Imported-Inputs Channel of Exchange Rate Pass-Through : Evidence from Korean Firm-Level Pricing Survey

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This paper studies the imported inputs channel of exchange rate pass-through to the prices of domestically produced goods, exploring the firm-level pricing survey conducted by the Bank of Korea. The survey data reveal that imported inputs play a major role in transmitting exchange rate fluctuations to domestic producer prices, and that the degree of exchange rate pass-through tends to be nonlinear and asymmetric: it is higher when changes in exchange rate are large or when the local currency depreciates. A further investigation of the sources of nonlinearity and asymmetry supports the model's prediction that nonlinear pass-through may arise because large exchange-rate movements trigger additional indirect effects via industry-level price movements, while asymmetric pass-through can be driven by capacity constrained firms.

Keywords: Exchange rate pass-through, Imported inputs channel, Nonlinearity, Asymmetry

JEL Classification: F1, F3, F4, E3

I. Introduction

The exchange rate affects the domestic price level. This may occur not just directly through imported final goods but also indirectly via imported inputs used in domestic goods production. The importance of the latter has particularly increased with recent developments in globalization and international supply chains that have raised the intensity of imported inputs in production.[1] This paper contributes to the literature on the imported inputs channel of exchange rate pass-through by exploring the firm-level pricing survey conducted by the Bank of Korea.

The main findings in this paper may be summarized as follows. First, imported inputs play a major role in transmitting exchange rate fluctuations to the price of domestically produced goods. An ordered probit regression result suggests that, as compared with the producer having a lower intensity of imported inputs, a producer with a higher intensity of imported inputs is 17 percentage points more likely to fully reflect a change in the exchange rate in adjusting the domestic price of its main product. This is only slightly offset by the countervailing forces embodied in mark-up or marginal cost adjustment processes. More interestingly, this study finds that the degree of exchange rate pass-through tends to be nonlinear and asymmetric: it is higher when changes in exchange rate are large or when the local currency depreciates.[2] This is furthermore found to be consistent with the model's prediction that nonlinear pass-through may arise because large movements in the exchange rate trigger additional indirect effects via industry-level price movements, while asymmetric pass-through can be driven by capacity constrained firms because they cannot easily expand outputs in response to a cost reduction in imported inputs induced by local currency appreciation.

Despite the conceptual clarity, it has often been challenging, if not impossible, to separately identify the imported inputs channel of exchange rate pass-through,

1) According to the Korean Input-Output tables, for example, the industry-level share of imported inputs in total inputs increased, on average, from 26 percent in 1995 to 31 percent in 2010.

2) The estimated coefficient on each dummy variable implies that large changes in the exchange rate and local currency depreciation increase any given firm's likelihood of changing its domestic price to fully reflect changes in the exchange rate by, on average, 12 percentage points and 5 percentage points, respectively.

not least because of a difficulty in distinguishing between final goods and inputs in the import price data or between domestic and imported inputs in production. This paper gets around the difficulty by using the data from the pricing survey that asks, in addition to various dimensions of firm characteristics, how much each respondent firm changes the domestic price of the main product in response to changes in the exchange rate, and the answer is then taken as the degree of exchange rate pass-through to the domestic price for each firm. One main advantage of this approach is that the degree of exchange rate pass-through is not a product of the estimation procedures, but rather an observable variable obtained at the firm level, which allows to investigate the determinants of the firm-level exchange rate pass-through. Another strength of the current survey data is that the survey collects the varying degree of exchange rate pass-through under four different scenarios – a large depreciation, a small depreciation, a large appreciation, and a small appreciation – separately for every firm, providing an excellent tool to evaluate the average within-firm pattern of nonlinearity as well as that of asymmetry in exchange rate pass-through.

Admittedly, studies using survey data face inherent limitations, and this paper may be no exception. Survey respondents tend to express their subjective views, possibly deviating from actual outcomes of decision making. For instance, the main question of the current survey, the degree of exchange rate pass-through, relies on respondents' own recollections of pricing behaviors in the past as well as their expectations in hypothetical situations.[3] Another limitation is due to the qualitative feature of the questionnaire that makes it difficult to derive quantitative interpretations. That said, this paper should be viewed as a useful complement to, not a superior substitute for, existing studies based on actual price data.

A growing number of central banks use firm-level pricing surveys to broaden understanding of actual price-setting behaviors. Notable examples include survey-based studies by Euro area central banks, of which results are consolidated and sum-

3) Unless recollection or expectation errors are correlated with actual degrees of exchange rate pass-through in a systematic way, which is highly unlikely, such errors will not contradict the findings of any of the main results in the paper. Further, as Blinder (1991) argues, it is important to note that studies using actual price data are not free from estimation errors either.

marized in Fabiani et. al. (2006). The current paper is one outcome of the Bank of Korea's firm-level pricing survey in 2012, which features additional questions expressly designed to explore firm-level exchange rate pass-through to domestic prices, similarly to that by the Central Bank of Iceland (Ólafsson, Pétursdóttir, and Vignisdóttir, 2011). Unlike them, however, the current study provides more robust and systematic econometric analysis.

Among a vast array of studies on exchange rate pass-through, this paper particularly builds on the literature with an explicit consideration of the imported input channel. Goldberg and Campa (2010) found cross-country and cross-industry evidence that the imported inputs channel play a dominant role in transmitting exchange rates to the CPI. Choi and Cook (2013) find that imported intermediate inputs tend to have a higher pass-through than imported final goods using the U.S. import prices data. Other recent studies focus on the implications for export prices: while amplifying the sensitivity of domestic prices to the exchange rate, the imported inputs channel will dampen that of export prices. Powers and Riker (2013) estimate exchange rate pass-through in export prices using value added contents of trade data with an idea to net out the imported inputs channel. Greenway, Kneller, and Zhang (2010) and Fauceglia, Shingal, and Wermelinger (2012) find supporting evidence for a potential role of imported inputs as a natural hedge against exchange rate risks for UK and Swiss exporters, respectively. Unlike the above studies that exploit variations in the industry-level use of imported inputs constructed from Input-Output tables, Amiti, Itskhoki, and Konings (2013) report firm-level evidence that more import-intensive exporters have significantly lower exchange rate pass-through into their export prices, which explains the low aggregate elasticity of exports to exchange rates.

