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Three essays on imperfect competition and exchange rate pass-through

in the presence of multiple exchange rates

by

Byoung-Ky Chang

A dissertation submitted to the graduate faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY

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ABSTRACT

This dissertation consists of three essays on exchange rates and prices. The first two essays are devoted to theoretical study, and the other is an empirical study. This research analyzes the strategic interactions between international firms. The first essay (chapter II) explores the relationship between price leadership and exchange rate uncertainty. The research investigates the incentives to lead and follow in a model in which exporting firms have the different degrees of exchange rate uncertainty. As exchange rate uncertainty increases, firms will take a flexible strategy as a dominant strategy. Over certain ranges of exchange rate variability, only one firm has a flexible strategy as its dominant strategy, and the other firm is induced to be a price leader, resulting in a dominant strategy Nashequilibrium. Which firm will be the price leader depends on the mark-up and substitutability of products. The particular attention of this research is also given to the implication of exchange rate variability for exchange rate pass-through.

The second essay (chapter III) focuses more on brand loyalty. In many markets, consumers who have previously purchased from one firm have (or perceive) costs of switching to a competitor's product, even when the two firm's products are functionally identical. I explicitly analyze the effect of rival exchange rate for diverse cases (perfect foresight for exchange rates, imperfect foresight for exchange rates, perfect capital mobility, and imperfect capital mobility). In the case of the imperfect foresight, the exchange rate pass-through is affected by exchange rate uncertainty. Due to the brand loyalty, current price decisions will affect future profits through market shares. The expected future profit is

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affected by expected competition situations that depend on the interactive movement of future exchange rates.

In the last essay (chapter IV), I test the strategic behaviors between exporting firms with simultaneous estimation techniques (three stage least squares). Exchange rate passthrough is estimated, and the effect of the rival exchange rate is emphasized. Also, I demonstrate the problem associated with tests which use a trade-weighted exchange rate. Most importantly, this research highlights the importance of market structure in exchange rate pass-through studies.

I. GENERAL INTRODUCTION

I.1 Introduction

Since the collapse of the Bretton-Woods agreement in the spring of 1973, a considerable increase in the variation of bilateral exchange rates has occurred. For example, the dollar-mark rate has fluctuated by as much as 20 percent within periods of several months or less. Figure I-1 shows the fluctuations of exchange rates in the major currencies per U.S. dollar from January 1975 to November 1998.¹ Such fluctuations have raised many questions and studies in relation to exchange rate uncertainty and changes; how much have the risks associated with international transactions increased and what impact has the increase in risk had on those transactions? In another side, how have the changes in the exchange rate influenced international firms' pricing behaviors (i.e., exchange rate pass-through)? The fields related to exchange rate movement that have been studied and analyzed by theoretical and empirical researchers are very broad.

The studies on the interaction of exchange rates and prices are important not only for what it may tell us about competition in international trade, but also because of its implications for the effect of currency appreciation or depreciation on the trade balance. In recent years, the existence of large and persistent external imbalances in many countries has prompted a new debate on the role of exchange rate changes in balance-of-payments adjustment processes. In the countries participating in the exchange rate mechanism of the

¹ Major currencies are Japanese yen, Canada dollar, U.K. pound, and Germany deutschmark. They are normalized in the following way; (nominal exchange rate - mean)/standard deviation.



Figure I-1. Trends of the major currencies per U.S. dollar normalized

European Monetary System, insistence on keeping nominal exchange rates fixed and on avoiding parity realignments is apparently predicated on the idea that exchange rate changes can not durably alter relative price competitiveness, or else that price competition is not a determinant factor. Similarly, the dramatic evolution of the exchange rates of major currencies over the last ten years seems to have had but a very modest impact on the external balances of those countries.

The existence of a stable relationship between exchange rates and traded good prices on the various national markets is an essential ingredient in external adjustment processes and a major channel of international transmission mechanisms. Recently, several theoretical analyses have questioned the traditional hypotheses about the repercussion of exchange rate variations on traded good prices. In general, however, empirical tests of the various rival hypotheses have not been very conclusive, mainly due to the fact that they have been performed on aggregate trade price data; aggregation tends to alter the statistical characteristics of individual price series. In order to circumvent some of these difficulties, I study firms' pricing behaviors at the level of specific industries.

Internationally traded manufactured goods are typically viewed as being highly differentiated and mainly sold in imperfectly competitive and segmented markets where arbitrage is costly, and mostly unprofitable. There is a considerable amount of empirical evidence to support this view about manufactured goods.² The theory of intra-industry trade of Krugman (1979), Lancaster (1980), and Helpman (1981) lends further support to the view that most traded manufactured goods are imperfectly substitutable. Therefore, the perfect competition model and monopoly model may have some limitations in understanding the real world of trade.

Nevertheless, there is little research that investigated the effect of exchange rate uncertainty using an imperfect competition model. Moreover, most existing literature ignores or strongly restricts the demand side of export and the competition situation in the export market. Based on this observation, I analyze the effect of exchange rate uncertainty on international trade using a model of imperfect competition. Furthermore, my model allows me to study the effect of rival's exchange rate considering the demand of export explicitly. There is no oligopoly literature that considers a rival's bilateral exchange rate, ignoring the possible situation that an exporter faces other foreign firms as rivals. Because the models in the existing literature deal with a foreign firm and a domestic firm, only a single bilateral exchange rate is involved in. However, if other foreign firms exist in the market, the rival

² See Norman (1975), Isard (1977), Knetter (1989), Marston (1990), and Kasa (1992).

countries' exchange rates and exchange rate variabilities also may affect the firm's strategic behavior.

On the other hand, the theoretical advances in the exchange rate pass-through literature can be viewed as an off-shoot of recent developments in the broader literature that aims to incorporate factors such as imperfect competition, product differentiation and the role of market structure (for instance, Dornbusch, 1987; Krugman, 1987,1989; Baldwin,1988; Baldwin and Krugman, 1989; Dixit, 1989a, 1989b; Fischer, 1989; Froot and Klemperer, 1989). However, these exchange rate pass-through studies also ignore the effect of rival exchange rate in their models. I will analyze the exchange rate pass-through issue, considering explicitly the change of rival's exchange rate, and show that ignoring the rival exchange rate movement can mislead the empirical studies of exchange rate pass-through.

My model is different from earlier studies in several regards. First, unlike other studies, essays in this dissertation deal with two or more foreign firms, including two or more bilateral exchange rates. Although the existence of domestic firms does not change the main economic points, I implicitly assume that the substitutability between export goods is much higher than the one between the export goods and the domestic good. Indeed, in the international export market, an exporter may face other foreign firms rather than domestic firms as major rivals. Then, we can analyze the effects of own and rival's exchange rates and their variabilities through the strategic interactions between international firms. Most of the literature ignored what could be called third-country effects. Second, a new industrial organization theory, focusing on game-theoretic analysis of the strategic behavior of rational agents within markets and firms, is applied to the international trade issues. Most of world

trade is in the products of industries that we have no hesitation in classifying as oligopolies when we see them in their domestic aspects. However, only a handful of papers have attempted to apply models of imperfect competition to international trade issues. Finally, in this dissertation I incorporated the exchange rate uncertainty issue into my model. Introduction of uncertainty represents a step towards greater realism. In a regime of fixed exchange rates or flexible exchange rates but with fully anticipated changes the differences between international transactions and domestic transactions have no real consequences for the behavior of exporters and importers of commodities. However, for more than a decade there has been a significant increase in exchange rate volatility which may affect international trade and pricing decisions.

I.2 Dissertation organization

This dissertation consists of three self-contained essays. Each essay contains its own introduction, sections on theory and applications, and conclusion. All references are in one reference section at the end of the dissertation. The first two essays are devoted to theoretical study, and the third is an empirical study. In the first essay (chapter II), I study the relationship between price leadership and exchange rate uncertainty. The paper investigates the incentives to lead and follow in a model in which exporting firms have different degrees of exchange rate uncertainty. Focusing on brand loyalty, the second essay (chapter III) investigates exchange rate pass-through under exchange uncertainty. In many markets, consumers who have previously purchased from one firm have (or perceive) costs of switching to a competitor's product, even when the two firm's products are functionally

identical. Finally, in the third essay (chapter IV), I test the strategic behavior between exporting firms with simultaneous estimation techniques (three stage least squares), using 7digit TSUSA (Tariff Schedule of the United States Annotated) data. Exchange rate passthrough is estimated, and the effect of the rival exchange rate is emphasized.

I.3 Literature review

I.3.1 Price leadership

The recent literature on price leadership has identified a number of factors facilitating the existence and identification of a price leader. Holthausen (1979) provided a model in which the major determinant of the identity of a leader is the firms' attitudes towards risk. In his model, there are n+1 firms, each having a concave von Neumann-Morgenstern utility function with profit as the argument. Firms also sell in product markets other than the one under consideration. Each firm may decide whether to continue charging its original price or to change its price under the uncertainty of rival firms' action. Holthausen (1979) showed that if all firms have a common utility function U, which exhibits decreasing absolute risk aversion, the firm with the greatest profit from other sources (with the greatest profit cushion against possible loss) can best afford the role of price leader. The main result is that larger, less risk averse firms are more apt to gamble on changing prices than are smaller, more risk averse firms.

Eckard (1982) and Rotemberg and Saloner (1990) examined the role of informational advantages in generating leadership. Eckard (1982) argued that firms with large market

shares will be relatively better informed about demand conditions and thus make its price response first. The cause of sudden unexpected change in sales cannot be immediately clear to the firm because such fluctuations in firm and industry demand occur normally due to both random event and demand change. With an assumption that information available to the firm regarding current industry demand is only its own recent sale experience, the lower the firm's share, the higher is the variance of its industry sales estimate because of uncertainty regarding its actual share of industry sale or, alternatively, a lack of knowledge of the sales experience of other firms relative to its own. Thus, smaller firms in the industry which take a long time to detect shifts in industry demand occasionally follow the leader. While Eckard's (1982) study did not use an analytical tool, Rotemberg and Saloner (1990) modeled a differentiated product duopoly in which the firms are asymmetrically informed. The characteristic of their model is that since the designated price leader typically earns higher profits, it might be expected that both firms would vie for the leadership position. This characteristic is due to the assumption of a shock which is beneficial to one firm and harmful to the other firm. The more informed firm, acting as a price leader, picks prices which raise its own profits at the expense of overall industry profits. At that time, the less informed firm prefers to be a follower if the variance of a common disturbance (which has the same effect on both demands) exceeds three times the variance of an idiosyncratic disturbance (which raises the demand of one firm by the same amount as it reduces the demand for the other firm). The benefit from information is dominant over a follower disadvantage.

Deneckere and Kovenock (1992) focused on size, as measured by capacity, as a determinant of leadership. They analyzed duopolistic price leadership games in which firms

produce a homogenous good and have a capacity constraint. They showed that when capacities are in the range where the simultaneous-move price setting game (with efficiently rationed demand) yields a mixed-strategy solution the large firm is indifferent between being a leader, a follower, or moving simultaneously. However, the small firm, while indifferent between being a leader and moving simultaneously, strictly prefers to be a follower. This motivates the discussion of games of timing with *ex-post* inflexible prices in which the large firm becomes an endogenously determined price leader. Deneckere, Kovenock and Lee (1992) further applied the notion of Deneckere and Kovenock (1992) by considering a price setting game in which firms have loyal consumer segments, but cannot distinguish them from price sensitive consumers. They constructed two games of timing of price announcements with *ex-post* inflexible prices in which the firm with the larger segment of loyal consumers becomes an endogenously determined price leader.

Although Albaek (1990) and Spencer and Brander (1992) considered a quantity game, rather than a price game, with cost uncertainty and demand uncertainty respectively, their studies are more comparable to our research, but they are different in some important respects, as described later in this paper. Albaek (1990) showed that a natural Stackelberg situation exists (does not exist) both when the goods are substitutable and when they are complements if quantities (prices) are the strategies. However, the results of Albaek (1990) are dependent on the assumption that information sharing is prohibited and their cost variances are sufficiently different. The firm that faces the large variance of cost is willing to be a quantity leader and reveals their cost structure to the rival. Then, under some conditions the other firm may prefer being a follower because he can explore the cost uncertainty.

Spencer and Brander (1992) considered several related strategic duopoly settings in which demand uncertainty creates an 'option value' from retaining flexibility by delaying investment or output decisions until after uncertainty is resolved. The value of flexibility must be weighed against the strategic value of pre-commitment, yielding a trade-off between flexibility and pre-commitment. They derived the conditions for Nash equilibrium with a linear demand and a homogeneous good. They also considered the possibility of endogenous Stackelberg leadership with firm specific marginal cost uncertainty. However, the emergence of Stackelberg leadership is not completely straightforward. It is not the case that simply allowing high variance for one firm and low variance for the other will lead to commitment by the low variance firm and flexibility by the high variance firm.

I.3.2 Theoretical studies on exchange rate pass-through

The theoretical explanations of incomplete exchange rate pass-through (PT) have emphasized the role of market structure first, followed by production differentiation. In this section, I concentrate on exchange rate pass-through theories rooted in imperfect competition.³ In an imperfectly competitive market, price is not set at marginal cost, and firms take a position to charge a mark-up on costs, which may lead to above normal profits even in the long run. The important issue is how this mark-up over marginal cost might vary in response to an exchange rate change.

³ Menon (1995) reported the many empirical supports for the claim that imperfect competition prevails in international trade markets.

Dornbusch (1987) considered a Cournot oligopoly model to focus on features of market structure and explored Dixit and Stiglitz's (1977) and Salop's (1979) models to capture the effect of imperfect substitutability and product differentiation on the price response to exchange rate changes. First, Dornbusch (1987) considered the case of a Cournot industry with a linear demand curve and constant marginal costs, and showed that the degree of pass-through is positively related to the ratio of the number of foreign firms to total firms and on the total number of firms. Then, with the Dixit-Stiglitz (1977) model and Salop's (1979) model he found that the degree of pass-through is directly related to the degree of substitutability between the domestic and imported goods. However, unlike my model, there exists only a bilateral exchange rate in his model because the foreign firms come from the same source country.

Close review of the Cournot oligopoly literature (Durnbusch ;1987) may be useful because it is probably the most widely accepted benchmark. There are n domestic suppliers and n^{\bullet} foreign firms with respective sales of q and q^{\bullet} per firm. The profit of each firm is given by:

 $\Pi = (p - w)[a - bp - (n - 1)q - n^{\bullet}q^{\bullet}]$ for domestic firms, $\Pi^{\bullet} = (p / e - w^{\bullet})[a - bp - nq - (n^{\bullet} - 1)q^{\bullet}]$ for foreign firms,

where $w(w') = \text{constant marginal cost of domestic (foreign) firms. Assuming firms simultaneously choose output levels, it is readily shown that the common equilibrium price in the industry is given by:$

$$p = (nw + n^{\circ}ew^{\circ}) / [N + a / bN]; \quad N \equiv n + n^{\circ} + 1.$$

The elasticity of the equilibrium price with respect to the exchange rate is:

$$\varphi = (\frac{n}{n+n+1})(\frac{ew}{p}).$$

We can see that the degree of pass-through is an increasing function of the ratio of foreign to domestic firms and $\lim_{n \to \infty} \varphi = \frac{ew}{p} \le 1$.

Silbert (1992) extended Dornbusch's (1987) analysis with general demands and linear cost curves and examined the effects that different degrees of collusion (e.g., Cournot behavior, joint profit maximization, and competitive firm behavior) and market shares of foreign firms have on pass-through. Sibert (1992) found that Dornbusch's result that passthrough is increasing in the number of foreign firms generalizes to a variety of behavioral assumptions.

Fischer (1989) considered the case where firms are Bertrand competitors (or Nash price setters) with a homogeneous good and where foreign firms produce for both the home and export market and can not price discriminate. The timing of firms' decisions is as follows. First, firms simultaneously announce binding offer prices in their own currencies. After the exchange rate is realized, world demand is allocated to the best offer. He found that given an expected appreciation, expected pass-through is seen to be higher if the domestic market is monopolistic relative to the foreign market; or home monopoly tends to increase pass-through while foreign monopoly tends to decrease it.

More recent innovations have extended the oligopoly pricing literature as it relates to exchange rate by focusing on ways of incorporating international competitive pressures into the determination of the optimal price. Froot and Klemperer (1989) investigated the passthrough from exchange rates to import prices when firms' future demands depend on current market shares and consider how temporary versus permanent exchange rate changes effect this decision. They employed a simple two-period model where market share in the first period will affect the price response to an appreciation in the second period. They showed that while foreign firms may either raise or lower their dollar export prices when the dollar appreciates temporarily (i.e., the pass-through may be perverse), an appreciation viewed as permanent leads to foreign firms pricing very aggressively to gain an increase in market share.

Tivig (1996) extended Froot and Klemperer (1989) by deriving a sufficient condition for perverse pass-through and a necessary condition for normal pass-through. These conditions become necessary and sufficient under the (possibly more realistic) assumption of imperfect capital mobility and they are robust to changes in the game structure (e.g., they do not hinge on the assumption of open- or closed-loop pricing). He also analyzed explicitly future, i.e. second-period, price effects of a temporary change in the exchange rate. Whereas the price of the domestic product preserves its initial direction of change, the price change of the imported good is partially reversed in the second period.

The approach that emphasizes dynamic and inter-temporal behavior also underlies the "hysteresis" models of pricing (Baldwin, 1988; Baldwin & Krugman, 1989; Dixit, 1989; Krugman, 1989). These models investigate the circumstances under which a temporary exchange rate fluctuation is likely to cause a permanent (and maybe hysteretic) price change. Since price reactions are usually derived from changes in aggregate supply via entry or exit of competitive firms, the focus is on entry and exit instead of strategy. The hysteresis effect suggests that competition in the market will remain unchanged as long as exchange rates

fluctuate within a set band, and that this band will be greater the higher the costs associated with entry and exit (i.e., irretrievable sunk costs). This will result in a lower rate of exchange rate pass-through as firms fight to either stay in the market or deter entry. If the exchange rate moves outside this band, however, then the entry and exit decisions which follow permanently alter the structure of the market. That is, the new firms that have entered the market will not leave easily, and the firms that have left may never re-enter. This may produce a structural break in the observed pass-through relationship, as the new competitive structure of the market may not be consistent with the historical rate of exchange rate pass-through.

I.3.3 Empirical studies on exchange rate pass-through

There have been over 50 published empirical studies on exchange rate pass-through over the last two decades. In those studies, a variety of methodology, model specification, variable construction and data were used. In this section, I will review the literature briefly rather than provide a comprehensive survey⁴, paying attention to the used data and major findings.

I.3.3.1 Data used

In the previous empirical studies there have been few attempts to test exchange rate pass-through at lower levels than the two-digit SIC (Standard Industrial Classification), SITC (Standard International Trade Classification), ISIC (International SIC), or TSUSA (Tariff Schedule of the United States Annotated) levels. The use of this type of highly aggregated

⁴ Menon (1995) provided a broad and comprehensive survey of exchange rate pass-through literature.

data generates a problem with aggregation bias. This bias results principally from the heterogeneity of the products contained within such wide-ranging categories. Only a handful of the studies have attempted to examine somewhat more disaggregated data. While Dunn (1970); Kreinin, Martin and Sheehey (1987); Hooper and Mann (1989) tested the exchange rate PT with 3- to 4- digit SIC, Feenstra (1989), Knetter (1989), and Marston (1989) used 5- to 7- digit SITC.

Many researchers pointed out a number of problems relating to the data used in previous studies. Those arguments relate mainly to the common resort to proxies such as unit values, and the lack of studies that use data disaggregated at the product level. Goldstein and Khan (1985) stated "... disaggregation is always better ..." if such data are available. They even complained that in most studies when the authors recognize a problem with aggregation bias there is no attempt to disaggregate beyond the one- or two-digit level of the data classification scheme being used. This is still a very high level of aggregation and calls into question the results of such studies. Mann (1989) observes that, "Most recent empirical work is grounded in models of imperfect competition, yet tested using aggregate data. This mismatch would be less worrisome if the industry and aggregate data behave similarly." This use of aggregate data to examine micro-level models is troublesome and leads to the decision to use 7-digit TSUSA data in the present study.

Like the measurement of the import price, the measurement of the exchange rate has attracted some attention in the literature. The use of aggregated data has led researchers to utilize various types of composites, or baskets, of exchange rates of major trading countries as exchange rate variables in their pass-through models. Most studies employ a trade

weighted exchange rate index, highlighting the importance of factors such as the number of currencies included and the weighting schemes employed to construct this index. These factors are likely to bear significantly on the degree to which the index understates or overstates the exchange rate fluctuation. Only Athukorara and Mennon (1994) employ a currency-contract-weighted exchange rate. Meanwhile, some studies using disaggregated data use bi-lateral exchange rate. Since all exchange rates are bilateral by their nature and one of the objectives of my research is to examine import pricing behavior at more micro levels than previous studies, the decision was made to examine U.S. import prices on a bilateral basis. Unlike other studies, my model employs rival exchange rates explicitly.

I.3.3.2 Studies using aggregated data

In the majority of studies, exchange rate pass-through (PT) is incomplete. Only a small number of studies reported complete or close to complete PT. However, there are significant differences in the estimates of PT reported in different studies for even a given country. The US is the best example of this since it has been so far the most thoroughly studied country. There are several studies that estimate the aggregate PT of exchange rate to import prices covering roughly the same period, starting around 1970 and ending 1988. The estimates range from a low of 48.7 percent reported by Alterman (1991) to a high of 91 percent reported by Helkie and Hooper (1988). Klein and Murphy (1988) and Moffet (1989) reported 85% and 50% respectively. Given that there is little difference between these studies in terms of commodity or time coverage, the diversity in PT estimates would seem to stem primarily from differences in method, model specification and variable construction.

The multi-country studies mainly found significant differences in the exchange rate PT across countries. However, the multi-country studies provide conflicting results. Kreinin (1977) found that PT tends to vary inversely with the size of the country. The individual country estimates from import pass-through of a 10 percent depreciation are as follows; US - 50%, Germany - 60%, Japan - 80%, Canada - 90%, Belgium - 90%, and Italy - 100%. On the other hand, Khosla and Teranishi (1989) found that PT is almost complete for the larger economies such as the US and Japan (87% and 92%, respectively), but it was very low for the smaller economies such as Indonesia and the Philippines (27% and 17%, respectively). Spitaeller (1980) showed that long-run pass-through is complete for all countries (i.e., France, Netherlands, Japan, UK, and US), having an exception of Germany which remains at 73 percent.

I.3.3.3 Studies using disaggregated data

Studies that have employed a disaggregated approach found that exchange rate passthrough (PT) tends to vary quite significantly across industries or product categories. Branson and Marston (1989), Feenstra (1989), Knetter(1989), and Menon (1992, 1993) found significant differences in PT across products raising the concern of possible aggregation bias. For Japan exporting to the US market, Feenstra (1989) showed the PT ranged between 69.7 % (for Truck) and 105.3 % (for Cycles), while Branson and Marston showed that PT varied quite significantly across 13 manufacturing industries, ranging between 20 and 50 percent.

