only few dimensions, making it difficult to draw any comparisons between them. Our study will be one of the first to provide a unified analysis of ERPT for a single country using micro-level data along multiple dimensions, which should help sharpen analysis on questions such as which structural determinants matter most towards driving heterogeneity in ERPT.

Finally, studies on ERPT for emerging countries, particularly those that are based on

micro-level data, are severely lacking. Existing macro-level studies, however, point out that the nature of ERPT for emerging economies differs significantly from advanced ones, owing to factors that relate to the state and structure of the economy such as the level of inflation, the degree of trade openness and import share in the consumption basket, as well as the country's level of integration into global value chains (Ca' Zorzi et al., 2007; Jašová et al., 2019; Ortega and Osbat, 2020). Therefore, we deem that our analysis which aims to uncover the underlying factors that drive differences in ERPT for an emerging country based on micro-level data is an important line of research that would help further our understanding of ERPT more generally.

A preview of our empirical results is as follows. First, we find that ERPT to import prices at the border in Thailand is moderate and incomplete across all time horizons. Despite being an emerging country, the magnitude of pass-through is in line with estimates of other advanced countries in the literature. We find evidence of both gradual time variation in ERPT, as well as significant differences in the sensitivities of prices to exchange rates across sectors. These sectoral differences in ERPT appear to relate to the different sectoral compositions of product types, given that sectors comprised mostly of homogenous goods such as 'Mineral Products', are more sensitive to exchange rate changes than those that are dominated by differentiated goods, such as 'Transportation'. To the extent that the pricing of homogenous goods are mostly influenced by world market conditions, this evidence is consistent with our firm-level analysis that firms with lower degrees of market power generally face higher ERPT.

Among the various structural determinants that we consider, we find that the strength of ERPT depends most cruicially on the choice of invoicing currency, which as emphasized in the literature, has important implications towards being able to identify the relevant exchange rate parity for gauging overall inflationary pressures. This point is particularly relevant to Thailand, which practices dominant currency pricing (DCP) to a considerable degree[2]. According to our results, import prices invoiced in a foreign currency are more sensitive to exchange rate changes compared to those invoiced in Thai baht across all

[2]More specifically, we find an overwhelming share of imports that are priced in the US dollar, despite only 5% of all imports belonging to the US. This sizable adoption of DCP for imported goods in Thailand is consistent with the pattern of invoicing currencies for other emerging countries as well as the international trade system as a whole (Campa and Goldberg, 2008; Gopinath et al., 2010; Gopinath, 2015).

time horizons. Consistent with the predictions of the DCP paradigm (Gopinath, 2015; Casas et al., 2017; Boz et al., 2017), we also find that for goods that utilize the US dollar as a vehicle currency, ERPT is also systematically higher with respect to the US dollar rather than the bilateral exchange rate against the exporter's currency, particularly in the short-run. In the medium run, however, the exporter's currency becomes equally relevant, implying that the exporters' marginal costs and markups are also sensitive to fluctuations in their own currency. Finally, we find robust evidence of import prices being more sensitive to currency depreciations than appreciations, particularly under the DCP paradigm, implying downward price rigidities in Thai imports. However, import prices do not appear to respond differently to exchange rate shocks of varying sizes.

The rest of the paper is organized as follows. The next section describes the data used for this study and highlights key stylized facts, with particular emphasis on the currency of invoice. Section 3 provides baseline estimates of ERPT for the full sample, and examines evidence of time-varying pass-through as well as analyzes ERPT by sector. Section 4 investigates whether heterogeneity in pass-through can be explained by product types as well as firm market power, while Section 5 considers the special role of the invoicing currency. Section 6 examines whether the price-exchange rate connection is asymmetric or non-linear with respect to the direction and size of exchange rate changes. Section 7 concludes with key policy implications.

2 Data and Descriptive Statistics

Our empirical study is based on import transactions drawn from the Thai customs database collected by the Customs Department at the Ministry of Finance. Other macroeconomic variables that are used for the analysis include bilateral exchange rates, real gross domestic product (RGDP), producer price indices (PPI) of exporting countries involved in the trade transaction, Thailand's consumer price index (CPI) and oil prices. These data series are obtained from the CEIC database, the IMF's International Financial Statistics database and Datastream.

2.1 Customs Data

While the customs dataset covers information on trade transactions at the Thai border from January 2001, we concentrate our analysis on the 2007-2019 subperiod since information on the measurement unit of import quantity is only available since then. For the purposes of our empirical analysis, we aggregate the data at the quarterly frequency, and form a unique identification (ID) for a given import transaction based on information drawn from the following six fields: good classification according to an 11-digit Harmonized System (HS-11), importing firm, country of origin, country of shipment (exporting country), unit of measurement (the majority being reported in "pieces" or"kilograms"), and the currency of invoicing. An example of a unique ID is boneless frozen meat of sheep, produced in Australia (country of origin), shipped from Singapore (country of shipment), imported by company A, with the US dollar as an invoicing currency and the import quantity measured in kilograms. Classifying an ID in this way allows us to identify 1,633,316 unique import transactions.

Unfortunately, a common feature that is also shared with customs declaration forms in other countries is that the Thai customs dataset does not contain information on import prices. To work around this problem, we follow the literature and rely on unit values as proxies for import prices. In particular, the unit value for a unique ID transaction in quarter t ($P_{ID,t}$) is calculated as: $P_{ID,t} = ImportValue_{ID,t}/ImportQuantity_{ID,t}$, where $ImportValue_{ID,t}$ denotes the import value in Thai baht. Note that a main drawback to the unit value approach is that a change in unit value could come from either changes in actual prices or changes in the composition or quality of goods. Thus, while our ID is identified at a very detailed level, spurious price swings could still occur.

We clean our dataset in several ways to help purge our dataset of spurious price changes. First, we drop transactions related to gold since in Thailand, gold is widely used as a store of wealth and is imported mainly for investment purposes rather than as an input to production. Next, we eliminate transactions with no classifications of industry[3], country of origin and country of shipment. Then, we drop transactions for which import quantity is zero but record positive import value. We keep only countries of

[3]Based on the International Standard Industrial Classification of All Economic Activities (ISIC) of the United Nations Statistics Division.

shipment, whose import value is larger than 0.5 percent of total over the periods studied. To minimize the influence of potential outliers, we choose to drop observations whose price is less than or greater than 1.5 standard deviations of all prices for a given HS-11 code, country, invoicing currency, unit and quarter combination, or for a given ID. After the elimination of potential outliers, we calculate standard deviations of unit values for each ID, and further eliminate IDs whose coefficient of variation (i.e., the ratio of a standard deviation to the corresponding mean) is greater than 100 percent. We also exclude IDs that trade infrequently, with the criteria that each ID must have more than 20 non-excluded observations, or contains more than 8 consecutive quarters of non-excluded observations. Finally, we trim our dataset at the 5th and 95th percentile of unit value changes for a given exporting country, currency of invoice, and quarter combination. We also further trim the dataset at the 1th and 99th percentile of all unit value changes. After cleaning, we are left with approximately 4.8 million observations, which constitute as almost 50 percent of the total import value.

2.2 Descriptive Statistics

Table 1 provides basic information on our cleaned dataset. During the 2007-2019 sample, we have a total of 4,787,486 observations that includes 23,199 firms, 11,624 products according to the HS-11 classification, 156 origin countries, and 28 exporting countries. While a typical firm imports an average of 9 goods, this number ranges widely (1 to 1397). On average, each firm imports from 3 different countries of origin and 2 countries of shipment. Country of origins and shipment cover a large range of countries in terms of economic development and regional coverage. The top 5 largest markets for the origins of Thai imports are Japan (21%), China (18%), the UAE (8%), Malaysia (7%) and US (5%), where the number in the parenthesis shows import share in terms of Thai baht value. Meanwhile, in terms of countries of shipment, the top 5 markets are Japan (20%), China (13%) the UAE (8%), Singapore (8%), and Malaysia (7%). Finally, the mean change in unit values is 2.5 percent per quarter, with transaction values for a variety of imported goods varying widely from 2 to 70.9 billion baht.

Next, we turn to examine the characteristics of invoicing currencies in our sample, whereby in our study, we classify the invoicing currency type based on the country of

Table 1: Summary Statistics

	Mean	Median	Stdev	Min	Max
Goods (HS-11)	11,624				
Importing firms	23,199				
Origin countries	156				
Exporting countries	28				
Invoicing currencies	33				
Goods per importer	9	3	24.6	1	1,397
Origins per importer	3	1	3.2	1	105
Exporters per importer	2	1	2.3	1	23
Invoicing currencies per importer	1	1	0.9	1	27
Change in unit values (percent)	2.5	-0.2	23.8	-50.4	101.3
Import value (baht)	8.2m	0.5m	193m	2	70.9b

Note: Summary statistics for the cleaned dataset obtained from the Thai Customs database, Ministry of Finance, over 2007-2019.

origin that produces the product. Figure 1 shows that the majority of Thai imports are invoiced in the US dollar, despite only 5% of all imports belonging to the US. In other words, we find a strong case of DCP for Thai imports, since an overwhelming share of imports with non-dollar origins are invoiced in the US dollar (75%)[4]. This pattern of invoicing currency whereby a single dominant currency is used for trade invoicing is consistent with evidence presented for other emerging economies such as Chile. For Chile, Giuliano and Luttini (2020) report an even more extreme case of DCP, consisting of more than 90% of Chilean imports being invoiced in the US dollar, and almost nonexistent cases of imports being invoiced in the local currency. Gopinath (2015) also emphasizes the outsized role of the US dollar as a universal currency of invoicing for the international trade system as a whole.

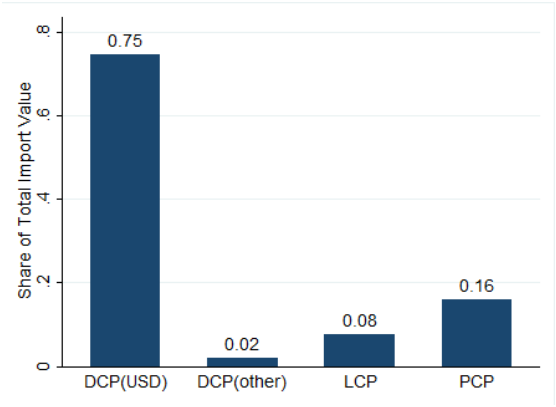
Another interesting takeaway from Figure 1 is the overwhelming share of Thai imports invoiced in foreign currencies. Given that the share of DCP is already 75%, and an additional 15% of all imports are priced in the currency of the producer (producer currency pricing or PCP), only 8% of all imports are invoiced in the local currency which is the Thai baht (local currency pricing or LCP)[5]. Nevertheless, while the role of the dollar as

[4]Note that in this paper, while there are other vehicle currencies employed under the DCP, given their exceptionally small share (2%), we drop them from our empirical analysis and only associate DCP with US dollar invoicing. The top three other vehicle currencies whether ranked by import value or by observations are the Japanese yen, the euro, and the Singaporean dollar.

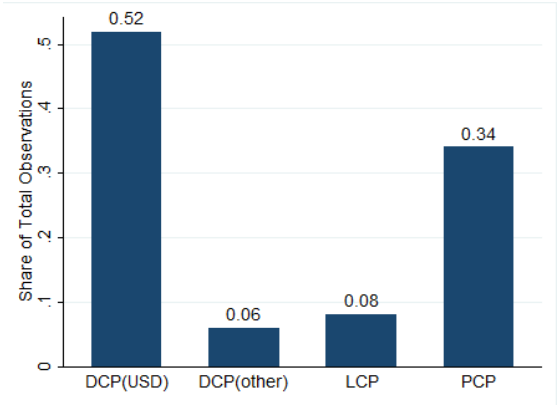
[5]In order to be consistent with the literature that also emphasizes the dominant role of the US dollar as an invoicing currency under DCP, this share is calculated based on the value of imports (see Gopinath, 2015). If calculated by number of observations, the share of the US dollar as an invoicing currency still remains dominant, but declines to 52% while the role of PCP slightly increases to 34%.

