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The Volatility of the Relative Price of Commodities In Terms of Manufactures Across Exchange Regimes: A Theoretical Model

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Abstract

This paper investigates the relationship between the nominal exchange rate regime and the volatility of relative commodity prices. The analysis shows that the relationship depends upon both the market structure and the economic agent's perception about future exchange rate movements. When the markets for manufactured goods are less competitive than the markets for primary commodities, the volatility of relative commodity prices rises when exchange rate uncertainty increases. If demand for manufactured goods is intertemporally dependent, even a small increase in exchange rate uncertainty can result in potentially large costs in terms of increased relative commodity price instability.

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Summary

This paper investigates the relationship between the nominal exchange rate arrangement and the volatility of relative primary commodity prices by examining the different mechanisms through which changes in exchange rates pass through to the prices of final goods. Using an industrial organization model with producers of manufactures facing an intertemporally dependent demand function and importing primary commodities as inputs, the paper shows that this relationship depends upon both the market structure and the economic agent's perception about future exchange rate movements. The analysis suggests that, when measured in local currency, changes in commodity input prices induced by changes in the exchange rate have little effect on the price of manufactured goods precisely because the exchange rate fluctuates so much. Increasing exchange rate variability leads to increased stickiness in the price of manufactured goods, which in turn leads to higher volatility in real commodity prices.

A better understanding of this issue is important not only because of its impact on trade adjustment in the face of nominal exchange rate changes, but also because of its implications for different export and import structures. Although many developing countries' export structure has shifted considerably away from primary commodities toward manufactured goods, their terms of trade may continue to experience greater fluctuations with floating exchange rates if there is asymmetric distribution of market power in their import and export markets.

I. Introduction

Two major theoretical frameworks have been proposed by economists to study the determination of nominal/real exchange rate. Sticky-price models show that adopting floating exchange rates implies higher nominal and real exchange rate variability.[2] In contrast, a class of equilibrium models satisfies "the nominal exchange regime neutrality proposition," i.e., the time series properties of all real variables are invariant to the choice of exchange regime.[3]

One of the stylized facts concerning exchange rates is that the volatility of real exchange rates has apparently experienced dramatic changes across exchange rate regimes.[4] This empirical regularity has generally been viewed as a consequence of price stickiness. Stockman (1983) illustrates, however, that some equilibrium models, for example those with nontradable as well as tradable goods—not just sticky price models—may also exhibit nonneutralities with respect to the exchange rate regime.

Interestingly, Cuddington and Liang (1998) show that the relative prices of primary commodities in terms of manufactures have time series characteristics that also vary across exchange rate regime. They document a new "stylized fact" regarding commodity prices using alternative data sets covering the period from 1880 to 1996. The volatility of real commodity prices, defined as nominal commodity prices deflated by the manufacturing unit value index, is higher under flexible-exchange rate regimes than fixed-exchange rate regimes. Furthermore, changes in exchange regime are associated with changes in the *persistence* of commodity price shocks.

The nonneutrality of nominal exchange regimes on two types of internationally *traded* goods, primary commodities and manufactures, is hard to explain in the context of equilibrium models, including those described by Stockman (1983). The nominal price of a traded good may increase during floating exchange period simply because of the mechanical effect of denominating the price in a common currency. If such mechanical effect influences two traded goods similarly, the relative price of these two goods should not be expected to exhibit volatility shifts across nominal exchange rate arrangements. The new "stylized fact" of commodity prices suggests that the mechanism linking the exchange rate with primary commodities may be different from that of manufactured goods. This in turn seems to reflect some form of price stickiness, perhaps arising from different market structures for the two types of goods.

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[2]See, e.g., Dornbusch (1976), Frenkel (1981), and Mussa (1982).

[3]See, e.g., Helpman (1981), Lucas (1982) and Stockman (1980).

[4]See Mussa (1986), Baxter and Stockman (1989), Flood and Rose (1995) and Rogers (1995).

Since the 1970s, there have been quite a few empirical studies of price-exchange rate relationships. Economists are increasingly persuaded that prices of different goods respond differently to exchange rate changes, reflecting the underlying market structure across industries.[5] Using data covering the period of 1972-82, Bui and Pippenger (1990) find that primary commodity prices, such as the prices of rubber and tin that are determined in the well-organized auction markets, are *more* volatile than exchange rates. On the other hand, studies of exchange rate pass-through and pricing to market have shown that, for a variety of manufactured goods, the local currency prices of foreign products do not respond fully to exchange rate changes.

Little research has been devoted to the factors behind the changes of pass-through behavior over time, in particular, how alternative exchange rate regimes affect firms' expectations about the future movements of exchange rates, and hence their dynamic pricing behavior.[6] Few studies have tried to explore the implications of the latter for relative prices when there is asymmetrical pricing behavior between perfectly competitive firms and firms with market power.