Only a small number of the disaggregated studies attempted to formally explain interindustry differences in PT. Kreinin et al. (1987) showed that PT is positively related to capital intensity and negatively related to labor intensity with annual 4 digit ISIC data for US

imports from the UK, Germany, and Japan. Meanwhile, Feinberg (1989, 1991) who studied PT to domestic prices reported that PT is much lower for highly capital intensive and concentrated industries and those protected by extensive barriers to entry. However, in the early paper (1989), an estimated coefficient of seller concentration is not significantly different from zero. Phillips (1988) attempted to explain inter-industry differences in PT using industrial organization variables, resulting in weak supports statistically.

More highly disaggregated data such as 7-digit SITC level was employed by Feenstra (1989), Knetter (1989), and Marston (1989). Feenstra (1989) examined three U.S. imports from Japan that were disaggregated to an approximation of the 7-digit SITC level. Feenstra's regression equation included explanatory variables other than the exchange rate and its polynomial lags. For example, he included a proxy for foreign factor prices (Japanese domestic wholesale prices for each product as a surrogate for production costs), a proxy for income (total U.S. expenditure on each product through an instrumental variable), and a proxy for the price of a domestic substitute (U.S. consumer prices or the U.S. price of steel). For Japan exporting to the US market, Feenstra (1989) showed the PT ranges from 60.7 to 105.4 %. His major finding was that pass-through of exchange rate and tariffs are symmetric.

Marston (1989) showed that PT varied quite significantly across 17 manufacturing industries, ranging between -11 and 72 %. Marston used the export shares of each product to calculate a weighted average exchange rate variable based on the exchange rates of the major importers of the product. This means that he cannot determine if there are differences in pass-through behaviors across countries as all importing countries are treated as one. In his log-log OLS regression, all variables were expressed as first differences of their log values to

ameliorate problems with spurious correlation between variables. Marston did include explanatory variables other than the pass-through variables (e.g., foreign (non-Japan) industrial production).

Knetter (1989) examined pass-through behavior for six U.S. exports and ten German exports at the 7-digit SITC level (the data for German exports were from German sources but were equivalent to the 7-digit SITC level). He used a panel data set consisting of export prices over time and across markets that allows him to control for shifts in the marginal cost of production that are unobservable but common to all markets and to isolate discriminatory country-specific effects. Knetter found that German export prices appear to be much more sensitive to exchange rate fluctuation. Adjustment tends to be stabilizing with respect to the local currency price in the destination market. However, the evidence indicates that U.S. export prices are rather insensitive to exchange rate fluctuations, and that when price adjustment does occur it frequently amplifies the effect of exchange rate fluctuations (perverse pass-through).

II. PRICE LEADERSHIP AND EXCHANGE RATE UNCERETAINTY: THE IMPLICATIONS FOR EXCHANGE RATE PASS-THROUGH

II.1 Introduction

In general, if duopoly firms have upward-sloping (downward-sloping) reaction functions, each firm will prefer to be a follower (a leader); that is, in the price game, each firm prefers that the other firm is a price leader while it behaves as a price follower. It is well known, in the price game, there exist two Nash-equilibria (leader, follower; follower, leader). However, who will be the price leader is an open question. Nevertheless, there is a large institutional literature documenting the prevalence of price leader-follower behavior.¹ The existence and identification of a price leader has been a major research topic over the past decade. The recent literature on price leadership has identified a number of factors facilitating the existence and identification of a price leader, such as firms' risk attitude, information advantages, and market shares.

In international trade decisions, a major source of uncertainty is due to exchange rate movements. Exporting firms based in different countries have faced notably large fluctuations in currency values, particularly since the advent of floating exchange rates. This chapter investigates the incentives to lead and follow in a model in which exporting firms have different degrees of exchange rate uncertainty. The preference of pre-commitment over a flexible strategy may depend upon the variances and covariance of exchange rates. I show that as exchange rate uncertainty increases firms will take a flexible strategy as a dominant

¹ See Scherer (1980) and Rotemberg & Saloner (1990).

strategy, because the first mover advantage compared to the flexible Bertrand equilibrium will be dominated by the uncertainty disadvantage.² Under high exchange rate variability, both firms have a flexible strategy as a dominant strategy and an equilibrium in which neither firm commits its price will be a unique Nash-equilibrium (a dominant strategy Nashequilibrium). Meanwhile, over certain ranges of exchange rate variability only one firm will have a flexible strategy as its dominant strategy, and thus the other firm will be induced to be a price leader, resulting in a price Stackelberg Nash-equilibrium. Which firm will be the price leader depends on the mark-up and substitutability of products. I obtain a direct algebraic representation of the commitment cost in the case of linear demand and show that high levels of exchange rate uncertainty can change the Nash-equilibrium (NE).

My model allows both firms the opportunity to move before uncertainty is resolved. I will be, therefore, able to characterize the conditions under which the first mover arises endogenously as a response to the trade-off between flexibility and commitment. I will show that asymmetries in firm-specific exchange rate uncertainty provide a natural reason for one firm to act before another does.

The particular attention of this research is paid to the implication of pricing behavior and exchange rate variability for the short-run exchange rate pass-through. If the firm chooses the role of price leadership, exchange rate pass-through (PT) is zero by precommitment.³ I will also show that the exchange rate PT with price leadership is less than that of a flexible Bertrand model. As the variability of exchange rates change, exchange rate

² See below for details and definitions

³ Of course, the expected change of exchange rate affects exchange rate PT.

pass-through varies because the game solution and the roles of firms are changed. As I show later, generally the larger is exchange rate variability, the larger is the exchange rate PT.

This chapter proceeds as follows. The basic model and game structure are presented in section 2. In section 3, I derive the Nash-equilibrium, conditioning on variances and covariance of exchange rates, whereas section 4 constructs simulation studies. In section 5, I discuss the implication for short-run exchange rate PT and concluding remarks are provided in section 6.

II.2 The model

Let us consider a heterogeneous duopoly with price strategies in which a country j firm and a country k firm export the differentiated goods j and k to the third market (say U.S.), respectively.⁴ For simplicity, I assume that the firms are symmetric except for exchange rates and marginal costs. The demand function for firm *i* is denoted as $q_i = a - bp_i + cp_s$, where p_i is own price in dollar, and p_s is rival price in dollar. Hence, both goods are substitutes for each other, and further we assume each good is produced with constant marginal cost d_i in own currency.⁵ Each firm's profit in local currency units is $\Pi_i = (e_i p_i - d_i)(a - bp_i + cp_s)$, where i, s = j, k $i \neq s$ and e_i is the exchange rate defined in units of country *i* currency per dollar. I make the following assumptions with respect to the model parameters: $a, b, c, d_i, e_i > 0$, b > c (the own price elasticity is higher than the cross price elasticity), and $E[e_i]$ is normalized as one. I abstract from the shut down options by

⁴ Although the existence of domestic (U.S.) firms does not change the main economic points, we implicitly assume that the substitutability between export goods is much higher than the one between an export good and a domestic good. Indeed, in the international export market, an exporter may face other foreign firms rather than domestic firms as major rivals.

⁵ The foreign producer's home market is separated on the technological side and may thus be neglected.

assuming that both firms would always produce positive outputs. The only question is whether to pre-commit or wait. The firms are assumed to be risk neutral so that preference relations are determined entirely in terms of expected profits. There are two periods in the game. In the first period, each firm chooses either (1) to set its price, or (2) to wait to set price until the exchange rates are known. The outcome of this decision is known by its rival. In the second period, uncertainty is resolved and the remaining decisions are made. If both firms have already made price decisions, no further decisions are made, and sales take place. If only one firm has pre-committed its price, the other firm chooses its follower price. If neither firm pre-committed its price, each chooses its *ex post* Bertrand price level.

Here, I use similar definitions with Spencer and Brander (1992). If both firms precommit to price before uncertainty is resolved, then the price equilibrium will be of the Bertrand type. I refer to this as the 'committed Bertrand' regime. If both firms wait to price until uncertainty is resolved, then the price equilibrium will also be of the Bertrand type but with realized exchange rates. I refer to this as the 'flexible Bertrand' regime. If one firm commits its price before exchange rates are revealed, while its rival chooses price after exchange rates are revealed, then sequential rationality implies that the price equilibrium will be of the Stackelberg price leader-follower type. The firms are referred to as the committed leader and the flexible follower respectively.

Four cases may occur because each firm has two options (commit and flexible). The possible cases are as in Table II-1.

	U		
<u> </u>	Firm j	Firm k	
Case A: $p_j, p_k \rightarrow e_j, e_k$	committed Bertrand	committed Bertrand	
Case B: $p_j \rightarrow e_j, e_k \rightarrow p_k$	committed leader	flexible follower	
Case C: $p_k \rightarrow e_j, e_k \rightarrow p_j$	flexible follower	committed leader	
Case D: $e_j, e_k \rightarrow p_j, p_k$	flexible Bertrand	flexible Bertrand	

Table II-1. Possible game structures

I examine and compare the *ex ante* expected profits for each case. For notational simplicity, I define some new variables as follows:

 $d = (d_j d_k)^{1/2}$, (geometric mean of marginal costs); $\rho_i = \frac{p_i}{d_i}$, (price over marginal cost);

$$X_i \equiv \rho_i - 1 = \frac{p_i - d_i}{d_i}$$
, (I will call it mark-up); $\phi \equiv \frac{a}{bd}$, $\delta \equiv \frac{c}{b}$, (approximation of

substitutability); $n_i \equiv \frac{d}{d_i}$, (inverse of relative marginal cost); $R_i \equiv \frac{1}{e_i} - 1$, $R_i^e \equiv E[\frac{1}{e_i} - 1]$,

$$N_i^e \equiv E[\frac{e_i}{e_s} - 1]$$
, and $S_i^e \equiv E[\frac{e_i}{e_s^2} - 1]$ where $i, s = j, k \ i \neq s$.

Under the assumption that both firms pre-commit their prices, each firm's problem is $\underbrace{Max}_{X_i} E[\Pi_i] = E[bd_i^2(e_iX_i + e_i - 1)(\phi n_i + \delta n_i^2 - 1 - X_i + \delta X_s n_i^2)],$ using the new definitions.

The first-order condition of each firm is $\frac{\partial E[\Pi_i]}{\partial X_i} = 2X_i - \delta n_i^2 X_s - \phi n_i - \delta n_i^2 + 1 = 0.$

Solving the associated first-order condition yields the equilibrium $X_{i}^{L,L}$ and expected profits. Similarly, if both firms do not commit their prices, each firm's problem is

$$\underset{X_i}{Max} \prod_i = bd_i^2 (e_i X_i + e_i - 1)(\phi n_i + \delta n_i^2 - 1 - X_i + \delta X_s n_i^2), \text{ and the first order condition is}$$

$$\frac{\partial \Pi_i}{\partial X_i} = 2X_i - \delta n_i^2 X_s - \phi n_i - \delta n_i^2 + 1 - R_i = 0.$$
 Then, we can get the equilibrium $X_i^{F,F}$ as a

function of the rival exchange rate, from an *ex-ante* perspective. We can thus obtain expected profits.

Next, we examine the expected profit of the leader (i) and the follower (s) under the assumption that one firm commits its price before exchange rates are revealed, while its rival chooses price after exchange rates are revealed. This involves first setting out the decision of the price follower, whose maximand is:

$$\underset{X_s}{\text{Max}} \Pi_s = bd_s^2 (e_s X_s + e_s - 1)(\phi n_s + \delta n_s^2 - 1 - X_s + \delta X_s n_s^2).$$
 By solving the first-order

condition, we can get the price follower's reaction function as a function of X_i :

$$X_{s} = \frac{1}{2}(\phi n_{s} + \delta n_{s}^{2} - 1 + R_{s} + \delta n_{s}^{2} X_{i}).$$
(II-1)

Ex ante, the leader maximizes

$$E[\Pi_{i}] = E\{bd_{i}^{2}(e_{i}X_{i} + e_{i} - 1)[\phi n_{i} + \delta n_{i}^{2} - 1 - X_{i} + \frac{1}{2}\delta n_{i}^{2}(\phi n_{s} + \delta n_{s}^{2} - 1 + R_{s} + \delta n_{s}^{2}X_{i})]\}.$$

Solving the associated first-order condition, we can get the equilibrium mark-up of the leader:

$$X_{i}^{L,F} = X_{i}^{L,L} + \frac{\delta^{2} X_{i}^{L,L} + \delta n_{i}^{2} N_{i}^{e}}{2(2 - \delta^{2})}.$$
 (II-2)

Then, inserting equation (II-2) into equation (II-1), we can get the equilibrium mark-up of the follower:

$$X_{s}^{F,L} = X_{s}^{L,L} + \frac{\delta n_{s}^{2}}{2} (X_{i}^{L,F} - X_{i}^{L,L}) + \frac{R_{s}}{2}.$$
 (II-3)

	Mark-up	Expected profit
Committed Bertrand (Case A)	$X_{i}^{I,I} = \frac{\phi(2+\delta)n_{i} + \delta n_{i}^{2} + \delta^{2} - 2}{4 - \delta^{2}}$	$E[\Pi_{i}^{L,L}] = (bd_{i}^{2})(X_{i}^{L,L})^{2}$
Committed leader (Case B for firm j, case C for firm k)	$X_{i}^{L,F} = X_{i}^{L,L} + \frac{\delta^{2} X_{i}^{L,L} + \delta n_{i}^{2} N_{i}^{\epsilon}}{2(2 - \delta^{2})}$	$E[\Pi_{i}^{L,F}] = E[\Pi_{i}^{L,I}] + bd_{i}^{2} \{ \frac{\delta^{4}(X_{i}^{L,L})^{2} + \delta^{2}n_{i}^{4}(N_{i}^{s})^{2} + 2\delta n_{i}^{2}(4 - \delta^{2})X_{i}^{L,I}N_{i}^{s}}{8(2 - \delta^{2})} + \frac{\delta n_{i}^{2}(N_{i}^{s} - R_{i}^{s})}{2} \}$
Flexible follower (Case C for firm j, case B for firm k)	$X_{i}^{F,L} = X_{i}^{L,L} + \frac{\delta n_{i}^{2}}{2} (X_{i}^{L,F} - X_{i}^{L,L}) + \frac{R_{i}}{2}$	$E[\Pi_{i}^{f,l}] = E[\Pi_{i}^{l,l}] + bd_{i}^{2} \{X_{s}^{l,l} \delta n_{i}^{2} J_{s} + \frac{(\delta^{2} n_{i}^{4} J_{s}^{2} + R_{i}^{e})}{4}\}, \text{ where } J_{i} \equiv \frac{\delta^{2} X_{i}^{l,l} + \delta n_{i}^{2} N_{i}^{e}}{2(2 - \delta^{2})}$
Flexible Bertrand (Case D)	$X_{i}^{F,F} = X_{i}^{L,L} + \frac{2R_{i} + \delta n_{i}^{2}R_{i}}{4 - \delta^{2}}$	$E[\Pi_{i}^{F,F}] = E[\Pi_{i}^{I,I}] + bd_{i}^{2} \{ \frac{(2-\delta^{2})^{2} R_{i}^{e} - 2(2-\delta^{2})\delta n_{i}^{2} (R_{s}^{e} - N_{i}^{e}) + \delta^{2} n_{i}^{4} (S_{i}^{e} - 2N_{i}^{e})}{(4-\delta^{2})^{2}} + \frac{2\delta n_{i}^{2} N_{i}^{e} X_{i}^{I,I}}{(4-\delta^{2})} \}$

Table II-2. Mark-up and *Ex-ante* profit for each case

Finally, we can get the expected profits inserting (II-2) and (II-3) into profit functions. Table II-2 summarizes the equilibrium mark-up and expected profit of firm i in each case. For cases A and D both firms have the same one, whereas cases B and C will be interchanged with each other, because firms are symmetric.

II.3 Nash-equilibrium and price leadership

There exist two Nash-equilibria in the price game with certainty. Under certainty, each firm's best strategy changes, depending on its rival strategy. If the rival firm were to commit its price, then the firm would like to adopt a flexible strategy, because being a flexible follower is better than the committed Bertrand regime. Conversely, if the rival firm were to remain flexible, then the firm would like to commit, because being a committed leader is better than the flexible Bertrand regime. However, when exchange rate uncertainty is introduced, the two Nash-equilibria may be reduced to a unique Nash-equilibrium. The existence and identification of a price leader can be solved by introducing uncertainties. In this section, we study how the change in the exchange rate uncertainty (the variances and covariance of exchange rates) may alter the Nash-equilibrium.

By inspection from the third profit equation of Table II-2, it is clear that $E[\Pi_{i}^{F,L}]$ is larger than $E[\Pi_{i}^{L,L}]$ independent of uncertainty because the second term on the right hand side is positive. Given that the rival firm wants to commit its price, firm i will choose to be a price follower. If $E[\Pi_{i}^{F,F}]$ is greater than $E[\Pi_{i}^{L,F}]$, firm i's dominant strategy will be a noncommitment strategy. Therefore, we need to compare $E[\Pi_{i}^{F,F}]$ with $E[\Pi_{i}^{L,F}]$. From Table II-2, we calculate the following;
$$E[\Pi_{i}^{F,F}] - E[\Pi_{i}^{L,F}] = bd_{i}^{2} \{ \frac{2(2-\delta^{2})^{2} R_{i}^{e} + \delta n_{i}^{2} (\delta^{4} - 4\delta^{2} + 8)(R_{s}^{e} - N_{i}^{e}) + 2\delta^{2} n_{i}^{4} (S_{i}^{e} - 2N_{i}^{e})}{2(4-\delta^{2})^{2}}$$

$$-\frac{\delta^{2}}{8(2-\delta^{2})}[(\delta X_{i}^{L,L}-n_{i}^{2}N_{i}^{e})^{2}+\frac{8n_{i}^{2}\delta N_{i}^{e}X_{i}^{L,L}}{(4-\delta^{2})}]\}.$$
 (II-4)

The uncertainty terms such as R_i^e , N_i^e , and S_i^e depend on the distribution of the exchange rate, while they result in zero under certainty. Thus, with certainty, $E[\prod_i^{L,F}]$ is greater than $E[\prod_i^{F,F}]$ because every term except a negative term $(-\frac{bd_i^2\delta^4(X_i^{L,L})^2}{8(2-\delta^2)})$ vanishes. However, with exchange rate uncertainty the terms involving R_i^e , N_i^e , and S_i^e can make $E[\prod_i^{F,F}] > E[\prod_i^{L,F}]$.

For further analysis, I assume the random shocks of exchange rates follow a bivariate log-normal distribution.⁶ Under a bivariate log-normal distribution, $R_i^e = Var[e_i]$,

$$N_i^e = \frac{Var[e_s] - Cov[e_i, e_s]}{1 + Cov[e_i, e_s]}, \text{ and } S_i^e = \frac{(1 + Var[e_s])^3}{(1 + Cov[e_i, e_s])^2} - 1.^7 \text{ Under these assumptions,}$$

equation (II-4) can be reduced to equation (II-5).

⁷ If $(x, y) = (\ln e_i, \ln e_s) \sim N(\mu_x, \mu_y, \sigma_x^2, \sigma_y^2, \sigma_{xy})$, $E[e_i] = Exp[\mu_x + \frac{\sigma_x^2}{2}] = 1$, and $E[e_s] = Exp[\mu_y + \frac{\sigma_y^2}{2}] = 1$, then $E[e_i^{\alpha} e_k^{\beta}] = \exp[\frac{\sigma_x^2}{2}(\alpha^2 - \alpha) + \frac{\sigma_y^2}{2}(\beta^2 - \beta) + \alpha\beta\sigma_{xy}]$. Using the facts that $Var[e_i] = E[e_i^2 - 1] = \exp[\sigma_x^2] - 1$, and $Cov[e_i, e_s] = E[e_i e_s - 1] = \exp[\sigma_{xy}] - 1$, we can get: $R_i^{e} = E[R_i] = E[\frac{1}{e_i} - 1] = \exp[\sigma_x^2] - 1 = Var[e_i]$, $N_i^{e} = E[\frac{e_i}{e_s} - 1] = \exp[\sigma_y^2 - \sigma_{xy}] - 1 = \frac{Var[e_s] - Cov[e_i, e_s]}{1 + Cov[e_i, e_s]}$, and $S_i^{e} = E[\frac{e_i}{e_s^2} - 1] = \exp[3\sigma_y^2 - 2\sigma_{xy}] - 1 = \frac{(1 + Var[e_s])^2}{(1 + Cov[e_i, e_s])^2} - 1$.

⁶ For the convenience of analysis, I assume the bivariate log-normal distribution. However, the use of other distributions such as bivariate normal distribution does not change the major results.

$$E[\Pi_{i}^{F,F}] - E[\Pi_{i}^{L,F}] = bd_{i}^{2} \{-\frac{\delta^{4}(X_{i}^{L,L})^{2}}{8(2-\delta^{2})} + \frac{(2-\delta^{2})^{2}}{(4-\delta^{2})^{2}}V_{i} + \frac{\delta n_{i}^{2}(\delta-4\delta^{2}+8)\frac{C(1+V_{s})}{1+C} + 2\delta^{2}n_{i}^{4}\frac{V_{s}^{3}+3V_{s}^{2}+V_{s}-2V_{s}C+C^{2}}{(1+C)^{2}}}{2(4-\delta^{2})^{2}} - \frac{\delta^{2}}{8(2-\delta^{2})}[\frac{2\delta^{3}n_{i}^{2}X_{i}^{L,L}}{(4-\delta^{2})}(\frac{V_{s}-C}{1+C}) + n_{i}^{4}(\frac{V_{s}-C}{1+C})^{2}]\}$$
(II-5)

where $V_i \equiv Var[e_i]$ and $C \equiv Cov[e_i, e_s]$. Although the effects of different marginal costs and covariance will be analyzed in the later simulation study, I here assume expected marginal costs are the same (or $n_i = 1$) and the covariance is zero. With these assumptions, equation (II-5) can be reduced to equation (II-6).

$$E[\Pi_{i}^{F,F}] - E[\Pi_{i}^{L,F}] = bd^{2} \left\{ -\frac{\delta^{4}(X_{i}^{L,L})^{2}}{8(2-\delta^{2})} + \frac{(2-\delta^{2})^{2}}{(4-\delta^{2})^{2}}V_{i} + \frac{8(2-\delta^{2})\delta^{2} - 2\delta^{5}(4-\delta^{2})X_{i}^{L,L}}{8(2-\delta^{2})(4-\delta^{2})^{2}}V_{s} + \frac{(32-16\delta^{2}-\delta^{4})\delta^{2}V_{s}^{2} + 8(2-\delta^{2})\delta^{2}V_{s}^{3}}{8(2-\delta^{2})(4-\delta^{2})^{2}} \right\}$$
$$= -U_{1} + U_{2}(V_{i}) + U_{3}(V_{s}). \qquad (II-6)$$

Equation (II-6) consists of three effects. The first term (U_1) on the right hand side shows a leader advantage when the rival firm does not commit its price, implying that $E[\Pi_i^{L,F}]$ is greater than $E[\Pi_i^{F,F}]$ under certainty. The second term (U_2) reveals the effect of the variance of own exchange rate, while the third and the fourth terms (U_3) reveal the effect of the variance of rival exchange rate on the follower advantage. Note that $E[\Pi_i^{F,F}] - E[\Pi_i^{L,F}]$ is a linear function of the variance of the exchange rate for the country from which the firm comes, while it is a nonlinear function of the variance of the other exchange rate. Although I study its sensitivity through simulations later, it can be seen that the effects of own and rival exchange rate variance are affected by δ (the substitutability between goods) and $X_i^{L,L}$ (the mark-up on the good). The leader advantage (the absolute value of the first term: U_1) increases as δ and/or $X_i^{L,L}$ increase. The effect of own variance is negatively related to δ , while the effect of rival variance is positively related to substitutability (δ) and negatively related to mark-up ($X_i^{L,L}$). Alternatively, as the substitutability between goods increases, the rival effect and the leader advantage increase.