Figure 1: Currency of Invoicing

(a) Based on Import Value



(b) Based on Number of Observations



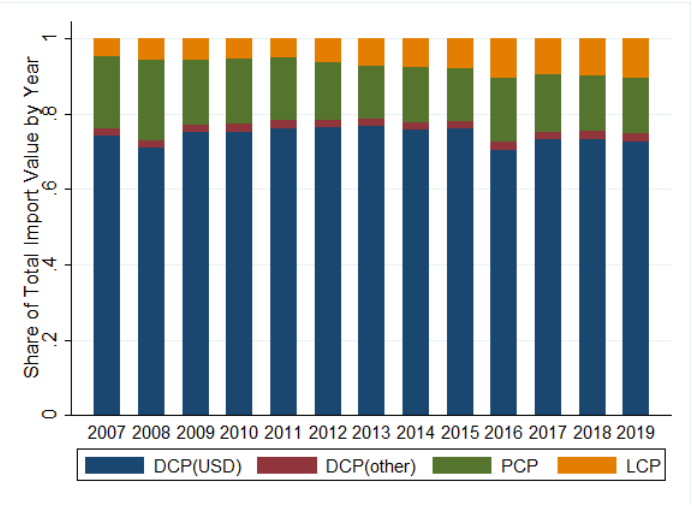
Note: Panels (a) and (b) show the import share by currency of invoicing (in %) in terms of Thai baht value and number of observations, respectively.

the dominant currency of invoice in Thailand has remained more or less stable over time, Figure 2 shows a slight increase in the share of Thai imports that are invoiced in the local currency. This evidence is consistent with the Bank of Thailand's support of the use of local currency for trade invoicing and settlement within the region.

Next, Figure 3 shows that in terms of the exporting country, Thai imports are also mostly invoiced in the US dollar. For the top 10 countries that report the highest value in imports, the share of imports that are priced in the US dollar under DCP are consistently greater than 80%, with the natural exception of the US since imports from the US that are invoiced in the US dollar are classified as PCP. Japan, however, is an interesting exception, where a large share of imports are invoiced in the Japanese yen (38%) and are thus classified as PCP. Nevertheless, for Japan, the DCP paradigm is still prominent, as approximately half of all imports from Japan are invoiced in the US dollar.

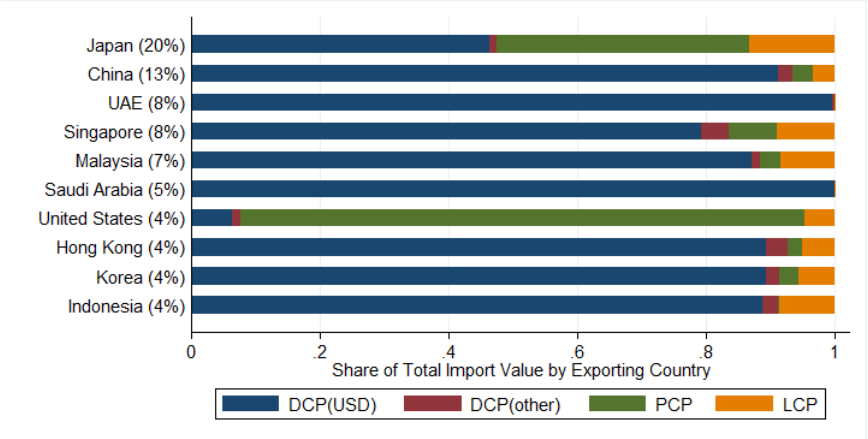
Finally, we provide some basic summary statistics on Thai import sectors and their corresponding composition of invoicing currency choices. Thai imports can be classified into 15 sectors according to their 2-digit Harmonized System codes. The importance of each sector is shown in Figure 4 alongside invoicing currencies that are adopted. Overall, the usage of US dollar as the dominant invoicing currency prevails across all sectors but there are some variations within. For the three largest sectors by import value in Thailand which are 'Machinery and Electrical' (31%), 'Mineral Products' (22%) and 'Metals' (13%), we observe rather high degrees of DCP in the US dollar, averaging at 82%. The

Figure 2: Currency of Invoicing Over Time



Note: Plotted are the import shares in terms of Thai baht value by currency of invoicing (in %) over time.

Figure 3: Invoicing Currency across Exporting Countries

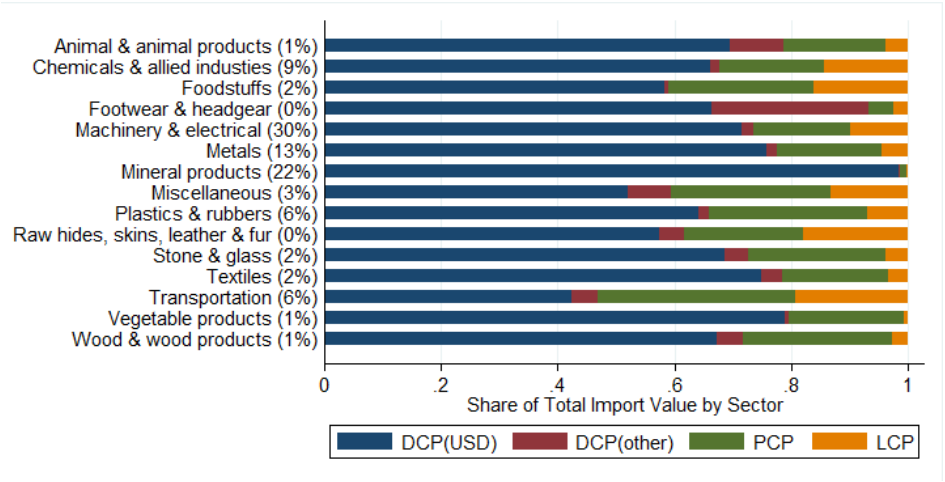


Note: This figure shows the import share in terms of Thai baht value by currency of invoicing (in %) for the top 10 largest exporting countries (during 2007-2019) to Thailand. The import share in terms of Thai baht value by exporting country (in %) is shown in parentheses.

'Mineral Products' sector in particular contains an exceptionally high share of DCP (98%), followed by 'Vegetable Products' (79%) as well as 'Metals' (76%). By contrast, in the 'Transportation' sector, DCP is practiced to a much lesser degree, with higher shares of imports being priced in the producer currency (34%) and the local currency (19%).[6]

[6]It is interesting to note that while the 'Footwear & Headgear' sector practices DCP to a significant extent, the vehicle currencies do not consist only of the US dollar but also the euro to a non-negligible degree (24%).

Figure 4: Invoicing Currency across Sectors



Note: This figure shows the import share in terms of Thai baht value by currency of invoicing (in %) across product sectors. Products are classified into 15 groups based on their HS code at 2-digit level. The import share in terms of Thai baht value by product sectors (in %) is shown in parentheses.

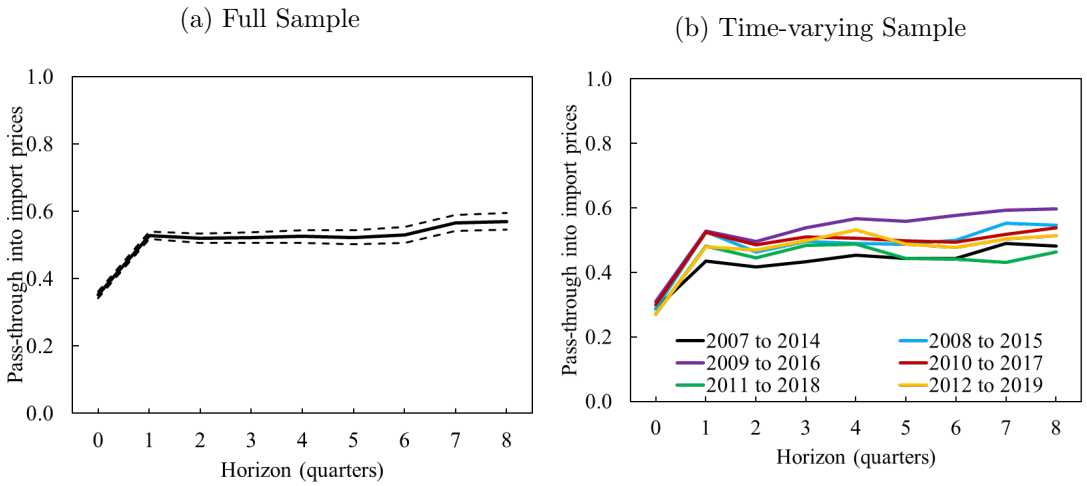
3 Empirical Estimates of ERPT

The literature offers extensive empirical estimates of ERPT based on macroeconomic data. Studies of pass-through that rely on micro-level data, on the other hand, are rather scarce, particularly for emerging economies. In this section, we utilize transaction-level data from the Thai customs dataset to form baseline results. The estimates of pass-through are for the full sample and are based on the following standard pass-through panel regression (Gopinath et al., 2010):

$$\Delta P_{ID,t} = \sum_{k=0}^{8} \beta_k^{FCTHB} \Delta FCTHB_{t-k} + \sum_{k=0}^{8} \gamma_k \Delta Z_{t-k} + \alpha + \epsilon_{ID,t}. \tag{1}$$

In the above specification, our proxy for import prices $P_{ID,t}$ is the unit value of a unique transaction ID in quarter t in the local currency (THB). To quantify how sensitive Thai import prices are to a change in exchange rates, the relevant exchange rate is $FCTHB_t$, which is the bilateral exchange rate between the domestic currency of the exporting country and the THB (an increase in this value indicates a depreciation of the Thai baht). Following the literature that estimates ERPT based on quarterly data, we include eight lags in our panel regression. This allows us to calculate short-run pass-through as the coefficient β_0^{FCTHB}, whereas the cumulative estimate $\beta(8) = \sum_{k=0}^{8} \beta_k^{FCTHB}$ evaluates

Figure 5: Exchange Rate Pass-Through to Import Prices



Note: Displayed are the cumulative exchange rate pass-through effects over an 8-quarter horizon. Dashed lines indicate 95% confidence bands. The figure in Panel (a) illustrates the results for the full sample while the figure in Panel (b) presents time-varying estimates over rolling eight-year sub-samples.

medium-run pass-through after two years.

In Eq. 1, we also include a standard set of control variables Z_t, being the exporter country's PPI and GDP, Thailand's CPI and GDP, and oil prices. α is a set of fixed effects which controls for ID-level characteristics (good, firm, exporting country, origin country, and unit), intended to capture factors such as product differentiation across countries and time-invariant firm characteristics (e.g., firm size and market power). α also includes a set of quarterly dummies for each good and origin country combination to control for seasonality. Finally, Δ denotes percentage differences and $\epsilon_{ID,t}$ is the error term.

Panel (a) of Figure 5 reports the estimation results for Eq. 1. In line with previous findings in the literature, we find that ERPT to import prices is moderate and incomplete (see Campa et al., 2005; Gopinath and Rigobon, 2008; Giuliano and Luttini, 2020; Ortega and Osbat, 2020; Chen et al., 2021)[7]. In particular, the magnitude of contemporaneous pass-through is 0.35, which signifies that a 100% depreciation of the bilateral exchange rate of the Thai baht vis-á-vis the exporting country's currency results in an increase in import prices of 35% at the border. Also, we observe that pass-through into import prices is rather immediate. This is because after one quarter ERPT increases rather sharply, quickly reaching 0.57 which is more or less its medium-run level.

