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# **A Non-parametric Approach to Modeling Exchange Rate Pass-through in Basic Commodity Markets**

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# **A Non-parametric Approach to Modeling Exchange Rate Pass-through in Basic Commodity Markets<sup>1</sup>**

## **1. Introduction**

If agents are rational and transportation, resale and distribution are costless then, due to arbitrage, identical goods will command the same price in common currency terms. In a perfectly competitive framework with frictionless markets, price transmission will be complete and markets will be fully integrated. A closely related dimension of price transmission involves the behavior of prices across international borders. When commodity trade is conducted using different national currencies, the price adjustment process is complicated by the potential for exchange rate distortions. The equilibrium price relationship in such cases involves an exchange rate in order to express prices in comparable terms. In such a context, there are three avenues for market shocks and adjustments to such shocks—the export market, the import market, and the exchange rate, which is generally considered to be exogenous to individual commodity prices. Adjustments to exchange rate shocks are of interest in their own right in that the “pass-through” of exchange rate shocks (ERPT) through adjustments to one or both prices is an important factor characterizing the performance of the market.

Exchange rate pass-through is typically evaluated using an empirical test that is based upon the presumed arbitrage equilibrium relationship  $P_t^1 = \Pi_t^{12} P_t^2$ , where  $P_t^i$  represents prices expressed in different currencies and  $\Pi$  is the exchange rate for the currencies. In logarithmic

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terms, this relationship is often evaluated in a regression model of the form  $p_t^1 = \alpha + \beta_1 \pi_t^{12} + \beta_2 p_t^2$ , where the lower-case letters denote logarithmic variables. Perfect pass-through of exchange rates shocks and efficiently linked markets implies that one should see  $\alpha = 0$  and  $\beta_1 = \beta_2 = 1$ . A significant proportion of international trade is invoiced in U.S. dollars. If both prices are expressed in a common currency, as is often the case, the conditions for perfect pass-through become  $\alpha = 0$ ,  $\beta_1 = 0$ , and  $\beta_2 = 1$ . Departures from these conditions are characterized as "overshooting" or "undershooting"—phenomena that are often observed in primary commodity markets. It reflects the fact that prices for such primary commodities are generally more flexible and free to adjust than may be the case for processed and manufactured goods, which may be bound by short-term contracts, or other factors that inhibit adjustments.

Although there is an upward trend of trade and economic integration among both developed and developing countries, previous studies have found the estimates of the degree of pass-through to be low, and diminishing over time (Goldberg and Knetter, 1997; Campa and Goldberg, 2005). A lack of pass-through may reflect imperfect arbitrage, inefficient trade, price rigidities due to contracts or menu costs, price discrimination, high transactions costs, and other factors such as the influences of government policies. Over the years, various theories and empirical refinements have been explored in an attempt to account for low and/or declining rates of ERPT. Among these, a relatively small number of recent studies have examined the possibility that there are asymmetries or nonlinearities in pass through (eg., Pollard and Coughlin 2004; Marazzi and Sheets 2007). For instance, if there are some menu costs of price adjustment, then relatively small changes in the exchange rate may not be passed through as adjustments to prices. Rather, only after exceeding a certain threshold would these be passed on to prices. On the other

hand, if prices react more to, say, depreciations than to appreciations, meaning there is asymmetry in the price reaction to exchange rate changes, this may reflect distortions in the markets.

The most recent literature in this area has applied smooth or discrete threshold time series models that typically consider refinements of autoregressive or vector error correction models in analyzing pass-through effects (eg., Goodwin, Holt, Prestemon 2012; Al-Abri and Goodwin 2009; Larue, Gervais and Rancourt 2010). Although this approach follows a long progression of the development of time-series methods for identifying nonlinear effects in empirical models, several issues remain in practice. First, the variable causing the ‘regime shift’ is assumed to be known even though economic theory rarely dictates a likely candidate. Second, there is typically little to no guidance on what the most appropriate functional form or transition function for a given application might be. Finally, the specifications applied in recent work typically involve a significant number of additional parameters to be estimated, and thus add significantly to the complexity of estimation and testing.

This paper proposes a fully nonparametric *Generalized Additive Modeling* (GAM) approach to analyzing these same types of time series data in a nonlinear fashion. Instead of testing for one particular kind of non-linearity or asymmetry, the approach chosen here allows for a more flexible model that encompasses many different types of nonlinearities. In this paper, we aim to assess the degree of pass-through in import prices for three highly traded, homogeneous commodities; and, to examine the role of nonlinearities in ERPT using nonparametric generalized additive modeling framework. In what follows, we give the

conceptual framework of our analysis, the description of the data, and the preliminary empirical results.