The positive relationship between { $E[\Pi_i^{F,F}] - E[\Pi_i^{L,F}]$ } and the variances means that as uncertainty increases, the value of retaining flexibility by delaying the price decision increases. The comparison of these expected values indicates that there are four possible solutions that might emerge. The best strategy of each firm is determined, in part, by the action of its rival. Although a firm might want to be a price follower, unless its rival acquiesces by opting for the role of a price leader, it cannot achieve this result. Thus, we can derive *Proposition II-1*.

Proposition II-1. Assuming that $Var[e_k] = 0$, and costs and demands are symmetric, (a) if $Max[U_2(V_j), U_3(V_j)] < U_1$, there exist two Nash-equilibria (commit, non-commit; non-commit, commit), the same result as with a standard Bertrand duopoly game. The existence and identification problem of a price leader remains. (b) if $U_3(V_j) < U_1 < U_2(V_j)$, then $E[\Pi_j^{F,F}] > E[\Pi_j^{L,F}]$ and $E[\Pi_k^{F,F}] < E[\Pi_k^{L,F}]$. Thus, firm j will have a non-commit strategy as a dominant strategy, and firm k's best response is to be a price leader. A unique Nash-equilibrium (non-commit, commit) with payoffs $(\Pi_j^{F,L}, \Pi_k^{L,F})$ results. (c) if

 $U_2(V_j) < U_1 < U_3(V_j)$, then $E[\Pi_j^{F,F}] < E[\Pi_j^{L,F}]$ and $E[\Pi_k^{F,F}] > E[\Pi_k^{L,F}]$. Thus, firm k will have a non-commit strategy as a dominant strategy, and firm j is induced to be a price leader. A unique Nash-equilibrium (commit, non-commit) with payoffs $(\Pi_j^{L,F}, \Pi_k^{F,L})$ results. (d) finally, if $Min[U_2(V_j), U_3(V_j)] > U_1$, both firms will have a non-commit strategy as a dominant strategy, and a unique Nash-equilibrium (non-commit, non-commit) with payoffs $(\Pi_j^{F,F}, \Pi_k^{F,F})$ results.

Proof.

If $Var[e_k] = 0$, and costs and demands are symmetric, then $E[\prod_{j=1}^{F,F} - \prod_{j=1}^{L,F}] = -U_1 + U_2(V_j)$, and $E[\prod_{k=1}^{F,F} - \prod_{k=1}^{L,F}] = -U_1 + U_3(V_j)$. The comparison of these expected values indicates that each firm's regime ranking can be changed by the variance of e_j . Each firm's regime rankings are as shown in Table II-3.

The result follows by inspection from Table II-3. When the rival leads, we know the firm's best response is to follow. Thus, if $U_1 < U_3(V_j)$, firm k has a non-commit strategy as a dominant strategy whereas if $U_1 > U_3(V_j)$, firm k's best response to follow (lead) is to lead (follow). Similarly, if $U_1 < U_2(V_j)$, firm j has a non-commit strategy as a dominant strategy whereas if $U_1 > U_2(V_j)$, firm j's best response to follow (lead) is to lead (follow). Hence, if $Max[U_2(V_j), U_3(V_j)] < U_1$, two Nash-equilibria result whereas if $U_3(V_j) < U_1 < U_2(V_j)$, firm j has a dominant strategy and (non-commit, commit) is a unique Nash-equilibrium. Similarly, if $U_2(V_j) < U_1 < U_3(V_j)$, firm k has a dominant strategy and (commit, non-commit) is a unique Nash-equilibrium whereas if $Min[U_2(V_j), U_3(V_j)] > U_1$, (non-commit, non-commit) is a unique Nash-equilibrium. I construct ordinal pay-off matrixes indicating

Table	II-3.	Regime	ranking ¹
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(1)	Firm	j's	(which	have a	volatile	exchange	rate)	ranking
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	$\Pi_{I}^{L,L}$	$\Pi_{j}^{L,F}$	$\Pi_{j}^{F,L}$	$\Pi_{j}^{F,F}$	_
$U_1 > U_2(V_j)$	4	2	1	3	
$U_1 < U_2(V_j)$	4	3	1	2	

(2) Firm k's (which have a stable exchange rate) ranking

	$\Pi_{k}^{L,L}$	$\Pi_{k}^{L,F}$	$\Pi_{k}^{F,L}$	$\prod_{k}^{F,F}$	 -
$U_1 > U_3(V_j)$	4	2	1	3	
$U_1 < U_3(V_j)$	4	3	1	2	

¹ The smaller number means the higher rank (or 1 means the best and 4 means the worst)

how each firm ranks each possible timing combination. Firm j can commit its price or remain flexible, as can firm k, yielding Table II-4. The first entry in each cell is firm j's ranking of that cell; the second entry is firm k's ranking. The bold letters in Table II-4 indicate Nash-equilibria.

		I	Firm k		-		
		С		NC	_		
	С	$(\Pi_{j}^{L,L},\Pi$	$\binom{L,L}{k}$	$(\Pi_{j}^{L,F},\Pi_{k}^{F,L})$	_		
Firm j	NC	$(\Pi_{j}^{F,L},\Pi$	<i>k</i> , <i>F</i>) ($(\Pi_{j}^{F,F},\Pi_{k}^{F,F})$	-		
Case (a))			Case (b)		
		Fir	m k			Firm	k
		C	NC			С	NC
	С	(4, 4)	(2, 1)		С	(4, 4)	(3, 1)
Firm j	NC	(1, 2)	(3, 3)	Firm j	NC	(1, 2)	(2, 3)
Case (c)				Case (d)		
		Firr	n k			Firm	k
		С	NC			С	NC
	С	(4, 4)	(2, 1)		С	(4, 4)	(3, 1)
Fi r m j	NC	(1, 3)	(3, 2)	Firm j	NC	(1, 3)	(2, 2)

Table II-4: Ordinal pay-off matrix¹

¹ The smaller number means the higher (or 1 means the best and 4 means the worst)

Q.E.D.

Proposition II-1 assumed that firm k does not face own currency exchange rate uncertainty, as would happen if k were a domestic firm. Thus, with one domestic and one foreign firm, the foreign firm j faces exchange rate variance, and the price leader will be determined in Proposition II-1. Next, allowing the variance of e_k to be positive, we can generalize equation (II-6) as $E[\Pi_i^{F,F}] - E[\Pi_i^{L,F}] = -U_1^i + U_2^i(V_i) + U_3^i(V_s)$ where i, s = j, kand $i \neq s$. Note that $U_1^j = U_1^k = U_1$ if costs and demands are the same. Then we can generalize the Proposition II-1 as Corollary II-1.

Corollary II-1. Assuming symmetric costs and demands, (a) if

equilibrium (non-commit, non-commit) with payoffs $(\Pi_{j}^{F,F},\Pi_{k}^{F,F})$ results.

both firms will have a non-commit strategy as a dominant strategy, and a unique Nash-

Proof.

Assuming symmetric costs and demands, the comparison of these expected values indicates that each firm regime ranking can be changed by variances of e_j and e_k . The possible regime rankings are in Table II-5. The proof is followed by inspection from Table II-5 and similar to the proof of proposition II-1.

Table II-5. Regime rankings¹

	$\Pi_{j}^{L,L}$	$\Pi_{j}^{L,F}$	$\Pi_{j}^{F,L}$	$\Pi_{j}^{F,F}$	
$U_1^{\prime} > U_2^{\prime} + U_3^{\prime}$	4	2	1	3	
$U_1' < U_2' + U_3'$	4	3	1	2	

(1) Firm j's (which have more volatile exchange rate) ranking

(2) Firm k's (which have less volatile exchange rate) ranking

	$\prod_{k}^{L,L}$	$\prod_{k}^{L,F}$	$\Pi_{k}^{F,L}$	$\prod_{k}^{F,F}$	
$U_1^k > U_2^k + U_3^k$	4	2	1	3	
$U_1^k < U_2^k + U_3^k$	4	3	1	2	

¹ The smaller number means the higher rank (or 1 means the best and 4 means the worst)

Q.E.D.

II.4 Simulation and sensitivity

For a more definitive analysis, I perform some simulations. Four possible areas are analyzed, and how the areas are changed for different values of parameters (δ and n_i) is studied. The effects of rival variance and covariance on the areas are also studied.

Figure II-1 classifies four possible ranges, given that $\delta = 0.9$, $Var[e_k] = 0$, and costs and demands are symmetric. While the horizontal axis represents the mark-up $(X_j^{L,L})$, the vertical axis represents $Var[e_j]$. In the area above (below) the thick jj line, $E[\Pi_j^{F,F}]$ is higher (lower) than $E[\Pi_j^{L,F}]$ as the thick jj line represents the locus such that $E[\Pi_j^{F,F}]$ equals $E[\Pi_j^{L,F}]$. Similarly, in the area above (below) the light kk line in the figure, $E[\Pi_k^{F,F}]$ is higher (lower) than $E[\Pi_k^{L,F}]$. Higher variance means more uncertainty (risk) and makes the flexible strategy more valuable, increasing the commitment cost. Therefore, we can classify four possible areas as follows.

Area (a): two Nash-equilibria exist; the area below both lines.

- Area (b): firm j has a dominant strategy (follow), and the unique NE = (non-commit, commit); the area that is above jj line and below kk line.
- Area (c): firm k has a dominant strategy (follow), and the unique NE = (commit, noncommit); the area that is below jj line and above kk line.
- Area (d): both firms' dominant strategy is follow, and the unique NE = (non-commit, noncommit); the area above both lines.

To illustrate in more detail, consider an industry in which δ and $X_{j}^{L,L}$ are 0.9 and 0.4 respectively. If $Var[e_{j}] < 0.079$, two NEs exist. If $0.079 < Var[e_{j}] < 0.129$, firm j will be a price follower and firm k will be a price leader. And, if $0.129 < Var[e_{j}]$, neither firm commits. Likewise, an industry in which δ and $X_{j}^{L,L}$ are 0.9 and 1.4 respectively, two NEs exist in the range that $Var[e_{j}] < 0.74$ while firm j will be a price leader, and firm k will be a price follower respectively in the range that $0.74 < Var[e_{j}] < 0.971$. If $0.971 < Var[e_{j}]$, both firms do not commit.

The more volatile is the exchange rate, the more likely it is that firms do not want to commit. Figure II-1 shows that, in the low mark-up industries, the firm that faces a volatile exchange rate has a stronger preference for holding flexibility; whereas the firm that faces low (or no) exchange rate volatility has a stronger preference for holding flexibility in the



Figure II-1. Firms' best regimes; $\delta = 0.9 (Var[e_k] = 0, n_i = 1)$

higher mark-up industries. Thus, in relatively competitive (low profit) industries the price leader is more likely to come from either the home country or a trading country whose exchange rate varies little, whereas in more profitable industries the price leader is more likely to come from a trading country whose exchange rate varies much.

Figures II-2, 3, 4 and 5 illustrate how the best regime areas change when other factors such as δ , $Var[e_k]$, $Cov[e_j, e_k]$ and $n_j(n_k)$ change. By inspection from Figure II-1 and II-2, we can see that jj line dramatically shifts down, while kk line shifts down relatively little, as δ decreases. The low level of substitutability (δ) gives firms monopoly powers which make the flexible strategy more valuable, and the interaction between firms less important. Thus, areas (b) and (d) are extended, and area (a) is shrunken. Meanwhile, area (c) disappears.⁸ This is not surprising since the effect of rival variance decreases as the

⁸ Of course, area (c) can exist with very high mark-ups and variances. However, it may not feasible in the real world.



Figure II-2. Firms' best regimes; $\delta = 0.7 \text{ vs.} \delta = 0.5 (Var[e_k] = 0, n_i = 1)$

substitutability of goods decreases. Area (c) exists only under large δ and/or high mark-up.⁹ Therefore, in the next simulation studies (Figure II-3,4,5), particular attention is paid to area (b) instead of area (c), using $\delta = 0.7$. However, under high δ and/or high mark-up, the area (c) may exist and the effects of $Var[e_k]$, $Cov[e_j, e_k]$ and $n_j(n_k)$ on area (c) are similar to the effects on area (b).

The effect of increased $Var[e_k]$ is showed in Figure II-3. When $Var[e_k]$ increases the kk line shifts down much while jj line shifts down relatively less. The result is that area (d) is extended, and areas (a) and (b) shrink, implying that a dominant strategy NE (non-commit, non-commit) becomes more likely. When $Cov[e_1, e_k]$ increases the downward shift of kk

⁹ According to my simulation studies, if $X_{i}^{L,L} > 0.34$ and $Var[e_{i}] > 0.13$ under $\delta = 1$, and/or if $X_{i}^{L,L} > 1$ and $Var[e_{i}] > 0.45$ under $\delta = 0.9$, area (c) may exist. Although it is an empirical issue, it seems that $Var[e_{i}]$ is not too big because $E[e_{i}] = 1$.

line is larger than that of jj line, resulting in area (d) increasing, and areas (a) and (b) shrinking (Figure II-4). Because firms have upward sloping reaction functions in the price game, it is natural that increases of $Var[e_k]$ and/or $Cov[e_j, e_k]$ make a flexible strategy more valuable, and that the small difference between variances shrinks the leader-follower equilibrium area.

Finally, Figure II-5 shows the effect of different marginal costs across firms on regime areas. In this simulation, $n_1^{10} = 1, 0.9, 0.7$, implying $n_k = 1, 1/0.9, 1/0.7$ respectively (by definition). Because I analyze the possible regime areas for firm j's mark-up levels in this simulation, jj line does not shift as n_1 decreases. Meanwhile, when n_1 decreases kk line



Figure II-3. Firms' best regimes; change of $Var[e_k]$ ($\delta = 0.7$, $Cov[e_j, e_k] = 0$, $n_i = 1$)

 $n_i < 1$ means that firm j is a high cost firm.



Figure II-4. Firms' best regimes; change of $Cov[e_1, e_k]$ ($\delta = 0.7, Var[e_k] = \frac{1}{2}Var[e_1], n_i = 1$)



Figure II-5. Firms' best regimes; change of n_i ($\delta = 0.7$, $Var[e_k] = 0$)

shifts up, resulting in area (b) extended and area (d) shrunken. It means that a low marginal cost firm has a lower likelihood of adopting a flexible strategy than does a high marginal cost firm.

From the above simulation studies, some general conclusions can be reached. First, asymmetric exchange rate uncertainty can give rise to the endogenous emergence of a leaderfollower structure. The interesting areas are (b) and (c) that identify a price leader. Who will be a price leader depends on various parameters, and it is not axiomatic that the firm from the country with higher exchange rate variability is likely to be the follower. In area (b), a firm that faces a high volatile exchange rate will have a non-commit strategy as a dominant strategy, and a firm that faces a stable exchange rate is willing to be a price leader: a result that perhaps best coincides with intuition. If the firm k is a domestic firm and foreign firm j has large variance of exchange rate, the domestic firm will be a price leader. However, in area (c), the firm that faces a stable (volatile) exchange rate is willing to be a price follower (leader). Paradoxically, the volatile exchange rate is more likely to induce the firm from the other country to be the follower. This case is most likely when goods are close substitutes, and profit margins are large. Next, when one exchange rate is fairly stable and/or the covariance is small, the endogenous emergence of a leader-follower structure is more likely; whereas, if both exchange rates are volatile and/or highly correlated, a dominant strategy (non-commit, non-commit) solution emerges. Finally, a firm that has a larger marginal cost has a stronger propensity to be a price follower under uncertainty.

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II.5 Implications to short-run exchange rate pass-through

Exchange rate changes are usually perceived as cost shocks for a foreign firm producing in its home country and selling in its export market. When the exchange rate changes, the firm may choose to pass the cost shock into its selling prices; this price change is called exchange rate pass-through (PT). We saw that in the area (b) the firm that has a small exchange rate volatility is willing to pre-commit and will be a price leader while the firm that faces the high uncertainty of exchange rate wants to be a follower. Clearly, the leader's PT will be zero in the short run.¹¹ We can also see that the follower's exchange rate PT in a price leadership equilibrium is less than the exchange rate PT with a flexible Bertrand equilibrium. From mark-up of Table II-2 we can get Table II-6 using the relationship that $p_i = (1 + X_i)d_i$.

	Price
Committed Bertrand (Case A)	$P_{t}^{L,L} = \frac{a+bd}{2b-c}$
Committed leader (Case B for firm j, case C for firm k)	$P_{i}^{L.F} = \frac{2ab + ac + 2b^{2}d + bcdE[\frac{e_{i}}{e_{s}}] - c^{2}d}{2(2b^{2} - c^{2})}$
Flexible follower (Case C for firm j, case B for firm k)	$p_{i}^{F,L} = \frac{a}{2b} + \frac{d}{2e_{i}} + \frac{c}{2b} p_{s}^{L,F}$
Flexible Bertrand (Case D)	$p_{i}^{F,F} = \frac{2ab + ac + \frac{2b^{2}d}{e_{i}} + \frac{bcd}{e_{s}}}{4b^{2} - c^{2}}$

Table II-6. Equilibrium price for each case (with $n_i = 1$)

¹¹ Of course, they will make pass-through for the expected change of exchange rate.

From Table II-6, we can compare the follower's exchange rate PT in a price leadership equilibrium with the exchange rate PT when a flexible Bertrand equilibrium

prevail.
$$\frac{\partial p_i^{F,L}}{\partial e_i} \frac{e_i}{p_i^{F,L}} = -\frac{d}{2} \frac{1}{e_i} \frac{1}{p_i^{F,L}}$$
, and $\frac{\partial p_i^{F,F}}{\partial e_i} \frac{e_i}{p_i^{F,F}} = -\frac{2b^2d}{4b^2 - c^2} \frac{1}{e_i} \frac{1}{p_i^{F,F}}$. Then, it is clear that $\left|\frac{\partial p_i^{F,L}}{\partial e_i} \frac{e_i}{p_i^{F,L}}\right| < \left|\frac{\partial p_i^{F,F}}{\partial e_i} \frac{e_i}{p_i^{F,F}}\right|$ because $\frac{2b^2d}{4b^2 - c^2} - \frac{d}{2} = \frac{c^2d}{2(4b^2 - c^2)} > 0$ and $p_i^{F,L} > p_i^{F,F}$ around $e_i = E[e_i]$. Furthermore, with a flexible Bertrand equilibrium firms pass-through their price for the change of rival exchange rate. Although exchange rate PT for

the change of rival exchange rate is zero for other equilibria,

$$\frac{\partial p_{i}^{F,F}}{\partial e_{s}} \frac{e_{s}}{p_{i}^{F,F}} = -\frac{bcd}{4b^{2}-c^{2}} \frac{1}{e_{s}} \frac{1}{p_{i}^{F,F}} < 0.$$

Intuitively, in the leader-follower model, the realized exchange rate will have only a direct effect on the follower's price, given the leader's price, whereas in the flexible Bertrand solution, firm i's price decision incorporates the indirect effect through the change of rival price due to the change of exchange rate. Since the reaction curves slope upward both firms adjust price in the same direction, leading greater price movements not only for the firm whose exchange rate has changed, but for the other firm as well. Although the model is all same, the solution differs and the exchange rate pass-through differs. The ranks of PT will be as follows: committed Bertrand = committed leader < flexible follower < flexible Bertrand. In the area (b), if the firm k is a domestic firm and a foreign firm j has a large variance of exchange rate, the foreign firm will be a price follower and PT will be smaller than one of flexible Bertrand model (in the area d).

Some general conclusions on short-run exchange rate PT can be reached. First, in most industries except high mark-up and/or high δ industries¹², as exchange rate variability increases the PT will be higher through the change of the firms' best regimes. Alternatively, high variance country's PT will be higher than lower variance country's. Next, as both country's volatility increases a flexible Bertrand regime may emerge and the PT is likely to be even higher. Also, with a flexible Bertrand equilibrium firms pass-through their price for the change of rival exchange rate. The exchange rate PT is affected by rival volatility through the equilibrium structural change, as well as by the rival's realized exchange rate. The PT is changed by which country's firm is a rival because rival's uncertainty can change the equilibrium structure. For example, *ceteris paribus*, if a Korean firm competes with an Indonesian firm rather than a Canadian firm as a rival, the pass-through is higher than the other, assuming that Korean and Indonesian currencies are highly volatile while Canadian currency is stable. Finally, by inspection from Figures II-1 and II-2, we conclude that in markets where there are less close substitutes, exchange rate PT is likely to be higher because follow is likely to be a dominant strategy under more moderate exchange rate variability.

II.6 Conclusion

In a simple model of price competition in a market with differentiated goods, symmetric costs, and linear demand curves, it is well known that there are two pure strategy Nash-equilibra, since each firm prefers to be a price follower, letting the other firm move

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¹² If the mark-up of a good market is big, there exist area (c) instead of area (b) (see Figure 1). In the area (c), high variance country's PT will be smaller than lower variance country's in the short-run. However, as both country's volatility increases the PT is more likely to be higher.

first, even though both firms prefer to be a leader in the Stackelberg game to the flexible Bertrand outcome. In this chapter I have shown that exchange rate uncertainty may lead to a unique NE. I also derived the NEs depending on the variances and covariance of exchange rates, substitutability between goods, and marginal costs. Even though the Nash-equilibrium is changed by various factors, a statement can be made. Over certain ranges of exchange rate variability only one firm will have a flexible strategy as its dominant strategy. Then, the other firm will be induced to be a price leader, resulting in a price leader-follower equilibrium. Which firm will be the price leader depends on the mark-up and substitutability of products.

These considerations for leadership also provide some implications for short-run exchange rate PT. Generally, my model predicts that firms from countries with highly volatile exchange rate will have greater pass-through than those from countries with more stable exchange rate. Also, the PT is changed by which country's firm is a rival because rival's uncertainty can change the equilibrium solution of the pricing game. If both country's volatilities are high, the PT is likely to be higher. Exchange volatility may produce a structure break in the observed pass-through relationship, as the new game structure of the market may not be consistent with the historical rate of exchange rate pass-through.

I obtained these results using a linear demand function and risk neutrality. Risk aversion would increase the importance of this effect. Nonlinear demands or non-constant costs could introduce ambiguities, and could magnify or diminish the effect of exchange rate uncertainty, but would clearly not undermine the basic economic points.