The purpose of this paper is to theoretically examine how the nominal exchange rate arrangement and the perceptions of exchange rate fluctuations affect the volatility of relative primary commodity prices in terms of manufactured goods. A better understanding of this issue is important not only because of its impact on trade adjustment in the face of nominal exchange rate changes, but also because of its implications for different export and import structures. On the one hand, some low-income developing countries still depend heavily on one or two primary commodities for their export earnings. Uncertainty in export revenues, as well as macroeconomic mismanagement in the face of commodity export booms and busts, can have negative effects on investment and growth. On the other hand, even though there has been a considerable shift in many developing countries' export structure away from primary commodities and toward manufactured goods, their terms of trade may continue to experience greater fluctuations with floating exchange rates if there is asymmetric distribution of market power in their import and export markets.

The model in this paper is intended to account for short and medium-run behavior of relative commodity prices for a given change in exchange rates. It suggests that, when measured in local currency, changes in commodity input prices induced by changes in exchange rate have little effect on the price of manufactured goods precisely because the exchange rate fluctuates so much. Increasing exchange rate variability leads to increased stickiness in the price of the manufactured goods, which in turn leads to increasing volatility in real commodity prices.

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[5]See Goldberg and Knetter's (1997) excellent survey on goods prices and exchange rates.

[6]For very recent exceptions, see Sapir and Sekkat (1995) and Bourdet (1996).

The paper is organized as follows. Section II presents a general dynamic model with producers of manufactures facing an intertemporally dependent demand function and importing primary commodities as inputs. It shows how alternative exchange rate regimes and different perceptions regarding exchange rate stability influence the pricing behavior of manufacturers with market power. Assuming a specific form of intertemporally dependent demand function, Section III derives explicitly how the degree of price stickiness for manufactured good increases when the nominal exchange rate becomes more volatile. The implications of the model for relative commodity prices are discussed in Section IV. The last section concludes.

II. Nominal Exchange Rate Regimes and Manufacturer's Pricing: Some Theoretical Considerations

The phenomenon of "sticky prices", i.e., the apparent insensitivity of prices to fluctuations in either demand or supply in the short and medium run, has long intrigued macro economists in search of micro foundations. To explain short to medium run price rigidity, early studies relied on so-called "menu costs", that is, costs incurred by firms in changing prices. One stream of recent studies on the puzzle have focused on the issue of mark-up adjustment. The theory of "pricing to market" developed by Krugman (1987) and Dornbusch (1987) emphasizes the role of market segmentation and price discrimination across destination markets. Another stream of research explores the rationales behind the slow adjustment of goods prices beyond the simple "menu cost" suggested in the early literature. In particular, some models introduce explicitly dynamic elements when considering how firms with market power respond to changes in costs over time (e.g. Froot and Klemperer (1989)). Generally speaking, temporary changes in costs are expected to induce more fluctuations in markups than permanent ones.

There are several channels through which past price choices affect current profit. On the supply side, the existence of significant economies of scale may induce firms to maintain their volume of sales and not to increase prices when facing temporary rises in input costs. On the demand side, past prices may affect the firms' current sales because of habit persistence in customer preferences. That is, for many goods, consumers tend to buy from the same company over time. Rigidity in individuals' purchasing pattern could result from a wide variety of sources. Theoretical literature has suggested reasons such as search costs faced by consumers (Phelps and Winter (1970)), consumers' uncertainty about the quality of alternative products (Nelson (1970)), network externalities (Katz and Shapiro (1985)), and switching costs composed of transaction costs, learning costs, and artificial costs imposed by firms (such as repeat-purchase discount) (Klemperer (1987)). The focal point of such rigidities is that a seller is concerned not only with the influence of today's prices on demand today, but also with its influence on future demand.

Once this dynamic element is added, the extent to which prices today will adjust in response to a given shock may change significantly. This reasoning suggests one explanation why prices in an industry with market power may be more stable over time than in a competitive industry: the former might fear substitution away from his products in the long run if he raises prices today. If costs rise unexpectedly in the short run but are believed by the monopolist to be only temporary, he then has an incentive to absorb the temporary cost changes so that the consumers will not mistake the current price increases as being permanent and react by switching away from the product in the long run (Carlton (1989)).

Extensive research has been done on how responsive trade prices are to exchange rate changes, especially in the U.S. economy. Most empirical studies have found that the volatility of bilateral exchange rates affects at least the speed of the pass-through of exchange changes to import and export prices, and possibly the long-run relationship as well.[7] Some theoretical explanations of this phenomenon have used dynamic models of imperfect competition and suggested that the pass-though elasticity depends on whether changes in exchange rate are perceived as temporary or permanent.[8] The novelty of the present model lies in the analysis of the relative prices of two goods with different market structures. The model also introduces explicitly firm's expectation about exchange rate stability conditional on the exchange rate regime in an infinite horizon set-up.

The analysis explores the relationship between exchange rate and relative prices from an industrial "home" country's point of view. The industrial country imports primary commodities from a developing country and uses the commodities as inputs to produce manufactured goods.