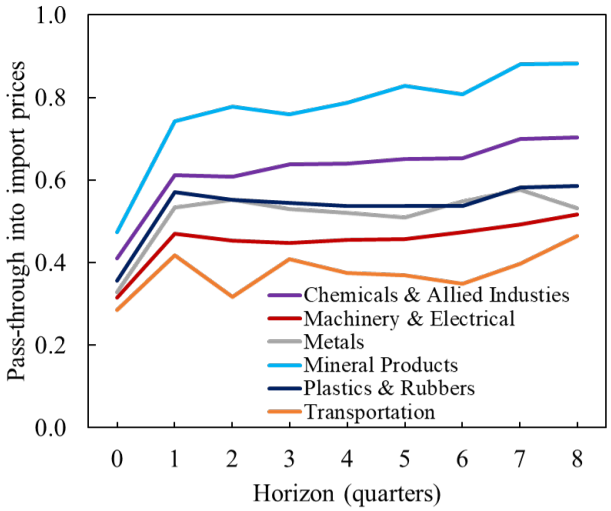
[7]A close comparison between the magnitude of pass-through across countries would be difficult due to differences in the time period of study and time horizons considered, measures of import prices (some only consider trade in goods while others consider both goods and services), as well as exchange rates chosen.

Next, we turn to investigate evidence of time variation in ERPT. For advanced economies, many studies document gradual changes in the pass-through coefficients over time to both import and consumer prices, with most of these changes occurring during the 1980s and 1990s (Sekine, 2006; Campa and Goldberg, 2008). In the post 1990s, however, ERPT has become broadly low and stable (Jašová et al., 2019; Ortega and Osbat, 2020). On the other hand, Jašová et al. (2019) finds that ERPT declined after the Global Financial Crisis (GFC) for a panel of emerging economies including Thailand. Our paper studies time variation in ERPT in the post GFC period for Thailand, based on estimating Eq. 1 repeatedly over eight-year rolling sub-samples. As shown in Panel (b) of Figure 5, the coefficients of pass-through appear to vary moderately over time, with differences that average around 0.1 over all time horizons. As suggested in earlier studies, these differences could stem from a variety of factors, both structural and cyclical in nature.

We next investigate ERPT along the cross-sectional dimension, asking whether import prices across disaggregated sectors have varying sensitivities to changes in the exchange rate. To our knowledge, few empirical studies examine ERPT at the sectoral level based on micro-level data, and those that do, focus on alternative issues. For example, Hjortsoe and Lewis (2020) investigate pass-through of exchange rate changes into UK import prices for 55 sectors by constructing sector-specific exchange rate indices. They observe variation in pass-through across sectors, and conclude that the compositional effects have not generated much variation in aggregate pass-through over time.

Figure 6 shows estimation results based on applying Eq. 1 to each of the 15 sectors. Due to space considerations, we only plot the dynamics of EPRT for the largest 6 sectors by import value share (see Figure 4). As shown, we find that the baseline pattern of ERPT carries through to the sectoral analysis as general trajectories are consistent with those shown in Figure 5(a). Nevertheless, we uncover important heterogeneity in the magnitude of pass-through across sectors, a characteristic also found for other countries such as those in the Euro area (Ortega and Osbat, 2020). In our sample, differences in pass-through across sectors can be quite substantial, ranging up to as high as 0.4 in the medium run. Sectors that consistently show lowest pass-through in both the short and medium run are 'Transportation' and 'Machinery & Electrical', while those with high pass-through are 'Mineral Products' and 'Chemicals & Allied industries'.

Figure 6: Sectoral-level Exchange Rate Pass-through



Note: Displayed are the cumulative exchange rate pass-through effects over an 8-quarter horizon for the largest 6 sectors by import value share.

As suggested by earlier work, differences in pass-through across sectors may be explained by factors such as product characteristics or firm market power. For example, Campa and Goldberg (2008) find ERPT to import prices in 18 industrialized economies to be higher for raw materials and energy products when compared to manufacturing products, a finding that supports an earlier study by Campa et al. (2005) for OECD economies. The authors explain that these differences may be driven by larger price discrimination practiced by firms in the manufacturing sector as opposed to commodities, which often have prices influenced by world market conditions. Given that we also observe high pass-through in raw material sectors such as 'Mineral Products' whereas 'Transportation' and 'Machinery & Electrical' exhibit lower ERPT, we see some evidence supporting this claim[8]. In what follows, we thus further investigate the role of structural determinants such as product characteristics and firm market power in explaining ERPT in Thailand.

[8]Consistent with our finding of high ERPT in the 'Mineral Products' sector, Nookhwun (2019) also finds high pass-through in retail oil prices when investigating sectoral differences in ERPT for consumer price inflation in Thailand.

4 Product and Firm Characteristics

In this section, we examine two key structural determinants that may explain differences in pass-through rates, specifically those related to the characteristics of products as well as the degree of market power exhibited by firms.

4.1 Product Characteristics

As suggested by the sectoral-level analysis in the previous section, different rates of pass-through could be related to the characteristics of goods that dominate each sector. To more formally investigate this hypothesis, we first apply the Rauch (1999) classification to our dataset, which is able to group around 90% of our imported goods into being either 'homogenous' or 'differentiated'. Based on Rauch (1999), goods that are traded on an organized exchange or have a referenced price in world markets are labeled as 'homogenous', whereas the remaining brand name products are classified as 'differentiated'[9]. Table 2 shows the percentage share of goods based on import value in each sector that can be classified as one of these two product types. As shown, 'Mineral Products' contains the highest share of homogeneous goods with a share of as high as 99 percent. 'Vegetable products' and 'Wood & Wood Products' also contain a large share of homogeneous goods with a share in excess of 80 percent. Meanwhile, a few sectors, such as 'Transportation' and 'Machinery & Electrical', and 'Footwear & Headgear' consist entirely of differentiated goods.

Recall from our earlier analysis that certain sectors such as 'Mineral Products' displayed higher rates of pass-through compared to others such as 'Transportation'. According to Table 2, we can already spot some correlation between the estimated degrees of sectoral pass-through rates as reported in Figure 6, and the types of goods that dominate each sector. For example, sectors that are associated with high degrees of pass-through ('Mineral Products' and 'Chemicals & Allied industries') are more or less dominated by

[9]To classify the goods, we rely on the concordance between the 6 digit harmonized system code and the SITC2 (Rev 2) codes provided by the United Nations International Trade Statistics. Note that the original classification by Rauch (1999) makes a delineation between 'homogeneous' and 'reference priced' goods, where goods that are traded on an exchange are labeled as 'homogenous' and goods that have prices listed in trade publication are classified as 'reference priced'. However, since the majority of goods that we can classify are 'heterogeneous' or 'differentiated', we group reference priced and homogeneous goods together under the 'homogeneous' label.

Table 2: Product Classification by Sectors

HS-2	Sector	Homogeneous	Differentiated
01-05	Animal & Animal Products	50	50
06-15	Vegetable Products	84	16
16-24	Foodstuffs	52	48
25-27	Mineral Products	99	1
28-38	Chemicals & Allied Industries	55	45
39-40	Plastics & Rubbers	38	62
41-43	Raw Hides, Skins, Leather, & Furs	0	100
44-49	Wood & Wood Products	82	18
50-63	Textiles	44	56
64-67	Footwear & Headgear	0	100
68-71	Stone & Glass	50	50
72-83	Metals	62	38
84-85	Machinery & Electrical	0	100
86-89	Transportation	0	100
90-97	Miscellaneous	0	100

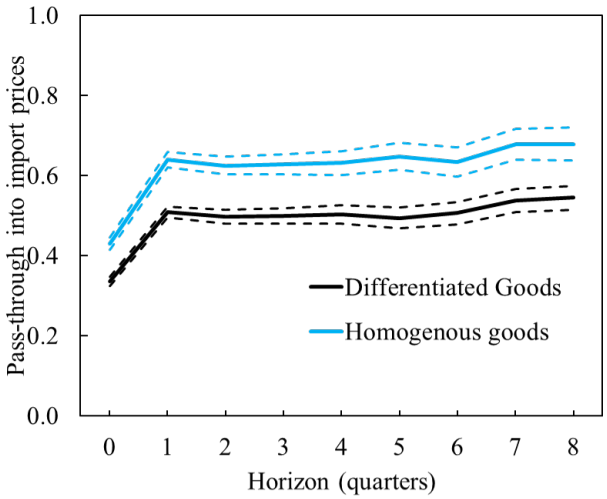
Note: As shown are the percentage share of goods (based on import value) that can be classified by product type to be 'homogenous' or 'differentiated' according to the Rauch (1999) classification.

homogeneous goods. On the other hand, low pass-through sectors ('Transportation' and 'Machinery & Electrical') consist primarily of differentiated goods.

Motivated by this casual observation that homogenous goods may be more sensitive to exchange rate changes when compared to differentiated goods, we formally examine the role of product characteristics in explaining heterogeneity in ERPT by estimating Eq. 1 separately for homogenous and differentiated goods. The results are reported in Figure 7. As shown, it is clear that homogenous goods exhibit significantly higher pass-through than differentiated goods. The difference in pass-through rates between the two types of goods ranges consistently between 0.095-0.134 over the short and medium run. We note that our findings are in line with Giuliano and Luttini (2020), who also illustrate a similar point despite their pass-through estimates being less precise due to larger confidence bands[10]. Thus, given that ERPT can crucially hinge upon the characteristics of products, the composition of products in the basket of imported goods can have implications for the level of ERPT for the country as a whole.

[10]Related literature considers product quality as an explanation for heterogeneity in exchange rate pass-through, where it is hypothesized that lower quality goods should be more sensitive to exchange rate movements than higher quality goods. See Auer and Chaney (2009), and Berner (2011).

Figure 7: Exchange Rate Pass-Through across Product Types



Note: Displayed are the cumulative exchange rate pass-through effects over an 8-quarter horizon for homogenous and differentiated goods as classified by the Rauch (1999) classification. Dashed lines indicate 95% confidence bands.

4.2 Firm Market Power and Competition

The higher sensitivity to exchange rate fluctuations that we observe for homogeneous goods could be related to the lack of pricing power of importers, since it would be difficult to negotiate over the prices of these types of goods that are determined in world markets. Nevertheless, research that investigates how firm market power as well as the degree of competition within markets can explain ERPT is still extremely limited, and tends to mostly focus on the export side. For example, Devereux et al. (2017), Auer and Schoenle (2016) and Garetto (2016) find that ERPT is U-shaped in the market share of exporting firms. That is, exporters with either small or large market share have little concern over the impact of raising prices on their market share, and therefore will pass most of any exchange rate movements into their product prices[11]. Meanwhile, exporters with intermediate market share take more consideration of any consequences from price changes on their sales. However, empirical evidence in support of this claim is still more or less inconclusive. For example, such U-shaped relationship is not found in Amiti et al. (2014) and Berman et al. (2012), who instead show a negative association between ERPT and the exporter's market share.

[11] In addition, it has been suggested that large firms may have greater capabilities in hedging against exchange rate changes via financial instruments, which should further decrease the rate of pass-through to product prices (see Dekle and Ryoo, 2007).

According to Bussière et al. (2020), market conditions in both the origin and destination countries play a key role in determining the size of ERPT. Therefore, it is also important to consider the characteristics of the importing firm for ERPT, yet studies that investigate this topic are still scarce. One important contribution includes Devereux et al. (2017), which based on a model of endogenous markups, predicts that ERPT should be monotonically declining in the market share of importers. Intuitively, importers with a larger market share tend to have a higher elasticity of demand for each exporter's product. ERPT for these firms, as a result, is lower since an exporter's market share will vary if it passes through exchange rate shocks. By bringing the model to micro data in Canada, the authors confirm a strong link between market share of importing firms and the size of ERPT.

