Daily Exchange Rate Pass-through into Micro Prices*

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Abstract

This paper estimates the exchange rate pass-through (ERPT) by using good-level daily data on wholesale prices of imported agricultural products, where the identification is achieved by using daily data on the domestic inflation rate. The results of standard empirical analyses are in line with existing studies that employ lower frequencies of data by showing evidence for *incomplete* daily ERPT of about 5 percent. The key innovation is achieved when nonlinearities in ERPT are considered, where ERPT is doubled to about 10 percent when daily nominal exchange rate changes are above 0.55 percent, daily frequencies of price change are above 3.12 percent, and storage life of a product is above 10 weeks. Important policy implications follow.

JEL Classification: E31, F14, F31

Key Words: Daily Agricultural Prices, Exchange Rate Pass-Through, Good-Level Analysis.

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1 Introduction

Exchange rate pass-through (ERPT) is the standard measure used to represent the relationship between nominal exchange rates (NER) and prices of internationally traded goods.[1] Since central banks that have the objective of price stability can intervene the exchange rate market to have full or partial control over the value of their currency, policy makers need to know how prices would react to changes in NER. Such knowledge is also essential for individual welfare through income and substitution effects, especially for small-open economies.

Within this picture, we investigate ERPT at the product-level by introducing a new data set that has two main advantages over the ones employed in the existing literature. First, we have daily wholesale price data on 52 imported agricultural products that cover the period between January 2005 and August 2015 in Turkey; to our knowledge, this is one of the few rich data sets based on daily observations of micro prices. Second, we have the corresponding daily prices for domestically produced agricultural products as well, so that the pure effects of NER changes on prices can be identified with respect to other macroeconomic developments.[2] Having a daily (rather than a lower frequency) investigation is essential for understanding the dynamics in the import prices of agricultural goods, because the effects of NER changes can only be investigated in a high frequency setup due to the perishable nature of these products (e.g., having a storage life of one week for raspberry). We combine the daily import price data of agricultural products with the corresponding data on NER, frequency of price change (measured over the sample period, thanks to the micro-price nature of the data) and storage life (a concept corresponding to the opposite of perishability/depreciation) to estimate ERPT, where we consider potential nonlinearities through estimated thresholds in these variables.

[1] This paper follows the textbook definition of ERPT as described in Knetter (1997) which is the percentage change in local currency import prices resulting from a one percent change in the exchange rate. Accordingly, *complete* ERPT corresponds to a value of 1 (or 100%), while *incomplete* ERPT corresponds to values below 1 (or 100%).

[2] Another daily data set is by Lott (2013) who has considered daily ERPT evidence based on *eBay* transactions of U.S. imports from Australia, Canada, Germany, Japan and the U.K. that constitute a small portion of the overall expenditure in the U.S. without controlling for domestic price changes; in comparison to such online price data, our data set not only represents offline wholesale prices of agricultural products that constitute about 22% of overall consumption expenditure in Turkey (according to the Turkish Statistical Institute) but also controls for domestic price changes.

This paper is closest to the recent empirical ERPT literature using nonlinear/threshold models. Within this literature, by estimating a nonlinear time series model for the U.S., Shintani, Terada-Hagiwara, and Yabu (2013) show that the period of low ERPT during the 1980s and 1990s is likely to be associated with low inflation. Similarly, Cheikh and Louhichi (2016) show, using a panel threshold framework for 63 countries, that the class of countries with higher inflation rates experiences higher degrees of ERPT; Ben Cheikh and Rault (2016) show, using logistic smooth transition models for five heavily indebted countries, that ERPT is higher when sovereign bond yield spreads exceed a given threshold; and Donayre and Panovska (2016) show, using a Bayesian threshold vector autoregression for Canada and Mexico, that ERPT is higher when the growth rate of output is larger. We contribute to this literature by considering thresholds in alternative variables of NER, frequency of price change, and storage life. Moreover, whereas these papers have considered low frequency macro-level data sets, this paper considers a daily micro-level data set that avoids any aggregation/measurement problem due to converting daily observations into lower frequency data sets.