A. Producer Behavior

To incorporate expectations regarding the variance of the exchange rate (not just its level) in firms' pricing decisions, the price in the previous period is added to the demand function to capture habit persistence in demand.[9] Although other indicators, such as market share and sales, are also important previous-period variables, the choice of price is more direct and simplifies the analysis greatly.[10]

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[7]See, e.g. Mann (1986), Baldwin (1988) and Knetter (1989).

[8]See, e.g. Dixit (1989), Baldwin and Krugman (1989), and Froot and Kemperer (1989).

[9]The theoretical framework of the model is partly stimulated by Baldwin and Lyons (1988) on exchange rate volatility and unresponsive trade prices. The setup here is in much more general form and avoids some unnecessary mathematical complications.

[10]See, e.g. Froot and Kemperer (1989).

The manufacturing industry is assumed to be characterized by one monopoly firm.[11] The firm imports one primary commodity and uses it as its sole input.[12] The dynamic element is captured by an intertemporally dependent demand function, i.e., the demand for the firm's final product in period t+1, D_{t+1}, depends upon the prices in both period t+1 and period t. A price increase today will decrease the demand tomorrow because of habit persistence.

Formally, the monopolist manufacturer seeks to maximize the present discounted value of its profits by choosing the home-currency price of its sales (p_t^m), that is:[13]

$$\max_{p_t^m} E_t\left\{\sum_{t=0}^{\infty} \delta^t \pi_t\left[p_t^m, p_{t-1}^m, s_t, p_t^{c*}\right]\right\} \tag{1}$$

π_t is the profit function at time t, s_t is the units of domestic currency per unit of foreign currency, p_t^{c*} is the foreign currency price of commodity input, and δ is the discount factor. Before choosing p_t^m, the firm observes s_t and all other previous period variables. The typical Euler equation becomes:

$$\frac{\partial \pi_t\left[p_t^m, p_{t-1}^m, s_t, p_t^{c*}\right]}{\partial p_t^m} + \delta E_t\left\{\frac{\partial \pi_{t+1}\left[p_{t+1}^m, p_t^m, s_{t+1}, p_{t+1}^{c*}\right]}{\partial p_t^m}\right\} = 0 \tag{2}$$

For simplicity, the marginal cost of commodity inputs is assumed to be constant in foreign currency terms, that is, $p_t^c = s_t\, p_t^{c*}$, hence:

$$\begin{gathered}\pi_t(p_t^m, p_{t-1}^m, s_t, p_t^{c*}) = (p_t^m - s_t p_t^{c*}) D_t(p_t^m, p_{t-1}^m), \text{ for all } t, \\ \text{and } \frac{\partial D_t(p_t^m, p_{t-1}^m)}{\partial p_{t-1}^m} < 0, \ \frac{\partial \pi_t}{\partial p_{t-1}^m} < 0\end{gathered} \tag{3}$$

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[11]The assumption of monopoly is primarily for reasons of mathematical simplification, and is not crucial for the qualitative results of the model.

[12]It is assumed here that the manufacturer buys the primary commodity on the spot market. Hence, the primary commodity he imports from abroad is nonstorable in the sense that he does not engage in the business of intertemporal commodity arbitrage.

[13]Regarding the currency of invoicing, we assume both input and final output are denominated in the currency of the industrial country. This assumption is in line with the fact that most primary commodity prices are quoted in the currencies of industrial countries.

Since a lower price in period t increases the firm's demand in period t+1, and therefore its profit, the second term in equation (2) is negative. This implies that the first term in equation (2) is positive, that is, the firm will choose lower prices than they would if there was no intertemporal dependence in its demand. The manufacturer balances the marginal benefit of further increase in its profit today through higher prices ($\partial\pi_t/\partial p_t^m$), against the expected marginal cost of decline in sales and profits tomorrow $\delta E_t \frac{(\partial\pi_{t+1})}{\partial p_t^m}$). Because the only uncertainty assumed in this model is exchange rate variability, the second term in equation (2) depends on the expectation of future exchange rates. The expectation is conditioned on all available information at time t. The solution of equation (2) will define p^m_{t+1} as a function of the current and expected future values of the exchange rates.

We can write this firm's optimal price at time t in reduced form as:

$$p_t^m = f\left(p_{t-1}^m, s_t, (s_{t+i}^e)_{i=1,\ldots,\infty}\right) \tag{4}$$

Totally differentiating equation (4), the effect of a proportional change in exchange rate on price at period t therefore is:

$$\frac{dp_t^m}{ds_t} = \frac{\partial f}{\partial s_t} + \sum_{i=1}^{\infty} \frac{\partial f}{\partial s_{t+i}} \frac{ds_{t+i}^e}{ds_t} \tag{5}$$

Clearly, when the firm's profit function is intertemporally dependent, the pass-through elasticity depends upon the perception regarding exchange rate stability. Under a fixed-but-adjustable exchange rate regime, revaluation of the nominal rate is likely to be viewed as a one-time permanent change in levels. Thus, $\frac{ds_{t+i}^e}{ds_t}$ equals one. On the other hand, under a floating exchange rate regime, there is the further complication of how current exchange rate changes affect economic agent's perception about the future trend of the exchange rate. That is, the second term in equation (5) may be positive, negative or zero.