In what follows, we aim to provide additional empirical evidence on how the importing firm's market power and its associated degree of competition within markets may influence ERPT. We rely on two well-known proxies to measure firm market power and the degree of competition. The first measure is a firm-specific one, calculated as the market share of firm m within the import market n of a given HS6 product category and exporting country, where market share is computed based on its import value[12]. The other proxy is a market-specific measure, namely the Herfindahl–Hirschman Index (HHI). The HHI is a popular measure of market concentration which describes the size distribution of firms. It is computed by squaring the market share of each firm that competes in a market (HS6 product-exporting country pair) and then summing across the resulting numbers. Calculated in this way, note that the HHI will be similar across importing firms within the same market in a particular calendar year. An equation below shows how the two measures relate to each other: $HHI_{n,t} = \sum_m IMS^2_{m,n,t}$, where $IMS_{m,n,t}$ is our firm m-specific measure of market power within the import market n.

To first get a sense of the overall properties of our two proxies, Figure 8 plots their distribution in terms of both total number of observations and total value of imports. For importing firms' market share, we show that importers with market share less than 20 percent account for the majority of imports, suggesting that most importing firms are

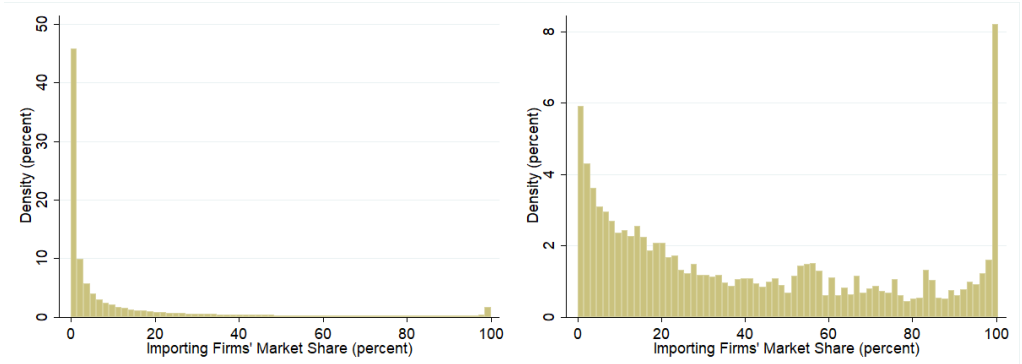
[12]Note that a single firm can have multiple market shares if they import multiple products. In addition, our definition of market share is calendar-year specific, and so a firm's market share can vary over time.

rather small. This is particularly the case if we count based on number of observations, where around 96% of them belong to this first quintile. However, in terms of import value, firms with a larger market share still account for a non-negligible portion of imports. Based on the distribution of the HHI in Panel (c), we also observe that most observations imply a rather low market concentration. However, unlike our firm-specific measure, there still remains a significant share of observations spread across the remainder of the distribution, suggesting that a significant share of markets are still highly concentrated. In particular, a few have the value of 100, implying that there is only a single firm importing from the market in that year.

Figure 8: Distribution of Market Concentration Measures

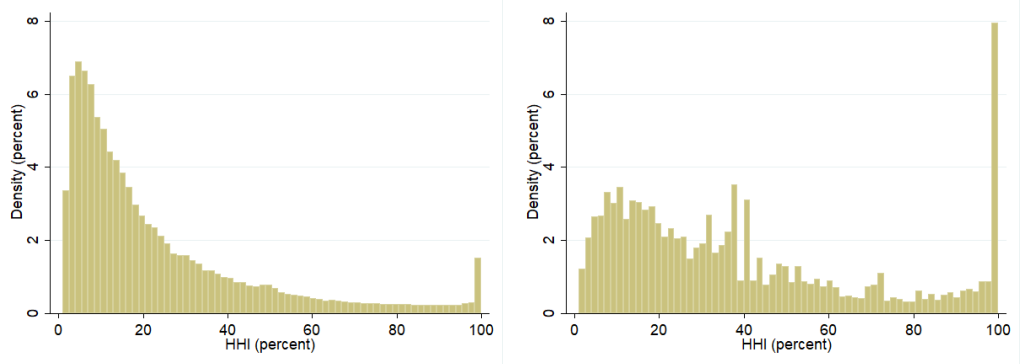
(a) Importing Firms' Market Share (by Observations)

(b) Importing Firms' Market Share (by Import Value)



(c) HHI (by Observations)

(d) HHI (by Import Value)



Note: As shown are the distribution of importing firms' market share and the HHI by number of observations in Panels (a) and (c), and by import value in Panels (b) and (d).

Next, we utilize both proxies of firm market power to estimate the following equation

to examine how ERPT may hinge upon the characteristics of importing firms:

$$\begin{aligned}\Delta P_{ID,t} = &\sum_{k=0}^{8} \beta_k \Delta FCTHB_{x,t-k} + \sum_{k=0}^{8} \beta_k^{MP} \Delta FCTHB_{x,t-k} \times MP_{m,n,t} \\ &+ \sum_{k=0}^{8} \beta_k^{MP^2} \Delta FCTHB_{x,t-k} \times MP_{m,n,t}^2 + \delta MP_{m,n,t} \\ &+ \sum_{k=0}^{8} \gamma_k \Delta Z_{x,t-k} + \alpha + \epsilon_{ID,t},\end{aligned} \tag{2}$$

where $MP_{m,n,t}$ is one of the measures of market power for an importing firm m in market n. In estimating this equation, we hypothesize that firms with a high market share or that operate in a highly concentrated market will likely have higher market power, thus experiencing lower ERPT to their import prices. Also note the interaction term between the exchange rate changes and the squared market power term in the above equation, whose role is to additionally examine whether the relationship between ERPT and importer market power is monotonic or not. In addition, to exploit the cross-sectional differences between market power across firms, we exclude firm fixed effects from the specification while assuming that market power should already be a prominent variable that helps absorb firm variations.

Table 3 reports the estimation results where for each proxy of market power, we estimate Eq. 2 with and without the squared market power term. Since we standardize each measure of market power before interacting it with the exchange rate changes, the coefficients β_k^{MP} and $\beta_k^{MP^2}$ translate to the marginal effects of an exchange rate change as the market power variable deviates from its mean by one standard deviation. Due to space considerations, we only show the medium-run impacts of ERPT, calculated as the cumulative sum of the pass-through effects over 8 quarters. Finally, we also provide accompanying plots of the medium-run ERPT for varying degrees of firm market power in Figure 9 to better visualize the results.

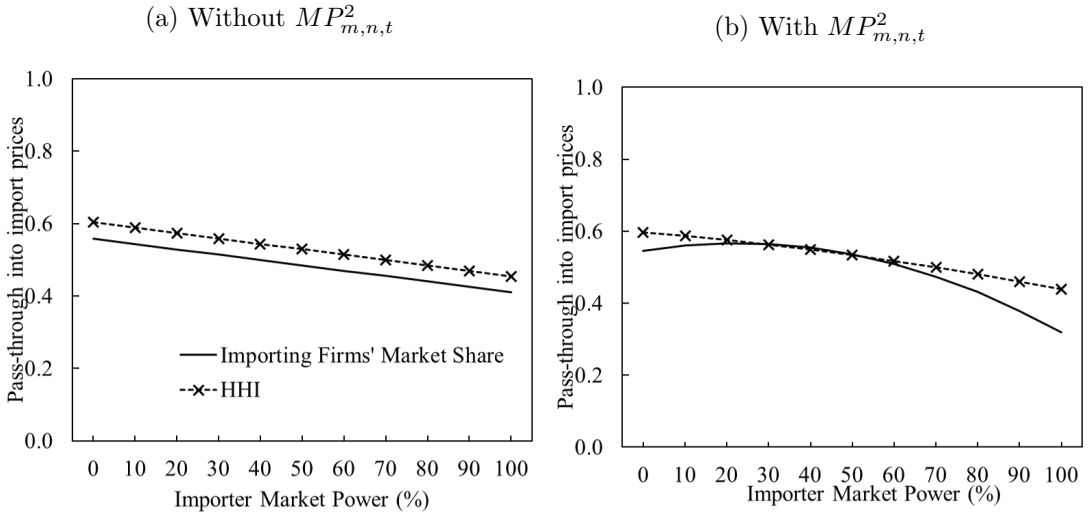
First, we interpret the ERPT results from the specification without the squared market power term (Columns I and III in Table 3). As shown, the coefficients on the interaction terms are all negative and statistically significant. Consistent with Devereux et al. (2017), this result suggests that ERPT declines in the market power of importing firms. More specifically, an increase in the market power measure by one standard deviation implies a lower ERPT coefficient by 0.035. When viewed from Panel (a) of Figure 9, this negative

Table 3: Firm Market Power and Medium-run Exchange Rate Pass-through

	Market Share		HHI	
	(I)	(II)	(III)	(IV)
Exchange Rate	0.539***	0.563***	0.569***	0.572***
	(0.012)	(0.014)	(0.013)	(0.015)
Market Power	-0.374***	-0.374***	0.016	0.016
	(0.018)	(0.018)	(0.030)	(0.030)
ER x Market Power	-0.035***	0.019	-0.034***	-0.028
	(0.009)	(0.021)	(0.010)	(0.018)
ER x Market Power^2		-0.024***		-0.003***
		(0.008)		(0.008)
Observations	4699643	4699643	4699643	4699643
R^2	0.06	0.06	0.10	0.10

Note: As shown are the cumulative exchange rate pass-through effect over 8 quarters, signifying medium-run ERPT based on two different proxies of market power. Robust standard errors are in parentheses. *,**,** denote statistical significance at the 10, 5 and 1 percent levels.

Figure 9: Medium-run Pass-through across Degrees of Firm Market Power



Note: Plotted are the medium-run ERPT estimates across varying degrees of importer market power based on two different proxies. Panels (a) and (b) show the plotted estimates from the regression with and without the $MP^2_{m,n,t}$ term, respectively.

relationship between ERPT and the market power of firms is also evident across both proxies of firm market power. More specifically, we find that firms with 100 percent market share experience a reduction in ERPT by approximately 0.15 when compared to those with almost zero share.

Upon including the squared market power term into our analysis, we confirm additional evidence of a monotonic ERPT relationship with firm market power. Similar to Devereux et al. (2017), we find that the coefficient on the squared interaction terms of

importing firms' market share is negative and statistically significant (Columns II in Table 3). Meanwhile, the inclusion of this squared interaction term takes off the statistical significance that we found earlier on the linear interaction term. For HHI, despite being insignificant at 10 percent level, the coefficient on the linear interaction term remains negative and is large relative to that of the squared interaction term (column IV), and is comparable to the corresponding estimate in column III. This finding is consistent with the monotonically decreasing relationship between pass-through and the degree of firm market power as shown in Panel (b) of Figure 9. In particular, such negative association is clearly evident when HHI is employed. For the firm-specific measure, the plot starts out as rather flat for firms with low degrees of market power (e.g. below 30 percent), but then ERPT starts to fall more rapidly. Some firms with large market share even experience an ERPT rate lower than 0.4. Our results here, therefore, suggest that there is a significant negative relationship between ERPT and the market power of importing firms. More specifically, large importers or importing firms in highly concentrated markets face lower ERPT than their small firm counterparts with low degrees of market power.