This paper also contributes to the literature that studies nonlinearity and asymmetry in exchange rate pass-through. Pollard and Coughlin (2004) and Bussière (2007) find evidence consistent with nonlinear and asymmetric pass- through in U.S. and G7 economies, respectively. The current paper identifies both nonlinearity and asymmetry at the firm-level, and further investigates the sources of such nonlinear and asymmetric pass-through beyond a common rationale in previous studies that attributes nonlinearity to menu cost pricing behavior and asymmetry to downward

nominal rigidity.

This paper proceeds as follows. Section 2 provides background theory on exchange rate pass-through via imported inputs, and the survey data are introduced in section 3. Section 4 discusses empirical findings and section 5 concludes.

Ⅱ. A Model of Exchange Rate Pass-Through

This section introduces a model of exchange rate pass-through that provides a conceptual background to understanding changes in the producer price of domestic goods in response to exchange rate movements. The model is a simple variant of the one discussed in Burstein and Gopinath (2013), featuring the use of imported inputs in domestic production.[4)]

Profit maximizing firm i in industry j sets an optimal price as the mark-up over marginal cost:

$$p_{ij} = \mu_{ij} + mc_{ij} \tag{1}$$

where each term is expressed in log with a lower case letter. The mark-up is a decreasing function of the firm's price relative to the aggregate industry-level price: a more productive firm with lower marginal cost charges higher mark-up. Marginal cost from a Cobb-Douglas cost function is specified in log as:

$$mc_{ij} = mc_{ij}(q_{ij}^{tot}, w_j, m_{ij}(e)) = A_{ij} + k_{ij}q_{ij}^{tot} + \beta_{ij}m_{ij}(e) + \gamma_{ij}w_j \tag{2}$$

where q_{ij}^{tot} is the total output (i.e., sum of domestic sales and exports), m_{ij} is the price of imported inputs, and w_j is the price of domestic inputs. e denotes the local currency value of foreign currency, which converts the price of imported inputs in foreign currency, p_{ij}^{m} into local currency (i.e., $m_{ij} = p_{ij}^{m} + e$). k_{ij} governs

4) Amiti, Itskhoki, and Konings (2013) look at the export prices of domestically produced goods.

the degree of returns to scale in the production technology, with $k_{ij}=0$ implying constant returns to scale and $k_{ij}>0$ corresponding to decreasing returns to scale. β_{ij} and γ_{ij} are the share of imported inputs and that of domestic inputs in total costs, respectively. A_{ij} denotes the constant term including the productivity level.

Total differentiating equations (1) and (2) give the log change in the optimal price as:

$$\triangle p_{ij} = -\Gamma_{ij}(\triangle p_{ij} - \triangle p_j) + k_{ij}\triangle q_{ij}^{tot} + \beta_{ij}(\triangle p_{ij}^m + \triangle e) + \gamma_{ij}\triangle w_j \tag{3}$$

where $\Gamma_{ij} = -\dfrac{\partial \mu_{ij}}{\partial (p_{ij}-p_j)} \geq 0$ is the elasticity of the mark-up with respect to the relative price, assumed to be decreasing in the relative price: the lower a firm's relative price, the more sensitive is the mark-up to changes in the relative price. Specifying the demand structure in the domestic market in a differentiated form as $\triangle q_{ij} = -\varepsilon_{ij}(\triangle p_{ij} - \triangle p_j) + \triangle q_j$ with $\varepsilon_{ij} = -\dfrac{\partial q(\bullet)}{\partial (p_{ij}-p_j)} > 0$ capturing the price elasticity of demand, equation (3) is then rearranged for exchange rate pass-through as:[5)]

$$\frac{\triangle p_{ij}}{\triangle e} = \overbrace{\frac{\beta_{ij}}{1+\Gamma_{ij}+\Phi_{ij}}\left[\frac{\triangle p_{ij}^m}{\triangle e}+1\right]}^{imported\ inputs\ channel} + \overbrace{\frac{1}{1+\Gamma_{ij}+\Phi_{ij}}\left[(\Gamma_{ij}+\Phi'_{ij})\frac{\triangle p_j}{\triangle e}+\gamma_{ij}\frac{\triangle w_j}{\triangle e}\right]}^{indirect\ effect} \tag{4}$$

where $\Phi_{ij} = \alpha_{ij}k_{ij}\varepsilon_{ij} \geq 0$ is the partial elasticity of marginal cost with respect to the relative price, and α_{ij} the share of domestic sales in total output.[6)] The exchange

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5) Strictly speaking, equation (4) describes the elasticity of optimal price with respect to changes in the exchange rate, which corresponds to the actual exchange rate pass-through only in a model with fully flexible prices. As long as the actual price movement is positively correlated with the optimal price movement, however, the qualitative aspect of the expression can be thought to be applicable in a state-dependent pricing model as well.

6) This expression is derived from approximating changes in firm-level total output as changes in domestic sales multiplied by the share of domestic sales in total output (i.e., $\triangle q_{ij}^{tot} \simeq \alpha_{ij}\triangle q_{ij}$) It follows from steps below:

$$\triangle q^{tot} = \log\left(\frac{Q'_D+Q_{ex}}{Q_D+Q_{ex}}\right) \simeq \left(\frac{Q_D+Q_D}{Q_D+Q_{ex}}\right) = \alpha' - \alpha$$

rate affects the domestic goods price directly via imported inputs, and indirectly through the industry-level price as well as the prices of domestic inputs .

Unless all the imported inputs follow local currency pricing, the price of imported inputs in local currency will respond to exchange rate (i.e., $\frac{\triangle p_{ij}^{m}}{\triangle e}+1>0$). The overall impact of such changes in the price of imported inputs on the price of domestic goods is proportional to the cost share of imported inputs in production, β_{ij} : the higher the share of imported inputs in total cost, the higher the exchange rate pass-through.