2 Data and Empirical Methodology

The micro-price data that cover daily wholesale prices of 52 *imported* agricultural goods in Istanbul, Turkey between January 2005 and August 2015 have been obtained from the web page of Istanbul Metropolitan Municipality.[3] The data source distinguishes between imported products and goods that are domestically produced in Turkey, which is a perfect fit to our daily investigation of ERPT for identification purposes; accordingly, in order to control for local macroeconomic developments, we construct the daily *domestic* inflation rate using daily price data of 311 agricultural goods produced within Turkey and sold in Istanbul.[4]

We combine this data set with the daily nominal exchange rate (NER) between Turkish Lira and U.S. dollar (which is the main currency used for Turkish imports) that has been

[3] The web page of Istanbul Metropolitan Municipality is www.ibb.gov.tr.

[4] In particular, for each day, we calculate the average percentage change in good-level prices, after ignoring the outlier goods defined as the ones that have price changes more than two standard deviations away from the average inflation.

obtained from the web page of The Central Bank of the Republic of Turkey. The usage of the NER between Turkish Lira and U.S. dollar is motivated by studies such as by Nazlioglu and Soytas (2011), Richards, Myers, Swinton, and Walker (2012) and Schaffnit-Chatterjee, Schneider, Peter, and Mayer (2010) who show that agricultural products are globally traded in U.S. dollars. Moreover, as shown in Gopinath (2015), the majority (60%) of Turkish imports are invoiced in U.S. dollars, while only 3% of them are invoiced in Turkish liras. Since Turkish imports from the U.S. represent only 6% of total Turkish imports, it is implied that the U.S. dollar is the main foreign currency used for Turkish imports, independent of the source country and product considered.

The micro-price data are also used in order to calculate the good-level frequencies of price change. Given that our data set consists of perishable imported goods, we would also like to study whether ERPT varies with respect to the storage life of a commodity. Our motivation comes from studies such as by Kryvtsov and Midrigan (2012) or Alessandria, Kaboski, and Midrigan (2013) who have shown that the optimal price (and thus markups) of any seller decreases with the depreciation rate of inventories. Intuitively, since sellers may want to sell more perishable goods as soon as possible due to their high depreciation rate, they may accept lower price offers, independent of NER changes. This translates into an ERPT that is higher for less-perishable products in relative terms. Accordingly, we use the storage life measures provided by Cantwell (2001) that cover all of our agricultural products.

Following studies such as by Campa and Goldberg (2005) and Burstein and Gopinath (2014), we use the following standard specification in order to measure ERPT:

$$\Delta p_{g,t} = \alpha + \left(\sum_{k=0}^{T} \beta_k \Delta e_{t-k} \right) + \gamma \pi_t + \delta_g + S_t + \epsilon_t \tag{1}$$

where $\Delta p_{g,t}$ is the daily change in log wholesale price of imported good g, β_k measures the exchange rate pass through of the k'th lag of the log NER change, Δe_{t-k} is the k'th lag of the log NER change, π_t is the daily domestic inflation rate (as a control variable), δ_g's are good-fixed effects, S_t represents seasonality controls, and ϵ_t is the error term.[5]

[5] Augmented Dickey-Fuller and Phillips-Perron unit root tests suggest that the level of prices and exchange rates are nonstationarity, but both variables become stationary after considering daily log changes; this is

The number of daily lags T in Equation (1) is determined by using standard criteria of AIC and BIC, together with the significance of the corresponding coefficients. The usage of the domestic inflation rate π_t as a control variable is essential to identify the pure effects of NER changes as a source of daily foreign shocks. Good fixed effects of δ_g's are useful to control for good-specific factors. Following studies using daily data sets such as by Al-Khazali (2008), Al-Ississ (2010), Anson, Boffa, and Helble (2014), and Ali and Akhter (2016), seasonality controls S_t include weekday fixed effects, monthly fixed effects, and Ramadan fixed effects, where the period of Ramadan changes each year with respect to the religious calendar.