Intuitively, a depreciation in period $t+i$ increases the marginal cost and lowers the profit in period $t+i$, and therefore, lowers the marginal benefit of increasing future profit by a price reduction today. Thus, $(\partial f/\partial s_{t+i})$ is positive. If the change in the exchange rate is believed to be transitory and is likely to reverse itself in the future period, i.e., a depreciation of the exchange rate today generates the expectation of an appreciation tomorrow, $\frac{ds_{t+i}^e}{ds_t}$ will be less than one. In this case, the second term in equation (5) can even become zero or negative.

Hence, when transitory changes in exchange rates are important in the floating exchange rate period, the pass-through of input cost changes into final prices will likely be less than that under a fixed exchange rate regime.

III. Monopoly Pricing When Demand Is Intertemporally Dependent

In this section, assuming a specific form of intertemporally dependent demand function, the relationship between exchange rate variability and the input cost pass-though is explicitly derived. Specifically, the demand function is assumed to be separable in p^m_{t+1} and p_t^m, and takes the form:[14]

$$D_t = (G-cp_{t-1}^m)(a-bp_t^m), \tag{6}$$

$$\text{where } a,b,c, G,(G-cp_{t-1}^m), \text{ and } (a-bp_t^m)>0$$

$(G\text{-}cp^m_{t-1})$ can be viewed as some goodwill generated by the firm's advertising efforts about the product, and is decreasing in the sales price in the previous period.

A. A Two-Period Model

To better understand the dynamics of the model, we first analyze a two-period version of it, and then proceed to derive the implications under an infinite horizon setup. In the second period, the manufacturer observes the second-period exchange rate and takes the demand function as given. The profit of the firm is:

$$\pi_2 = (p_2^m - s_2 p_2^{c*})(G-cp_1^m)(a-bp_2^m) \tag{7}$$

The equilibrium price equals:

$$p_2 = \frac{a}{2b} + \frac{s_2 p_2^{c*}}{2}, \tag{8}$$

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[14]These assumptions simplify the math greatly in part by ensuring all the third derivatives are zero. There is little economic theory that describes the signs of third derivatives, nor the second derivatives of demand function. The qualitative results of this model will still hold if the second derivatives of demand function are greater or equal to zero, i.e., they are convex in prices.

which is the usual solution for monopoly pricing. Any observed changes in the exchange rate level at period 2 will be passed on to the final price accordingly:[15]

$$\frac{dp_2}{ds_2} = \frac{p_2^{c*}}{2} \tag{9}$$

In the first period, consumers have not yet formed any loyalty to any particular product. The manufacturer observes the first-period exchange rate, and tries to maximize the sum of its first period and discounted second period profits:

$$\begin{aligned} \pi &= \pi_1 + \delta E_1(\pi_2) \\ &= G(a-bp_1^m)(p_1^m - s_1 p_1^{c*}) + \delta E_1\left\{\left(G-cp_1^m\right)\left(a-bp_2^m\right)\left(p_2^m - s_2 p_2^{c*}\right)\right\} \end{aligned} \tag{10}$$

The first-period profit-maximizing price is:

$$p_1 = \frac{a}{2b} + \frac{s_1 p_1^{c*}}{2} - \frac{\delta c}{8b^2} E_1\left[\left(a - bs_2 p_2^{c*}\right)^2\right] \tag{11}$$

The last term is positive, hence the first period price is lower than the price that the manufacturer would have charged if there were no persistence in consumers' purchasing pattern (i.e., if c=0).

If the current level of exchange rate changes ($ds_1 \neq 0$) while other variables remain constant ($p_1^{c*} = p_2^{c*} = p^{c*}$), the degree of pass-through clearly depends on how the first period exchange rate changes affect the manufacturer's perception about the second period exchange rate, that is how $E(ds_2)$ is going to move. If the manufacturer perceives the change in exchange rate as permanent, as likely to be the case during a fixed exchange rate regime where realignment of the exchange rate is rare, the pass-through derivative is given by:

$$\frac{dp_1^m}{ds_1}\Big|_{E(ds_2)=ds_1} = \frac{p^{c*}}{2} + \frac{\delta c}{4b}\left(a - bs_1 p^{c*}\right)p^{c*} \tag{12}$$

[15]The solution of the cost pass-through elasticity depends on the specific demand function. It can be greater, less, or equal to one as in the case of a demand function with constant elasticity.

Interestingly, because the second term in equation (12) is positive, the degree of pass-through is larger than in the case when there is no intertemporal dependence in demand. The intuition is that, when the manufacturer perceives a permanent depreciation of its own currency, its incentive in investing in consumers' loyalty is reduced because of its perception of permanent reduction in its future profits.