5 Currency of Invoice

The currency of invoice is another important structural determinant of ERPT that has been heavily emphasized by the recent literature. Based on our micro-level dataset, we therefore examine whether the choice of invoicing currency can determine the extent by which import prices respond to an exchange rate movement. In doing so, we extend Eq. 1 by interacting dummy variables with relevant exchange rates to separate the effect of ERPT under three currency paradigms, where each import transaction is classified as practicing (i) LCP if it is invoiced in the local currency ($D_{invoice=THB} = 1$), (ii) PCP if it is invoiced in the producer's currency x ($D_{invoice=x} = 1$) and (iii) DCP if it is exported from non-dollar countries but invoiced in the US dollar ($D_{invoice=USD} = 1$)[13]. For PCP and LCP, the associated exchange rate is the bilateral exchange rate of the exporting country's currency and the THB, while the exchange rate between the US dollar and

[13]Note that transactions whose producer's home currency is the US dollar and have their goods invoiced in the US dollar are classified as PCP. Also, under DCP, we discard transactions that utilize other vehicle currencies other than the US dollar since they constitute a very small share of all DCP trade transactions.

THB (USDTHB) is the relevant exchange rate parity for those transactions invoiced in the US dollar under DCP. We also include fixed effects for each currency of invoice. This results in the following specification:

$$\begin{aligned}\Delta P_{ID,t} = &\sum_{k=0}^{8} \beta_k^{LCP} \Delta FCTHB_{x,t-k} \times D_{invoice=THB} \\ &+ \sum_{k=0}^{8} \beta_k^{PCP} \Delta FCTHB_{x,t-k} \times D_{invoice=x} \\ &+ \sum_{k=0}^{8} \beta_k^{DCP} \Delta USDTHB_{t-k} \times D_{invoice=USD} + \sum_{k=0}^{8} \gamma_k \Delta Z_{x,t-k} + \alpha + \epsilon_{ID,t},\end{aligned} \tag{3}$$

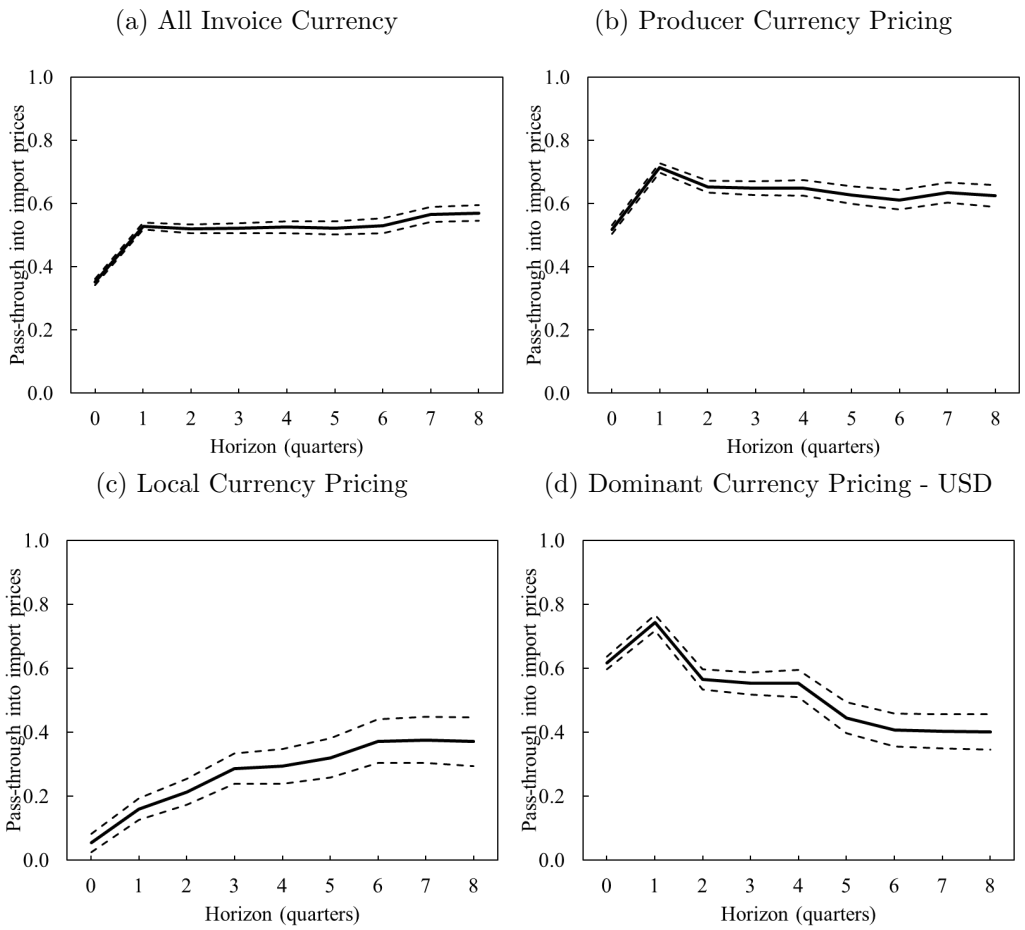
where our hypothesis is that there should be significant differences among short-run and medium-run estimates of β^{LCP}, β^{PCP} and β^{DCP} should the currency of invoice matter for ERPT.

Figure 10 contains the panel regression results that belong to the above specification. For ease of reference, we plot the baseline results that ignores the currency of invoice (Figure 5) in Panel (a), which is to be compared against Panels (b)-(d) that contain the ERPT result across the PCP, LCP and DCP invoicing currency paradigms respectively[14]. We highlight a few key observations. First, we find that both the degree and dynamics of ERPT vary substantially across invoicing currency choices, especially for transactions invoiced in the local vis-á-vis the foreign currency. This finding suggests that the baseline regression per Eq. 1 in Panel (a) hides a considerable degree of heterogeneity in ERPT at all horizons.

Second, we observe that the short-run effect of ERPT to import prices for goods priced in a foreign currency (PCP and DCP) are significantly higher than those priced in Thai baht (LCP). More specifically, the initial pass-through is comparable under DCP (0.6) and PCP (0.5), but is close to zero for LCP. In terms of this magnitude, Gillitzer and Moore (2016), Gopinath et al. (2010) and Chen et al. (2021) all report more or less insignificant short-run pass-through for imported goods priced in the local currency for Australia, US, and the UK. Our estimates of ERPT for imported goods priced in foreign currencies, however, while more or less in line with Chen et al. (2021) for the UK (0.6), are comparably lower than those of other countries. For the US, Gopinath et al. (2010)

[14]For robustness checks, we also estimate similar panel regressions over the 6 largest sectors by import value share. According to the results in Figure 16 of the Appendix, we find that the sectoral results across currency paradigms are in line with full-sample estimates.

Figure 10: Exchange Rate Pass-Through to Import Prices by Invoicing Currency



Note: Plotted are the cumulative effects of exchange rate pass-through to import prices over 8 quarters for various currency pricing paradigms. Dashed lines indicate 95% confidence bands.

find nearly complete pass-through for PCP (0.98), while for Chile, Giuliano and Luttini (2020) also report a higher sensitivity to exchange rates in the short run (0.95 and 0.78 for PCP and DCP respectively).

Third, as per the adjustment of import prices to an exchange rate shock over the medium run horizon, we observe that ERPT under LCP and DCP converges to 0.4, while pass-through under PCP remains elevated at 0.6. This leaves a permanent wedge of about 0.2 across invoicing currencies. While considered as statistically significant, this estimated gap is much smaller than those in the literature (see Gopinath et al., 2010; Giuliano and Luttini, 2020; Chen et al., 2021, for the US, Chile, and UK respectively) since our ERPT estimates under LCP increase while those under DCP fall to a comparably larger degree

in the medium run, rather than staying relatively stable[15]. Theoretically, the difference between ERPT across invoicing choices should disappear in the medium run given an exogenous currency choice where prices are sticky in the short run but fully adjustable in the long run (Obstfeld and Rogoff, 1995; Betts and Devereux, 2000; Devereux and Engel, 2003), but can persist if firms endogenously choose their currency of invoicing based on their desired magnitude of pass-through over the duration that prices are fixed (see Engel, 2006; Burstein and Gopinath, 2014; Gopinath et al., 2010). Therefore, unlike past studies, our results only lend mild support to the theory of endogenous currency invoicing.

Finally, we additionally investigate whether the USDTHB exchange rate is the relevant exchange rate parity for DCP transactions. According to the DCP literature, a clear outsized role for the dollar over the exporter's currency in price pass-through regressions has been emphasized (Boz et al., 2017; Casas et al., 2017; Gopinath et al., 2020). To test this claim, we again estimate the dummy pass-through regression in Eq. 3, but include the bilateral exchange rate of exporters' currency against THB (FCTHB) as an additional explanatory variable for DCP transactions, similar to Giuliano and Luttini (2020).

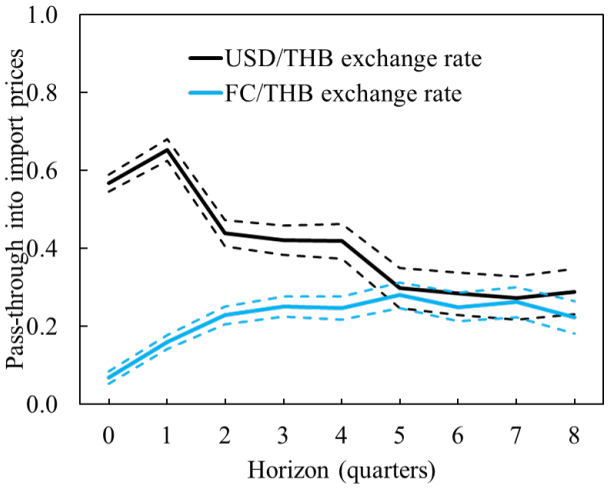
As shown in Figure 11, our findings are broadly consistent with the DCP paradigm. By adding FCTHB as an additional regressor, we observe that the coefficient on the USDTHB is significantly higher than that of the exporters' currency in the short run by a magnitude of approximately 0.6, implying that the relevant exchange rate parity for goods that are invoiced in USD is the US dollar rather than the bilateral exchange rate of the exporting country's currency. This result, however, only holds in the short run. The magnitude of ERPT tied to both exchange rates converges after five quarters, giving an equally important role to the exporter currency in the medium run[16]. For Chile, Giuliano and Luttini (2021) uncover similar results for imported goods that are invoiced in the US dollar, but their analysis shows that while the bilateral exchange rate against

[15] Under LCP, exchange rate changes directly impact exporters' revenue in their own currency, prompting them to negotiate price adjustments. This results in some pass-through to import prices over the medium run. Meanwhile, a reduction in ERPT for imported goods under DCP may reflect responses of exporters to changes in their price competitiveness. Firm market power could also be at play since exporting firms, endowed with higher market power, may desire to raise their product prices when the baht appreciation triggers an initial decline in prices. This will be further explored in the next section.

[16] A strong version of DCP paradigm in the medium run implies a negligible role of exporting currencies once the USDTHB parity has been taken into account. Another way to test this claim is to consider an alternative specification as in Chen et al. (2021), where they include the bilateral exchange rate between the USD and the exporting country's currency (in our case, USDFC) for vehicle currency pricing transactions. We also consider this as a robustness test and arrive at similar results.

the exporting country's currency also starts out as less important, it becomes even more relevant than the exchange rate parity against the US dollar in the medium run.

Figure 11: Exchange Rate Pass-Through under the Dominant Currency Pricing Paradigm



Note: Plotted are the cumulative effects of exchange rate pass-through to import prices over 8 quarters under DCP. The top black line corresponds to ERPT based on the coefficients in front of the USDTHB exchange rate, while the bottom blue line signifies the magnitude of pass-through based on the estimated coefficients of the bilateral exchange rate of the exporter's currency against THB (FCTHB). Dashed lines indicate 95% confidence bands.

6 Asymmetries and Non-Linearities in ERPT

Apart from determinants related to the structure of the economy, the degree of pass-through has also been suggested to be state-dependent. In particular, a strand of the literature argues that ERPT may differ between depreciation and appreciation episodes, as well as be contingent upon large versus small exchange rate changes.