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I focused on the variabilities of exchange rates. However, in the general content, it may be related to cost uncertainty.¹³ Albaek (1990) showed that a natural Stackelberg situation does not exist if prices are the strategies. However, the results of Albaek rely on the assumption that information sharing is prohibited. If the information is public, similar but adverse conclusions can be derived. Alternatively, the firm that faces the large variance of cost wants to be a price follower and the firm that has a small uncertainty is willing to be a price leader. Spencer and Brander (1992), in the quantity game, considered the possibility of endogenous Stackelberg leadership with firm specific marginal cost uncertainty. However, the emergence of Stackelberg leadership is not completely straightforward and unstable. Although cost uncertainty in reciprocal form is complicated compared to marginal cost uncertainty, this research implies that, in the price game, the emergence of Stacklberg leadership is completely straightforward, different from the case of quantity game. The difference between the price game and the quantity game is due to the different properties of reaction functions. In fact, an existing matured firm may have the low level of cost uncertainty while a new entrant or a growing firm faces the high level of cost uncertainty. It is not surprising that the existing, usually big, firm is a price leader in the real world.

¹³ If the firms' objective function is changed to $\Pi_i = (p_i - \frac{d}{e_i})(a - bp_i + cp_s)$, it is related to cost uncertainty.

III. EXCHANGE RATE PASS-THROUGH IN AN INTERNATIONAL DUOPOLY MODEL WITH BRAND LOYALTY: THE EFFECT OF RIVAL EXCHANGE RATE

III.1 Introduction

Since the advent of floating exchange rates, firms based in different countries have faced notably large fluctuations in currency values. Exchange rate changes are usually perceived as cost shocks for a foreign firm producing in its home country and selling in its export market. When the exchange rate changes, the firm may choose to pass the cost shock into its selling prices; it is called exchange rate pass-through (PT). In general, it is widely observed that import prices in importer's currency move very little compared to movements in exchange rates (incomplete pass-through).

A number of authors have studied the underlying relationship between exchange rates and prices of internationally traded goods trying to explain the imperfect pass-through. The theoretical literature distinguishes between exchange rate pass-through in the short-run and the long-run. Some studies have noted that while incomplete pass-through is very common in the short run, it does not carry through to the long-run, implying that complete passthrough would prevail as some long-run equilibrium relationship between exchange rates and prices (for example, Blejer and Hillman, 1982; Dohner, 1984). These studies have identified a number of factors which may affect the pace of adjustment of trade prices to exchange rate changes: costs of changing prices, costs of changing supply, order and payment lags, lags in demand adjustment, and currency denomination of contracts, etc. However, even in the long-run, it is at large observed that exchange rate pass-through is not complete, roughly ranging between 50 and 80 percent. We might expect exporters to sell their goods at a higher price in a country where currency appreciates than in other countries. The theoretical explanations of long-run incomplete pass-through have emphasized the role of market structure and product differentiation. The major contributions are Dornbusch (1987), Krugman (1987,1989), Baldwin (1988), Baldwin and Krugman (1989), Dixit (1989a, 1989b), Fischer (1989), and Froot and Klemperer (1989).¹ Meanwhile, Branson (1989) claimed that by ignoring the important role played by non-tariff barriers a significant explicator of the pass-through puzzle has been omitted.

Although there has been much research on exchange rate pass-though, no literature paying attention to rival's exchange rate was found. The existing exchange rate pass-through (PT) literature is based on an imperfect competition model of a foreign firm and a domestic firm, including only a bilateral exchange rate. However, if other foreign firms exist in the market, the foreign firm's pricing behavior will be affected by rival countries' exchange rates. In the international export market, an exporter may often face other foreign firms rather than domestic firms as major rivals. Indeed, in some markets, there does not exist a domestic firm. Even when domestic firms exist, the substitutability between export goods may be much higher than the one between an export good and a domestic good. Then, rival exchange rate may give a significant effect to the firm's pricing decision through strategic interaction. The importance of strategic interaction in an export market was mentioned by Goldberg and Knetter (1997, p. 1265).

¹ In chapter I we reviewed the literature more thoroughly.

International economists typically impose the Armington assumption - i.e., they assume that products within an industry are differentiated according to the country of production. An extreme interpretation of the Armington assumption implies that goods produced in different countries represent different markets. ... The competition from these other sources is accounted for by including the prices of substitutes in the set of demand shifters or rotators; but this treatment fails to capture the strategic interaction.

In this chapter, I explicitly analyze the effect of rival exchange rate on exchange rate PT. First, in section 2, I suggest the new analytical definitions of exchange rate PT with a simple duopoly model. The definition of PT is clear only in a two-country world with one exchange rate, but is less clear in a model with two or more exporting countries and with two or more distinct exchange rates. Next, I study the effect of rival's exchange rate with a variant of Froot and Klemperer's model (1989) in section 3. With the three new definitions of exchange rate PT, I will show the effects of rival exchange rates due to strategic interaction. When the rival's exchange rate moves in the same (opposite) direction with its own change, the PT is magnified (minimized). If the change of rival's exchange rate is in the opposite direction to the change of the firm's exchange rate and relatively large enough, the exchange rate pass-through is perverse even with elastic demand. In Froot and Klemperer (1989); Tivig (1996); and section 2 of this chapter, an unrealistic assumption, perfect foresight, is made. However, in section 4, I drop this assumption and instead assume that the firm's pricing decision must be made before future exchange rates (but after current exchange rates) are known. Interestingly, with imperfect foresight we can see that PT is affected by the covariance and variances of both its own and rival's exchange rate. In section 5 some conclusions are drawn.

III.2 Exchange rate pass-through and the analytical definition

When the exchange rate changes, the firm may choose to pass the cost shock into its selling prices. The elasticity of equilibrium price with respect to the exchange rate is called exchange rate pass-through (PT). However, this verbal definition is not entirely clear, in both theoretical analysis and empirical study, if there are two or more exporting countries with different exchange rates.

The existing exchange rate pass-through literature modeled only a foreign country and a domestic country, including only one bilateral exchange rate. In these models the definition of exchange rate PT is clear, and both an importing country and an exporting country face the same exchange rate pass-through:

$$PT = \frac{\partial p^m}{\partial e} \frac{e}{p^m}$$

where p^{m} = price of imported (or exported) good.

If, however, two or more exporting countries exist, the definition of PT is not clear and may differ across counties even in the same industry. I show the new definition of PT with a duopoly model to emphasize the fact that the market structure is a significant explicator of exchange rate pass-through. No literature has considered the different expressions of PT across countries.

There are three countries (j, k, and U.S) in a duopoly model in which a country j and a country k firm each export differentiated products to the U.S. market. Assuming that firms move simultaneously and that prices are the strategic variable, each firm's optimization problem is:

$$\operatorname{Max}_{p_{j}} \Pi^{j} = (e_{j} p_{j} - \gamma^{j}) q_{j} (p_{j}, p_{k}), \qquad (\text{III-1a})$$

$$\underset{p_{k}}{Max} \Pi^{k} = (e_{k} p_{k} - \gamma^{k}) q_{k} (p_{j}, p_{k}),$$
(III-1b)

where γ' is own currency marginal cost of producer i, and e_i is an exchange rate defined in units of exporter i's currency per \$.

The first order condition will be:

$$\Pi_{j}^{\prime} = e_{j} \left(\frac{\partial q_{j}}{\partial p_{j}} p_{j} + q_{j} \right) - \gamma^{\prime} \frac{\partial q_{j}}{\partial p_{j}} = 0, \qquad (\text{III-2a})$$

$$\Pi_{k}^{k} = e_{k} \left(\frac{\partial q_{k}}{\partial p_{k}} p_{k} + q_{k} \right) - \gamma^{k} \frac{\partial q_{k}}{\partial p_{k}} = 0.$$
(III-2b)

The comparative static reactions to the changes in exchange rates are:

$$\begin{bmatrix} dp_{j} \\ dp_{k} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \Pi_{kk}^{k} & -\Pi_{jk}^{j} \\ -\Pi_{kj}^{k} & \Pi_{jj}^{j} \end{bmatrix} \begin{bmatrix} -\Pi_{je_{j}}^{j} de_{j} \\ -\Pi_{ke_{k}}^{k} de_{k} \end{bmatrix}$$
(III-3)

where $\Delta = \prod_{y}^{j} \prod_{kk}^{k} - \prod_{jk}^{j} \prod_{kj}^{k} > 0$ by a stability condition, and $\prod_{st}^{i} = \frac{\partial^{2} \prod^{i}}{\partial p_{s} \partial p_{i}}$.

From (III-3), we can get:

$$dp_{j} = Ade_{j} + Bde_{k},$$

$$dp_{k} = \overline{A}de_{k} + \overline{B}de_{j},$$
where $A = \frac{-\prod_{kk}^{k}\prod_{je_{j}}^{j}}{\Delta}, B = \frac{\prod_{jk}^{j}\prod_{ke_{k}}^{k}}{\Delta}, \overline{A} = \frac{-\prod_{jj}^{j}\prod_{ke_{k}}^{k}}{\Delta}, \text{ and } \overline{B} = \frac{\prod_{kj}^{k}\prod_{je_{j}}^{j}}{\Delta}.$

Then, the exchange rate PT that each country faces are follows:

Country j's PT;
$$= \frac{dp_j}{de_j} \frac{e_j}{p_j} = (A + B \frac{de_k}{de_j}) \frac{e_j}{p_j},$$
 (III-4a)

Country k's PT;
$$= \frac{dp_k}{de_k} \frac{e_k}{p_k} = (\overline{A} + \overline{B} \frac{de_j}{de_k}) \frac{e_k}{p_k}$$
, (III-4b)

Country U.S's PT; =
$$\frac{dp_T}{de_T} \frac{e_T}{p_T} = \left[\frac{\alpha(Ade_j + Bde_k) + \beta(\overline{B}de_j + \overline{A}de_k)}{\alpha de_j + \beta de_k}\right] \frac{e_T}{p_T}$$
, (III-5)

where α = market share of country j,

 β = market share of country k,

- e_T = trade weighted exchange rate (= $\alpha e_1 + \beta e_k$),
- p_T = trade weighted price (= $\alpha p_j + \beta p_k$).

These new definitions and analytical forms include the effect of rival's exchange rate change explicitly. Equation (III-4) shows that, for the same change of own exchange rate, the exchange rate PT varies depending on the covariance between exchange rates. Although points a, b, c and d of Figure III-1 represent the same change of e_i (from e_{i0} to e_{i1}), the exchange rate pass-through will be different due to different correlation between exchange rates. The point a indicates the highest correlation and yields the biggest exchange rate PT. It means that ignoring the rival exchange rate may introduce a serious bias, particularly in the empirical studies. For example, if Korean firms' major rivals are Japanese firms in the U.S. market, an empirical study that tests Korean firms' exchange rate PT to U.S. market without considering Japanese exchange rate will be biased. Furthermore, if the correlation between won/dollar and yen/dollar is significant, the bias is likely to be more serious. Equation (III-5) shows that the exchange rate PT varies, for the same change of trade weighted exchange rate, depending on which exchange rate changes the trade weighted exchange rate; or points e, f, g, and h of Figure III-2 display different PT with the same change of e_r . The analytical proof is



Figure III-1. The same change of own exchange rate; with changed rival exchange rate



Figure III-2. The same change of trade weighted exchange; from different sources (The slope of $de_r = c$ line is decided by market share)

shown in *Proposition III-1*. Although many empirical studies use a trade weighted exchange rate and a price, the trade weighted exchange rate can introduce a serious bias.

Proposition III-1. If firms are not perfectly symmetric, importer's exchange rate PT in terms of the trade weighted exchange rate varies with the vector of exchange rate changes.

Proof.

By definition, $e_T = \alpha e_j + \beta e_k$ and $p_T = \alpha p_j + \beta p_k$. For a given change of the trade weighted exchange rate, we want to see how the composition of the exchange rate changes affects price.

Let
$$de_T = \alpha de_j + \beta de_k = c$$
, (*)
 $dp_T = \alpha dp_j + \beta dp_k = \alpha (Ade_j + Bde_k) + \beta (\overline{B}de_j + \overline{A}de_k)$, (**)

where c = constant.

Substituting (*) into (**) we can get:

$$dp_{T}|_{de_{T}=c} = [\alpha A + (1-\alpha)\overline{B} - (\frac{\alpha^{2}}{1-\alpha})B - \alpha \overline{A}]de_{T} + [(\frac{\alpha}{1-\alpha})B + \overline{A}]c \neq \text{constant.} \quad (***)$$

If $A = \overline{A}, B = \overline{B}$ and $\alpha = \frac{1}{2}$ (symmetric firms), $dp_T|_{de_T = c} = (A + B)c$ is independent of de_r .

However, if firms are not perfectly symmetric, equation (***) shows that dp_{τ} is affected by the composition of the exchange rate changes. Particularly, the more asymmetry, the more the trade weighted price can vary, for a given change in the trade weighted exchange rate. For example, assuming $A = \overline{A}, B = \overline{B}$, if the trade weighted exchange rate is changed by the exchange rate that a small market shared firm face, exchange rate PT will be bigger.

Q.E.D.

III.3 Perfect foresight and exchange rate pass-through

In this section, I study a two-period duopoly model with brand loyalty.² In many markets, consumers who have previously purchased from one firm have (or perceive) costs of switching to a competitor's product, even when the two firm's products are functionally identical. Examples of switching costs include the learning cost incurred by switching to a new make of computer after having learned to use one make, and the transactions cost of closing an account with one bank and opening another with a competitor. Another kind of switching cost arises when uncertainty about product quality makes consumers reluctant to switch to untested products. These brand loyalties give firms a degree of market power over their repeat-purchasers, and mean that firms' current market shares are important determinants of their future profits. This model is a variant of Froot and Klemperer (1989) and Tivig (1996). However, in my model, two different bilateral exchange rates are involved because each firm is based in a different foreign country. I also distinguish three different PTs by the new definition of section 2.

There are two firms: a country j firm and a country k firm, which compete with differentiated products in the export (say, U.S.) market.³ Own currency marginal costs of

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² Klemperer (1995) explained and illustrated the different types of switching costs, or reasons for "brand loyalty", that consumers may face.

³ Although the existence of domestic (U.S.) firms does not change the main economic points that the PT is affected by rival's exchange rate, we implicitly assume that the substitutability between export goods is much higher than the one between an export good and a domestic good.

producer j and k are γ' and γ' , respectively.⁴ Consumers are assumed to exhibit a certain brand loyalty. Demand and thus profits in the second period depend on first-period sales. Firms behave noncooperatively and act simultaneously.

The export firms' problems will be:

$$\max_{p_{j1},p_{j2}} \prod^{j} = (e_{j1}p_{j1} - \gamma^{j})q_{j1}(p_{j1}, p_{k1}) + \lambda^{j}[(e_{j2}p_{j2} - \gamma^{j})q_{j2}(S^{j}, p_{j2}, p_{k2})], \quad (\text{III-6a})$$

$$\max_{p_{k1}, p_{k2}} \prod^{k} = (e_{k1}p_{k1} - \gamma^{k})q_{k1}(p_{j1}, p_{k1}) + \lambda^{k}[(e_{k2}p_{k2} - \gamma^{k})q_{k2}(S^{k}, p_{j2}, p_{k2})], \quad (\text{III-6b})$$

where $\lambda' = \text{discount factor of firm } i$,

$$e_u$$
 = t-period exogenous exchange rates defined in units of country *i* currency per dollar,

- p_{ii} = price of good *i* in period t,
- q_{ii} = quantity demanded for good *i* in period t,
- S' =market share of firm *i* in period 1.

The subgame of period two is solved first. In period two, the second-period dollar prices are chosen to maximize the own currency second-period profits :

$$\underset{p_{j2}}{\operatorname{Max}} \prod_{2}^{j} = (e_{j2}p_{j2} - \gamma^{j})q_{j2}(S'(p_{j1}, p_{k1}), p_{j2}, p_{k2}), \qquad (\text{III-7a})$$

$$\max_{p_{k_2}} \prod_{k_2}^{k} = (e_{k_2} p_{k_2} - \gamma^k) q_{k_2} (S^k (p_{j_1}, p_{k_1}), p_{j_2}, p_{k_2}).$$
(III-7b)

Solving the associated first order conditions for the problems in (III-7), the second-period equilibrium prices are derived as functions of first-period prices, second-period exchange rates and second-period own currency marginal costs. The reduced form solutions are the followings:

⁴ The foreign producers' home market is separated on the technological side and may thus be neglected.

$$p_{j2}^{\bullet} = p_{j2}(p_{j1}, p_{k1}, e_{j2}, e_{k2}, \gamma^{j}, \gamma^{k}), \qquad (\text{III-8a})$$

$$p_{k2}^{\bullet} = p_{k2}(p_{j1}, p_{k1}, e_{j2}, e_{k2}, \gamma^{j}, \gamma^{k}).$$
(III-8b)

In the first period, firms maximize the present discounted value of own-currency profits by choosing the first-period prices:

$$\max_{p_{j1}} \Pi^{j} = (e_{j1}p_{j1} - \gamma^{j})q_{j1}(p_{j1}, p_{k1}) + \lambda^{j} \Pi^{j}_{2}[S^{j}(p_{j1}, p_{k1}), p^{*}_{j2}, p^{*}_{k2}, e_{j2}], \quad (\text{III-9a})$$

$$\max_{p_{k1}} \Pi^{k} = (e_{k1}p_{k1} - \gamma^{k})q_{k1}(p_{j1}, p_{k1}) + \lambda^{k} \Pi^{k}_{2}[S^{k}(p_{j1}, p_{k1}), p^{\bullet}_{j2}, p^{\bullet}_{k2}, e_{k2}], \quad (\text{III-9b})$$

where Π_2^i = second- period own currency profits of firm *i*.

The first order condition will be:

$$\Pi_{j}^{\prime} = e_{j1} \left(\frac{\partial q_{j1}}{\partial p_{j1}} p_{j1} + q_{j1} \right) - \gamma^{\prime} \frac{\partial q_{j1}}{\partial p_{j1}} + \lambda^{\prime} \frac{\partial \Pi_{2}^{\prime}}{\partial p_{j1}} = 0, \qquad \text{(III-10a)}$$

$$\Pi_{k}^{k} = e_{k1} \left(\frac{\partial q_{k1}}{\partial p_{k1}} p_{k1} + q_{k1} \right) - \gamma^{k} \frac{\partial q_{k1}}{\partial p_{k1}} + \lambda^{k} \frac{\partial \Pi_{2}^{k}}{\partial p_{k1}} = 0.$$
(III-10b)

It is assumed that $\frac{\partial \Pi_2'}{\partial p_{i1}} = \left[\frac{\partial \Pi_2'}{\partial S'}\frac{\partial S'}{\partial p_{i1}} + \frac{\partial \Pi_2'}{\partial p_{s2}}\frac{\partial p_{s2}}{\partial p_{i1}}\right] < 0$ holds; or the first

negative term dominate the second positive term.⁵ Therefore, firms choose lower prices than they would if market share had no value. It is further assumed that the second order conditions for profit maximization are fulfilled, and that the actions of the duopolists are strategic complements, i.e. the marginal profit of an own price increase rises with a higher

price of the rival:
$$\frac{\partial^2 \Pi'}{\partial p_{i1} \partial p_{s1}} \equiv \Pi'_{is} > 0$$
, $i, s = j, k, i \neq s$.

⁵ See Froot and Klemperer (1989).

To calculate the comparative static reactions for the changes of exchange rates, we differentiate (III-10) and get:

$$\begin{bmatrix} dp_{j1} \\ dp_{k1} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \Pi_{kk}^{k} & -\Pi_{jk}^{j} \\ -\Pi_{kj}^{k} & \Pi_{jj}^{j} \end{bmatrix} \begin{bmatrix} A \\ C \end{bmatrix},$$
(III-11)

where $\Delta = \prod_{j} \prod_{k} \prod_{k} - \prod_{j} \prod_{k} \prod_{k} > 0$ by a stability condition and

$$A = q_{j1}(\varepsilon_1^j - 1)de_{j1} - \lambda^j \left[\frac{\partial^2 \Pi_2^j}{\partial p_{j1} \partial e_{j2}}de_{j2} + \frac{\partial^2 \Pi_2^j}{\partial p_{j1} \partial e_{k2}}de_{k2}\right],$$
$$C = q_{k1}(\varepsilon_1^k - 1)de_{k1} - \lambda^k \left[\frac{\partial^2 \Pi_2^k}{\partial p_{k1} \partial e_{k2}}de_{k2} + \frac{\partial^2 \Pi_2^k}{\partial p_{k1} \partial e_{j2}}de_{j2}\right].$$

Then, we obtain the comparative static:

$$dp_{j1} = \frac{1}{\Delta} \{ \Pi_{kk}^{k} q_{j1} (\varepsilon_{1}^{j} - 1) de_{j1} - [\Pi_{kk}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{j2}} - \Pi_{jk}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{j2}}] de_{j2} + \Pi_{jk}^{j} q_{k1} (1 - \varepsilon_{1}^{k}) de_{k1} + [\Pi_{jk}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{k2}} - \Pi_{kk}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{k2}}] de_{k2} \}, \quad (\text{III-12a})$$

$$dp_{k1} = \frac{1}{\Delta} \{ \Pi'_{y} q_{k1} (\varepsilon_{1}^{k} - 1) de_{k1} - [\Pi'_{y} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{k2}} - \Pi^{k}_{ky} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{k2}}] de_{k2} + \Pi^{k}_{ky} q_{j1} (1 - \varepsilon_{1}^{j}) de_{j1} + [\Pi^{k}_{ky} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{j2}} - \Pi^{j}_{y} \lambda^{k} \frac{\partial^{2} \Pi^{k}_{2}}{\partial p_{k1} \partial e_{j2}}] de_{j2} \}.$$
(III-12b)

The third and fourth terms of (III-12) reflect the effect of rival's exchange rate change. If these terms are zero, the expression will be similar to Froot and Klemperer's (1989) and Tivig's (1996). However, if the change of exchange rate comes from the U.S. policy (e.g., an increase in the money supply in the U.S.), $Cov(e_{j1}, e_{k1})$ will be generally positive and the third and fourth terms will be significant. Also, when the change has its origin in rival country's domestic policy, rival's exchange rate may change without any change of its own currency value relative to dollar. My model suggests that the price may be changed by rival's exchange rate even when there is no change of its own exchange rate. A major and indeed important factor for exchange rate PT has simply been missed. If rival's (third country) exchange rate is not considered, theoretical analyses are misconceived and empirical studies are biased and inefficient.⁶ Particularly, empirical tests based on a bilateral trade and an exchange rate may face serious mis-specification problems if rival exchange rate is not hold as a constant. We first analyze it for four cases when imperfect capital mobility is assumed,⁷ differently from Froot and Klemperer (1989).

[1] Temporary change of e_{μ} only.

$$de_{12} = de_{k1} = de_{k2} = 0$$
 (or $Cov(e_{11}, e_{k1}) = Cov(e_{11}, e_{12}) = Cov(e_{11}, e_{k2}) = 0$).