In contrast, if the manufacturer perceives the exchange rate level in period one to be temporary, the pass-through derivative depends on how the expectation of the second-period exchange rate is affected. An interesting case is when the change in the exchange rate in the first period is expected to completely reverse itself in the second period. Specifically, if the manufacture's expectation about the second period exchange rate is formed as:

$$E(s_2) = s_1, \ \text{for} \forall \, ds_1$$

The degree of pass-through then equals:

$$\frac{dp_1^{m}}{ds_1}\Big|_{E(ds_2)=0} = \frac{p^{c*}}{2} \tag{13}$$

The pass-through derivative is clearly smaller than in the case when the change in the first period exchange rate is assumed to be permanent. It is the same as in the case when the demand function is not intertemporal dependent, because there is no change in the expected future cost.

Another interesting case is when the change in exchange rate in the first period is expected to be more than offset itself in the second period. That is, $\frac{ds_{t+i}^{e}}{ds_t}<0$, a depreciation of the current rate today generates expectation of a large appreciation tomorrow. For example, if $\frac{ds_{t+i}^{e}}{ds_t} = -1$ the pass-through derivative then equals:

$$\frac{dp_1^{m}}{ds_1}\Big|_{E(ds_2)=-ds_1} = \frac{p^{c*}}{2} - \frac{\delta c}{4b}\left(a - bs_1 p^{c*}\right)p^{c*} \tag{14}$$

The expected appreciation of the exchange rate increases the expected profits in the future, and hence increases the cost of raising prices today. The degree of cost pass-through is therefore much lower. Depending on how strongly past price influences current sales, the pass-through derivative can be nonpositive. A large enough c could reverse the sign in equation (14).

B. An Infinite Horizon Model: The Implications of Increasing Exchange Rate Uncertainty

The effects of exchange rate changes on the first-period price in the two-period model are present in every period in an infinite horizon model. In addition, an infinite horizon model allows the analysis of not just the changes in levels but also changes in the variance of the exchange rate. The purpose of this section is to show how the magnitude of $\frac{dp_t^m}{ds_t}$ is decreasing in exchange rate uncertainty.

For any period t, the firm chooses price p^m_t to maximize the present discounted value of its profits:

$$\max_{p_t^m} E_t\left\{\sum_{t=0}^{\infty} \delta^t\left[\left(G-cp_{t-1}^m\right)\left(a-bp_t^m\right)\left(p_t^m-sp_t^{c*}\right)\right]\right\} \tag{15}$$

The Euler equation is:

$$\left(G-cp_{t-1}^m\right)\left(a-bp_t^m\right)-b\left(G-cp_{t-1}^m\right)\left(p_t^m-sp_t^{c*}\right)-\delta cE_t\left[\left(a-bP_{t+1}^m\right)\left(p_{t+1}^m-s_{t+1}p_{t+1}^{c*}\right)\right]=0 \tag{16}$$

By rearranging terms and totally differentiating equation (16) with respect to p_t and then s_t, it can be shown that the pass-through elasticity equals:

$$\theta \equiv \frac{dp_t^m}{ds_t}=\frac{p_t^{c*}}{2}-\frac{\delta c\dfrac{\partial E_t\left[\left(p_{t+1}^m-s_{t+1}p_{t+1}^{c*}\right)\left(a-bp_{t+1}^m\right)\right]}{\partial s_t}}{2b\left(G-cp_{t-1}^m\right)} \tag{17}$$

This expression can be positive or negative, depending on the sign of the second term in equation (17). It is proved later that the second term is negative if the distribution of the exchange rate is perceived to be leptokurtic (i.e., they exhibit "fat tails").[16]

A convenient way of introducing changes in exchange rate volatility is to employ a family of s_{t+1} densities, $f(s_{t+1}, \xi)$, where increase in ξ is defined by Rothschild and

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[16]For high frequency data, one of the stylized facts about the distributional properties of exchange rates documented by researchers is that the unconditional distribution of percentage changes in foreign exchange are leptokurtic. See, e.g., Bollerslev (1987), Baillie and Bollerslev (1987), and Lastrapes (1989).

Stiglitz (1970) as mean-preserving-spread (MPS), and represents an increase in risk. Adding a MPS to the density function of a random variable is equivalent to adding white noise to the random variable, and it shifts the probability weight from the center to the tails. By assuming that the distribution of s_{t+1} is completely characterized by two parameters, there is a one-to-one correspondence between a MPS and the conditional variance of the exchange rate.

The sign of the following derivative determines how the parameter of price stickiness reacts to increases in risk:

$$\frac{d\theta}{d\xi} = -\frac{\delta c}{2b\left(G-P_{t-1}^{m}\right)} \frac{d\left[\frac{\partial E_t \Phi\left(s_{t+1}\right)}{\partial s_t}\right]}{d\xi} \tag{18}$$

$$\text{where } \Phi\left(s_{t+1}\right) \equiv \left(p_{t+1}^{m} - s_{t+1} p_{t+1}^{c*}\right)\left(a - b p_{t+1}^{m}\right)$$

The sign of this derivative depend on $\frac{d\left[\frac{\partial E_t \Phi(s_{t+1})}{\partial s_t}\right]}{d\xi}$. If it is positive, the sign of equation (18) will be negative.