On the other hand, concurrent mark-up adjustment (Γ_{ij}) and changes in marginal cost (Φ_{ij}) will dampen the degree of exchange rate pass-through. The mark-up adjustment will be larger for firms with higher mark-ups, while the marginal cost effect is stronger for firms with steeper marginal cost curves (i.e., higher k_{ij}), both leading to a lower exchange rate pass-through. The marginal cost effect is also stronger for non-exporters because the elasticity of total output with respect to domestic sales is higher, being approximated by the share of domestic sales in total output, α_{ij}. Likewise, a higher price elasticity of demand leads to a stronger marginal cost effect.

The marginal cost effect is particularly interesting because it leads to a striking prediction that the degree of exchange rate pass-through for capacity constrained firms will be lower when the local currency appreciates than when it depreciates, and that this asymmetric pattern will be less pronounced for exporters. This is because capacity constrained firms, by definition, find it more costly to increase output in response to a reduction in input costs induced by currency appreciation, which can be captured by a discrete jump upward in k_{ij} for these firms.[7] For exporters, however, such capacity constraints may matter less because they can shift

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and $\triangle q=\log\left(\frac{Q'_D}{Q_D}\right)=\log\left(\frac{\alpha'}{\alpha}\right)\simeq\frac{\alpha'-\alpha}{\alpha}$, where Q_D and Q_{ex} are domestic sales and exports, respectively. Here, to simplify the expression, it is assumed that $Q_{ex}=Q'_{ex}$ with a rationale that the use of imported inputs leads to a lower sensitivity of exports to the exchange rate than that of domestic sales. In addition, the price elasticity of demand at the industry-level is assumed as 1(i.e., $\triangle q_j=-\triangle p_j$), yielding $\Phi'_{ij}=\alpha_{ij}k_{ij}(\varepsilon_{ij}-1)$.

7) This hypothesis may be traced back to Knetter (1994), Gil-Pareja (2000), and Pollard and Coughlin (2004).

a portion of their export sales to the domestic market without incurring an increase in the total output level.[8)]

Another interesting feature of the model in equation (4) is that it provides an alternative explanation for nonlinearity in exchange rate pass-through beyond what the menu cost model suggests. To the extent that industry-level prices do not react to small changes in the exchange rate, the indirect effect channel will be in play only when the exchange rate movement is large enough to affect industry-level prices. This will lead to a nonlinear exchange rate pass-through, increasing in line with the size of exchange rate movements. The equation further reveals that nonlinearity from this specific channel will be amplified as the mark-up elasticity or the marginal cost elasticity is higher.

The rest of the paper introduces the survey data, and evaluates the empirical relevance of the key features in the model described above.

Ⅲ. Data

This paper explores the firm-level pricing survey data collected by the Bank of Korea in 2012. The Bank of Korea occasionally conducts a survey of firm-level pricing behaviors, one of many such tools that help the monetary authority implement monetary policy effectively with a thorough understanding of inflation dynamics, complementing the CPI or PPI data. In particular, the survey of firm-level pricing behaviors aims to provide detailed information on the frequency of pricing decisions as well as contributing factors for price changes, along with rich information on firm-level characteristics. The current survey restricts the price of goods for consideration in the questionnaire exclusively to the domestic market price of the main product for each firm. The sample firms in the survey are carefully selected from a population of around 300,000 incorporated firms in Korea.[9)] The dataset is

8) Such export-domestic sales switching behavior for capacity constrained firms is documented in Ahn and McQuoid (2012) and Soderbery (2011.

9) The sample is designed to be as representative and efficient as possible, given the highly skewed

constructed based on responses from 693 firms out of 1,678 manufacturing firms selected in the original sample, marking a response rate of 41 percent.

The key question of particular interest to the paper is the degree of exchange rate pass-through. Specifically, the survey asks how much a firm reflects changes in the exchange rate into the domestic price of the main product, and each respondent chooses a corresponding answer among "fully", "partially", and "not at all" under four different and separate scenarios (i.e., a large depreciation, small depreciation, large appreciation, and small appreciation).[10)]

<Table 1> summarizes the degree of exchange rate pass-through for importers and non-importers separately. Overall, among the 693 respondents that participated in the survey, 548 firms use imported inputs in their production while 145 firms do not use any imported inputs. The degree of exchange rate pass-through is classified as High, Low, and Zero, depending on whether firms reflect changes in the exchange rate in the domestic price fully, partially, or not at all. Unsurprisingly, firms with imported inputs tend to change the domestic price more than firms without any imported inputs in response to changes in the exchange rate. Panel A shows that, in response to a large depreciation, 83 percent of non-importers do not change the domestic price, whereas only 35 percent of importers do not change the price. Similar patterns are found for a small depreciation, large appreciation, and small appreciation (Panel B-D). A quick comparison across panels also hints at two interesting patterns: non-linear and asymmetric exchange rate pass-through. A larger proportion of firms reported that they do not change the domestic price in response to smaller changes in the exchange rate (45 percent vs 66 percent in panel A and B, and 53 percent vs 75 percent in Panel C and D) and in response to a local currency appreciation rather than a depreciation (53 percent vs 45 percent in Panels C and A, and 75 percent vs 66 percent in Panels D and B). Although revealing, caution is warranted against drawing any conclusions from these simple

population distribution, by applying Lavallee and Hidiroglou's algorithm. A detailed description of the sampling procedure is provided in Park and Song (2013, in Korean), an English translated version of which is available on request.

10) Given the prevalence of price stickiness, the survey is designed to measure the degree of cumulative exchange rate pass-through, by adding the auxiliary question: How long does it take for the firm to change the price, if at all, in response to changes in the exchange rate?

statistics because it is likely that importers may share other characteristics that lead to a higher degree of exchange rate pass-through, which are absent in non-importers. On the other hand, if importers happened to have more offsetting factors than non-importers, the distinction between importers and non-importers in terms of the degree of exchange rate pass-through in <Table 1> could have been under-reported.