Then, the comparative static will be:

.

$$\frac{dp_{j1}}{de_{j1}} = \frac{1}{\Delta} \prod_{kk}^{k} q_{j1} (\varepsilon_{1}^{j} - 1), \qquad (\text{III-13a})$$

$$\frac{dp_{k1}}{de_{j1}} = \frac{1}{\Delta} \prod_{kj}^{k} q_{j1} (1 - \varepsilon_{1}^{j}), \qquad (\text{III-13b})$$

$$\frac{dp_{T_1}}{de_{T_1}} = \frac{1}{\Delta} (\Pi_{kk}^k - \frac{\beta}{\alpha} \Pi_{kj}^k) q_{j1} (\varepsilon_1^j - 1), \qquad (\text{III-13c})$$

where α = market share of country j,

⁶ In some empirical studies, the effect of rival exchange rate is partially reflected by rival prices (usually domestic price). However, there exists simultaneous bias problem because it fails to capture the strategic interaction.

⁷ I think the assumption of imperfect capital mobility is more realistic.

 $\beta = 1 - \alpha =$ market share of country k,

 $e_T = \alpha e_1 + \beta e_k$ = trade weighted exchange rate,

 $p_T = \alpha p_1 + \beta p_k$ = trade weighted price.

Hence, if first-period demand is inelastic (elastic), pass-through is perverse (normal). Equation (III-13) shows the PTs in all three definitions, depending on the elasticity of good j's first period demand. When $\varepsilon_1^j < 1$,⁸ market share is not seriously affected and firm j wants to enjoy current profits. Firm k just reacts to firm j's action as price on strategic complements. This is similar to proposition 2 of Tivig (1996), substituting another (rival) foreign firm instead of a domestic firm; that is, "With imperfect capital mobility, the elasticity of first-period import demand is a necessary and sufficient condition for PT direction of a temporary exchange rate change to first-period prices. Prices of the imported and of the domestically produced good always move in the same direction. The magnitude of change is greater for the imported good." However, if the rival exchange rate is also changed, the implication will be different. We now study the rival effect.

[2] Temporary change of both e_{j1} and e_{k1} .

$$de_{12} = de_{k2} = 0$$
 (or $Cov(e_{11}, e_{12}) = Cov(e_{11}, e_{k2}) = 0$).

Then, the comparative static will be:

$$\frac{dp_{j1}}{de_{j1}} = \frac{1}{\Delta} \{ \prod_{kk}^{k} q_{j1} (\varepsilon_{1}^{j} - 1) + \prod_{jk}^{j} q_{k1} (1 - \varepsilon_{1}^{k}) \frac{de_{k1}}{de_{j1}} \}, \qquad (\text{III-14a})$$

⁸ Generally, duopolists produce their output in the elastic demand area. However, in the intertemporal optimization problem we can not eliminate the possibility of producing their output in the inelastic area, because current market shares affect future profits.

$$\frac{dp_{k1}}{de_{j1}} = \frac{1}{\Delta} \{ \Pi_{jj}^{j} q_{k1} (\varepsilon_{1}^{k} - 1) \frac{de_{k1}}{de_{j1}} + \Pi_{kj}^{k} q_{j1} (1 - \varepsilon_{1}^{j}) \}, \qquad \text{(III-14b)}$$

$$\frac{dp_{T1}}{de_{T1}} = \frac{(\alpha \Pi_{kk}^{k} - \beta \Pi_{kj}^{k})q_{j1}(\varepsilon_{1}^{j} - 1)de_{j1} + (\beta \Pi_{jj}^{j} - \alpha \Pi_{jk}^{j})q_{k1}(\varepsilon_{1}^{k} - 1)de_{k1}}{\Delta(\alpha de_{j1} + \beta de_{k1})}.$$
 (III-14c)

First, let see the PT of exporter side (equation III-14a and 14b). If $\frac{de_{k1}}{de_{j1}} > 0$ (or

 $Cov[e_{j1}, e_{k1}] > 0$) and $\varepsilon_1^j, \varepsilon_1^k > l(< 1)$, the exchange rate pass-through is more normal (perverse) than the case that we do not consider the change of rival's exchange rate. This also implies that pass-through of greater than unity is possible in some case. More interesting is the case of $\frac{de_{k1}}{de_{j1}} < 0$ (or $de_{k1} < 0$ and $de_{j1} > 0$). The elasticity of first-period import

demand is no longer a necessary and sufficient condition for the "normal" PT of a temporary exchange rate change to first-period prices. For example, consider a case that e_{j1} increases by 10% and e_{k1} decreases by 20%. $\varepsilon_1^J > 1$ does not guarantee the decrease of p_{j1} due to the second term of (III-14a). While an increase of e_{j1} may induce the firm to decrease p_{j1} , the increase of p_{k1} motivated by the decrease of e_{k1} may result in an increase in p_{j1} . Also, prices of the firm j and k do not always move in the same direction. If the relative change of e_{k1} is large enough, firm j may have perverse pass-through while firm k has normal exchange rate pass-through.⁹ Even though the goods are strongly substitutable, we can observe, in some level, that firm j decreases the price while firm k increases the price of a good. Of course, this is related to an empirical issue. If the rival exchange rate is hold constant as in an

⁹ If duopoly (or oligopoly) firms produce in an elastic area (better match with the duopoly theory), Froot and Klemperer (1989) and Tivig (1996) can not explain the perverse exchange rate pass-through.

empirical test, perverse pass-through in terms of exporters is not possible in the elastic demand area. Again, it emphasizes that rival exchange rate should be considered in the passthrough estimation.

Next, equation (III-14c) represents exchange rate PT faced by an importer. If a change of e_{j1} and a change of e_{k1} are in the same direction, the PT direction of a temporary exchange rate change to first-period prices only depends on ε_1^j and ε_1^k ; that is, if both ε_1^j and ε_1^k is greater (less) than unit, PT is normal (perverse), and if one of ε_1^i s is less than unity and the other is greater than unit, the direction of PT is not obvious. However, it is clear that the possibility of perverse PT can not be eliminated even in the elastic demand area if a change of e_{j1} and a change of e_{k1} are in the opposite direction. Particularly, the perverse pass-through may often happen if a small firm's demand is more elastic.

[3] Permanent change of e_i only.

$$\frac{de_{j2}}{de_{j1}} = 1 \text{ (or } de_{j1} = de_{j2} = de_{j} \text{) and } \frac{de_{k1}}{de_{j1}} = \frac{de_{k2}}{de_{j1}} = 0$$

Then, the comparative static will be:

$$\frac{dp_{j1}}{de_j} = \frac{1}{\Delta} \{ \Pi_{kk}^k q_{j1} (\varepsilon_1^j - 1) + [\Pi_{jk}^j \lambda^k \frac{\partial^2 \Pi_2^k}{\partial p_{k1} \partial e_{j2}} - \Pi_{kk}^k \lambda^j \frac{\partial^2 \Pi_2^j}{\partial p_{j1} \partial e_{j2}}] \}, \qquad (\text{III-15a})$$

$$\frac{dp_{k1}}{de_{j}} = \frac{1}{\Delta} \left\{ \Pi_{kj}^{k} q_{j1} (1 - \varepsilon_{1}^{j}) + \left[\Pi_{kj}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{j2}} - \Pi_{jj}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{j2}} \right] \right\}, \qquad (\text{III-15b})$$

$$\frac{dp_{T1}}{de_T} = \frac{1}{\Delta} \{ (\Pi_{kk}^k - \frac{\beta}{\alpha} \Pi_{kj}^k) q_{j1} (\varepsilon_1^j - 1) + \lambda^j \frac{\partial^2 \Pi_2^j}{\partial p_{j1} \partial e_{j2}} (\frac{\beta}{\alpha} \Pi_{kj}^k - \Pi_{kk}^k) \}$$

$$+\lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{kl} \partial e_{j2}} (\Pi_{jk}^{\prime} - \frac{\beta}{\alpha} \Pi_{jl}^{\prime}) \}.$$
(III-15c)

This is similar with Froot and Klemperer (1989) showing that exchange rate passthrough will be more likely to be normal because the second period (negative¹⁰) effect is added to (III-13).

[4] Permanent change of both e_j and e_k .

$$\frac{de_{j2}}{de_{j1}} = \frac{de_{k2}}{de_{k1}} = 1 \text{ (or, } de_{j1} = de_{j2} = de_{j} \text{ and } de_{k1} = de_{k2} = de_{k} \text{).}$$

Then, the comparative static will be:

$$\frac{dp_{j1}}{de_{j}} = \frac{1}{\Delta} \{ [\Pi_{kk}^{k} q_{j1}(\varepsilon_{1}^{j} - 1) - \Pi_{kk}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{j2}} + \Pi_{jk}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{j2}}]
+ [\Pi_{jk}^{j} q_{k1}(1 - \varepsilon_{1}^{k}) + \Pi_{jk}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{k2}} - \Pi_{kk}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{k2}}] \frac{de_{k}}{de_{j}} \}, \quad (\text{III-16a})
\frac{dp_{k1}}{de_{j}} = \frac{1}{\Delta} \{ [\Pi_{kj}^{k} q_{j1}(1 - \varepsilon_{1}^{j}) de_{j1} + \Pi_{kj}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{j2}} - \Pi_{jj}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{k1} \partial e_{j2}}]$$

$$+ \left[\Pi_{y}^{j} q_{k1}(\varepsilon_{1}^{k}-1) - \Pi_{y}^{j} \lambda^{k} \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{k1} \partial e_{k2}} + \Pi_{kj}^{k} \lambda^{j} \frac{\partial^{2} \Pi_{2}^{j}}{\partial p_{j1} \partial e_{k2}}\right] \frac{de_{k}}{de_{j}} \}, \qquad (\text{III-16b})$$

$$\frac{dp_{T1}}{de_T} = \frac{1}{\Delta(\alpha de_j + \beta de_k)} \times \{ [(\alpha \Pi_{kk}^k - \beta \Pi_{kj}^k)q_{j1}(\varepsilon_1^j - 1) + \lambda^j (\beta \Pi_{kj}^k - \alpha \Pi_{kk}^k) \frac{\partial^2 \Pi_2^j}{\partial p_{j1} \partial e_{j2}} \}$$

¹⁰ Since $\frac{\partial \Pi_2'}{\partial p_{i1}} < 0$ and Π_2' is second- period own currency profits of firm i, we derive that $\frac{\partial^2 \Pi_2'}{\partial p_{i1} \partial e_{i2}} < 0$. Furthermore, generally, $|\frac{\partial^2 \Pi_2'}{\partial p_{i1} \partial e_{i2}}| > |\frac{\partial^2 \Pi_2'}{\partial p_{i1} \partial e_{s2}}|$.
$$+ \lambda^{k} (\alpha \Pi_{jk}^{\prime} - \beta \Pi_{jl}^{\prime}) \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{kl} \partial e_{j2}}] de_{j}$$

$$+ [(\beta \Pi_{jl}^{\prime} - \alpha \Pi_{jk}^{\prime}) q_{kl} (\varepsilon_{l}^{k} - l) + \lambda^{k} (\alpha \Pi_{jk}^{\prime} - \beta \Pi_{jl}^{\prime}) \frac{\partial^{2} \Pi_{2}^{k}}{\partial p_{kl} \partial e_{k2}}$$

$$+ \lambda^{\prime} (\beta \Pi_{kl}^{k} - \alpha \Pi_{kk}^{k}) \frac{\partial^{2} \Pi_{2}^{\prime}}{\partial p_{ll} \partial e_{k2}}] de_{k} \}. \qquad \text{(III-16c)}$$

The effect of each exchange rate change is added by the second period terms compared to (III-14). Certainly, equation (III-16a and 16b) imply that the importance of rival's exchange rate change is increased if own exchange rate change is temporary and the change of rival exchange rate is permanent. Interestingly, unlike Froot and Klemperer (1989), it is possible that a firm makes a perverse pass-through strategy even with a permanent exchange rate change if the change of rival's exchange rate is relatively large enough and in the opposite direction.¹¹ Equation (III-16c) shows that, with the permanent changes of exchange rates and in the elastic demand areas, the possibility of perverse PT in terms of trade weighted can not be eliminated if a change of e_j and a change of e_k are in the opposite direction.

III.4 Imperfect foresight and the exchange rate pass-through

In Froot and Klemperer (1989), Tivig (1996), and section 2 of this chapter, it is assumed that the level of the exchange rate at successive instants of time are known (or perfectly forecasted). While theories need simplifying assumptions, this is unrealistic.

¹¹ Again, it is related with an empirical issue. Of course, if a rival exchange rate is hold as constant in the empirical test, perverse pass-through is not possible.

Therefore, in this section, I will assume that a firm's pricing decision is made after current exchange rates are known, but before future exchange rates are known. In the two period model, the events are as follows:

 $e_{j1}, e_{k1} \rightarrow p_{j1}, p_{k1} \rightarrow e_{j2}, e_{k2} \rightarrow p_{j2}, p_{k2}$; when each firm chooses p_{j1} and p_{k1} respectively, they know e_{j1} and e_{k1} but do not know e_{j2} and e_{k2} .¹²

The export firms' problems (III-6) will be modified as in (III-17):

$$\max_{p_{j1},p_{j2}} E[\Pi^{j}] = E\{(e_{j1}p_{j1} - \gamma^{j})q_{j1}(p_{j1},p_{k1}) + \lambda^{j}[(e_{j2}p_{j2} - \gamma^{j})q_{j2}(S^{j},p_{j2},p_{k2})]\}, \quad (\text{III-17a})$$

 $\max_{p_{k1},p_{k2}} E[\Pi^{k}] = E\{(e_{k1}p_{k1} - \gamma^{k})q_{k1}(p_{j1},p_{k1}) + \lambda^{k}[(e_{k2}p_{k2} - \gamma^{k})q_{k2}(S^{k},p_{j2},p_{k2})]\}.$ (III-17b)

The subgame of period two is solved first. In period two, the second-period dollar prices are chosen to maximize the own currency second-period profits :

$$\max_{p_{j_2}} \prod_{j=1}^{j} = (e_{j_2} p_{j_2} - \gamma^j) q_{j_2} (S^j (p_{j_1}, p_{k_1}), p_{j_2}, p_{k_2}),$$
(III-18a)

$$\max_{p_{k2}} \prod_{2}^{k} = (e_{k2} p_{k2} - \gamma^{k}) q_{k2} (S^{k} (p_{j1}, p_{k1}), p_{j2}, p_{k2}).$$
(III-18b)

The first order conditions for the problem in (III-18) are:

$$\frac{\partial \Pi_{2}^{\prime}}{\partial p_{12}} = e_{12}q_{12} + (e_{12}p_{12} - \gamma^{\prime})\frac{\partial q_{12}}{\partial p_{12}} = 0, \qquad \text{(III-19a)}$$

$$\frac{\partial \Pi_{2}^{k}}{\partial p_{k2}} = e_{k2}q_{k2} + (e_{k2}p_{k2} - \gamma^{k})\frac{\partial q_{k2}}{\partial p_{k2}} = 0.$$
(III-19b)

¹² Some careful readers may think that the problem of order and payment lags does not justify this structure. Although this paper does not deal with hedging issues, the existence of currency futures market strongly supports this game structure. Indeed, whereas the short term futures market is easily available and practical, long term futures market is not available or very costly.

The second-period equilibrium prices are derived as functions of first-period prices, second-period exchange rates and second-period own currency marginal costs. The reduced form solutions are the following:

$$p_{j2}^{*} = p_{j2}(p_{j1}, p_{k1}, e_{j2}, e_{k2}, \gamma^{j}, \gamma^{k}), \qquad (\text{III-20a})$$

$$p_{k2}^{\bullet} = p_{k2}(p_{j1}, p_{k1}, e_{j2}, e_{k2}, \gamma^{j}, \gamma^{k}).$$
(III-20b)

In the first period, firms maximize the present discounted value of own-currency profits by choosing first-period prices:

$$\underset{p_{j1}}{\operatorname{Max}} E[\Pi^{j}] = \underset{e_{j2}, e_{k2}}{E} \{ (e_{j1}p_{j1} - \gamma^{j})q_{j1}(p_{j1}, p_{k1}) + \lambda^{j} [(e_{j2}p_{j2}^{*} - \gamma^{j})q_{j2}(S^{j}, p_{j2}^{*}, p_{k2}^{*})] \},$$
(III-21a)

$$\underset{p_{k1}}{\operatorname{Max}} E[\Pi^{k}] = \underset{e_{j2}, e_{k2}}{\operatorname{E}} \{ (e_{k1}p_{k1} - \gamma^{k})q_{k1}(p_{j1}, p_{k1}) + \lambda^{k} [(e_{k2}p_{k2}^{\bullet} - \gamma^{k})q_{k2}(S^{k}, p_{j2}^{\bullet}, p_{k2}^{\bullet})] \}.$$
(III-21b)

Using the envelope theorem we find the first-order necessary conditions for the problem in (III-21):

$$\frac{\partial E[\Pi^{j}]}{\partial p_{j1}} = e_{j1}q_{j1} + (e_{j1}p_{j1} - \gamma^{j})\frac{\partial q_{j1}}{\partial p_{j1}} + \lambda^{j} \underbrace{E}_{e_{j2},e_{k2}}[(e_{j2}p_{j2}^{*} - \gamma^{j})(\frac{\partial q_{j2}}{\partial S^{j}}\frac{\partial S^{j}}{\partial p_{j1}} + \frac{\partial q_{j2}}{\partial p_{k2}^{*}}\frac{\partial p_{k2}^{*}}{\partial p_{j1}})], \quad (\text{III-22a})$$

$$\frac{\partial E[\Pi^{\prime}]}{\partial p_{k1}} = e_{k1}q_{k1} + (e_{k1}p_{k1} - \gamma^{k})\frac{\partial q_{k1}}{\partial p_{k1}}$$

$$+ \lambda^{k} \underbrace{E}_{e_{j2},e_{k2}} \left[(e_{k2} p_{k2}^{\bullet} - \gamma^{k}) (\frac{\partial q_{k2}}{\partial S^{k}} \frac{\partial S^{k}}{\partial p_{k1}} + \frac{\partial q_{k2}}{\partial p_{j2}^{\bullet}} \frac{\partial p_{j2}^{\bullet}}{\partial p_{k1}}) \right].$$
(III-22b)

Substituting (III-20) into (III-22), the reduced form solution of first-period prices are:¹³

$$p_{j1}^{\bullet} = p_{j1}(e_{j1}, e_{k1}, E[e_{j2}], E[e_{k2}], Var[e_{j2}], Var[e_{k2}], Cov[e_{j2}, e_{k2}], \gamma^{j}, \gamma^{k}, \lambda^{j}, \lambda^{k}), \quad (\text{III-23a})$$

$$p_{k1}^{\bullet} = p_{k1}(e_{j1}, e_{k1}, E[e_{j2}], E[e_{k2}], Var[e_{j2}], Var[e_{k2}], Cov[e_{j2}, e_{k2}], \gamma^{j}, \gamma^{k}, \lambda^{j}, \lambda^{k}). \quad (\text{III-23b})$$

In the case of imperfect foresight, second-period exchange rates are not known, and each firm's first-period price decision relies upon the expected exchange rates, and variances and covariance of exchange rates. Due to brand loyalty, a current period pricing decision affects not only current profit but also future profit through its impact on a market share. At that time, the expected future profit (or the value of current market share) is effected by expected competition situations which depend on the interactive movement of future exchange rates.

To obtain more precise results, I analyze exchange rate PT using an example of Tivig (1996) in which demand functions are linear and symmetric in current prices. This demand structure corresponds to the Hotelling model of differentiated products presented as the "Linear City Case" in Tirole (1990, chapter 7.1.1):

$$q_{i1} = \frac{1}{2} - p_{i1} + p_{s1} \Rightarrow Q_1 = q_{j1} + q_{k1} = 1, \ S' = \frac{q_{i1}}{Q_1} = q_{i1},$$

$$q_{i2} = S' - p_{i2} + p_{s2} \Longrightarrow Q_2 = q_{j2} + q_{k2} = 1; \ i, s = j, k; \ i \neq s,$$

where Q_1 and Q_2 are the first- and second-period market demand, respectively, normalized at one. Following the steps from (III-17) through (III-19), we obtain the solution of the second-period prices:

¹³ p_{j1}^{*} and p_{k1}^{*} depend on the distribution of e_{j2} and e_{k2} . Assuming that it can be captured by the five parameters ($E[e_{j2}], E[e_{k2}], Var[e_{j2}], Var[e_{k2}], Cov[e_{j2}, e_{k2}]$), we can get equation III-23.

$$\begin{bmatrix} p_{j2}^{*} \\ p_{k2}^{*} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} S' + \frac{\gamma'}{e_{j2}} \\ S^{k} + \frac{\gamma^{k}}{e_{k2}} \end{bmatrix}.$$
 (III-20)'

Then, following the steps from (III-21) to (III-22) we can get the solution of the firstperiod prices:

$$\begin{bmatrix} p_{j1}^{*} \\ p_{k1}^{*} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} 2 - \frac{2}{9}\beta_{k} & 1 - \frac{2}{9}\beta_{j} \\ 1 - \frac{2}{9}\beta_{k} & 2 - \frac{2}{9}\beta_{j} \end{bmatrix} \begin{bmatrix} \frac{3 - 2\beta_{j}}{6} + C_{j1} + \frac{2}{9}\beta_{j}C_{j2} - \frac{2}{9}\beta_{j}C_{k2}\theta_{k} \\ \frac{3 - 2\beta_{k}}{6} + C_{k1} + \frac{2}{9}\beta_{k}C_{k2} - \frac{2}{9}\beta_{k}C_{j2}\theta_{j} \end{bmatrix}, \quad (\text{III-23})'$$

where $\Delta \equiv 3 - \frac{2}{9}(\beta_i + \beta_k)$, $C_u \equiv \frac{\gamma'}{E[e_u]}$: marginal cost in \$, $\beta_i \equiv \lambda_i \frac{E[e_{i_2}]}{e_{i_1}}$, and

$$\theta_{i} \equiv E\left[\frac{e_{s2}}{e_{i2}}\right] \frac{E[e_{i2}]}{E[e_{s2}]}.$$

Equation (III-23)' shows that the change of exchange rates affects each firm's pricing decision through (1) the change of dollar costs (C_u), (2) the effect on real interest rates (β_i), and (3) the uncertainty effect (θ_i which depends on the distribution of exchange rate¹⁴). If costs adjust instantaneously, C_u is independent of exchange rates, and the cost effect due to the change of the exchange rate is zero. If costs adjust only to the anticipated change of exchange rate, C_{i1} is changed by the unanticipated movement in e_{i1} , while C_{i2} is not affected; that is, a permanent shock where cost adjusts with a one period lag is comparable to a transitory shock. Equation (III-23)' also shows that prices decrease as uncertainties increase. In this study, the particular attention is paid to the uncertainty effect on exchange

rate pass-through. In the study of uncertainty effect, I distinguish between the cases of perfect and imperfect capital mobility.

III.4.1 Perfect capital mobility

With perfect capital mobility discount factors are related through the interest parity condition implying that β_i is fixed. Then, we can derive *Proposition III-2* and *III-3*.

Proposition III-2. With perfect capital mobility, for a temporary exchange rate shock, exchange rate PT increases as own and/or rival exchange rate uncertainties increase while exchange rate PT decreases as the covariance of exchange rates increases

Proof.