At this point, it is further assumed that capital is perfectly mobile internationally in the sense that the uncovered interest rate parity condition holds. The ratio of s_{t+1} and s_t, therefore, equals the ratio of the home and foreign nominal interest rates:

$$k \equiv \frac{s_{t+1}}{s_t} = \frac{1+i_t}{1+i_t^*} \tag{19}$$

Since s_t is predetermined, we can write $s_{t+1}=s_t k$. Applying change of variable, the last term in equation (18) then equals:

$$\frac{d}{d\xi}\left[\frac{\partial E_t \Phi\left(s_{t+1}\right)}{\partial s_t}\right] = \int_{k=0}^{\infty} \frac{\partial \Phi\left(s_{t+1}\right)}{\partial s_t} \frac{\partial f(k,\xi)}{\partial \xi} dk \tag{20}$$

As discussed before, $\frac{\partial f(k,\xi)}{\partial \xi}$ represents MPS. Rothchild and Stiglitz (1970) show that:

$$F(0)=F(\infty)=0, \text{ where } F(x)=\int_0^x \frac{\partial f(k,\xi)}{\partial \xi}dk$$

$$T(\infty)=0, \text{ where } T(y)=\int_0^y F(k,\xi)dk \tag{21}$$

$$T(y)>0 \text{ for } 0<y<\infty$$

Equation (21) is called the integral conditions for a single MPS.

Applying equation (21) and integrating equation (20) by parts twice, we find the derivative in equation (20) equals:

$$\left\{\int_0^\infty 2\Phi_{kk}(s_{t+1})s_t\left[\int_0^k F(x,\xi)dx\right]dk\right\} \tag{22}$$

$\Phi(s_{t+1})$ is the profit function at time t without the term involving the past price. Since marginal cost is assumed to be constant, the profit function $\pi(s_{t+1})$ is convex in s_{t+1}. Therefore $\Phi(s_{t+1})$ is convex in s_{t+1}, i.e., Φ_{kk} is positive. Hence, the derivative in equation (20) is positive.

This finishes the proof that $d\theta/d\xi$ is negative, i.e., the pass-through elasticity is decreasing in the conditional variance of the exchange rate. It is therefore valid in what follows to specify the parameter of price stickiness, θ, as a function of the conditional variance of the exchange rate, σ_e^2:

$$\theta = h(\sigma_e^2), \text{ where } h'(\sigma_e^2)<0. \tag{23}$$

IV. Relative Price Volatility and Exchange Rate Uncertainty

Expressed in common currency and natural log terms, the relative price of commodities in terms of manufactured goods equals:

$$R_t \equiv s_t + p_t^{c*} - p_t^m = s_t + p_t^{c*} - \theta(s_t + p_t^{c*}) = (1-\theta)(s_t + p_t^{c*}) \tag{24}$$

Intuitively, fluctuations in this relative price will increase when the exchange rate movements become more uncertain, because the latter has a one-to-one effect on primary commodity price volatility and a dampened effect on the manufactured goods price. Formally, the conditional variance of the real commodity price equals:

$$\begin{aligned} Var(R) &= Var\left(s_t p_t^{c*}\right) - 2cov\left(p_t^{m}, s_t p_t^{c*}\right) + Var\left(p_t^{m}\right) \\ &= (1-\theta)^2 \sigma_e^2 - 2(1-\theta) cov\left(p_t^{c*}, s_t\right) + (1-\theta)^2 var\left(p_t^{c*}\right) \end{aligned} \qquad (25)^{17}$$

For a given primary commodity price process in primary producing countries, and assuming there is no covariance between it and the nominal exchange rate, the effect of increase in exchange rate uncertainty on relative price volatility equals:

$$\frac{d\,var(R)}{d\sigma_e^2} = (1-\theta)^2 + 2(1-\theta)\left(-\frac{d\theta}{d\sigma_e^2}\right)\left(\sigma_{p_t^{c*}}^2 + \sigma_e^2\right) \qquad (26)$$

The second term was shown to be positive in equation (18); this is the main result of Section III. Expressed in common currency terms, the covariance between the manufactured price and the primary commodity price is positive because of profit maximization. However, the degree to which they covary decreases as the nominal exchange rate becomes more volatile. Therefore, the sign of equation (26) is positive: volatility of relative commodity price is an increasing function of the underlying exchange rate uncertainty.

The theoretical results of this paper are summarized in Table 1. It can be seen that the interaction between the nominal exchange regime and the relative commodity price volatility depends on the underlying market structure. If the markets for both goods are characterized by perfect competition, the volatility of relative commodity prices should not be influenced by the nominal exchange rate arrangements. On the other hand, if there is an asymmetry in market power, the neutrality of exchange regime no longer holds. Furthermore, if market power is intertemporally dependent, the degree of price stickiness increases when the exchange rate becomes more uncertain, and so does the volatility of relative commodity prices.

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[17] The following variance and covariance are conditional on all information available at time t.