We also consider potential nonlinearities in the determination of ERPT. The literature studying nonlinearities in ERPT (introduced above) has made use both of the threshold approach and of the smooth transition framework. In a threshold regression, the transition from one regime to the next is instantaneous in the sense that the nonlinearity kicks in fully and immediately once the transition variable passes its threshold value, while in a smooth transition regression the transition across extreme regimes is gradual. The choice of one approach over another depends on whether the analysis is at the macro or microeconomic level as discussed in details by Ben Cheikh and Rault (2017). Within this context, since we employ micro-price data, we consider the following threshold regression:

$$\Delta p_{g,t} = \alpha + \left(\sum_{k=0}^{T} \beta_k \Delta e_{t-k} I \left(q_{g,t} \leq \tau \right) \right) + \left(\sum_{k=0}^{T} \beta_k \Delta e_{t-k} I \left(q_{g,t} > \tau \right) \right) + \gamma \pi_t + \delta_g + S_t + \epsilon_t \quad (2)$$

where $q_{g,t}$ is the threshold variable (representing NER, frequency of price change, or storage life), τ is the corresponding threshold value, $I\left(q_{g,t} \leq \tau\right)$ is an indicator function taking a value of 1 if $q_{g,t} \leq \tau$ and 0 otherwise, and $I\left(q_{g,t} > \tau\right)$ is an indicator function taking a value of 1 if $q_{g,t} > \tau$ and 0 otherwise. Following studies such as by Chan (1993) and Hansen (2000), τ is estimated using least squares with the objective of minimizing the residual sum of squares.

the reason behind our specification. Cointegration tests based on the Engle-Granger procedure suggest that residuals are I(0).

3 Empirical Results

The results for the benchmark specification in Equation (1) are given in Table 1, where we show the estimation results based on lags of NER up to $T = 1$, although we considered lags up to $T = 8$.[6] Although the criteria of AIC and BIC both select $T = 1$ (followed by $T = 0$), the corresponding coefficient of lagged NER is statistically insignificant in all specifications; accordingly, we consider the lag selection of $T = 0$ for the rest of our investigation, which is in line with studies based on daily data such as by Lott (2013). It is implied that the coefficient of the current log NER change β_0 corresponds to the measure of ERPT as well. Within this picture, the results in Table 1 show that ERPT is about 5% on average across goods and time. Compared to the existing studies in the literature, this ERPT measure is very similar to the ones estimated at the good level, especially for the category of foods (e.g., see Ben Cheikh and Rault (2017), Aron, Farrell, Muellbauer, and Sinclair (2014), Gopinath, Itskhoki, and Rigobon (2010) or Lott (2013)). The results are also robust to the consideration of alternative control variables, where domestic inflation contributes to log price changes with a coefficient of about 0.34 when $T = 0$ and all control variables are included in the regression in column (7).

The results for the threshold analyses represented by Equation (2) are given in Table 2, where we distinguish between all price changes and non-zero price changes similar to studies such as by Gopinath, Itskhoki, and Rigobon (2010).[7] When all price changes are included in the regression (including zero price changes), there is evidence for incomplete ERPT of around 10% only when log daily NER changes are above 0.55%, when goods with frequency of price change over 3.12% are considered, or when goods with storage life of more than 10 weeks are considered, while ERPT is statistically insignificant below these threshold values. When only non-zero price changes are included in the regression, the tables turn with showing evidence for *complete* ERPT, since a positive and significant coefficient of 1 (i.e., 100%) is within any confidence interval. In this case, the consideration of a threshold in storage life

[6] The results based on higher number of lags have much higher AIC and BIC criteria (and thus are not selected) that have been skipped to save space, but they are available upon request.

[7] In order to focus on daily ERPT, we use a slightly different approach compared to Gopinath, Itskhoki, and Rigobon (2010) who consider cumulative changes in nominal exchange rates when a price change is observed, whereas we consider daily (instantaneous) changes in the nominal exchange rate.