In this section, we are therefore interested in examining such potential pass-through asymmetries and non-linearities based on our micro-level dataset. First, we ask whether pass-through is asymmetric, that is, does a 1% appreciation have the same impact on import prices, with the opposite sign as a depreciation of the same magnitude? Throughout this paper, the term appreciation (depreciation) is used to describe an increase (decrease) in the value of the importer's local currency vis-á-vis the foreign currency. In addition, we investigate whether import prices respond in a linear or non-linear fashion to large versus small exchange rate changes.

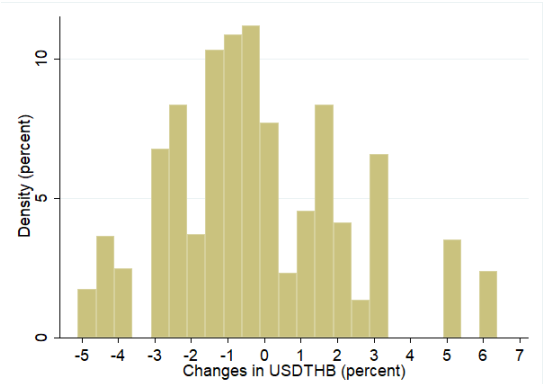
While it is typically assumed that ERPT is symmetric and linear, a number of microeconomic factors might generate asymmetric or non-linear responses in ERPT. Empirical evidence on ERPT asymmetry and non-linearity, however, appears rather mixed, and the bulk of empirical studies tend to focus on the experiences of advanced economies. For those that investigate whether depreciations pass through with the same magnitude as appreciations, empirical work that utilizes macro level data includes Delatte and López-Villavicencio (2012), Bussiere (2013), El bejaoui (2013), Brun-Aguerre et al. (2017), Jašová et al. (2019) and Colavecchio and Rubene (2020), among others. A growing number of studies also investigate this issue at the industry level, such as Coughlin and Pollard (2004), Campa et al. (2008), and Yang (2007). However, with high degrees of cross-country as well as cross-industry heterogeneity in results, there is still inconclusive evidence on whether appreciations or depreciations pass through more strongly to prices. The same can be said about the state of empirical work on the impact of size of exchange rate changes on ERPT. In other words, it still remains inconclusive on whether ERPT is really a linear phenomenon (see Faust et al., 2005; Frankel et al., 2012; Bussiere, 2013).

Given that any asymmetries and non-linearities in ERPT can be washed out in aggregate data, transaction-level data can be useful towards uncovering such evidence. However, studies that utilize micro-level data for this purpose are still extremely limited, and to our knowledge only include Berner (2011) and Kim et al. (2019), who find that import prices at the dock are less responsive to currency appreciations in the case of Germany and the US respectively. Nevertheless, these authors do not find significant evidence that larger exchange rate changes pass through at a different rate from smaller ones.

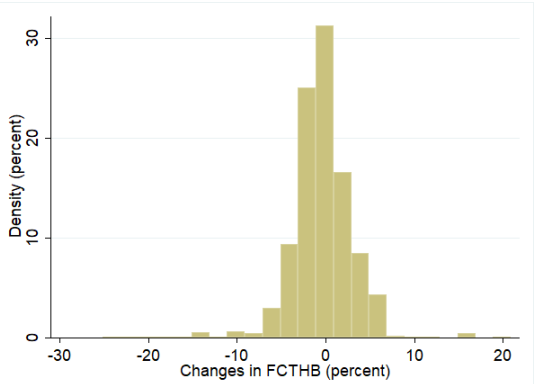
In what follows, we aim to contribute to this literature by using our detailed dataset to investigate whether ERPT to Thai import prices at the dock would respond differently according to the direction or size of an exchange rate change. As shown in Figure 12, we have a large sample of both appreciation and depreciation episodes of various magnitudes for this purpose. Given the important role of the invoicing currency for ERPT, we also take into account the currency of invoice in the latter part of our analysis.

Figure 12: Distribution of Exchange Rate Changes

(a) Changes in USDTHB



(b) Changes in FCTHB



Note: The figures show the frequency of changes in the USDTHB exchange rate and the bilateral exchange rate of the exporting country's currency against THB over the full sample.

6.1 Ignoring the Role of Invoicing Currency

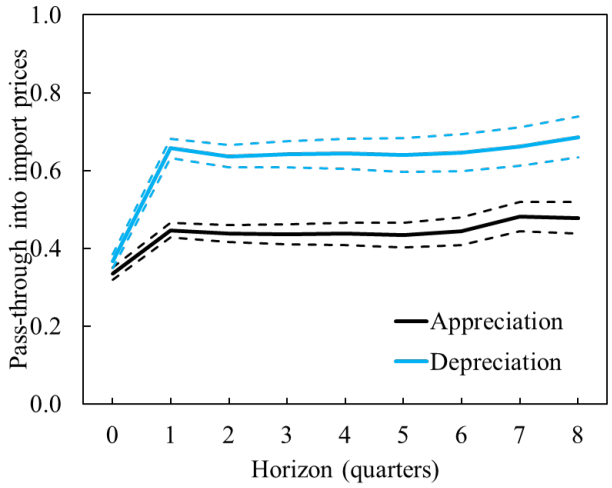
We form baseline results by first investigating the presence of asymmetry and non-linearity in ERPT to import prices at the Thai border by ignoring the currency of invoice. First, we consider the specification below that augments the baseline panel pass-through regression in Eq. 1 to account for the fact that appreciations and depreciations may pass through to import prices asymmetrically:

$$\begin{aligned}\Delta P_{ID,t} = &\sum_{k=0}^{8} \beta_k^{FCTHB} \Delta FCTHB_{t-k} + \sum_{k=0}^{8} \beta_k^{FCTHB,depr} \Delta FCTHB_{t-k} \\ &\times D_{t-k}^{FCTHB,depr} + \sum_{k=0}^{8} \gamma_k \Delta Z_{t-k} + \alpha + \epsilon_{ID,t},\end{aligned} \tag{4}$$

where $D_t^{FCTHB,depr}$ is the dummy variable that is equal to 1 if $\Delta FCTHB_t > 0$ and 0 otherwise. According to the above specification, pass-through is asymmetric if the effect of a currency appreciation as captured by the coefficient β_k^{FCTHB} is different from a currency depreciation, as captured by $\beta_k^{FCTHB} + \beta_k^{FCTHB,depr}$. Note that since we are not yet accounting for the currency of invoice, the bilateral exchange rate against the exporting country (FCTHB) is the relevant exchange rate in the panel regression.

Figure 13 contains the estimation results from Eq. 4. Similar to our previous findings, we observe ERPT in both directions to be moderate and incomplete. However, there are significant differences in the magnitude of pass-through depending on the direction of exchange rate changes, suggesting that pass-through regressions that assume symmetry

Figure 13: Directional Asymmetry in Exchange Rate Pass-Through



Note: Displayed are cumulative exchange rate pass-through effects for depreciations/appreciations over an 8-quarter horizon. Dashed lines indicate 95% confidence bands.

can mask out important differences in directional responses. The impact of Thai baht depreciations vis-á-vis the exporting country's currency is stronger by about 0.2 within the first quarter. This difference persists even in the medium run.

The finding that depreciations pass through more strongly than appreciations confirms that Thai import prices, set by exporters, may be rigid downwards. More specifically, our findings are consistent with theories of downward nominal price rigidities where there is typically resistance for prices to be revised downwards than to be increased upwards. That is, in response to a local currency appreciation, exporters facing increased price competitiveness are able to raise their good prices to increase markup, hence curtailing the ERPT. On the contrary, there is more reluctance to cut prices when facing lower price competitiveness due to a Thai baht depreciation. The impact of exchange rate changes in this latter case thus passes strongly into import prices in local currency. A related explanation is put forth by Delatte and López-Villavicencio (2012), who attribute the stronger ERPT during depreciations to a weak competition structure. This is likely the case in emerging market economies, whose importers have limited power against their trade partners. Exporters, therefore, have low incentives to reduce margins, hence passing on the losses from a currency depreciation onto product prices.

Our results on directional asymmetry echo the empirical findings of Brun-Aguerre et al. (2017) who analyze ERPT to import prices for 33 developed and emerging countries, as

well as Webber (2000) who investigates asymmetric pass-through for 8 Asian economies. Furthermore, they are similar to Delatte and López-Villavicencio (2012) who find that, for developed countries, depreciations pass through to the general price level more strongly than appreciations. Based on a comparable micro dataset, Berner (2011) and Kim et al. (2019) also document similar findings for Germany and the US.

Next, we turn to investigate the possibility of non-linearity in pass-through with respect to the size of exchange rate changes. To do so, we consider the following specification which allows small versus large exchange rate changes to affect import prices differently:

$$\begin{aligned}\Delta P_{ID,t} = &\sum_{k=0}^{8} \beta_k \Delta FCTHB_{x,t-k} + \sum_{k=0}^{8} \beta_k^{sq} \Delta FCTHB_{x,t-k}^2 \\ &+ \sum_{k=0}^{8} \beta_k^{cu} \Delta FCTHB_{x,t-k}^3 + \sum_{k=0}^{8} \gamma_k \Delta Z_{x,t-k} + \alpha + \epsilon_{ID,t},\end{aligned} \tag{5}$$

where any evidence of size non-linearity will be reflected in the magnitude and significance of the squared and cubic terms coefficients. For robustness checks, we also consider estimating the following equation that allows for the possibility that the size of an exchange rate change may impact pass-through differently depending on whether it is an appreciation or depreciation:

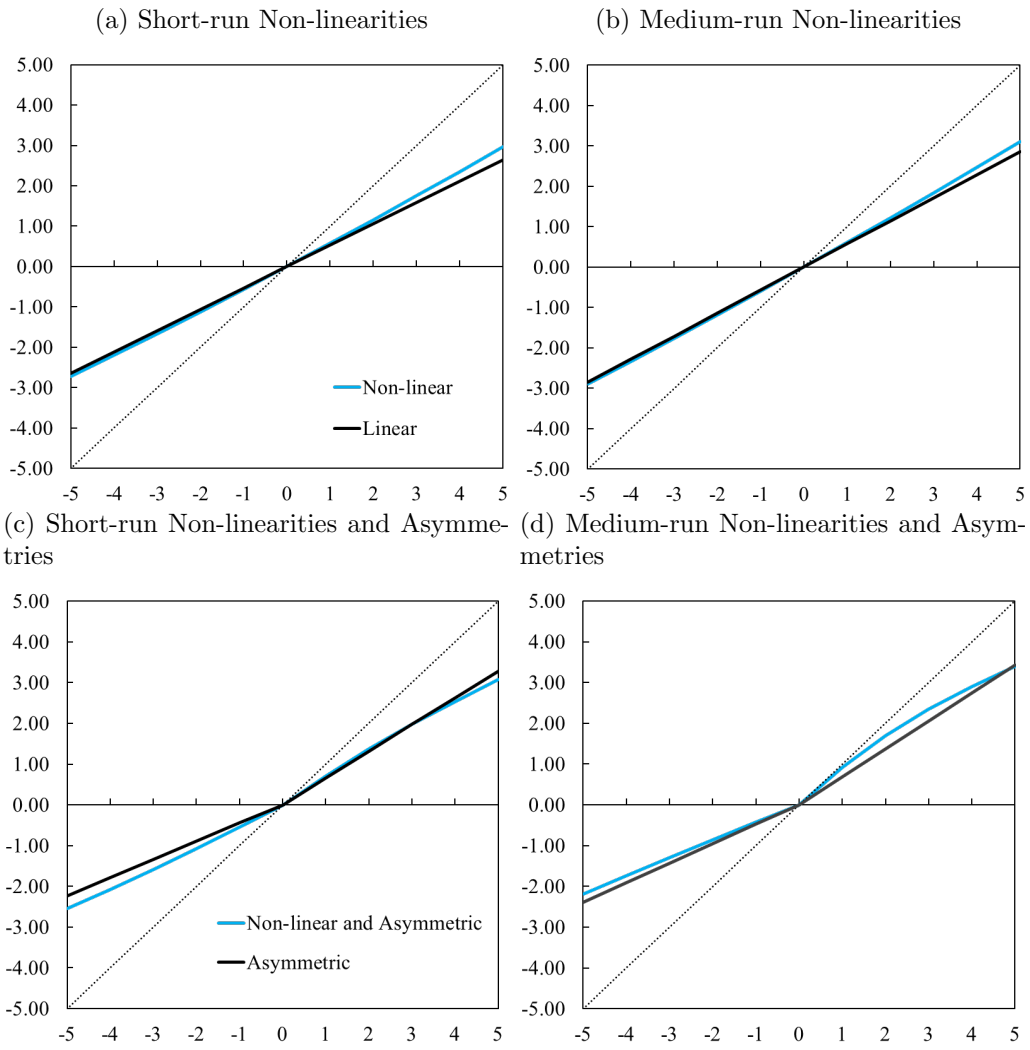
$$\begin{aligned}\Delta P_{ID,t} = &\sum_{k=0}^{8} \beta_k \Delta FCTHB_{x,t-k} + \sum_{k=0}^{8} \beta_k^{dep} \Delta FCTHB_{x,t-k} \times D_{t-k}^{FCTHB,depr} \\ &+ \sum_{k=0}^{8} \beta_k^{sq} \Delta FCTHB_{x,t-k}^2 + \sum_{k=0}^{8} \beta_k^{sq,depr} \Delta FCTHB_{x,t-k}^2 \times D_{t-k}^{FCTHB,depr} \\ &+ \sum_{k=0}^{8} \beta_k^{cu} \Delta FCTHB_{x,t-k}^3 + \sum_{k=0}^{8} \beta_k^{cu,depr} \Delta FCTHB_{x,t-k}^3 \times D_{t-k}^{FCTHB,depr} \\ &+ \sum_{k=0}^{8} \gamma_k \Delta Z_{x,t-k} + \alpha + \epsilon_{ID,t},\end{aligned} \tag{6}$$