Table 1. Exchange Rate Regimes and the Relative Commodity Prices

Both p_t^c and p_t^m are Competitively Determined

Fixed Exchange Rate Regime: $\frac{dp_t^m}{ds_t} = 1, \ \frac{dR_t}{ds_t} = 0$

Flexible Exchange Rate Regime: $\frac{dp_t^m}{ds_t} = 1, \ \frac{dR_t}{ds_t} = 0, \ \frac{dVar(R_t)}{d\sigma_e^2} = 0$

p_t^c is Competitively Determined, whereas p_t^m is not:

Fixed Exchange Rate Regime:

without intertemporal dependence in sales: $\frac{dp_t^m}{ds_t} = \theta \leq or \geq 1, \ \frac{dR_t}{ds_t} = 1-\theta$

with intertemporal dependence in sales: $\bar{\theta} > \theta, \ \frac{dR_t}{ds_t} = 1-\bar{\theta}$

Flexible Exchange Rate Regime:

without intertemporal dependence in sales: $\frac{dp_t^m}{ds_t} = \theta \leq or \geq 1, \ \frac{dR_t}{ds_t} = 1-\theta,$

$$\frac{dVar(R_t)}{d\sigma_e^2} = (1-\theta)^2$$

without intertemporal dependence in sales: $\bar{\theta} \leq or \geq \theta$ *depending on* $\frac{ds_{t+i}^e}{ds_t}$

$$\frac{dR_t}{ds_t} = 1-\bar{\theta},$$

$$\frac{dVar(R_t)}{d\sigma_e^2} = (1-\bar{\theta})^2 + 2(1-\bar{\theta})(-h'(\sigma_e^2))\left(\sigma^2_{p_t^{c*}} + \sigma_e^2\right)$$

V. CONCLUSION

This paper has investigated the relationship between the nominal exchange rate regime and the volatility of relative commodity prices by examining the different mechanisms through which changes in the exchange rate pass-through to the prices of final goods. The theoretical analysis shows that the relationship depends upon both the market structure and economic agents' perceptions about the future exchange rate movements. The main conclusion of the analysis is that the exchange rate regime matters for relative price adjustment, because it affects economic agents' perception about the future exchange rate movements. When the markets for manufactured goods are less competitive than the markets for primary commodities, the volatility of relative commodity prices rises when the exchange rate uncertainty increases. If the demand in the manufactured goods markets is intertemporally dependent, even a small increase in the exchange rate uncertainty can result in potentially large costs in terms of increased relative commodity price instability.

Many economic studies have recognized the differences in the market structures between the manufactured goods and the primary commodities.[18] The model presented in this paper examines the interaction between these differences and the nominal exchange rate regimes, and the implications for the commodity terms of trade for primary products. Although the export structure in some LDCs has shifted away from primary commodities toward manufactured goods, many low-income developing countries still depend heavily on primary commodity exports. Moreover, large shares of the LDCs imports continue to be capital goods and consumer durables, whereas the share of their exports in this category is much smaller. The LDCs are important suppliers of clothing, nonferrous metals and textiles, the markets of which tend to be more competitive than those of capital goods.[19] The analysis of this paper suggests that, even as the share of the manufactured goods in their export increases, the terms of trade for many developing countries will continue to be more volatile under flexible exchange rates.

One policy implication of this study is that, besides the usual argument in favor of more rigidly managed exchange rates (such as the disciplinary effects on government policies), lower variability in nominal exchange rates may provide additional benefits of more stable terms of trade to the LDCs. Policies that help enhance the perception of exchange rate stability, including the choice of a system of pegged exchange rates, may reduce the costs associated with fluctuations in their terms of trade.

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[18]See, e.g., Dornbush (1985), Fleisig and Wijinbergen (1985), and Frankel (1986).

[19]Studies of pricing behavior in LDCs are extremely rare, probably due to lack of accurate data. In a study of Taiwanese footwear exports during 1974-85, Aw (1993) finds that the hypothesis of perfect competition can not be rejected in three out of four its major destination markets: Hong Kong, Saudi Arabia and the United States.

References

Aw, B., 1993, "Price Discrimination and Markups in Export Markets," *Journal of Development Economics*, No. 42, pp. 315-36.

Baillie, R.T., and T. Bollerslev, 1987, "The Message in Daily Exchange Rates: A conditional Variance Tale," Unpublished manuscript.

Baldwin, R., 1988, "Hysteresis in Import Prices: The Beachhead Effect," *American Economic Review*, No. 78, pp. 773-85.

——— and P. Krugman, 1989, "Persistent Trade Effects of Large Exchange Rate Shocks," *Quarterly Journal of Economics*, No. 104, pp. 635-54.

——— and R. Lyons, 1988, "The Mutual Amplification Effect of Exchange Rate Volatility and Unresponsive Trade Prices," NBER Working Paper, No. 2677.

Baxter, M., and A.C. Stockman, 1989, "Business Cycles and the Exchange-Rate Regime: Some International Evidence," *Journal of Monetary Economics*, No. 23, pp. 377-400.

Bollerslev, T., 1987, "A Conditionally Heteroskedastic Time Series Model for Speculative Prices and Rates of Return," *Review of Economics and Statistics*, No. 69, pp. 542-47.