We can think that θ_j is an approximation of own exchange rate uncertainty while θ_k is an approximation of rival exchange rate uncertainty.¹⁵ In this "Linear City case", from equation (III-23)' we calculate the comparative static reactions to a temporary change in the exchange rate as follows:

$$PT' = \frac{dp_{j1}}{de_{j1}} \cdot \frac{e_{j1}}{p_{j1}} < 0 \text{ because } \frac{dp_{j1}}{de_{j1}} = \frac{2}{\Delta} (1 - \frac{\beta_k}{9}) \frac{\partial C_{j1}}{\partial e_{j1}} < 0. \text{ Then,}$$

$$\frac{\partial PT'}{\partial \theta_i} = \frac{\partial p_{j1}}{\partial e_{j1} \partial \theta_i} \frac{e_{j1}}{p_{j1}} - \frac{\partial p_{j1} \partial p_{j1}}{\partial e_{j1} \partial \theta_i} \frac{e_{j1}}{p_{j1}^2} < 0, \quad i = j, k.$$

¹⁵ See footnote 16 and 17.

Exchange rate pass-through increases because uncertainty reduces the price level without the second-order effect. Meanwhile, because the covariance is negatively related to θ_i we can figure out the covariance effect on exchange rate pass-through as follows:

$$\frac{\partial PT'}{\partial Cov} = \underbrace{\frac{\partial p_{j1}}{\partial e_{j1}\partial Cov}}_{0} \underbrace{\frac{e_{j1}}{p_{j1}}}_{0} - \underbrace{\frac{\partial p_{j1}}{\partial e_{j1}}}_{0} \frac{\partial p_{j1}}{\partial e_{j1}}}_{0} \underbrace{\frac{\partial p_{j1}}{\partial e_{j1}}}$$

Proposition III-3. With perfect capital mobility, for a permanent exchange rate shock, (1) exchange rate PT increases as rival exchange rate uncertainty increases; (2) exchange rate PT decreases as own exchange rate uncertainty increases; and (3) exchange rate PT increases as the covariance of exchange rates increases.

Proof.

In this "Linear City case", from equation (III-23)' we calculate the comparative static reactions to a permanent change in the exchange rate as follows:

$$PT^{j} = \frac{dp_{j1}}{de_{j}} \cdot \frac{e_{j}}{p_{j1}} = \frac{e_{j}}{\Delta p_{j1}} \{ (\frac{2}{9}\beta_{k} - 2)(\frac{C_{j1}}{e_{j1}} + \frac{2}{9}\frac{C_{j2}}{E[e_{j2}]}\beta_{j}) + (1 - \frac{2}{9}\beta_{j})(\frac{2}{9}\frac{C_{j2}}{E[e_{j2}]}\beta_{k}\beta_{j}) \} < 0, \text{ and}$$

$$\frac{\partial PT'}{\partial \theta_{j}} = \frac{\partial p_{j1}}{\partial e_{j} \partial \theta_{j}} \frac{e_{j}}{p_{j1}} - \frac{\partial p_{j1} \partial p_{j1}}{\partial e_{j} \partial \theta_{j}} \frac{e_{j}}{p_{j1}^{2}} > 0.$$
 Here, the first positive term dominates the

second negative term; or

$$\frac{\partial PT'}{\partial \theta_{j}} = \frac{C_{j2}}{\Delta^{2} p_{j1}^{2}} \frac{2}{9} \beta_{k} (1 - \frac{2}{9} \beta_{j}) \left\{ (2 - \frac{2}{9} \beta_{k}) (\frac{3 - 2\beta_{j}}{6} - \frac{2}{9} \beta_{j} C_{k2} \theta_{k}) \right\}$$

+
$$(1 - \frac{2}{9}\beta_j)(\frac{3 - 2\beta_k}{6} + C_{k1} + \frac{2}{9}\beta_k C_{k2})$$
 > 0. Meanwhile,

Q.E.D.

$$\frac{\partial PT'}{\partial \theta_k} = \frac{\partial p_{j1}}{\partial e_j \partial \theta_k} \frac{e_j}{p_{j1}} - \frac{\partial p_{j1} \partial p_{j1}}{\partial e_j \partial \theta_k} \frac{e_j}{p_{j1}^2} < 0.$$
 Exchange rate pass-through increases

because uncertainty just reduces price without the second-order effect. Finally, from the fact that the covariance is negatively related to θ_i , we can figure out the covariance effect on

exchange rate pass-through as follows:
$$\frac{\partial PT'}{\partial Cov} = \frac{\partial p_{j1}}{\partial e_j \partial Cov} \frac{e_j}{p_{j1}} - \frac{\partial p_{j1}}{\partial e_j} \frac{\partial p_{j1}}{\partial cov} \frac{e_j}{p_{j1}^2} < 0.$$

Here, the first negative term dominates the second positive term.

III.4.2 Imperfect capital mobility

With imperfect capital mobility β_i is not fixed. Assuming $\lambda^j = \lambda^k = 1$ to simplify, we can get the solution of first-period prices. Then, equation (III-23)' can be modified as equation (III-23)'':

$$\begin{bmatrix} p_{j1} \\ p_{k1} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \frac{2}{9} \overline{e}_{k2} - 2e_{k1} & \frac{2}{9} \overline{e}_{j2} - e_{j1} \\ \frac{2}{9} \overline{e}_{k2} - e_{k1} & \frac{2}{9} \overline{e}_{j2} - 2e_{j1} \end{bmatrix} \begin{bmatrix} -\frac{1}{2}e_{j1} + \frac{1}{3}\overline{e}_{j2} - \frac{11}{9}\gamma' + \frac{2}{9}\gamma' E[\frac{e_{j2}}{e_{k2}}] \\ -\frac{1}{2}e_{k1} + \frac{1}{3}\overline{e}_{k2} - \frac{11}{9}\gamma' + \frac{2}{9}\gamma' E[\frac{e_{k2}}{e_{j2}}] \end{bmatrix}, \quad \text{(III-23)''}$$

where $\Delta = (\frac{2}{9}\overline{e}_{j2} - 2e_{j1})(\frac{2}{9}\overline{e}_{k2} - 2e_{k1}) - (\frac{2}{9}\overline{e}_{j2} - e_{j1})(\frac{2}{9}\overline{e}_{k2} - e_{k1})$ and $\overline{e}_{i2} = E[e_{i2}].$

The $E[\frac{e_{i2}}{e_{i2}}]$ term depends on the distribution of exchange rate uncertainties. For the

further analysis, here I assume the random shocks of exchange rates follow a bivariate normal

distribution.¹⁶ Then,
$$E[\frac{e_{i_2}}{e_{i_2}}] \approx E[e_{i_2}](\frac{1}{E[e_{i_2}]} + \frac{Var[e_{i_2}]}{E[e_{i_2}]^3}) - \frac{Cov[e_{i_2}, e_{i_2}]}{E[e_{i_2}]^2}$$
 by Taylor

extension.¹⁷ From (III-23)" we can see that the exchange rate PT will be affected by the

 $E\left[\frac{e_{i2}}{e_{s2}}\right] = \frac{E[e_{i2}]^{2}(Var[e_{s2}] + E[e_{s2}]^{2})}{E[e_{s2}]^{2}(E[e_{s2}]E[e_{i2}] + Cov[e_{i2}, e_{s2}])} \text{ (using the fact that if (x, y) = (ln e_{i}, ln e_{s}) ~ N(\mu_{x}, \mu_{y}, \sigma_{x}^{2}, \sigma_{y}^{2}, \sigma_{xy}), E[e_{i}^{\alpha}e_{s}^{\beta}] = \exp[\alpha\mu_{x} + \beta\mu_{y} + 1/2(\alpha^{2}\sigma_{x}^{2} + 2\alpha\beta\sigma_{xy} + \beta^{2}\sigma_{y}^{2})]). \text{ For the proof of the Proposition III-4, only the } \frac{\partial E[e_{i2}/e_{s2}]}{\partial Var[e_{i2}]}, \frac{\partial E[e_{i2}/e_{s2}]}{\partial Var[e_{s2}]} \text{ and } \frac{\partial E[e_{i2}/e_{s2}]}{\partial Cov[e_{i2}, e_{s2}]} \text{ terms are changed under bivariate log-normal distributions, resulting in the same results with the case of a bivariate normal distribution. However, the analysis for a permanent shock ($ *Proposition III-5* $) is more complicated because of the interactive relationship of variance and covariance in the <math>E[e_{i2}/e_{s2}]$ term. I could get the same results with *Proposition III-5* at some particular points only; that is, marginal effects at the point that covariance is zero are the same with the case of a bivariate normal distribution, by Taylor extension we can get: 1) $Cov[e_{i}, 1/e_{s2}] = E\{(e_{i} - E[e_{i}])(\frac{1}{e_{s}} - E[\frac{1}{e_{s}}])\} \approx -\frac{Cov[e_{i}, e_{s}]}{E[e_{s}]^{2}}$ and 2) $E[\frac{1}{e_{s}}] \approx \frac{1}{E[e_{s}]} + \frac{Var[e_{s}]}{E[e_{s}]^{3}}$. Using 1) and 2) we can get: $E[\frac{e_{i}}{e_{s}}] = E[e_{i}]E[\frac{1}{e_{s}}] + Cov[e_{i}, \frac{1}{e_{s}}] \approx E[e_{i}](\frac{1}{E[e_{s}]^{2}}) - \frac{Cov[e_{i}, e_{s}]}{E[e_{s}]^{2}}$. Proof of 1): $(e_{i} - E[e_{i}])(\frac{1}{e_{s}} - E[\frac{1}{e_{s}}]) \approx (e_{i} - E[e_{i}])(\frac{1}{E[e_{s}]} - E[\frac{1}{e_{s}}]) + (e_{i} - E[e_{i}])(-\frac{1}{E[e_{s}]^{2}})(e_{s} - E[e_{s}])$ Then,

$$E\{(e_{i} - E[e_{i}])(\frac{1}{e_{s}} - E[\frac{1}{e_{s}}])\} \approx -\frac{Cov[e_{i}, e_{s}]}{E[e_{s}]^{2}} + E\{(e_{i} - E[e_{i}])(e_{s} - E[e_{s}])^{2}\} = -\frac{Cov[e_{i}, e_{s}]}{E[e_{s}]^{2}} \text{ because}$$

$$E\{(e_{i} - E[e_{i}])(e_{s} - E[e_{s}])^{2}\} = E\{E[(e_{i} - E[e_{i}])(e_{s} - E[e_{s}])^{2}|e_{s}]\} = E\{E[(e_{i} - E[e_{i}])|e_{s}](e_{s} - E[e_{s}])^{2}\}$$

$$= E\{\frac{\sigma_{e,e_{s}}}{\sigma_{e,e_{s}}}(e_{s} - E[e_{s}])(e_{s} - E[e_{s}])^{2}\} = E\{e_{s}\{\frac{\sigma_{e,e_{s}}}{\sigma_{e,e_{s}}}(e_{s} - E[e_{s}])^{3}\} = 0$$

¹⁶ For bivariate log-normal distribution, the analytic results of proposition III-4 and 5 are similar. If the random shocks of exchange rates follow a bivariate log-normal distribution,

covariance and variances of exchange rates as well as current own- and rival bilateral exchange rates and expected future exchange rates. To illustrate, I show how the covariance and variance of exchange rates affect the exchange rate PT.

Proposition III-4. With imperfect capital mobility, for a temporary exchange rate shock, [A] If normal pass-through prevails (or $\varepsilon'_1 > 1$), around a symmetric equilibrium, (1) exchange rate PT increases as the covariance of exchange rates increases; (2) exchange rate PT decreases as the variance of rival's exchange rate increases; and (3) exchange rate PT increases as the variance of own exchange rate increases. [B] If perverse pass-through prevails (or $\varepsilon'_1 < 1$), around a symmetric equilibrium, (1) perverse exchange rate PT decreases as the covariance of exchange rates increases; (2) perverse exchange rate PT increases as the variance of rival's exchange rates increases; (2) perverse exchange rate PT decreases as the covariance of exchange rates increases; (2) perverse exchange rate PT increases as the variance of rival's exchange rate increases; and (3) the direction of exchange rate PT is ambiguous as the variance of own exchange rate increases.

Proof.¹⁸

In this "Linear City case", equation (III-22) is written as

$$\frac{\partial E[\Pi^{j}]}{\partial p_{j1}} = e_{j1} (\frac{1}{2} - 2p_{j1} + p_{k1}) + \gamma^{j} + \lambda^{j} \underbrace{E}_{e_{j2}, e_{k2}} [(e_{j2}p_{j2}^{*} - \gamma^{j})(-\frac{2}{3})], \quad (\text{III-22a})^{\prime}$$

¹⁸ In the proof of *Proposition III-2* and 3, I just use the definition of PT^{J} . However, the results are the same for the definition of $P\overline{T}^{k} = \frac{dp_{k1}}{de_{j1}} \cdot \frac{e_{j1}}{p_{k1}}$ and $PT^{T} = (\frac{dp_{j1}}{de_{j1}} + \frac{dp_{k1}}{de_{j1}}) \frac{e_{T1}}{p_{T1}}$ because each firm's reaction is complementary and $de_{k1} = 0$.

$$\frac{\partial E[\Pi^{k}]}{\partial p_{k1}} = e_{k1} \left(\frac{1}{2} - 2p_{k1} + p_{j1}\right) + \gamma^{k} + \lambda^{k} \sum_{e_{j2}, e_{k2}} \left[(e_{k2}p_{k2} - \gamma^{k})(-\frac{2}{3}) \right].$$
(III-22b)'

To calculate the comparative static reactions to a temporary change in the exchange rate, we differentiate (III-22)' and get:

assuming $de_{kl} = 0$,

$$\begin{bmatrix} dp_{j1} \\ dp_{k1} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \frac{2}{9}\overline{e}_{k2} - 2e_{k1} & \frac{2}{9}\overline{e}_{j2} - e_{j1} \\ \frac{2}{9}\overline{e}_{k2} - e_{k1} & \frac{2}{9}\overline{e}_{j2} - 2e_{j1} \end{bmatrix} \begin{bmatrix} (-\frac{1}{2} + 2p_{j1} - p_{k1})de_{j1} \\ 0 \end{bmatrix}.$$

Then,
$$PT' = \frac{dp_{j1}}{de_{j1}} \cdot \frac{e_{j1}}{p_{j1}} = \frac{e_{j1}}{\Delta \cdot p_{j1}} (\frac{2}{9}\overline{e}_{k2} - 2e_{k1})(\varepsilon_1' - 1)q_{j1}$$

$$= \frac{e_{j1}}{\Delta} (2e_{k1} - \frac{2}{9}\overline{e}_{k2}) (\frac{(1+2p_{k1})}{2p_{j1}} - 2) \stackrel{<}{=} 0 \text{ as } \varepsilon_{1}^{j} \stackrel{>}{=} 1$$

(1)
$$\frac{\partial PT'}{\partial Cov[e_{j_2}, e_{k_2}]} = \frac{e_{j_1}}{\Delta} (2e_{k_1} - \frac{2}{9}\overline{e}_{k_2}) \frac{2p'_{k_1} \cdot 2p_{j_1} - (1 + 2p_{k_1}) \cdot 2p'_{j_1}}{(2p_{j_1})^2}$$

$$=\frac{e_{j1}}{\Delta}(2e_{k1}-\frac{2}{9}\tilde{e}_{k2})\frac{4p'_{k1}p_{j1}-4p_{k1}p'_{j1}-2p'_{j1}}{(2p_{j1})^2} < 0 \text{ around symmetry.}$$

Where
$$p'_{j1} = \frac{\partial p_{j1}}{\partial Cov[e_{j2}, e_{k2}]} = \frac{2}{\Delta \cdot 9} \{ (2e_{k1} - \frac{2}{9}\overline{e}_{k2}) \frac{\gamma^{k}}{(\overline{e}_{k2})^{2}} + (e_{j1} - \frac{2}{9}\overline{e}_{j2}) \cdot \frac{\gamma^{j}}{(\overline{e}_{j2})^{2}} \} > 0,$$

$$p'_{k_1} = \frac{\partial p_{k_1}}{\partial Cov[e_{j_2}, e_{k_2}]} = \frac{2}{\Delta \cdot 9} \{ (e_{k_1} - \frac{2}{9}\overline{e}_{k_2}) \frac{\gamma^k}{(\overline{e}_{k_2})^2} + (2e_{j_1} - \frac{2}{9}\overline{e}_{j_2}) \frac{\gamma^j}{(\overline{e}_{j_2})^2} \} > 0.$$

For symmetric firms, $p_{j1} \approx p_{k1}$ and $p'_{j1} \approx p'_{k1}$. Then,

$$\frac{\partial PT^{j}}{\partial Cov[e_{j2}, e_{k2}]} \approx -\frac{e_{j1}}{\Delta} (2e_{k1} - \frac{2}{9}\overline{e}_{k2}) \frac{2p'_{j1}}{(2p_{j1})^{2}} < 0.$$

(2)
$$\frac{\partial PT'}{\partial Var[e_{k_2}]} = \frac{e_{j1}}{\Delta} (2e_{k_1} - \frac{2}{9}\overline{e}_{k_2}) \frac{2p_{k_1}' \cdot 2p_{j_1} - (1 + 2p_{k_1}) \cdot 2p_{j_1}''}{(2p_{j_1})^2} > 0$$
 around symmetry.

Where
$$p_{j1}'' = \frac{\partial p_{j1}}{\partial Var[e_{k2}]} = \frac{1}{\Delta} (\frac{2}{9} \overline{e}_{k2} - 2e_{k1}) \frac{2}{9} \gamma^{k} \frac{\overline{e}_{j2}}{(\overline{e}_{k2})^{3}} < 0,$$

 $\partial p_{k1} = \frac{1}{2} \frac{2}{2} - \frac{1}{2} \frac{\overline{e}_{j2}}{(\overline{e}_{k2})^{3}} < 0,$

$$p_{k1}'' = \frac{\partial p_{k1}}{\partial Var[e_{k2}]} = \frac{1}{\Delta} (\frac{2}{9}\overline{e}_{k2} - e_{k1}) \frac{2}{9} \gamma^{k} \frac{e_{j2}}{(\overline{e}_{k2})^{3}} < 0.$$

Thus, sign $\frac{\partial PT'}{\partial Var[e_{k_2}]} = \text{sign} \left[p_{k_1}'' \cdot 2p_{j_1} - p_{j_1}''(1+2p_{k_1}) \right] > 0$ because $|p_{k_1}''| < |p_{j_1}''|$ and

 $2p_{j1} < (1+2p_{k1})$ around symmetry.

(3)
$$\frac{\partial PT'}{\partial Var[e_{j_2}]} = \frac{e_{j_1}}{\Delta} (2e_{k_1} - \frac{2}{9}\overline{e}_{k_2}) \frac{2p_{k_1}''' \cdot 2p_{j_1} - (1 + 2p_{k_1}) \cdot 2p_{j_1}'''}{(2p_{j_1})^2}$$
? 0 around symmetry.

Where
$$p_{j1}^{\prime\prime\prime} = \frac{\partial p_{j1}}{\partial Var[e_{j2}]} = \frac{1}{\Delta} (\frac{2}{9} \overline{e}_{j2} - e_{j1}) \frac{2}{9} \gamma' \frac{\overline{e}_{k2}}{(\overline{e}_{j2})^3} < 0,$$

$$p_{k_1}^{\prime\prime\prime} = \frac{\partial p_{k_1}}{\partial Var[e_{j_2}]} = \frac{1}{\Delta} (\frac{2}{9}\overline{e}_{j_2} - 2e_{j_1}) \frac{2}{9} \gamma^{\prime} \frac{\overline{e}_{k_2}}{(\overline{e}_{j_2})^3} < 0.$$

Then, sign $\frac{\partial PT'}{\partial Var[e_{j_2}]} = \text{sign} \left[p_{k_1}^{\prime\prime\prime} \cdot 2p_{j_1} - p_{j_1}^{\prime\prime\prime\prime} (1 + 2p_{k_1}) \right]$: we can not determine because

$$|p_{k1}'''| > |p_{j1}'''|$$
 and $2p_{j1} < (1+2p_{k1})$. $\frac{\partial PT'}{\partial Var[e_{j2}]} < 0$ as $\frac{p_{k1}'''}{p_{j1}'''} < \frac{(1+2p_{k1})}{2p_{j1}}$.

However, if $\varepsilon_1^{\prime} \ge 1$, $\frac{\partial PT^{\prime}}{\partial Var[e_{\prime^2}]} < 0$.

If $\varepsilon_1^j \ge 1 \iff -\frac{1}{2} + 2p_{j1} - p_{k1} \ge 0 \iff p_{j1} \ge \frac{1}{2}$ around symmetry.

Then, sign $[p_{k1}''' \cdot 2p_{j1} - p_{j1}'''(1+2p_{k1})] =$ sign $[2p_{j1}(\frac{2}{9}\overline{e}_{j2} - 2e_{j1}) - (1+2p_{k1})(\frac{2}{9}\overline{e}_{j2} - e_{j1})]$ = sign $[-2p_{j1}e_{j1} - \frac{2}{9}\overline{e}_{j2} + e_{j1}] < 0.$

However, if
$$\varepsilon_1^{\prime} < 1$$
, $\frac{\partial PT^{\prime}}{\partial Var[e_{\prime 2}]}$? 0. Q.E.D.

Proposition III-5. With imperfect capital mobility, for a permanent exchange rate shock, (1) exchange rate PT increases as the covariance of exchange rates increases; (2) exchange rate PT increases as the variance of rival's exchange rate increases; and (3) exchange rate PT decreases as the variance of own exchange rate increases.

Proof.