Table 1 - Daily ERPT with Alternative Lags and Control Variables

	Dependent Variable: Δ Log Daily Product-level Price							
	Without Fixed Effects				With Fixed Effects			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Log Daily Exchange Rate	0.0466**	0.0372	0.0516**	0.0454*	0.0452**	0.0367	0.0490**	0.0438*
	(0.0220)	(0.0242)	(0.0231)	(0.0254)	(0.0223)	(0.0245)	(0.0230)	(0.0255)
Δ Log Daily Exchange Rate, Lag 1		-0.0354		-0.0363		-0.0389		-0.0386
		(0.0278)		(0.0278)		(0.0291)		(0.0289)
Daily Domestic Inflation			0.358***	0.351***			0.335***	0.325***
			(0.0745)	(0.0737)			(0.0694)	(0.0684)
Good Fixed Effects	NO	NO	NO	NO	YES	YES	YES	YES
Seasonality	NO	NO	NO	NO	YES	YES	YES	YES
AIC	-122766	-123944	-123365	-124572	-122976	-124180	-123466	-124685
BIC	-122748	-123918	-123339	-124538	-122831	-124027	-123312	-124523
R-squared	0.000	0.000	0.016	0.017	0.006	0.007	0.019	0.021
Observations	37,806	36,950	37,806	36,950	37,806	36,950	37,806	36,950

Notes: *** *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

Table 2 - Daily ERPT with Thresholds and Non-zero Price Changes

	Dependent Variable: Δ Log Daily Product-level Price					
	All Price Changes			Non-zero Price Changes		
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Δ Log Daily Exchange Rate > Threshold of 0.55%	0.110***			1.201**		
	(0.0389)			(0.494)		
Δ Log Daily Exchange Rate <= Threshold of 0.55%	-0.0166			-0.0329		
	(0.0392)			(0.342)		
(Δ Log Daily Exchange Rate) x (Frequency of Price Change > Threshold of 3.12%)		0.0905***			0.732**	
		(0.0245)			(0.317)	
(Δ Log Daily Exchange Rate) x (Frequency of Price Change <= Threshold of 3.12%)		-0.0307			-0.712	
		(0.0328)			(1.521)	
(Δ Log Daily Exchange Rate) x (Storage Life > Threshold of 10 weeks)			0.0940**			1.553**
			(0.0361)			(0.647)
(Δ Log Daily Exchange Rate) x (Storage Life <= Threshold of 10 weeks)			0.0356			0.432
			(0.0269)			(0.280)
Daily Domestic Inflation	0.335***	0.335***	0.335***	1.680***	1.674***	1.681***
	(0.0694)	(0.0694)	(0.0694)	(0.101)	(0.0993)	(0.0999)
Goods FE	YES	YES	YES	YES	YES	YES
Seasonality	YES	YES	YES	YES	YES	YES
AIC	-123467	-123468	-123464	-4434	-4432	-4431
BIC	-123305	-123305	-123302	-4315	-4313	-4311
R-squared	0.019	0.019	0.019	0.116	0.115	0.115
Observations	37,806	37,806	37,806	3,989	3,989	3,989

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Following Chan (1993) and Hansen (2000), thresholds have been estimated by minimizing the overall residual sum of squares.

contributes most to the investigation by leading into an ERPT of about 155% for products with storage life of more than 10 weeks, followed by an ERPT of about 120% for days when the NER change is higher than 0.55%, and an ERPT of about 73% for products with a frequency of price change larger than 3.12%.

These results are in line with existing studies in the literature (that employ lower frequency data sets) such as: (i) Burstein, Eichenbaum, and Rebelo (2005) who have shown that the magnitude of NER changes may be effective in the determination of ERPT; (ii) Gopinath and Itskhoki (2010) and Antoniades and Zaniboni (2016) who have shown that there is a positive relationship between frequency of price change and ERPT; and (iii) Kryvtsov and Midrigan (2012) or Alessandria, Kaboski, and Midrigan (2013) who have shown that the optimal price (and thus markups) of any seller decreases with the depreciation rate of inventories. Intuitively, since sellers may want to sell the more perishable goods as soon as possible due to their high depreciation rate, they may accept lower price offers, independent of NER changes. This translates into an ERPT that is higher for less-perishable products in relative terms, which is new in this paper.