Bourdet, Y., 1996, "Exchange Rate Regimes and Import Pricing: The Case of the Swedish Car Market," *Review of Industrial Organization*, No. 11, pp. 79-91.

Bui, N., and J. Pippenger, 1990, "Commodity Prices, Exchange Rates and Their Relative Volatility," *Journal of International Money and Finance*, No. 9, pp. 3-20.

Carlton, D.W., 1989, "The Theory and the Facts of How Markets Clear: Is Industrial Organization Valuable for Understanding Macroeconomics?" In Schmalensee and Willig (Ed.), Handbook of Industrial Organization, Vol. I (New York: Elsevier Science Publishers B.V.), pp. 909- 46 .

Cuddington, J.T., H. Liang, 1997, "Commodity Price Volatility Across Exchange Regimes," Georgetown Working Paper, No. 97-17.

Dixit, A., 1989, "Hysteresis, Import Penetration and Exchange Rate Pass-Through," *Quarterly Journal of Economics*, No. 104, pp. 205-28.

Dornbusch, R., 1976, "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*, No. 84, pp. 1161-76.

———, 1985, "Exchange Rates and Prices," NBER Working Paper, No. 1769.

Fleisig, H., and S. Wijnbergen, 1985, "Primary Commodity Prices, the Business Cycle and the Real Exchange Rate of the Dollar," CEPR Discussion Paper, No. 90.

Flood, R.R., and A.K. Rose, 1995, "Exchange Rates: A Virtual Quest for Fundamentals," *Journal of Monetary Economics*, No. 36, pp. 3-37.

Frankel, J.A., 1981, "Flexible Exchange Rates, Prices and Role of "News": Lessons from the 1970s," *Journal of Political Economy*, No. 89, pp. 665-90.

———, 1986, "Expectations and Commodity Price Dynamics: The Overshooting Model," *American Agricultural Economics*, pp. 344-48.

Froot, K.A., and P.P. Klemperer, 1989, "Exchange Rate Pass-Through When Market Share Matters," *American Economic Review*, No. 79, pp. 637-54.

Goldberg, P.K., and M.M. Knetter, 1997, "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature*, No. 35, pp. 1243-72.

Helpman, E., 1981, "An Exploration in the Theory of Exchange-Rate Regimes," *Journal of Political Economy*, No. 89, pp. 865-90.

Katz, M., and C. Shapiro, 1985, "Network Externalities, Competition, and Compatibility," *American Economic Review*, No. 75, 424-40.

Klemperer, P., 1987, "Markets with Consumer Switching Costs," *Quarterly Journal of Economics*, No. 102, pp. 375-94.

Knetter, M., 1989, "Price Discrimination by United States and German Exporters," *American Economic Review*, No. 79, pp. 198-210.

Krugman, P., 1987, "Pricing to Market When the Exchange Rate Changes," In S. Arndt and J.D. Richardson (Eds.), Real-Financial Linkages Among Open Economies, (Cambridge, Massachusetts: MIT Press), pp. 49-70.

Lastrapes, W.D., 1989, "Exchange Rate Volatility and U.S. Monetary Policy: An ARCH Application," *Journal of Money, Credit and Banking*, No. 21, pp. 66-77.

Lucas, R., 1982, "Interest Rates and Currency Prices in a Two-Country World," *Journal of Monetary Economics*, No. 10, pp. 335-60.

Mann, C., 1986, "Prices, Profit Margins, and Exchange Rates," Federal Reserve Bulletin, No. 72, pp. 366-79.

Mussa, M., 1982, "A Model of Exchange Rate Dynamics," *Journal of Political Economy*, No. 90, pp. 74-104.

———, 1986, "Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications," Carnegie-Rochester Conference Series on Public Policy, No. 25, pp. 117-214.

Nelson, P., 1970, "Information and Consumer Behavior," *Journal of Political Economy*, No. 78, pp. 311-29.

Phelps, E., and S. Winter, 1970, "Optimal Price Policy Under Atomistic Competition," In Phelps et al., Microeconomics Foundations of Employment and Inflation Theory, (New York: Norton), pp. 309-37.

Rogers, J.H., 1995, "Real Shocks and Real Exchange Rates in Really Long-Term Data," International Finance Discussion Papers, Board of Governors of the Federal Reserve System, No. 493.

Rothschild, M., and J.E. Stiglitz, 1970, "Increasing Risk: A Definition," *Journal of Economic Theory*, No. 16, pp. 302-16.

Sapir A., and K. Sekkat, 1995, "Exchange Rate Regimes and Trade Prices: Does the EMS Matter?" *Journal of International Economics*, No. 38, pp. 75-94.

Stockman, A., 1980, "A theory of Exchange Rate Determination," *Journal of Political Economy*, No. 88, pp. 673-98.

———, 1983, "Real Exchange Rates under Alternative Nominal Exchange-Rate Systems," *Journal of International Money and Finance*, No. 2, pp. 147-66.