Table 1: The degree of exchange rate pass-through for importers and non-importers

A: Large depreciation

	degree of exchange rate pass-through			
	High	Low	Zero	Total
Non-importer	6	19	120	145
(in percent)	(4)	(13)	(83)	
Importer	148	208	192	548
(in percent)	(27)	(38)	(35)	
Total	154	227	312	693
(in percent)	(22)	(33)	(45)	

B: Small depreciation

	degree of exchange rate pass-through			
	High	Low	Zero	Total
Non-importer	5	10	130	145
(in percent)	(3)	(7)	(90)	
Importer	51	169	328	548
(in percent)	(9)	(31)	(60)	
Total	56	179	458	693
(in percent)	(8)	(26)	(66)	

C: Large appreciation

	degree of exchange rate pass-through			
	High	Low	Zero	Total
Non-importer	3	13	129	145
(in percent)	(2)	(9)	(89)	
Importer	91	216	241	548
(in percent)	(17)	(39)	(44)	
Total	94	229	370	693
(in percent)	(14)	(33)	(53)	

D: Small appreciation

	degree of exchange rate pass-through			
	High	Low	Zero	Total
Non-importer	2	7	136	145
(in percent)	(1)	(5)	(94)	
Importer	31	135	382	548
(in percent)	(6)	(25)	(70)	
Total	33	142	518	693
(in percent)	(5)	(20)	(75)	

Notes: This table summarizes the degree of exchange rate pass-through for importers and non-importers separately. The degree of exchange rate pass-through (ERPT) is High for firms that fully reflect changes in exchange rate in domestic price, Low for firms that partially reflect, and Zero for firms that do not reflect any. Importer classifies firms with a positive share of imported inputs in total production cost, and Non-importer includes all firms without any imported inputs.

In this regard, <Table 2> summarizes other characteristics of sample firms that might have a potential impact on the degree of exchange rate pass-through, broken down by import status. These include the degree of competition, market share, the share of intra-group transaction, the share of exports, firm size, and the share of sales to frequent buyers.[11] Several patterns emerge from the summary table. Irrespective of the import status, the majority of sample firms seem to face tough competition and sell mostly to unrelated but frequent buyers. Firms that use imported inputs, however, are more likely than non-importers to export, to have a larger market share, and to be medium and large in size. Identifying the relative role of each of these therefore requires a careful econometric analysis controlling for all the relevant factors at the same time.

Table 2: Characteristics of sample firms broken down by import status.

	Degree of competition				Market share				Intra-firm transaction			
	0	1	2	Total	0	1	2	Total	0	1	2	Total
Non-importer	4	29	112	145	28	107	10	145	123	12	10	145
(in percent)	(3)	(20)	(77)		(19)	(74)	(7)		(85)	(8)	(7)	
Importer	19	199	330	548	56	409	83	548	434	71	39	544
(in percent)	(3)	(36)	(60)		(10)	(75)	(15)		(80)	(13)	(7)	
Total	23	228	442	693	84	516	93	693	557	83	49	689
(in percent)	(3)	(33)	(64)		(12)	(74)	(13)		(81)	(12)	(7)	

11) The degree of competition is 2 for firms with more than 5 competitors in domestic markets, 1 for firms with number of competitors between 1 and 4, and 0 for firms with no competitor. Market share is 2 for firms with market share larger than 50 percent, 1 for firms with market share between 10 and 50 percent, and 0 for firms with market share less than 10 percent. Intra-group transactions is 2 for firms with a share of intra-firm sales in total revenue larger than 50 percent, 1 for firms with intra-firm sales share between 0 and 50 percent, and 0 for firms with no intra-group sales. Export intensity is 2 for firms with a share of exports in total sales larger than 50 percent, 1 for firms with export share between 0 and 50 percent, and 0 for non-exporters. Size is 2 for small firms (fewer than 50 employees), 1 for medium firms (between 50 and 300 employees), and 0 for large firms (more than 30 employees. Sales to frequent buyers are 2 for firms with a share of frequent buyer sales larger than 50 percent, 1 for firms with a share of frequent buyers sales share between 0 and 50 percent, and 0 for firms with no frequent buyers.

	Export intensity				Size				Sales to frequent buyers			
	0	1	2	Total	0	1	2	Total	0	1	2	Total
Non-importer	110	25	10	145	4	50	91	145	3	20	122	145
(in percent)	(76)	(17)	(7)		(3)	(34)	(63)		(2)	(14)	(84)	
Importer	229	204	115	548	87	228	233	548	18	51	475	544
(in percent)	(42)	(37)	(21)		(16)	(42)	(43)		(3)	(9)	(87)	
Total	339	229	125	693	91	278	324	693	21	71	597	689
(in percent)	(49)	(33)	(18)		(13)	(40)	(47)		(3)	(10)	(87)	

Notes: This table summarizes other characteristics of sample firms that might have a potential impact on the degree of exchange rate pass-through, broken down by import status. Importer classifies firms with a positive share of imported inputs in total production cost, and Non-importer includes all firms without any imported inputs. Degree of competition is 2 for firms with more than 5 competitors in domestic markets, 1 for firms with number of competitors between 1 and 4, and 0 for firms with no competitor. Market share is 2 for firms with market share larger than 50 percent, for firms with market share between 10 and 50 percent, and 0 for firms with market share less than 10 percent. Intra-firm transaction is 2 for firms with a share of intra-firm sales in total revenue larger than 50 percent, 1 for firms with intra-firm sales share between 0 and 50 percent, and 0 for firms with no intra-firm sales. Export intensity is 2 for firms with a share of exports in total sales larger than 50 percent, 1 for firms with export share between 0 and 50 percent, and 0 for non-exporters. Size is 2 for small firms, 1 for medium firms, and 0 for large firms. Sales to frequent buyers is 2 for firms with a share of sales to frequent buyers larger than 50 percent, 1 for firms with frequent buyers sales share between 0 and 50 percent, and 0 for firms with no frequent buyers.