4 Policy Suggestions and Concluding Remarks

Policy makers are interested in exchange rate pass-through (ERPT) measures not only because of price-stability concerns especially in small-open economies, but also because ERPT measures are mapped into real effects of nominal exchange rate (NER) changes. By using daily good-level wholesale price data on imported agricultural products, this paper has shown that ERPT is *incomplete* on average across goods and time in Turkey, robust to the consideration of nonlinearities or control variables such as daily domestic inflation rate. Although complete ERPT is observed when non-zero price changes are considered, since frequency of daily price changes is low on average across goods in our sample, the overall evidence for *incomplete* ERPT remains intact.

These results can be perceived as positive for Turkish policy makers, since low and incomplete pass-through as in this paper (i) ensures that NER shocks do not destabilize the price level and thus facilitates the prediction of future Turkish inflation, (ii) helps the stabilization of CPI inflation (targeting) rather than that of non-traded goods prices, and (iii) provides higher degrees of freedom to the monetary authority to conduct an independent policy, without having a trade-off between real stability and inflation stability, because high nominal exchange rate volatility is allowed to stabilize the real economy in face of external shocks (e.g., see Vega, Winkelried, et al. (2005), Choudhri and Hakura (2006), Devereux, Lane, and Xu (2006), or Winkelried (2014)).

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Appendix: Table A.1 - Descriptive Statistics (FOR ONLINE PUBLICATION)