or in other words, it allows for both directional asymmetry and size non-linearity to influence the magnitude of ERPT.

Figures 14 plots the results at chosen short and medium term horizons (1 and 8 quarters, respectively). In Panels (a) and (b), we show the total pass-through effects by multiplying the estimated ERPT coefficients with changes in the relevant exchange rates

from the non-linear (Eq. 5) and linear (Eq. 1) models. Should results differ significantly, we would infer that the addition of squared and cubic term coefficients are necessary to help capture non-linearities in pass-through. Similarly, Panels (c) and (d) compare the results from the non-linear and asymmetric case (Eq. 6) to the asymmetric-only scenario (Eq. 4).

Figure 14: Non-linearities and Asymmetries in Exchange Rate Pass-through



Note: Displayed are the total effects of ERPT at the short and medium-run horizons (1-quarter and cumulated 8-quarter horizons). Total ERPT is calculated as the product of the estimated pass-through coefficients with corresponding exchange rate changes. Panels (a) and (b) contrast the non-linear and linear cases while Panels (c) and (d) contrast the non-linear and asymmetric case with the asymmetric-only scenario.

As shown in Panels (a) and (b), the results from the non-linear regression are nearly economically identical to the linear case. This finding is robust even after allowing for asymmetry in Panels (c) and (d), that is, treating appreciation and depreciation episodes

differently. Therefore, similar to Kim et al. (2019), we find that the strength of pass-through to import prices at the dock in Thailand differs by only the direction of exchange rate changes, but not by size. In light of this evidence, we thus proceed to investigate ERPT asymmetry in more depth by also accounting for the role of invoicing currencies.

6.2 Asymmetries Across Currencies of Invoice

Do patterns of ERPT asymmetry differ by currency of invoice? To investigate this issue, we add additional dummy variables for currency of invoice and their interaction terms with the relevant exchange rates to Eq. 4, resulting in the following specification:

$$\begin{aligned}
\Delta P_{ID,t} = & \sum_{k=0}^{8} \beta_k^{LCP} \Delta FCTHB_{x,t-k} \times D_{invoice=THB} \\
& + \sum_{k=0}^{8} \beta_k^{LCP,depr} \Delta FCTHB_{x,t-k} \times D_{invoice=THB} \times D_{t-k}^{FCTHB,depr} \\
& + \sum_{k=0}^{8} \beta_k^{PCP} \Delta FCTHB_{x,t-k} \times D_{invoice=x} \\
& + \sum_{k=0}^{8} \beta_k^{PCP,depr} \Delta FCTHB_{x,t-k} \times D_{invoice=x} \times D_{t-k}^{FCTHB,depr} \\
& + \sum_{k=0}^{8} \beta_k^{DCP} \Delta USDTHB_{t-k} \times D_{invoice=USD} \\
& + \sum_{k=0}^{8} \beta_k^{DCP,depr} \Delta USDTHB_{t-k} \times D_{invoice=USD} \times D_{t-k}^{USDTHB,depr} \\
& + \sum_{k=0}^{8} \gamma_k \Delta Z_{x,t-k} + \alpha + \epsilon_{ID,t}.
\end{aligned} \tag{7}$$

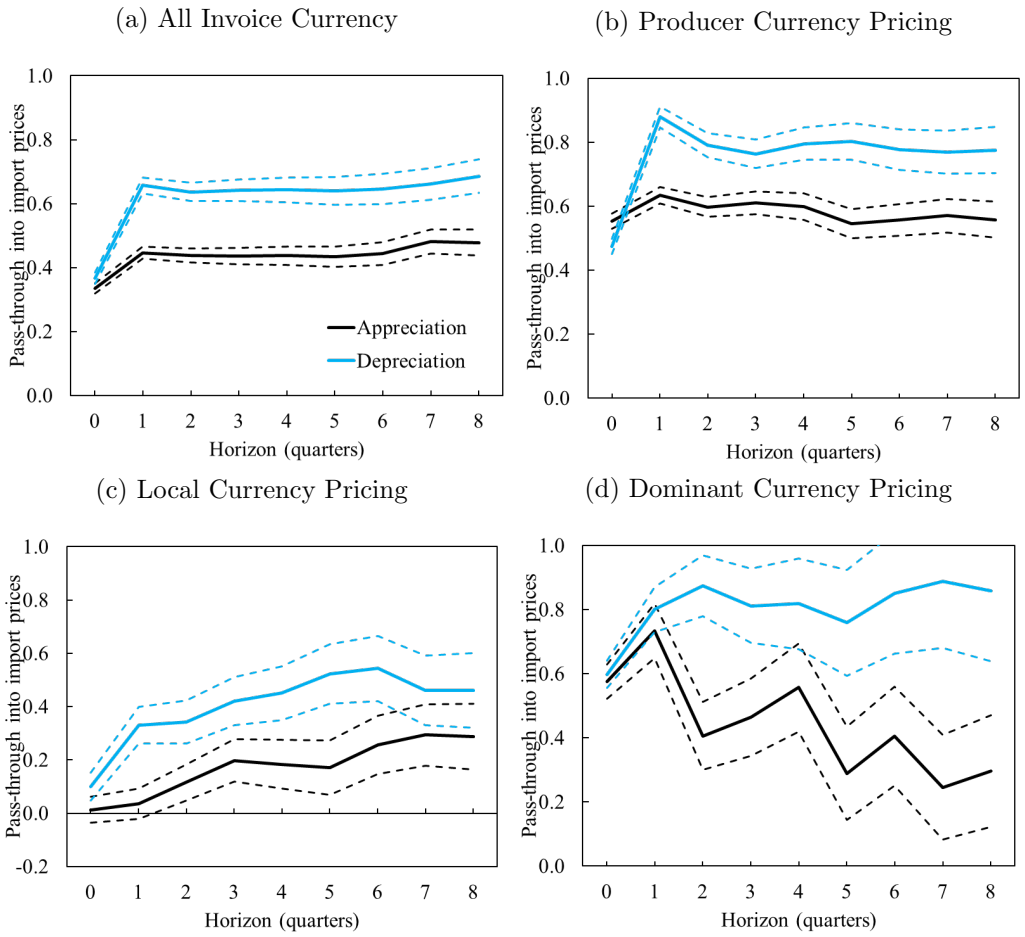
In the above specification, the potentially heterogenous pass-through effects associated with the three pricing paradigms $y = \{LCP, PCP, DCP\}$ are captured by β^y and $\beta^y + \beta^{y,depr}$ for appreciation and depreciation episodes respectively. Note again that the dummy variables $D_t^{FCTHB,depr}$ and $D_t^{USDTHB,depr}$ take on the value of 1 if $\Delta FCTHB_t > 0$ or $\Delta USDTHB_t > 0$, and 0 otherwise.

Based on the estimation of Eq. 7, Figure 15(b)-(d) illustrates our findings[17]. Note that for ease of reference, we plot the regression result that allows for ERPT asymmetry but ignores the currency of invoice (Figure 15(a)). Upon first glance, we confirm two of our previous findings. First, patterns of pass-through for exchange rate changes are incomplete in the short run for all invoicing currencies. However, compared to the baseline case for asymmetry in Panel (a), we observe closer to full pass-through for depreciation episodes under PCP and DCP (80%). In fact, ERPT estimates for DCP are not significantly different from one in latter quarters, which may indicate the case of complete pass-through. Second, we confirm that depreciations pass on more strongly than appreciations across all invoicing currencies, reiterating that downward price rigidity seems to be an important characteristic of Thai imports. This directional asymmetry also persists through to the medium run, regardless of invoicing currency types.

A closer inspection of Figure 15(b)-(d) reveals additional insights about how exporters and importers respond to changes in their price competitiveness and/or profit margins resulting from currency fluctuations across different invoicing currency paradigms. For example, we observe that under PCP, the difference between the strength of pass-through for appreciations and depreciations is generally within the range of 0.2. The gap in ERPT is largest in the short run at about the 1-quarter horizon, as exporters are reluctant to cut their product prices in response to local currency depreciation despite facing declining price competitiveness, as described earlier. However, over time, importers whom are disadvantaged from higher import prices in local currency, have the incentive to negotiate for lower prices. This explains why we observe a slight reduction in ERPT over the following two quarters, where it reaches its medium-run estimate thereafter. On the appreciation side, medium-run EPRT is achieved rather immediately, as exporters adjust their product prices upward in response to gains in price competitiveness. Meanwhile, having benefited from cheaper import prices, importers have less incentives for prices to be negotiated or revised afterwards.

[17]For robustness checks, we also consider alternative definitions of appreciation and depreciation episodes. For example, we let the dummy variable that define appreciations and depreciations take on the value of 1 based on both the direction of an exchange rate change in that quarter, and also upon whether the currency appreciates or depreciates over the cumulation of n = 2, 3, and 4 quarters. Figure 17 in the Appendix contains the estimation results that correspond to the four quarter case, while due to space considerations, results for other cases are available upon request. As shown, the plots produce qualitatively similar results.

Figure 15: Directional Asymmetry in Exchange Rate Pass-Through by Invoicing Currency



Note: Displayed are cumulative exchange rate pass-through effects over an 8-quarter horizon for appreciation/depreciation episodes across different currencies of invoice. Dashed lines indicate 95% confidence bands.

Under LCP, the intuition for the general shape of pass-through responses are slightly different. Given that import prices are agreed in Thai baht terms, exchange rate fluctuations matter directly for exporters' profit margins. With a local currency depreciation, exporters lose from declined earnings when converted back into their own currency, thus having incentives to push for some price increases in the local currency to soften the blow from the initial impact of the exchange rate change. Thus, we find such pass-through to be rather immediate. On the other hand, in the case of currency appreciations, exporters gain and may decide to slightly adjust export prices downward, explaining the gradual increase in ERPT over time.