Ⅳ. Econometric Analysis

A. Imported inputs channel

The main prediction of the model is that the degree of exchange pass-through is proportional to the share of imported inputs in total costs, reflecting the imported inputs channel, but that it is offset simultaneously by other factors via adjustments in mark-up and marginal cost. The baseline specification to evaluate the validity of the model is thus given as:

$$ERPT_{ij} = \delta ImportedInputs_{ij} + \theta X_{ij} + FE_j + e_{ij} \quad (5)$$

where the dependent variable $ERPT_{ij}$ is the degree of exchange rate pass-through for firm i in industry j in response to the change in exchange rate, and FE_j denotes an industry fixed effect.[12] The degree of exchange rate pass-through is 2 for firms that fully reflect changes in the exchange rate in the domestic price, 1 for firms that partially reflect it, and 0 for firms that do not reflect it at all. *ImportedInputs* measures the imported inputs intensity: 2 for firms with a share of imported inputs in total production cost larger than 25 percent, 1 for firms with a cost share between 0 and 25 percent, and 0 for firms without any imported inputs.[13] A firm-level vector X_{ij} includes all other control variables such as the degree of competition, market share, the share of intra-group transactions, the share of exports, firm size, and the share of sales to frequent buyers, all of which are considered to affect the degree of exchange rate pass-through via mark-up adjustments or changes in marginal cost. In particular, the share of intra-group transactions and that of sales to frequent buyers are expected to capture the firm-specific price elasticity of demand because affiliated firms or frequent buyers are likely to be less sensitive to changes in price. Similarly, the degree of competition is supposed to proxy the firm-specific elasticity of substitution between rival goods, while the market share variable is directly related to mark-up level and thus firm-level relative price. Any other systemic pattern related to firm size or export status will be captured by firm size and the share of exports variables. All these control variables are as defined in the previous section.

The ordered nature of discrete outcomes in the dependent variable, the degree of exchange rate pass-through ($ERPT_{ij}$), suggests the ordered probit model as an appropriate tool in this context. <Table 3> summarizes regression results from the ordered probit model, run separately for four different scenarios: a large depreciation, a small depreciation, a large appreciation, and a small appreciation. Taking

12) Industry classifications used in this paper are broadly comparable with the three-digit North American Industry Classification System (NAICS). These industries are Food, Textile and Leather, Wood and Paper, Print, Petroleum and Coal, Chemical, Non-metallic manufacturing, Metal manufacturing, General machinery, Electronic and Electrical equipment, Precision instruments, Transportation equipment, and Furniture and Other manufacturing.

13) Given the categorical nature of discrete responses in the questionnaire, a threshold value of 25 percent is arbitrarily chosen to distinguish between high imported inputs intensity firms and low imported inputs intensity firms. All the results are robust at different threshold values such as 50 percent or under an alternative two-category scheme that distinguishes only between non-importers and importers.

a close look at each panel, panel A shows that, in response to a large depreciation, firms that use imported inputs more intensively tend to have a higher degree of exchange rate pass-through (Panel A, column 1).

The estimated coefficient implies that, from the average marginal effect analysis, a producer with a higher intensity of imported inputs in productive inputs is, compared to a producer with a lower intensity of imported inputs, 17 percentage points more likely to fully reflect changes in adjusting the domestic price of its main product. Adding other firm characteristics that may affect the degree of exchange rate pass-through lowers the size of the coefficient estimate on imported inputs intensity slightly, but the difference is not statistically significant (Panel A, column 2). This suggests the dominant role of imported inputs in transmitting changes in exchange rate to domestic prices is only partially offset by other alleviating factors. A positive coefficient estimate on export intensity supports the models' prediction that the degree of exchange rate pass-through decreases in the share of domestic sales in total output, corroborating the presence of a marginal cost effect that lessens the degree of exchange rate pass-through due to decreasing returns to scale technology.[14] On the other hand, other firm characteristics that control for mark-up adjustments do not have any significant effect. Adding an industry fixed- effect shows very similar results, confirming that the results are not driven by any industry characteristics (Panel A, columns 3 and 4).

14) The estimated coefficient on export intensity suggests that the average marginal impact is such that more intensive exporters have a higher probability of reflecting the exchange rate fully in adjusting their price than less intensive exporters by around 4 percentage points.

Table 3: Regression results for four different scenarios separately

A: Large depreciation — Dependent variable: degree of ERPT

	(1)	(2)	(3)	(4)
Imported inputs intensity	0.653 ***	0.606 ***	0.653 ***	0.607 ***
	(0.060)	(0.063)	(0.060)	(0.063)
Degree of competition		−0.028		−0.030
		(0.086)		(0.087)
Market share		0.109		0.080
		(0.092)		(0.096)
Intra-firm transaction		0.066		0.066
		(0.078)		(0.081)
Export intensity		0.139 **		0.142 **
		(0.063)		(0.065)
Size		0.024		0.021
		(0.064)		(0.067)
Sales to frequent buyers		0.145		0.124
		(0.108)		(0.112)
Industry FE	N	N	Y	Y
Pseudo R2	0.084	0.091	0.091	0.097
OBS	693	685	693	685

B: Small depreciation — Dependent variable: degree of ERPT

	(1)	(2)	(3)	(4)
Imported inputs intensity	0.431 ***	0.375 ***	0.440 ***	0.384 ***
	(0.066)	(0.068)	(0.067)	(0.069)
Degree of competition		0.043		0.050
		(0.095)		(0.096)
Market share		0.162		0.145
		(0.099)		(0.102)
Intra-firm transaction		0.190 **		0.202 **
		(0.080)		(0.084)
Export intensity		0.190 ***		0.171 **
		(0.068)		(0.070)
Size		0.063		0.030
		(0.070)		(0.073)
Sales to frequent buyers		0.250 **		0.233 *
		(0.119)		(0.124)
Industry FE	N	N	Y	Y
Pseudo R2	0.040	0.059	0.054	0.072
OBS	693	685	693	685