	Daily Price Change						
Imported Good Name - Unit	Average	Median	Minimum	Maximum	Standard Deviation	Storage Life in Weeks	Frequency of Daily Price Change
Apple (Gransimit) - Box	0.02%	0.00%	-51.08%	44.18%	4.30%	6	15.31%
Apple (Gransimit) - Kilogram	0.03%	0.00%	-28.77%	28.77%	5.43%	6	16.73%
Apple (Red) - Box	0.06%	0.00%	-28.77%	32.54%	4.40%	6	9.49%
Apple (Red) - Kilogram	0.00%	0.00%	0.00%	0.00%	0.00%	6	0.00%
Apple (Red) - Number	-0.89%	0.00%	-22.31%	0.00%	4.46%	6	4.00%
Apple (Starking) - Box	0.01%	0.00%	-28.77%	25.13%	3.63%	6	11.55%
Apple (Starking) - Kilogram	-2.39%	0.00%	-11.78%	0.00%	4.47%	6	23.53%
Apricot - Kilogram	0.00%	0.00%	0.00%	0.00%	0.00%	2	0.00%
Asparagus - Box	0.00%	0.00%	0.00%	0.00%	0.00%	3	0.00%
Asparagus - Kilogram	0.01%	0.00%	-55.96%	51.08%	6.15%	3	16.75%
Avocado - Quantity	-0.11%	0.00%	-40.55%	40.55%	5.41%	3	6.21%
Banana (1st Quality) - Box	0.05%	0.00%	-39.83%	28.77%	4.71%	3	40.33%
Banana (2nd Quality) - Box	0.04%	0.00%	-18.23%	40.55%	2.40%	3	3.12%
Banana (2nd Quality) - Kilogram	0.02%	0.00%	-25.13%	18.23%	2.03%	3	1.94%
Carambola - Box	-0.04%	0.00%	-26.24%	33.65%	1.71%	4	0.91%
Cherry - Kilogram	0.00%	0.00%	0.00%	0.00%	0.00%	7	0.00%
Coconut - Quantity	0.02%	0.00%	-51.08%	69.31%	3.50%	6	1.61%
Fresh Coconut - Quantity	0.00%	0.00%	0.00%	0.00%	0.00%	6	0.00%
Garlic - Box	-0.07%	0.00%	-18.23%	20.07%	2.87%	26	5.39%
Garlic - Kilogram	-0.02%	0.00%	-31.85%	35.67%	2.75%	26	2.18%
Ginger (Ginger) - Kilogram	-0.02%	0.00%	-61.90%	69.31%	3.88%	24	3.44%
Ginger (Ginger) - Number	0.02%	0.00%	0.00%	6.06%	0.38%	24	0.38%
Grape (Red) - Box	-0.12%	0.00%	-47.00%	18.23%	5.46%	14	8.93%
Grape (Red) - Kilogram	0.00%	0.00%	0.00%	0.00%	0.00%	14	0.00%
Grapefruit - Kilogram	0.48%	0.00%	-22.31%	47.00%	7.11%	7	9.93%
Grapes - Kilogram	0.18%	0.00%	-30.54%	33.65%	5.25%	14	13.35%
Grapes (Black) - Kilogram	-0.31%	0.00%	-45.20%	33.65%	4.44%	14	3.62%
Grapes (seedless) - Box	-0.08%	0.00%	-47.00%	18.23%	6.44%	14	10.14%
Grapes (seedless) - Kilogram	-0.05%	0.00%	-10.54%	4.08%	1.04%	14	1.68%
Iceberg - Box	-0.63%	0.00%	-40.55%	23.64%	6.33%	3	9.73%
Iceberg - Fund	-2.03%	0.00%	-18.23%	10.54%	6.05%	3	20.69%
Kiwi - Package	0.00%	0.00%	-51.08%	43.08%	5.88%	16	21.16%
Kiwi (30s) - Package	0.07%	0.00%	-35.67%	61.31%	5.96%	16	3.27%
Limes - Box	0.07%	0.00%	-40.55%	54.86%	3.31%	7	1.75%
Limes - Kilogram	0.04%	0.00%	-51.08%	30.23%	5.34%	7	15.29%
Mango - Quantity	-0.09%	0.00%	-281.34%	40.55%	6.55%	3	3.60%
Melon - Kilogram	-0.35%	0.00%	-34.83%	35.67%	4.15%	3	7.96%
Nectarine - Kilogram	-0.05%	0.00%	-15.42%	15.42%	1.82%	3	1.81%
Papaya - Quantity	0.07%	0.00%	-51.08%	69.31%	3.79%	2	2.74%
Pears - Kilogram	-0.04%	0.00%	-28.77%	36.77%	4.27%	18	6.12%
Pears - Package	-0.54%	0.00%	-30.54%	13.35%	7.35%	18	13.64%
Pepino - Kilogram	-0.01%	0.00%	-69.31%	69.31%	5.71%	4	3.39%
Pineapple - Quantity	0.01%	0.00%	-53.06%	58.78%	6.16%	3	21.82%
Pomegranate - Kilogram	-0.09%	0.00%	-55.00%	28.77%	6.58%	10	11.51%
Pomelo - Quantity	-0.03%	0.00%	-28.77%	87.55%	5.21%	7	3.09%
Physalis - Box	-0.03%	0.00%	-51.08%	61.90%	4.55%	4	3.91%
Physalis - Kilogram	-0.13%	0.00%	-15.42%	0.00%	1.38%	4	0.92%
Physalis - Quantity	0.00%	0.00%	0.00%	0.00%	0.00%	4	0.00%
Raspberry - Box	0.00%	0.00%	0.00%	0.00%	0.00%	1	0.00%
Tangerines - Kilogram	-0.31%	0.00%	-13.35%	0.00%	2.04%	3	2.33%
Watermelon (1st Quality) - Kilogram	-0.53%	0.00%	-69.31%	56.80%	9.51%	3	7.28%
Watermelon (2nd Quality) - Kilogram	-1.20%	0.00%	-28.77%	0.00%	5.87%	3	4.17%
Daily Exchange Rate	0.03%	-0.02%	-11.94%	7.04%	0.86%		
Daily Domestic Inflation	-0.07%	0.00%	-19.15%	8.82%	1.70%		

Notes: The micro-price data cover daily wholesale prices of 52 imported agricultural goods in Istanbul, Turkey between January 2005 and August 2015.