For a permanent change of one exchange rate, a perverse exchange rate PT in this model is not possible.¹⁹ To calculate the comparative static reactions to a permanent change in the exchange rate, we differentiate (III-22)' and get:

assuming $de_k = 0$ and $de_{j1} = d\overline{e}_{j2}$,

$$\begin{bmatrix} dp_{j1} \\ dp_{k1} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \frac{2}{9}\overline{e}_{k2} - 2e_{k1} & \frac{2}{9}\overline{e}_{j2} - e_{j1} \\ \frac{2}{9}\overline{e}_{k2} - e_{k1} & \frac{2}{9}\overline{e}_{j2} - 2e_{j1} \end{bmatrix} \times$$

¹⁹ See Froot and Klemperer (1989).

$$\begin{bmatrix} \left(-\frac{1}{6} + \frac{16}{9}p_{j1} - \frac{7}{9}p_{k1} + \frac{2}{9}\gamma^{k}\left(\frac{1}{\overline{e}_{k2}} + \frac{Var(e_{k2})}{\overline{e}_{k2}^{3}}\right)\right)de_{j} \\ \left(\frac{2}{9}\gamma^{j}\left(-\frac{\overline{e}_{k2}}{\overline{e}_{j2}^{2}} - \frac{3\overline{e}_{k2}Var(e_{j2})}{\overline{e}_{j2}^{4}} + \frac{2Cov(e_{j2}, e_{k2})}{\overline{e}_{j2}^{3}}\right)\right)de_{j} \end{bmatrix}.$$
Then, $PT^{j} = \frac{dp_{j1}}{de_{j}} \cdot \frac{e_{j}}{p_{j1}} = \frac{e_{j}}{\Delta} \left[(2e_{k1} - \frac{2}{9}\overline{e}_{k2}) \left(\frac{\frac{1}{6} + \frac{7}{9}p_{k1} - \frac{2}{9}\gamma^{k}\left(\frac{1}{\overline{e}_{k2}} + \frac{Var(e_{k2})}{\overline{e}_{k2}^{3}}\right) - \frac{16}{9}\right)$

$$+(e_{j1}-\frac{2}{9}\bar{e}_{j2})\frac{2}{9}\gamma'\left(\frac{\frac{\bar{e}_{k2}}{\bar{e}_{j2}^{2}}+\frac{3\bar{e}_{k2}Var(e_{j2})}{\bar{e}_{j2}^{4}}-\frac{2Cov(e_{j2},e_{k2})}{\bar{e}_{j2}^{3}}}{p_{j1}}\right)\right]<0.$$

$$(1) \frac{\partial PT'}{\partial Cov[e_{j_2}, e_{k_2}]} = \frac{e_{j_1}}{\Delta p_{j_1}^2} \left\{ \left[(2e_{k_1} - \frac{2}{9}\overline{e}_{k_2})\frac{7}{9}p_{k_1}' - (e_{j_1} - \frac{2}{9}\overline{e}_{j_2})\frac{4}{9}\frac{\gamma'}{\overline{e}_{j_2}^3} \right] p_{j_1} - \left[(2e_{k_1} - \frac{2}{9}\overline{e}_{k_2})(\frac{1}{6} + \frac{7}{9}p_{k_1} - \frac{2}{9}\gamma'(\frac{1}{\overline{e}_{k_2}} + \frac{Var(e_{k_2})}{\overline{e}_{k_2}^3})) + (e_{j_1} - \frac{2}{9}\overline{e}_{j_2})\frac{2}{9}\gamma'(\frac{\overline{e}_{k_2}}{\overline{e}_{j_2}^2} + \frac{3\overline{e}_{k_2}Var(e_{j_2})}{\overline{e}_{j_2}^4} - \frac{2Cov(e_{j_2}, e_{k_2})}{\overline{e}_{j_2}^3}) \right] p_{j_1}' \right\},$$

where $p_{j_1}' = \frac{\partial P_{j_1}}{\partial Cov[e_{j_2}, e_{k_2}]} = \frac{2}{\Delta \cdot 9} \{ (2e_{k_1} - \frac{2}{9}\overline{e}_{k_2})\frac{\gamma'}{(\overline{e}_{k_2})^2} + (e_{j_1} - \frac{2}{9}\overline{e}_{j_2}) \cdot \frac{\gamma'}{(\overline{e}_{j_2})^2} \} > 0,$
 $p_{k_1}' = \frac{\partial P_{k_1}}{\partial Cov[e_{j_2}, e_{k_2}]} = \frac{2}{\Delta \cdot 9} \{ (e_{k_1} - \frac{2}{9}\overline{e}_{k_2})\frac{\gamma'}{(\overline{e}_{k_2})^2} + (2e_{j_1} - \frac{2}{9}\overline{e}_{j_2})\frac{\gamma'}{(\overline{e}_{j_2})^2} \} > 0.$
For symmetric firms, $p_{j_1} \approx p_{k_1}, p_{j_1}' \approx p_{k_1}', \gamma' = \gamma^k$ and $e_{j_1} = e_{k_1} = \overline{e}_{j_2} = \overline{e}_{k_2}$ initially.

For symmetric firms, $p_{j1} \approx p_{k1}$, $p'_{j1} \approx p'_{k1}$, $\gamma' = \gamma^{-1}$ and $e_{j1} = e_{k1} = e_{j2} = e_{k2}$ initially. Then, the first [] term is negative. Next, we use the fact that (a) $Var(e_{i2}) < \overline{e}_{i2}^2$ from the assumption that e_i is a positive number and follow a normal distribution, and (b) nonnegative profit condition. Then, second [] term is positive. Therefore, we can get

$$\begin{aligned} \frac{\partial PT'}{\partial Cov[e_{j_2}, e_{k_2}]} < 0. \\ (2) \quad \frac{\partial PT'}{\partial Var[e_{k_2}]} &= \frac{e_j}{\Delta p_{j_1}^2} \left\{ (2e_{k_1} - \frac{2}{9}\overline{e}_{k_2}) \frac{2}{9} \frac{\gamma^k}{\overline{e}_{k_2}^3} \left[\frac{1}{\Delta} (\frac{25}{9}e_{k_1} - \frac{2}{9}\overline{e}_{k_2})\overline{e}_{j_2} - 1 \right] \\ & - \left[(2e_{k_1} - \frac{2}{9}\overline{e}_{k_2}) (\frac{1}{6} - \frac{16}{9}p_{j_1} + \frac{7}{9}p_{k_1} - \frac{2}{9}\gamma^k (\frac{1}{\overline{e}_{k_2}} + \frac{Var(e_{k_2})}{\overline{e}_{k_2}^3})) \right. \\ & + (e_{j_1} - \frac{2}{9}\overline{e}_{j_2}) \frac{2}{9}\gamma^j (\frac{\overline{e}_{k_2}}{\overline{e}_{j_2}^2} + \frac{3\overline{e}_{k_2}Var(e_{j_2})}{\overline{e}_{j_2}^4} - \frac{2Cov(e_{j_2}, e_{k_2})}{\overline{e}_{j_2}^3}) \right] p_{j_1}'' \right\} \\ \text{where } p_{j_1}'' = \frac{\partial p_{j_1}}{\partial Var[e_{k_2}]} = \frac{1}{\Delta} (\frac{2}{9}\overline{e}_{k_2} - 2e_{k_1}) \frac{2}{9}\gamma^k \frac{\overline{e}_{j_2}}{(\overline{e}_{k_2})^3} < 0, \\ p_{k_1}'' = \frac{\partial p_{k_1}}{\partial Var[e_{k_2}]} = \frac{1}{\Delta} (\frac{2}{9}\overline{e}_{k_2} - e_{k_1}) \frac{2}{9}\gamma^k \frac{\overline{e}_{j_2}}{(\overline{e}_{k_2})^3} < 0. \end{aligned}$$

With the fact that initially $e_{j1} = e_{k1} = \overline{e}_{j2} = \overline{e}_{k2}$, the first [] term is zero. Next, second [] term

is negative because $\frac{dp_{j1}}{de_j} < 0$. Then, we can get $\frac{\partial PT'}{\partial Var[e_{k2}]} < 0$.

$$(3) \frac{\partial PT'}{\partial Var[e_{j2}]} = \frac{e_{j}}{\Delta p_{j1}^{2}} \left\{ \left[(2e_{k1} - \frac{2}{9}\bar{e}_{k2})\frac{7}{9}p_{k1}^{\prime\prime\prime} + (e_{j1} - \frac{2}{9}\bar{e}_{j2})\frac{2}{9}\gamma'\frac{3\bar{e}_{k2}}{\bar{e}_{j2}^{4}} \right] p_{j1} - \left[(2e_{k1} - \frac{2}{9}\bar{e}_{k2})(\frac{1}{6} + \frac{7}{9}p_{k1} - \frac{2}{9}\gamma'(\frac{1}{\bar{e}_{k2}} + \frac{Var(e_{k2})}{\bar{e}_{k2}^{3}})) + (e_{j1} - \frac{2}{9}\bar{e}_{j2})\frac{2}{9}\gamma'(\frac{\bar{e}_{k2}}{\bar{e}_{j2}^{2}} + \frac{3\bar{e}_{k2}Var(e_{j2})}{\bar{e}_{j2}^{4}} - \frac{2Cov(e_{j2}, e_{k2})}{\bar{e}_{j2}^{3}}) \right] p_{j1}^{\prime\prime} \right\},$$

where
$$p_{j1}^{\prime\prime\prime} = \frac{\partial}{\partial} \frac{p_{j1}}{Var[e_{j2}]} = \frac{1}{\Delta} \left(\frac{2}{9} \overline{e}_{j2} - e_{j1}\right) \frac{2}{9} \gamma^{\prime} \frac{\overline{e}_{k2}}{(\overline{e}_{j2})^3} < 0,$$

 $p_{k1}^{\prime\prime\prime} = \frac{\partial}{\partial} \frac{p_{k1}}{Var[e_{j2}]} = \frac{1}{\Delta} \left(\frac{2}{9} \overline{e}_{j2} - 2e_{j1}\right) \frac{2}{9} \gamma^{\prime} \frac{\overline{e}_{k2}}{(\overline{e}_{j2})^3} < 0.$
Similarly with (1), we can get $\frac{\partial}{\partial} \frac{PT^{\prime}}{Var[e_{j2}]} > 0.$ Q.E.D.

These main results are due to brand loyalty and imperfect foresight for exchange rates. The decision of current price influences future profit through market shares as well as a current profit. The effects of exchange rate uncertainty on pass-through depend on the curvature of future profitability on future exchange rates. For example, for a temporary shock, the second period profit is a convex function of own exchange rate. With the switching costs, each firm may act as a monopolist in its first-period share of the market, and a monopolist's profit is a convex function of its cost. Therefore, greater uncertainty of own exchange rate increases the value of market shares, hence lowers a current price to increase the market share. Likewise, for a temporary shock, the second period profit is a concave function of a rival exchange rate and PT decreases as rival's exchange rate uncertainty increases. A risk neutral profit maximizer increases the PT and attacks the market when covariance between own- and rival exchange rate is high. Intuitively, the firm will not hesitate to change its price because a higher covariance guarantee a more stable or insured competition condition in the future market. For example, *ceteris paribus*, if a Korean firm competes against a Japanese rather than a German firm, the pass-through is higher assuming that the won/dollar rate is more closely correlated to the yen/dollar rate.

III.5 Conclusions

If other foreign firms exist in an imperfect competition market, the foreign firm's pricing behavior is affected by rival countries' exchange rates through strategic interactions. In this chapter, I explicitly analyzed the effect of rival exchange rate both in the case of perfect foresight and in the case of imperfect foresight. Although the assumption of perfect foresight is not realistic, it makes the analysis easier and tractable. In section 2, my results add to those of Froot and Klemperer's (1989). First, pass-through of greater than unity is possible in some cases (especially, in the definition of exporter PT). It is shown that if the change of own exchange rate is in the same direction with rival's, the normal exchange rate pass-through is magnified by the rival, and the PT can be greater than one. Indeed, some empirical studies have shown that the PTs are over 100 % for some industries.²⁰ Second, if the change of own exchange rate is in the opposite direction to that of the rival's and is relatively small compared to the rival's, perverse exchange rate pass-through happens even with elastic demands. Also, it is possible that the firm chooses a perverse pass-through strategy even with a permanent exchange rate change. Third, the possibility of perverse PT in terms of a trade weighted exchange rate can not be eliminated either for permanent or for temporary shocks, even in the elastic demand area, if the change of e_{i} and the change of e_{k} are in opposite directions. If duopoly (or oligopoly) firms produce in the elastic area (which is a better match with the duopoly theory), Froot and Klemperer (1989) and Tivig (1996) can not explain the perverse exchange rate pass-through.

²⁰ See Marquez (1991), Feenstra (1989) and Phillips (1988).

In the case of the imperfect foresight, the exchange rate PT is affected by the covariance and variances of exchange rates as well as current exchange rates and expected future exchange rates. Due to brand loyalty, current price decisions will affect future profits through market shares. The expected future profit is effected by expected competition situations which depend on the interactive movement of future exchange rates. *Proposition III-2* and *III-3* summarize the uncertainty effect on exchange rate PT in the case of perfect capital mobility while *Proposition III-4* and *III-5* summarize how the interactive movement of exchange rates affects the exchange rate PT in the case of imperfect capital mobility.

Most importantly, this research emphasizes the importance of market structure in exchange rate pass-through studies. The specification of market structure changes the analytical form and also raises questions concerning the definition of PT. Most existing theoretical and empirical studies on exchange rate PT do not pay an attention to the competition between goods that produced in different source countries.

Much additional research needs to be done in this area. In particular, the extension to an n-period dynamic game would be useful, and a general equilibrium approach and cost structure with the consideration for stochastic functional form of exchange rate would be more in keeping with the environment in which real world firms must make decisions.

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IV. EMPIRICAL STUDY OF EXCHANGE RATE PASS-THROUGH: THE EFFECT OF RIVALS' EXCHANGE RATES

IV.1 Introduction

Exporting firms based in different countries have faced notably large fluctuations in currency values, particularly since the advent of floating exchange rates. In an export market, the major uncertainty may result from the change of exchange rate. Exchange rate changes are usually perceived as cost shocks for a foreign firm producing in its home country and selling in its export market. When the exchange rate changes, the firm may choose to pass the cost shock into its selling prices; it is called exchange rate pass-through.

During the last two decades, there have been over 50 published empirical studies on exchange rate pass-through (PT). Over half of the studies employed an aggregate approach. However, the aggregate approach raises the concern of possible aggregation bias in the passthrough estimates, especially given the fact that studies such as Feenstra (1989), Feinberg (1989), Kasa (1992) and Athukorala and Mennon (1994) found significant differences in pass-through rates across industries, possibly reflecting differences in demand and cost conditions. Thus exchange rate-price relationships cannot be meaningfully studied without referring to disaggregated data. Furthermore, Citrin (1989) and Lawrence (1990) argued that much of the "pass-through puzzle" lies in the data and not in actual behavior. They suggested that previous findings of incomplete pass-through for US imports have resulted from the inclusion of computer and other business machines imports, whose prices have fallen quite dramatically during the 1980s. Studies using disaggregated data in sectors or industries, which is still a very high level of aggregation, also often face a proxy bias. Previous studies have frequently relied on price proxies such as import or export unit values. For example, in a sectoral analysis, bilateral disaggregated import data for the United States are reported only in current dollars and appropriate price deflators are not available. Alterman (1991) emphasized the bias introduced into estimates of pass-through as a result of measurement errors inherent in price proxies.

Existing empirical research has documented several stylized facts about pass-through. While Kreinin (1977), Spitaeller (1980), Khosla and Teranishi (1989), and Knetter (1989) found that PT behavior differs across source countries, Feenstra (1989), Feinberg (1989), Kasa (1992), and Knetter (1993) found significant differences in PT rates across industries or product categories. Especially, Knetter (1993) found strong evidence of differences in PT behavior across industries and relatively little evidence of differences across source countries within the same industry. However, there is little disaggregated research attempting to formally explain inter-industry differences in PT.

Incomplete pass-through is a common and pervasive phenomenon across a wide range of countries. Much of the literature explains the incomplete PT with an imperfect competition model. Although there are many empirical studies estimating imperfect competition model, those were tested with aggregate data. This mismatch should be of concern if the industry and aggregate data behave differently.

This line of research has paid little attention to the differences of competition situation across destination countries and commodities. There is no literature giving attention

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to strategic interactions with other foreign rivals (e.g., how the existence of other foreign rivals and the movement of rival countries' exchange rates affect pass-through). The existing exchange rate pass-through (PT) literature is based on an imperfect competition model of a foreign firm and a domestic firm, including only one bilateral exchange rate. However, if other foreign firms exist in the market, the foreign firm's pricing behavior will be affected by rival countries' exchange rates through the strategic interaction. Intuitively, a firm with small market share may choose its price depending on rival's price rather than its own exchange rate. In an export market, an exporter may often face other foreign firms rather than domestic firms as major rivals. Indeed, in some markets, a domestic firm does not exist. Even when domestic firms exist, the substitutability between imported goods is often much higher than the one between an imported good and a domestic good. Thus, rival exchange rates may have a significant effect on the firm's price decision through the strategic interaction. The importance of strategic interaction in an export market was recognized by Goldberg and Knetter (1997, p. 1265) as follows.

International economists typically impose the Armington assumption - i.e., they assume that products within an industry are differentiated according to the country of production. An extreme interpretation of the Armington assumption implies that goods produced in different countries represent different markets. ... The competition from these other sources is accounted for by including the prices of substitutes in the set of demand shifters or rotators; but this treatment fails to capture the strategic interaction.

This research is different from earlier empirical studies in several regards. First, this study employs the disaggregated data at the finest level. The 7-digit level TSUSA (Tariff Schedule of the United States Annotated) data that I use here contains over 16,000 product categories while the 7-digit level SITC (Standard International Trade Classification) contains

about 3000 categories. The result of the tests, for the market of specific commodities, will be freer from the aggregation bias mentioned above and better matched with an imperfect competition model. Furthermore, the disaggregated data should also enable more accurate estimation of the time-lags involved in the transmission of exchange rate changes to prices (Hopper & Mann, 1989). The use of such micro-level data may shift the emphasis of the study to the level of the firm and make the study useful to international marketers as they determine their pricing strategies. However, this study will also generate some implications at the macro-level that will be further explained in the results section. Specifically, in export price pass-through studies, an export price is affected not only by own trade weighted exchange rate but also by rivals' exchange rates in each destination market.

Second, this research emphasizes the role of strategic behavior between foreign firms in a market, by expanding the data sample to include two or three major exporting countries that compete in a common export (U.S.) market in the same industries. The competition structure differs across destination markets as well as across industries or goods. The different exchange rate PT may result from the differences in the degree and structure of competition across destination markets as well as the differences in destination-specific demand for a good. Furthermore, the existence of foreign rivals and the movement of rival countries' exchange rates may be an explanation for inter-industry differences in PT. The particular attention of this empirical study is focused on the effect of rival exchange rates. Actually, in a price decision, the rival's exchange rate may have as much affect on the firm's decision as its own exchange rate. For example, a Korean exporter of electronic goods will be sensitive to the value of Japanese currency. In this chapter, I will study the effect of rival's

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exchange rate using data of specific commodities. Because of data limitations, I postpone the comparison across destination markets, testing only the U.S. import markets.

This chapter proceeds as follows. The imperfect competition model is presented in section 2. In section 3, I derive the econometric model, whereas section 4 reviews the data used. In section 5, I present and discuss the empirical results, and concluding remarks are provided in section 6.

IV.2 The imperfect competition model

I consider a heterogeneous oligopoly whose firms use price strategies. There are n firms based in different source countries.¹ Therefore, each firm faces a different exchange rate. Each firm i exports the differentiated good i to a destination market (say U.S.), respectively. The foreign spot prices of the destination currency are denoted by e_i (foreign country i's currency/\$). The destination currency prices of the imported varieties of a differentiated product are denoted by p_i . I will treat a rival prices' vector as \mathbf{P}_{-i} . Then, I can write import demand as $q_i(p_i, \mathbf{P}_{-i}, \mathbf{Z})$, where \mathbf{Z} denotes a vector of all variables shifting demand. The foreign firms maximize profits in its own currency, treating \mathbf{P}_{-i} as exogenous.² I assume that its pricing decision is made after the exchange rate is known with certainty. If, however, its pricing decision must be made before the exchange rate is known, the rational

¹ Here, I exclude the US domestic firms in this competition because domestic data that match 7-digit TSUSA commodity categories are not available. I implicitly assume that the substitutability among imported goods is much higher than the one between an imported good and a domestic good. Indeed, in the international export market, an exporter may face other foreign firms rather than domestic firms as major rivals. Patriotism may also help the model justification.

² Thus, I assume that the foreign firms act as Bertand competitor. However, my generalized empirical model which can match conjectural variation behavior is independent of this assumption.

expectation on expected exchange rate can justify the model. As discussed by Baron (1976), McKinnon (1979), and Giovannini (1988), the foreign firms then face a decision as to which currency to use in announcing its price. I will not analyze this problem, but rely on the fact that 85 percent of U.S. imports are invoiced in dollars.³ Since my empirical work deals with this market, I simply assume that the foreign firms set their price in the destination market currency (\$). I also assume that the cost functions in the foreign currency are separable in quantity and input prices so that it can be written as $\varphi_i(q_i)\phi_i(\mathbf{W}_i)$ and marginal cost is $\varphi'_i(q_i)\phi_i(\mathbf{W}_i)$, where q_i is the output of good i, and \mathbf{W}_i is a vector of firm i's input factor prices. The foreign firms' profit maximization problems can be written as:

$$\underset{\rho_{i}}{Max}[e_{i}p_{i}q_{i}(p_{i},\mathbf{P}_{-i},\mathbf{Z})-\varphi_{i}(q_{i})\phi_{i}(\mathbf{W}_{i})]$$
(IV-1)

where i = 1, 2, ... n. The first-order condition for (IV-1) is:

$$\varphi_i'(q_i)\phi_i(\mathbf{W}_i) = e_i p_i (1 - \frac{1}{\eta_i})$$
(IV-2)

where $\eta_i = -\frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i}$ denotes the (positive) elasticity of demand for firm i. Rearranging

equation (IV-2) yields a markup model of price determination which prevails in previous empirical studies in this field (e.g., Athukorala, 1991; Athukorala and Menon, 1994; Hooper and Mann, 1989).

$$p_i = mk_i \cdot mc_i / e_i \tag{IV-3}$$

where $mk_i = (1 - \frac{1}{\eta_i})^{-1}$. The typical exporting firm sets an export price (p_i) in importer

currency (\$) at a markup (mk_i) over its marginal cost of production (mc_i / e_i) . If perfect

³ See Hamada and Horiuchi (1987).

competition prevails ($\eta_i = \infty$), then a price is equal to a marginal cost, and pass-through is perfect.

Assuming that
$$[\varphi_i''(q_i)\frac{\partial q_i}{\partial p_i}\phi_i(\mathbf{W}_i) - e_i\frac{\partial r_i}{\partial p_i}] \neq 0$$
, where $r_i = p_i(1-\frac{1}{\eta_i})$, we can

convert (IV-2) to obtain the pricing equation:

$$p_{i} = \pi_{i}(e_{i}, \phi_{i}(\mathbf{W}_{i}), \mathbf{P}_{-i}, \mathbf{Z}).$$
(IV-4)

IV.3 The econometric model

Differently from other oligopoly empirical studies in exchange rate pass-through, I estimate a system of equations to see the effect of rival exchange rate. Since most studies approximate the competitor prices as a domestic price or a trade weighted price, and regard the competitor prices as an independent variable, only a single equation estimation method could be used. However, these estimations hide the effect of rival's exchange rate fluctuation and are both biased (i.e., the effect of own exchange rate is overstated) and inconsistent as well known.