C: Large appreciation — Dependent variable: degree of ERPT

	(1)	(2)	(3)	(4)
Imported inputs intensity	0.592 ***	0.528 ***	0.598 ***	0.530 ***
	(0.061)	(0.064)	(0.061)	(0.064)
Degree of competition		−0.096		−0.117
		(0.084)		(0.085)
Market share		−0.082		−0.067
		(0.096)		(0.100)
Intra-firm transaction		0.044		0.055
		(0.085)		(0.090)
Export intensity		0.165 **		0.142 **
		(0.064)		(0.066)
Size		−0.175 **		−0.203 ***
		(0.069)		(0.072)
Sales to frequent buyers		0.124		0.114
		(0.110)		(0.116)
Industry FE	N	N	Y	Y
Pseudo R2	0.070	0.087	0.082	0.099
OBS	693	685	693	685

D: Small appreciation — Dependent variable: degree of ERPT

	(1)	(2)	(3)	(4)
Imported inputs intensity	0.395 ***	0.309 ***	0.408 ***	0.326 ***
	(0.067)	(0.071)	(0.070)	(0.073)
Degree of competition		−0.022		−0.025
		(0.098)		(0.100)
Market share		−0.003		−0.014
		(0.104)		(0.108)
Intra-firm transaction		0.102		0.110
		(0.089)		(0.094)
Export intensity		0.281 ***		0.218 ***
		(0.073)		(0.075)
Size		−0.062		−0.120
		(0.077)		(0.078)
Sales to frequent buyers		0.379 **		0.360 **
		(0.147)		(0.148)
Industry FE	N	N	Y	Y
Pseudo R2	0.034	0.066	0.068	0.094
OBS	693	685	693	685

Notes: This table summarizes regression results from the ordered probit model, run separately for four different scenarios: a large depreciation, a small depreciation, a large appreciation, and a small appreciation. Dependent variable in Panel A, B, C, D is the degree of exchange rate pass-through (ERPT) in response to large depreciation, small depreciation, large appreciation, and small appreciation, respectively. The degree of ERPT is 2 for firms that fully reflect changes in exchange rate in domestic price, 1 for firms that partially reflect, and 0 for firms that do not reflect any. Imported inputs intensity is 2 for firms with a share of imported inputs in total production cost larger than 25 percent, 1 for firms with a cost share between 0 and 25 percent, and 0 for firms without any imported inputs. Degree of competition is 2 for firms with more than 5 competitors in domestic markets, 1 for firms with number of competitors between 1 and 4, and 0 for firms with no competitor. Market share is 2 for firms with market share larger than 50 percent, 1 for firms with market share between 10 and 50 percent, and 0 for firms with market share less than 10 percent. Intra-firm transaction is 2 for firms with a share of intra-firm sales in total revenue larger than 50 percent, 1 for firms with intra-firm sales share between 0 and 50 percent, and 0 for firms with no intra-firm sales. Export intensity is 2 for firms with a share of exports in total sales larger than 50 percent, 1 for firms with export share between 0 and 50 percent, and 0 for non-exporters. Size is 2 for small firms, 1 for medium firms, and 0 for large firms. Sales to frequent buyers is 2 for firms with a share of sales to frequent buyers larger than 50 percent, 1 for firms with frequent buyers sales share between 0 and 50 percent, and 0 for firms with no frequent buyers. Columns (3) and (4) include industry fixed effects. Robust standard errors are in parentheses. Significance: * 10 percent; ** 5 percent; *** 1 percent.

Panel B shows that qualitatively similar results hold in response to a small depreciation, except that firms that sell a larger share of their products to related parties or frequent buyers tend to have a higher degree of exchange rate pass-through (Panel B, columns 2 and 4). This may explain the role of the underlying price elasticity of demand (ε), to the extent that the price elasticity is lower for related firms or frequent buyers and thus the marginal cost effect is weaker for these firms. Firms' response to a large appreciation shows a similar pattern to that for a large depreciation, with the additional feature that smaller firms tend to have a lower degree of exchange rate pass-through (Panel C, columns 2 and 4). One interpretation will be that smaller firms are more likely to face capacity constraints, hence a stronger marginal cost effect dampening the imported inputs channel. Intuitively, smaller firms facing binding quantity constraints and thus unable to increase production in response to large appreciation will not have an incentive to lower price following a reduction in input costs. Lastly, firms respond to a small appreciation in a similar manner to a small depreciation, although the share of intra-group transactions becomes marginally insignificant.

Overall, in all four cases, the use of imported inputs is found to be a major channel through which the exchange rate affects the domestic price, and the marginal cost effect that alleviates the degree of exchange rate pass-through is weaker for more intensive exporters.

One caveat of the specification in equation (5) is that it does not control for the term $\left[\frac{\triangle p_{ij}^{m}}{\triangle e}+1\right]$ in equation (4). That is, the implicit assumption of the current approach is that the elasticity of the cost of imported inputs with respect to the exchange rate is identical across firms, or at least unrelated with other firm characteristics. Unless this assumption holds, the coefficient estimates reported in <Table 3> would be biased. One way to check the robustness of the results in this context is to replace the dependent variable with another question in the survey that asks "How much a firm adjusts the domestic price of its main product in response to changes in the price of imported inputs".[15] This is equivalent to the degree of

15) Unlike the question about the degree of exchange rate pass-through, this question in the survey does not distinguish four different scenarios. Also, the question is phrased so as to preclude responses by

imported inputs cost pass-through (i.e., $\frac{\triangle p_{ij}}{\triangle m_{ij}}$), and by ignoring the indirect effect term in equation (4), it is then approximated as:

$$\frac{\triangle p_{ij}}{\triangle m_{ij}} = \frac{\frac{\triangle p_{ij}}{\triangle e}}{\frac{\triangle m_{ij}}{\triangle e}} \simeq \frac{\beta_{ij}}{1+\Gamma_{ij}+\Phi_{ij}} \tag{6}$$

This corresponds to a specification in (5) with the new dependent variable, and the estimation results are reported in <Table 4>. It shows exactly identical qualitative results that the intensity of imported inputs is a major determinant of the degree of pass-through, and that marginal cost effect is weaker for more intensive exporters, thus supporting the validity of the results in <Table 3>.