## 2. Conceptual Framework

Although micro foundations underlying exchange rate pass-through are very similar to those that motivate the Law of One Price (LOP), investigations of ERPT emphasize the separate effects of price and exchange rate shocks in commodities that are traded in different currencies.

In the classical pass-through literature the basic long-run price relationship may be stated as (Following Goldberg and Knetter; 1997):

$$P_{it} = \Pi_t^{\beta_1} P_{jt}^{\beta_2}, \beta_1, \beta_2 > 0, t=1, \dots, T. \quad (1)$$

where  $P_{it}$  is the (nominal) import price in country i for the good in question in period t (denominated in country i's currency);  $P_{jt}$  is the corresponding (nominal) export price in country j (denominated in country j's currency); and  $\Pi_t$  is the nominal exchange rate, expressed in terms of the importer's currency relative to the exporter's currency. As well,  $\beta_1$  and  $\beta_2$  are parameters such that with perfect pass-through  $\beta_1 = \beta_2 = 1$ . Taking natural logarithm of Equation 1 yields the following estimable equation:

$$p_{it} = \beta_1 \pi_t + \beta_2 p_{jt} + \varepsilon_t \quad (2)$$

where lower case denotes natural logarithmic form.  $\beta_1$  and  $\beta_2$  are parameters to be estimated and  $\varepsilon_t$  is an additive error term. Testing full (complete) exchange rate pass-through would be associated with the null hypothesis  $H_0 : \beta_1 = \beta_2 = 1$ .

If the import prices are expressed as units of foreign currency (i.e.  $\tilde{p}_{it} = p_{it} - \pi_t$ ), the relationship in (2) can be rewritten as:

$$\tilde{p}_{it} = (\beta_1 - 1)\pi_t + \beta_2 p_{xt} + \varepsilon_t \quad (3)$$

For complete pass-through we again require  $\beta_1 = \beta_2 = 1$ , which in turn reduces (3) to a stochastic version of the law of one price relationship. In other words, with common (exporter's) currency pricing, complete pass-through implies that exchange rates should have no long-term impact on the import price. Equation (3) is the basis to the empirical analysis.

### 3. Methods

Instead of testing for one particular kind of non-linearity or asymmetry, the approach chosen here allows for a more flexible model that encompasses many different types of nonlinearities. Generalized additive models were first proposed by Hastie and Tibshirani (1986, 1990). These models assume that the mean of the response variable depends on an additive predictor through a link function. The appealing feature of GAMs is their ability to deal with highly non-linear and non-monotonic relationships between the response and the set of explanatory variables. To our

knowledge, this particular nonparametric model has not been previously applied in studies of pass-through in international commodity markets.

We use *backfitting* algorithms to fit our generalized additive model. The estimated nonparametric component of a GAM may be thought of as estimates of the functions transforming each explanatory variable so as to maximize the fit of their additive combination to the dependent variable, subject to constraints about the *smoothness* of the link function. We focus on two types of link functions; locally weighted regression smoothers and cubic smoothing splines, which have well-understood properties. We use graphical methods to interpret the nonparametric component of a GAM. These graphs reveal the nature of any estimated nonlinearities in the relationship between variables of interest. We compute standard errors and confidence regions of the nonparametric components) and consider various metrics of the goodness of fit, providing a guide as to whether the fitted function is distinguishable from a linear fit.

#### **4. Data and Preliminary Results**

Our application is to prices for major softwood lumber products that are traded between the U.S. and Japan. In particular, we use biweekly export and import prices of Douglas-fir, Hemlock Squares and Western spruce-pine-fir published by *Random Lengths*. Japanese Yen-USD exchange rates are obtained from the Federal Reserve Bank of St. Louis.

Preliminary results from nonparametric generalized additive models indicate that there is considerable evidence in favor of nonlinearity and asymmetry of exchange rate pass through.



The fitted nonparametric models are superior to their linear counterparts for both commodities that we consider. We find that the pass-through of exchange rate shocks into softwood lumber prices seems incomplete in both the U.S. and Japan. Furthermore, in cases where stronger nonlinear patterns are implied by GAMs, larger exchange rate changes result in higher pass-through to import prices than in situations when exchange rate changes are small. We discuss implications of our results for the performance of international softwood lumber markets and the adjustment of prices to exchange rate shocks, and we compare our findings to those obtained in more conventional time series models.

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