Finally, a different picture emerges for DCP, where ERPT asymmetry is the largest. In the case of a depreciation, the magnitude of ERPT starts out high and approaches full

pass-through, implying that importers may not be able to negotiate any price declines with the exporter to reverse initial losses from the exchange rate change. As such, this may signal the lack of market power by importers for price negotiations to improve their positions after a currency depreciation. This observation is consistent with the direction of price responses on the appreciation side. In this case, ERPT declines rather rapidly from around 0.6 to 0.3 over the medium run, signifying that any gains to the importer from a currency appreciation would be reversed in the medium term by exporters that hold more market power.[18] Overall, our results thus suggest that the degree of market power of firms involved in the trade may have an important bearing on the degree of ERPT, which may cause pass-through to be asymmetric and heterogeneous under different types of invoicing strategies.

7 Conclusion

Using detailed transaction-level customs data for Thai imports at the dock, this paper documents considerable heterogeneity in ERPT at both short and medium term horizons of up to two years. We find various factors responsible, including product and firm characteristics, the currency of invoicing as well as the direction of exchange rate changes. Given that the sensitivity of prices to currency movements are state-dependent and are shown to depend on certain structural characteristics of the economy, this implies that policymakers should move beyond using aggregate 'rules of thumb' in predicting how currency movements will affect import prices and inflation.

Our series of results offer policy implications along various dimensions. First, to the extent that policymakers are concerned about limiting domestic price exposures to foreign exchange rate fluctuations, beyond the promotion of effective hedging practices and tools, central bankers may also want to consider the differential impacts that exchange rates may have across different currencies of invoicing. Based on our findings, imported goods priced in a local currency are less susceptible to changes in the exchange rate compared to those invoiced in producer currencies or the US dollar, thus taking further steps to promote the adoption of local currency pricing as a more popular currency choice could prove fruitful,

[18] It is also possible that at times the Thai baht is appreciating, the exporter's currency also strengthens against the USD, prompting the exporter to raise their product prices over time to curtail valuation losses.

especially for small open economies like Thailand that are highly susceptible to volatile exchange rate shocks, and with still few trade transactions that take place in the local currency.

Second, misleading predictions of ERPT into import prices and thus consumer price inflation could take place if we ignore the currency of invoicing. We report significantly higher ERPT in the short run for goods that adopt DCP as a currency of invoice once we allow their prices to depend on the US dollar rather than the bilateral exchange rate of the exporting country's currency. Therefore, for many countries including Thailand where DCP is pervasive, an important implication of this result is that policy considerations of ERPT should place more emphasis on the value of the prominent vehicle currency that is actually used in trade invoicing rather than the bilateral exchange rate of the exporter currency. More generally, an effective exchange rate that is based on invoicing currency weights rather than trade weights, should be able to lead to more accurate predictions of ERPT and consequently, imminent inflationary risks for any given country.

Our findings on asymmetry in the price-exchange rate connection also reiterates the importance of ERPT considerations that should be state dependent. Under the majority of trade transactions that are invoiced under DCP, we find that pass-through while starting out moderate for both appreciation and depreciation episodes, declines rapidly in the case of appreciations, but climbs within a short period of time to full pass-through under depreciations. This result is interesting insofar as appreciations under DCP delivers limited inflation risks, whilst it implies that policymakers should closely monitor price pressures that could quickly materialize under currency depreciations. To the extent that we also find modest evidence of time variation in ERPT, our results more generally highlight the importance of adjusting estimates of ERPT over time to more accurately predict the impact of currency movements on inflation.

Finally, our results show that structural characteristics such as the product type of imported goods as well as the degree of firm market power can lead to considerable variations in ERPT. To this end, exchange rate changes can have significant allocative consequences, which may ultimately pass through into costs of production along the production lines and eventually to consumer prices. Understanding the underlying mechanisms of how this takes place in a unified framework that could account for differential pass-through

impacts on producing firms, retailers and consumers across industries is thus a promising area of research that would not only be of interest to monetary policymakers for its implications on aggregate inflation, but would also help us further our understanding about heterogeneity in ERPT along the entire price distribution chain. While we do not further pursue this area of work due to limitations in our dataset, we leave this important research agenda for future research.

Declaration of interest: none

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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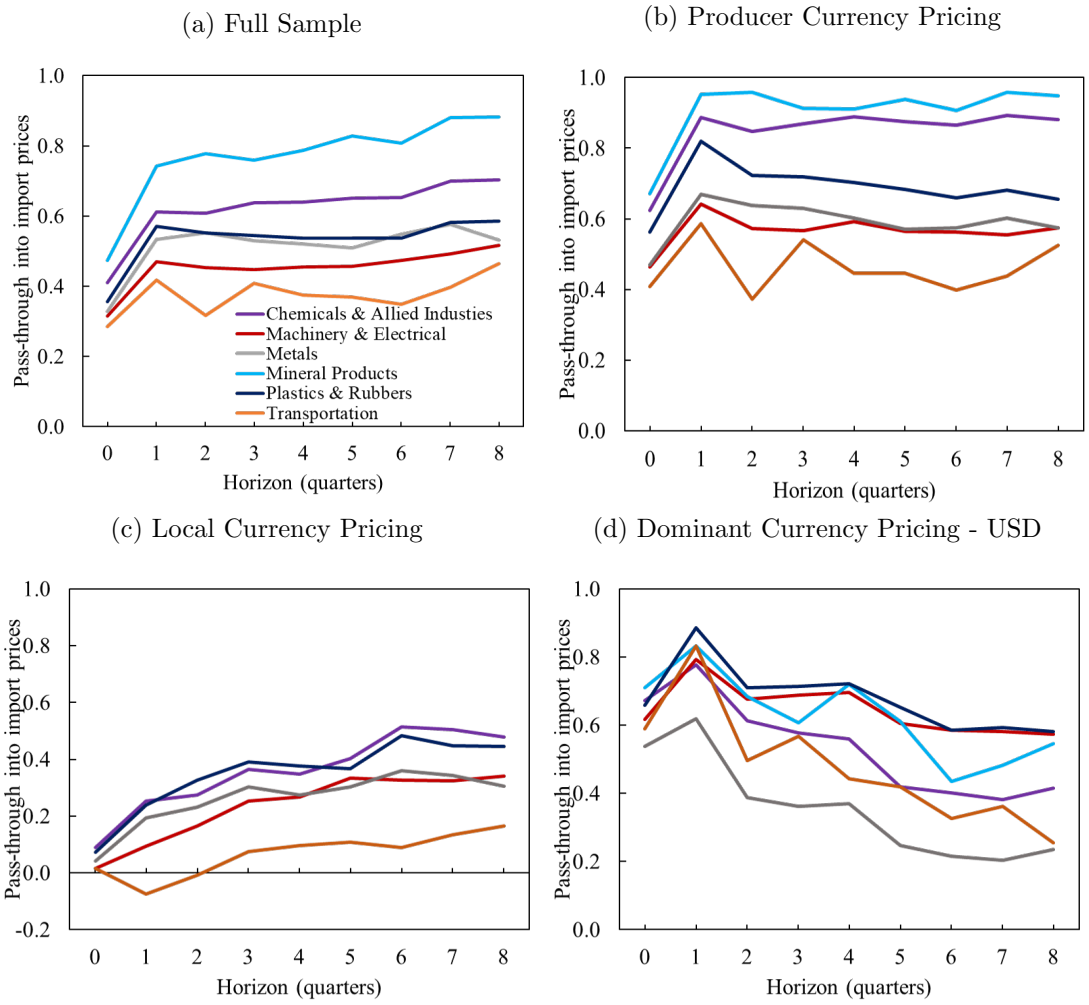
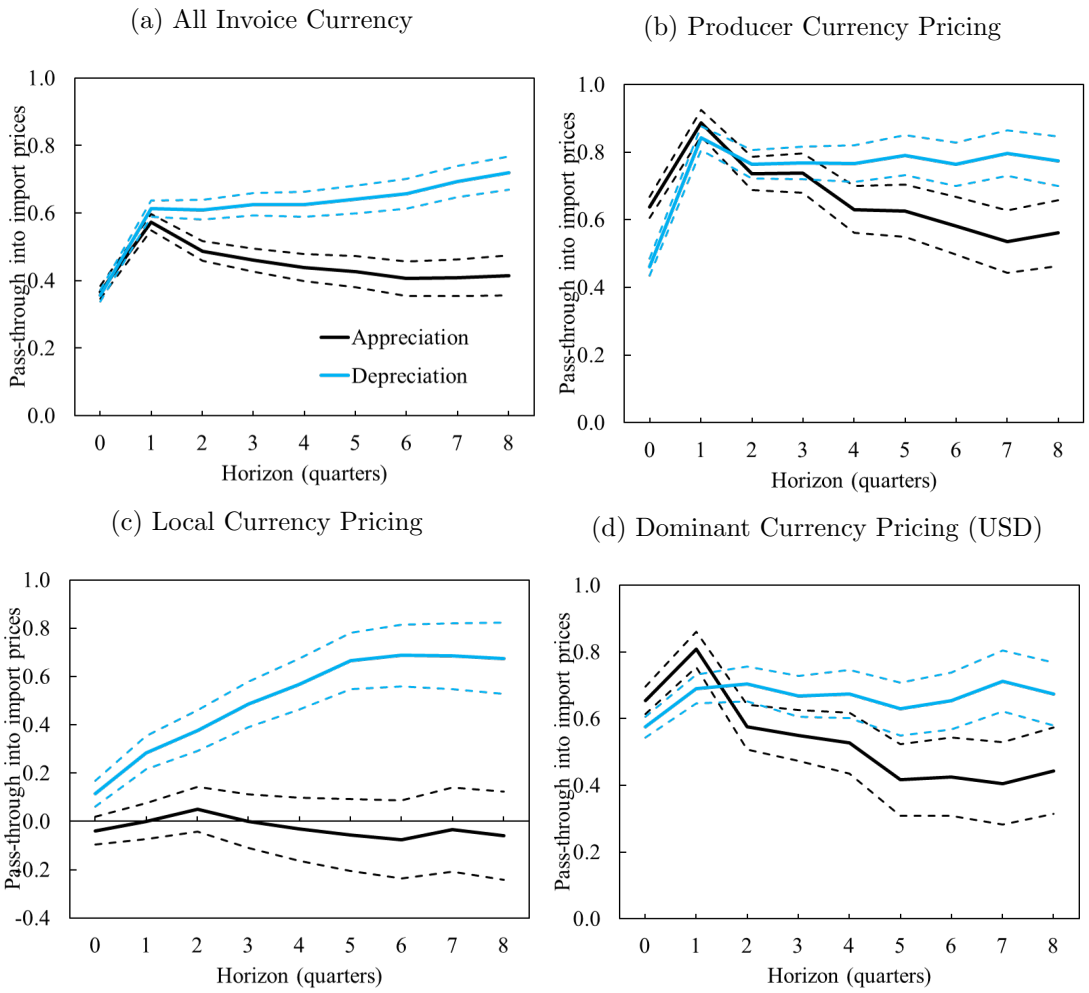
Appendix: Robustness Checks

Figure 16: Exchange Rate Pass-Through across Product Sectors



Note: Displayed are the cumulative exchange rate pass-through effects over an 8-quarter horizon for the largest 6 sectors by import value share.

Figure 17: Asymmetry of Exchange Rate Pass-Through by Invoicing Currency



Note: Displayed are cumulative exchange rate pass-through effects over an 8-quarter horizon. Appreciation/depreciation episodes are defined based on an appreciation/depreciation occurring over a phase of 4 successive quarters. Dashed lines indicate 95% confidence bands.