Table 4: Pass-through regression results: ordered probit model (6)

Dependent variable: degree of imported inputs cost pass-through

	(1)	(2)	(3)	(4)
Imported inputs intensity	0.426 ***	0.403 ***	0.431 ***	0.400 ***
	(0.105)	(0.107)	(0.111)	(0.113)
Degree of competition		-0.046		-0.066
		(0.098)		(0.104)
Market share		0.106		0.173
		(0.117)		(0.124)
Intra-firm transaction		-0.029		-0.033
		(0.086)		(0.089)
Export intensity		0.141 *		0.120
		(0.075)		(0.079)
Size		0.085		0.008
		(0.075)		(0.080)
Sales to frequent buyers		0.159		0.064
		(0.114)		(0.124)

non-importers .

	(1)	(2)	(3)	(4)
Industry FE	N	N	Y	Y
Pseudo R2	0.016	0.025	0.071	0.078
OBS	548	540	548	540

Notes: This table summarizes regression results from the ordered probit model specified in (5), with dependent variable replaced with the degree of imported inputs cost pass-through. Dependent variable is the degree of imported inputs cost pass-through. It is 2 for firms that reflect changes in the price of imported inputs in to domestic price by more than 50 percent, 1 for firms that reflect by more than 10 percent but less than 50 percent, and 0 for firms that reflect by less than 10 percent. All other variables are as defined in Table 3. Columns (3) and (4) include industry fixed effects. Robust standard errors are in parentheses. Significance: * 10 percent; ** 5 percent; *** 1 percent.

B. Nonlinearity and Asymmetry

Despite their qualitative similarities, <Table 3> reveals possible discrepancies between small and large changes as well as depreciation and appreciation. One of the most novel features of the current survey data is that every firm reports the degree of exchange rate pass-through under four different scenarios, making it possible to construct firm-level balanced panel data. The consequent panel dataset will have four observations per firm, corresponding respectively to a large depreciation, a small depreciation, a large appreciation, and a small appreciation. Including dummy variables for a (small and large) depreciation and a large (depreciation and appreciation) along with firm-fixed effects provides an excellent tool to evaluate the average within-firm pattern of nonlinearity as well as asymmetry in exchange rate pass-through. Further, interacting these dummy variables with firm characteristics will shed light on potential sources of nonlinear or asymmetric exchange rate pass-through. The baseline specification for this purpose is thus given as:

$$ERPT_{ijk} = I_{k=large} + I_{k=Denp} + interactions_{ijk} + FE_i + e_{ijk} \quad (7)$$

where $I_{k=Large}$ is an indicator function that turns on for a large depreciation and a large appreciation, and $I_{k=Dep}$ is similarly defined for a large depreciation and a small depreciation. FE_i denotes firm fixed effects, and $interactions_{ijk}$ includes

various interaction terms between dummy variables and firm characteristics.

<Table 5> summarizes the regression results from the ordered probit model specified in (7). The first two columns report that the degree of exchange rate pass-though is indeed higher when changes in exchange rate change are large, and such nonlinearity is amplified for firms with a higher share of imported inputs (columns 1 and 2). The next two columns show that the degree of exchange rate pass-through is higher when currency depreciates, but such asymmetric pass-through is not related to the use of imported inputs (columns 3 and 4). These results are unchanged when both the magnitude and the direction of exchange rate movements are considered together (columns 5 and 6). The estimated coefficient on each dummy variable implies that large changes in the exchange rate and the local currency depreciation respectively increase any given firm's chance of adjusting the domestic price fully in response to changes in the exchange rate by, on average, 12 percentage points and 5 percentage points.

Table 5: Pass-through regression results: ordered probit model(7)

Dependent variable: degree of ERPT

	(1)	(2)	(3)	(4)	(5)
Large	1.554 ***	0.950 ***			1.664 ***
	(0.075)	(0.186)			(0.079)
Imported inputs intensity × Large		0.382 ***			
		(0.108)			
Depreciation			0.587 ***	0.548 ***	0.770 ***
			(0.063)	(0.175)	(0.071)
Imported inputs intensity × Depreciation				0.024	
				(0.101)	
Firm FE	Y	Y	Y	Y	Y
Pseudo R2	0.533	0.533	0.614	0.616	0.638
OBS	2,772	2,772	2,772	2,772	2,772

Dependent variable: degree of ERPT

	(6)	(7)	(8)	(9)
Large	1.005 ***	2.997 ***		3.214 ***
	(0.190)	(0.508)		(0.531)

	(6)	(7)	(8)	(9)
Imported inputs intensity	0.419 ***	0.422 ***		0.488 ***
× Large	(0.111)	(0.112)		(0.116)
Degree of competition		−0.282 **		−0.298 **
× Large		(0.131)		(0.137)
Market share		−0.257 *		−0.238
× Large		(0.151)		(0.157)
Intra-firm transaction		−0.228 *		−0.211
× Large		(0.121)		(0.129)
Export intensity		−0.219 **		−0.246 **
× Large		(0.094)		(0.098)
Size		−0.190 *		−0.170
× Large		(0.102)		(0.106)
Sales to frequent buyers		−0.468 **		−0.553 ***
× Large		(0.181)		(0.190)
Depreciation	0.683 ***		−0.431	−0.461
	(0.189)		(0.452)	(0.514)
Imported inputs intensity	0.059		0.070	0.134
× Depreciation	(0.109)		(0.104)	(0.114)
Degree of competition			0.075	0.081
× Depreciation			(0.120)	(0.134)
Market share			0.416 ***	0.555 ***
× Depreciation			(0.138)	(0.154)
Intra-firm transaction			0.167	0.207
× Depreciation			(0.115)	(0.128)
Export intensity			−0.131	−0.198 **
× Depreciation			(0.087)	(0.097)
Size			0.394 ***	0.536 ***
× Depreciation			(0.094)	(0.105)
Sales to frequent buyers			−0.046	−0.128
× Depreciation			(0.160)	(0.186)
Firm FE	Y	Y	Y	Y
Pseudo R2	0.641	0.541	0.624	0.658
OBS	2,772	2,740	2,740	2,740

Notes: This table summarizes the regression results from the ordered probit model specified in (7). Dependent variable is the degree of exchange rate pass-through (ERPT) in response to large depreciation, small depreciation, large appreciation, and small appreciation, respectively. The degree of ERPT is 2 for firms that fully reflect changes in exchange rate in domestic price, 1 for firms that partially reflect, and 0 for firms that do not reflect any. Large is a dummy variable with 1 for large depreciation and large appreciation and 0 otherwise. Depreciation is a dummy variable with 1 for large depreciation and small depreciation and 0 otherwise. All other variables are as defined in Table 3 and interacted with Large and Depreciation dummy variables. All columns include firm fixed effects. Robust standard errors are in parentheses. Significance:
* 10 percent; ** 5 percent; *** 1 percent.

Nonlinear exchange rate pass-through is consistent with the models' prediction that larger exchange rate movements will trigger additional indirect effects by affecting industry-level prices. However, it is also consistent with the menu cost model that firms are more likely to change prices when changes in the exchange rate are large enough to rationalize the menu cost involved in price changes. In fact, the finding that firms with a higher share of imported inputs show stronger nonlinear pass-through can be interpreted as evidence that foreign exporters' pricing behavior follows the menu cost model: the price of imported inputs in local currency changes more when changes in exchange rate are large because of the menu cost borne by foreign exporters (i.e., $\frac{\triangle p_{ij}^{m}}{\triangle e}+1$ being higher in equation (4)). One way to check the validity of the model's prediction that nonlinear exchange rate pass-through also comes from additional indirect effects, apart from the menu cost, will be to check further if the degree of nonlinearity has any systematic relationship with other model parameters as predicted in equation (4). This is summarized in columns 7 and 9.

Similarly, asymmetric exchange rate pass-through is consistent with the model in that the degree of exchange rate pass-through will be higher when the local currency depreciates due to capacity constrained firms, but that it is not necessarily related to the intensity of imported inputs. In order to confirm that the asymmetric pass-through may be indeed due to capacity constrained firms, additional interaction terms between dummy variables and other firm characteristics are included in columns 8 and 9.

Column 9 summarizes the result from an extensive set of interaction terms included in a regression, supporting the validity of the model in terms of the sources of nonlinear and asymmetric pass-through. It reveals that nonlinearity is weaker for firms with more competitors, more frequent buyers, or higher export intensity. To the extent that having more competitors implies lower mark-ups, and hence smaller mark-up adjustments (i.e., Γ_{ij}) and that a higher share of sales to frequent buyers leads to a smaller change in marginal cost due to a lower price elasticity of demand (i.e., lower Φ'_{ij}), the results are consistent with the model's prediction that indirect effects (hence, nonlinearity) will be weaker as the mark-up adjustments or changes

in marginal cost are smaller. It is clear from the definition of the partial elasticity of marginal cost, Φ'_{ij}, that firms with a larger share of exports will also show weaker nonlinearity.

As for asymmetric exchange rate pass-through, it is interesting that additional interaction terms lead to an insignificant coefficient estimate on the depreciation dummy, implying that the asymmetric pattern of exchange rate pass-through found for average firms in earlier columns (columns 3-6) is entirely driven by those firms having a higher market share or a lower export share, or being smaller in size. Noting that the model predicts asymmetric pass-through for capacity constrained firms, this can be interpreted as evidence supporting the model to the extent that smaller firms or firms with a higher market share, both conditional on other firm characteristics, are more likely to be capacity constrained. On the other hand, exporters, even when they are capacity constrained, can avoid it by shifting some portion of their export sales to domestic markets in response to local currency appreciation.

In sum, the results support the model's predictions that exchange rate pass-through tends to be higher when the local currency depreciates, and when changes in the exchange rate are larger.

V. Conclusions

This paper studies exchange rate pass-through to the price of domestically produced goods, exploring the firm-level pricing survey. The survey is conducted by the Bank of Korea, with an aim of broadening the monetary authority's understanding of actual price-setting behaviors. The main findings of this study not only highlight the need for monitoring movements in imported input prices but also underline the importance of considering broader industrial activity conditions in order to better assess the effect of the exchange rate on inflation.

A careful econometric analysis of the survey data reveals that imported inputs play a major role in transmitting exchange rate fluctuations to domestic producer

prices, and that the degree of exchange rate pass-through tends to be nonlinear and asymmetric. A further investigation of the sources of nonlinearity and asymmetry finds that nonlinearity can be partly attributed to indirect effects via industry-level movements, beyond the menu-cost pricing mechanism, and that asymmetry is driven by capacity constrained firms that cannot make the most of cost reductions in imported inputs induced by local currency appreciation. These findings support the predictions of the model introduced in the paper that features the use of imported inputs, varying mark-ups, and increasing marginal cost.

The paper also explicitly acknowledges the limitation of survey-based studies; namely, the likely subjectiveness of survey responses and the qualitative nature of interpretations. To the extent that the current survey data can fill the gap left in the literature, the current paper usefully complements previous studies based on actual price data.

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<Abstract in Korean>

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본 연구는 한국은행이 2012년 실시한 기업단위 가격설정행태 조사결과를 이용하여 국내 생산에 사용되는 수입원자재를 통해 환율변동이 기업단위 국내가격 결정에 어떻게 영향을 미치는지를 규명한 것이다.

서베이 데이터는 수입원자재가 국내생산자 가격에 환율변동을 전가하는 중요한 통로가 되고 있고, 환율전가는 비선형성 및 비대칭성이 있음을 보여주었다. 환율전가 정도는 환율변동이 크거나 평가절하 시 더 크게 나타났다.

수입원자재를 통한 환율전가 모형을 구축하고 계량분석한 결과도 환율변동은 수입원자재를 통해 국내 생산자가격에 전이되고, 환율 전가 정도는 비선형이거나 비대칭적인 경향이 있음을 확인시켰다. 그리고 비선형성은 부분적으로 산업 수준 변동에 의한 간접적 영향에 기인하고 비대칭성은 통화가치 상승에 의해 수입 원자재비용이 낮아짐에도 생산을 확대할 수 없는 기업에 의해 야기된다는 사실도 확인하였다.

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