To test the effect of rival's exchange rate change, I use a log-linear specification for (IV-4) which is a variant of Feenstra's (1989) model.⁴

$$\ln p_{u} = \alpha_{i0} + \alpha_{i1} \ln y_{i}^{us} + \alpha_{i2} \ln e_{u} + \alpha_{i3} \ln \phi_{i}(\mathbf{W}_{u}) + \sum_{j=1, j \neq i}^{n} \beta_{ij} \ln p_{ji} + \varepsilon_{u}$$
(IV-5)

where ε_u is a random error and i, j = 1,2,...n. The vector of variables shifting demand (Z) is represented by the economic activity of destination country (y_t^{us}). The demand function

⁴ Feenstra(1989) estimated just a single equation with instrumental variables because he did not consider strategic behaviors between exporters.

corresponding to the specification (IV-5) can be obtained by assuming constant pass-through and solving the resulting differential equation.⁵

To estimate (IV-5) we must specify how the cost function in input price is determined. I assume that each firm uses two inputs, labor and capital. Firms are assumed to minimize the unit cost of production by choosing the best combination of labor and capital. The cost function in input price ($\phi_i(\mathbf{W}_u)$) is given by a Cobb-Douglas cost function. The time trend is used to capture the effects of productivity change:

 $\ln \phi_i(\mathbf{W}_u) = \ln a_{i0} + a_{i1} \ln wg_u + a_{i2} \ln in_u + f_{i0} + f_{i1}t + f_{i2}t^2 + \xi_u$. Where wg_u and in_u are prices of labor and capital at time t for each firm i, and $f_u = f_{i0} + f_{i1}t + f_{i2}t^2$ is a time trend. Then our estimating simultaneous equations are derived as:

$$\ln p_{u} = c_{i0} + c_{i1}t + c_{i2}t^{2} + \alpha_{i1}\ln y_{i}^{us} + \alpha_{i2}\ln e_{u} + \sum_{j=1,j\neq i}^{n}\beta_{ij}\ln p_{jt} + \delta_{i1}\ln wg_{u} + \delta_{i2}\ln in_{u} + \varepsilon_{u}$$
(IV-6)

where $i, j = 1, 2 \cdots n$; $c_{i0} = \alpha_{i0} + \alpha_{i3}(\ln a_{i0} + f_{i0})$, $c_{i1} = \alpha_{i3}f_{i1}$, $c_{i2} = \alpha_{i3}f_{i2}$, and $\delta_{i3} = \alpha_{i3}a_{i3}$.

⁵ See Feenstra (1989) for detail. Totally differentiating (IV-2), we obtain

 $⁽dp_i / de_i)(e_i / p_i) = -1/[(\varphi_i'q_i / \varphi_i')\eta_i + (\partial r_i / \partial p_i)(p_i / r_i)]$. For example, to obtain a pass-through elasticity of -1/2 set $\varphi_i'' = 0$ and $(\partial r_i / \partial p_i)(p_i / r_i) = 1 + (p_i^2 / r_i \eta_i^2)(\partial \eta_i / \partial p_i) = 2$. Then the solution is obtained as $q_i = (k_i / p_i) - q_i^0$, where $q_i^0 > 0$ and $k_i > 0$ can depend on P_{-i} and y^{us} . By choosing $k_i = (P_{-i})^e (y^{us})^f$, and solving for the optimal price, we obtain a log-linear specification as (IV-5). The demand curves leading to a constant pass-through unequal to -1/2 are more complex.

We have n equations with a n firms' oligopoly market and estimate n simultaneous equations as a system (3SLS).⁶ The equations in the system are identified.⁷ The interest of estimation is the pattern of the coefficients α_{i2} , which indicate the rate at which exchange rate changes are passed through to import prices. The responsiveness of export price in \$ (p_i) to change in own bilateral exchange rate (e_i) and the effect of rivals' exchange rates changes on export price in \$ (p_i) are calculated from:

$$\begin{bmatrix} \ln p_1 \\ \ln p_2 \\ \vdots \\ \ln p_n \end{bmatrix} = \begin{bmatrix} 1 & -\beta_{12} & \dots & -\beta_{1n} \\ -\beta_{21} & 1 & \dots & -\beta_{2n} \\ \vdots & \dots & \dots & \vdots \\ -\beta_{n1} & \dots & \dots & 1 \end{bmatrix}^{-1} \begin{bmatrix} \alpha_{12} \ln e_{1t} \\ \alpha_{22} \ln e_{2t} \\ \vdots \\ \alpha_{n2} \ln e_{nt} \end{bmatrix}.$$

For example, for n = 2, while $\frac{\alpha_{i2}}{1 - \beta_{ij}\beta_{ji}}$ measures the responsiveness of export price in \$ (p_i)

to change in own bilateral exchange rate (e_i), $\frac{\beta_{ij}\alpha_{j2}}{1-\beta_{ij}\beta_{ji}}$ scales the effect of rival exchange

rates changes (e_i) on export price in (p_i) .

Alternative specifications:

I may also estimate the reduced form of (IV-6). To see only the effect of rival's exchange rate change, the structural form estimation is not required. The reduced form for each firm i will be:

⁶ Although full information maximum likelihood (FIML) is theoretically favorable, since three stage least squares (3SLS) does not require a normality assumption, it is a frequently used method for relatively small samples as in our data.

⁷ Kelejian and Oates (1989) demonstrate that the necessary condition for identification in a simultaneous equations system in which endogenous variables enter nonlinearly is $A_{11} \ge A_{21}$. Where $A_{11} =$ number of predetermined variables appearing in the model but not appearing in the *i*th equation and $A_{21} =$ number of endogenous variables appearing as a regessor in the *i*th equation. In this system, $A_{11} = 3(n-1)$ and $A_{22} = n-1$.

$$\ln p_{t} = v_{0t} + v_{1} \ln y_{t}^{us} + \sum_{j=1}^{n} v_{2j} \ln wg_{jt} + \sum_{j=1}^{n} v_{3j} \ln in_{jt} + \sum_{j=1}^{n} v_{4j} \ln e_{jt} + \mu_{t}$$
(IV-7)

where $v_{0i} = v_{00} + v_{01}t + v_{02}t^2$. While v_{4i} measures the effect of export price in (p_i) to change in own bilateral exchange rate (e_i) , v_{4j} scales the effect of rival j's exchange rate (e_i) change on export price in (p_i) .

VI.4 Data description

I estimate the US import markets for specific industries or goods. The use of highly disaggregated data is motivated by the fact that individual commodities differ with regard to demand, cost conditions and competition situations, and estimates at the aggregate level tend to mask such differences. For specific commodities, the U.S. import data $(q_u, p_u \text{ and } q_u p_u)$ are obtained by commodity by country of origin on annual base from the U.S. Department of commerce, Bureau of the Census. The TSUSA data at the 7-digit level in the present study are compiled at the finest level of aggregation available in publicly distributed trade statistics. However, publicly distributed annual data may not be desirable for this research because of low frequency.

Fortunately, I could get the unpublished TSUSA monthly data at the 7-digit level from Dr. William R. Smith (the author of Exchange Rates and Prices: The Case of United States Imports). He kindly provided 112 product data covering from January of 1978 through December of 1988. Although the TSUSA contains over 16000 product categories, Smith (1996) chose 112 products through several sample selection criteria:⁸ (1) chose products

⁸ See Smith (1996, p. 66-75) for detail.

whose total import values are during 1988 at least \$75 million, (2) removed products whose total import value are zero in 1978, (3) removed heterogeneous product categories, (4) removed products whose quantities are expressed in different quantity measures at different times or by different importers, (5) excluded by initial examination for price heterogeneity, etc. The time period was chosen for some reasons including (1) exchange rates of most major US trading partners were floating, (2) many important traded products, such as certain types of electronics, were not produced in earlier time period, (3) since 1990, the 7-digit categories were changed to 10 digit.

The distinguishing feature of this data is that the import prices are genuine prices which are free from well-known limitations as price proxies. However, we have to regard all foreign firms that are based in the same country as a representative firm (or firms of the same country are identical) because of data limitations. Since these firms are affected by the same bilateral exchange rate, it seems not to affect our test too seriously. In choosing commodity markets, I added some additional rules to Smith (1996)'s. First, I choose goods imported from only a few countries, to avoid monopoly or perfect competition markets. Next, I transform the monthly data into quarterly data to reduce some data problems (order-delivery lag, etc.). I also remove goods which have any zero value through the whole sample period (i.e., quarter one of 1978 through quarter four of 1988). Finally, I remove products whose major exporters are Brazil, Hong Kong, Malaysia, Philippines, Singapore, Taiwan and Thailand. For these countries, wage and/or interest rate data are not available for the whole sample period.⁹ After implementing these criteria, I am left with 20 product markets to test.

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⁹ Smith (1996)'s study included these countries because his model does not employ any other variable except exchange rates and prices.

The twenty products and their classification codes are: beer (1670515), wall paper (2560500), benzene (4011000), sodium hydroxide (4210800), polybutadiene rubber (4461516), electrodes, partially carbon or graphite (5176100), steel pipe, unalloyed, welded, not casing (6103955), steel wire stand, brass plated (6421110), piston-type diesel engine, excluding auto and mfg. (6604260), motor vehicle pumps, liquid (6609720), wheel-type front-end loaders (6640720), chainsaws (6747025), shavers with self-contained electric motor (6835020), spark plug (6836060), relays with contacts under 10 amps (6859034), insulated power cable, less than 601 volt capacity (6880465), wheel-type agri tractors, 40 to 80 hp (6923406), eyeglasses with frames (7084720), silver halide paper for color picture negatives (7233030), and grand pianos (7250320). Other data sources are as follows, and all data are available on quarterly basis.

 p_i = dollar price (importer currency) of exports from country *i* to the U.S.

- y^{ur} = economic activity of U.S. As a proxy real GNP is available as quarterly base
 (source: Main Economic Indicators, OECD).
- e, = exchange rate of country *i*; exporter i currency/\$ (source: International Financial Statistics, IMF).

*wg*_i = average wage of country i (source: International Financial Statistics, IMF).

in, = interest rate of country i. Due to availability for a whole sample period, different interest rates across countries are used (treasury bill rates for Canada, Mexico and U.K.; discount rates for Korea; money market rates for other countries), (source: International Financial Statistics, IMF).

IV.5 Estimation results and discussion

Twenty U.S. import industry models are estimated with quarterly data. It seems that the estimation of 3SLS does not have any advantage compared to the reduced form estimation in viewing the effect of exchange rates because economic theory tells us that reduced form parameters are the long-run multipliers associated with the model. However, in the over-identified case, the pass-through estimates from 3SLS are biased, but consistent and more efficient than those from the reduced form (Kennedy; 1992, p. 168);

If the structural equations are over-identified, more efficient estimates of the reducedform parameters can be obtained by taking structural parameter estimates (that incorporate the over-identifying restrictions) and using them to estimate directly the reduced-form parameters. Although these "derived" reduced form estimates are biased (whereas the OLS reduced form estimates are not), they are consistent, and because they incorporate the over-identifying information, are asymptotically more efficient than the OLS reduced form estimates. Monte Carlo studies have shown the derived reduced form estimates to have desirable small sample properties. Of course, if the over-identifying restrictions are untrue, the OLS reduced form estimates will superior; a suggested means of testing over-identifying restrictions is through comparison of predictions using OLS reduced-form estimates and derived reducedform estimates.¹⁰

We can think, in the over-identified case, 3SLS estimates are restricted by structural

parameters while reduced estimations are an unrestricted regression. Furthermore, we, from 3SLS, can see the coefficients for structural forms and figure out the economical meanings.¹¹ To increase the degree of freedom, T^2 or interest rate terms which are not employed by most researchers were removed if the coefficients were not statistically significant. The reason

¹⁰ Following the suggested means, I tested the over-identifying restrictions. Derived reduced form estimates are superior to OLS reduced form estimates in 11 markets (wall paper, benzene, electrodes, steel pipe, steel wire stand, front-end loaders, chainsaws, relays, eyeglasses, silver halide paper, and grand pianos).

¹¹ Other coefficients than PT are not reported here because there are too many coefficients from 45*2 equations. Although many coefficients are not significant statistically, resulting in relatively weak support, there is little that is adverse to economic sense.

why interest rates are not employed by other literature is that, in the short run, capital is fixed. Results for the twenty U.S. import products are reported in Table IV-1. For each product the table reports the pass-through of own exchange rate and rivals' exchange rates from both 3SLS estimates and reduced form estimates. The countries included in the model are the major exporters. Also, average market shares during whole sample period are reported. For example, in the polybutadiene rubber market, 3SLS (reduced form) estimation tell us that a Canadian exporter passes 76.6% (77.0%) of own exchange rate fluctuation to its export price in U.S. dollar while a Japanese exporter passes 65.6% (54.4%) of the fluctuation of Canadian exchange rate. Other PTs are not statistically significant. The average market shares in the polybutadiene rubber import market of U.S. are 46% for Canada and 25% for Japan.

Both estimations show significant normal pass-through¹² for rival exchange rate as well as own exchange rate in most product markets. With 3SLS estimation, we can see that 23 exporters from 17 commodity markets show significant normal pass-through for own exchange rate while 11 exporters from 10 commodity markets show significant normal passthrough for rivals' exchange rates. It supports the conventional wisdom that exporters capable of price adjustment pass cost shocks induced by exchange rate fluctuations to their export prices. The reduced form estimation also indicates that 17 exporters from 16 commodity markets show significant normal pass-through for rival exporters from 12 commodity markets show significant normal pass-through for rival

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¹² In our model, normal pass-through will be negative pass-through for both own and rival exchange rates.

				3SLS		Reduced form			
Product (TSUSA#)	Source country	Import Market	Own exchange	Rival1 exchange	Rival2 exchange	Own exchange	Rival1 exchange	Rival2 exchang	
		Share	rate	rate	rate	rate	rate	e rate	
_	- .				• • • •				
Beer	Canada	22%	-0.427*	-0.168	0.154	-0.280	-0.791**	0.776**	
1670515	_		(0.249)	(0.157)	(0.150)	(0.251)	(0.368)	(0.367)	
	Germany	15%	-0.155	-0.207	0.012	-0.168	-0.023	0.039	
			(0.129)	(0.158)	(0.124)	(0.191)	(0.130)	(0.190)	
	Netherlands	44%	-0.691***	-0.256	-0.067	-0.728**	-0.550**	-0.058	
			(0.101)	(0.168)	(0.102)	(0.316)	(0.216)	(0.317)	
Wall paper	Canada	38%	-1.203***	0.324	-0.078	-0.984**	0.206	-0.063	
2560500			(0.436)	(0.277)	(0.064)	(0.482)	(0.312)	(0.118)	
	Korea	12%	-0.055	-0.932**	0.100	-0.472	-0.294	0.179	
			(0.175)	(0.396)	(0.084)	(0.541)	(0.835)	(0.205)	
	UK	18%	0.053	-1.546**	0.319	0.325	-0.175	-0.408	
			(0.063)	(0.646)	(0.357)	(0.194)	(0.788)	(0.511)	
Banzana	Canada	30%	-1 682**	0 664		-1.775**	0 482		
4011000			(0.804)	(0.877)		(1 020)	(1.037)		
1011000	Janan	15%	0 767	-2 204**		0 785	-2 200**		
	ocpun		(0.923)	(1.097)		(0.448)	(0.984)		
Hydroxide	Canada	53%	-2.876***	0.362		-2.980***	0.644***		
4210800			(0.498)	(0.429)		(0.489)	(0.216)		
	Germany	13%	-1.508**	-4.969***		0.400	-4.409***		
			(0.740)	(1.174)		(0.625)	(1.417)		
Polybutadiene	Canada	46%	-0.766***	0.042		-0.770**	-0.015		
rubber			(0.203)	(0.066)		(0.302)	(0.135)		
4461516	Japan	25%	0.130	-0.656***		-0.001	-0.545*		
			(0.097)	(0.169)		(0.129)	(0.287)		
Electrodes	Canada	5%	-5.786	1.418		2.011	1.449		
5176100			(13.093)	(1.213)		(3.322)	(1.158)		
	Japan	66%	-0 481***	0 708		-0.481**	0.581		
	ouper.		(0.161)	(2.302)		(0.180)	(0.516)		
Steel nine	Canada	51%	.1 972***	0.052		-1 026***	0.071		
6103055	Janaua	J170	-1.0/3	0.000		-1.550 (0.105)	0.071		
0103333	lanan	40%	0 225**	1 220***		.0 120	0.862***		
	Japan	+U70	-0.335	-1.320		-0.120	-0.000		
			(0.107)	(U.200)		(0.030)	(U.Z14)		

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Table IV-1.	Exchange rate	pass-through "*

¹ Standard errors that are calculated by a delta method are shown in parentheses. Statistical significance is based on asymptotic t-ratios: *** at the 1 percent level, ** at the 5 percent level, * at the 10 percent level.

² Rival 1 and rival 2 are ordered alphabetically. For example, in the beer market, the rival 1 of Germany is Canada, and the rival 2 of Germany is Netherlands.

				3SLS			Reduced form		
Product (TSUSA#)	Source country	Import Market	Own exchange	Rival1 exchange	Rival2 exchange	Own exchange	Rival1 exchange	Rival2 exchang	
	·	Share	rate	rate	rate	rate	rate	e rate	
Steel wire	Italy	10%	0 071	0.017		0 224	-0 126		
stand	italy	.070	(0.100)	(0.070)		(0.193)	(0.200)		
6421110	Janan	41%	-0.013	0.061		0.131	-0.111		
0421110	oupe		(0.050)	(0.089)		(0.230)	(0.222)		
			(0.000)	(0.000)		(0.200)	()		
Diesel engine	Germany	18%	-1.051	-0.053	-0.344	-0.667	-0.784*	-0.646	
6604260	-		(0.685)	(0.470)	(0.804)	(0.456)	(0.475)	(0.516)	
	Japan	25%	-0.766	0.786	-0.086	0.325	0.606	0.862	
			(1.122)	(1.125)	(0.370)	(0.650)	(0.624)	(0.706)	
	UK	37%	-0.491	-0.401	-0.549	0.480	0.455	-0.837	
			(1.067)	(1.012)	(1.209)	(1.069)	(0.945)	(0.985)	
				•	· · ·		÷	-	
Motor vehicle	Germany	23%	0.558	-1.593*		0.660	-1.726**		
pumps			(0.683)	(0.906)		(0.644)	(0.806)		
6609702	Japan	43%	-1.412**	0.306		-1.628***	0.528		
			(0.594)	(0.438)		(0.572)	(0.457)		
Front-end	Canada	37%	-1.850***	0.050		-2.217***	0.164		
loaders			(0.480)	(0.090)		(0.628)	(0.318)		
6640720	Japan	29%	0.157	-1.306**		0.486	-1.511*		
			(0.258)	(0.619)		(0.457)	(0.903)		
Chainsaws 6747025	Germany	31%	-0.766***	-0.002	0.045	-0.196	-0.028	-0.529	
			(0.183)	(0.058)	(0.142)	(0.274)	(0.218)	(0.371)	
	Japan	17%	0.422	-0.706	-0.229	0.352	-0.061	-0.398	
			(0.327)	(0.460)	(0.333)	(0.447)	(0.562)	(0.759)	
	Sweden	31%	0.295	-0.716**	0.063	0.768	-0.920**	0.047	
			(0.260)	(0.289)	(0.099)	(0.464)	(0.344)	(0.273)	
Shavers	Japan	11%	-0.628*	0.156		0.688	-0.337		
6835020			(0.345)	(0.243)		(0.492)	(0.348)		
	Netherlands	73%	-0.599***	0.402		-0.468*	0.210		
			(0.197)	(0.332)		(0.242)	(0.341)		
.	-	070/	A 10000	0.440			0.000		
Spark plug 6836060	Germany	3/%	-0.425***	0.112		-0.644***	0.068		
		co	(0.136)	(0.215)		(0.151)	(0.200)		
	Japan	52%	-0.443**	0.129		-0.390	0.085		
			(0.170)	(0.091)		(0.278)	(0.209)		
	1	20%	0.550	0 074++		0.070	0.047**		
Relays	Japan	29%	0.555	-0.2/1		0.273	-0.21/**		
6859034		000/	(0.482)	(0.127)		(0.208)	(0.089)		
	Mexico	33%	-0.061	-0.420		-0.099	-0.070		
			(0.099)	(0.268)		(0.071)	(0.166)		

Table IV-1 Continued

			3SLS			Reduced form		
Product	Source	Import	Own	Rival1	Rival2	Own	Rival1	Rival2
(TSUSA#)	country	Market	exchange	exchange	exchange	exchange	exchange	exchang
		Share	rate	rate	rate	rate	rate	e rate
	Canada	50%	4 650	0 400		4.004	0 400	
Power cable	Canada	50%	-1.059****	-0.193		-1.864	-0.192***	
6880465			(0.336)	(0.051)		(0.384)	(0.049)	
	Mexico	12%	-1.001***	0.671		-0.936***	0.481	
			(0.196)	(1.235)		(0.204)	(1.610)	
Ag. Tractors	Germany	35%	-0.523**	0.473		-0.703***	-0.270	
6923406			(0.219)	(0.813)		(0.234)	(0.380)	
	ПК	35%	-0 574	-0.043		2 814**	0 771	
	UN		(0.882)	(0.474)		(1.084)	(0,668)	
			(0.002)	(0.424)		(1.004)	(0.000)	
Eyeglasses	France	21%	-2.006	1.867	0.005	-1.031	-0.025	0.471
7084720			(1.715)	(1.477)	(0.399)	(0.852)	(1.010)	(0.470)
	Italy	24%	-2.275	1.241	-0.207	-0.820	-0.367	0.152
			(2.015)	(2.289)	(0.559)	(1.303)	(1.099)	(0.607)
	Japan	15%	-0.815***	0.527	-0.395	-0.903**	-0.041	0 179
	ouper.		(0.233)	(0.756)	(0.951)	(0 417)	(0.754)	(0.895)
			(0.200)	(0.100)	(0.001)	(0.111)		(0.000)
Silver halide	Germany	21%	-0.448***	0.244		-0.442**	0.265	
paper	•		(0.148)	(0.200)		(0.198)	(0.263)	
 7233030	Japan	55%	0.164	0.016		0.130	-0.001	
			(0.130)	(0 107)		(0.259)	(0.195)	
			(0.100)	(0)		(0.200)	(0.100)	
Grand pianos	Japan	64%	-0.276**	-0.111		-0.289**	-0.178	
7250320			(0.134)	(0.137)		(0.129)	(0.175)	
	Korea	24%	-0.094	-0.058		-0.181	-0.246*	
			(0.127)	(0.097)		(0.176)	(0.130)	

Table IV-1 Continued

exchange rate in the reduced form estimation. Like other literature the exchange rate passthrough varies quite significantly across industries or source countries. However, we can see PT of higher than 100% for some exporters in some markets. This is puzzling. The simplicity of the model may preclude a clear interpretation of the effect of exchange rate changes on import prices. First, other omitted factors (or firm specific factors) that are systematically related to exchange rates may change elasticities over time. Second, there is no attempt to control for the U.S. domestic good prices of close substitutes. Finally, it is possible that aggregation could bias the coefficients. Even though the 7-digit level TSUSA is compiled at the finest level of aggregation available, it may still not free entirely from the problem of aggregation. If there is heterogeneity within a product, changes in the composition of exports may be correlated with exchange rates if the elasticities of demand for varieties differ.

This research manifests the importance of rival exchange rate effect. The 3SLS estimation indicates that 11 exporters from 10 commodity markets pass-through significantly for rival exchange rates, while the reduced form estimation indicates that 13 exporters from 12 commodity markets show significant normal pass-through for rival exchange rates. Many studies have ignored the rival's behavior without considering strategic interactions in a market. In some empirical studies, the effect of rival exchange rate is partially reflected by rival prices (usually domestic good price). However, there exists simultaneous bias problems because it fails to capture the strategic interaction. A major and indeed important factor for exchange rate PT has simply been missed. If rival's (third country) exchange rate is not considered, theoretical analyses are misconceived and empirical studies are biased and inefficient. Specifically, empirical tests based on a bilateral trade and exchange rate may face serious mis-specification problems. This finding will also generate an implication to studies with aggregated data. In export price pass-through studies, an export price is affected by not only own trade weighted exchange rate but also rivals' exchange rates in each destination market.

Another interesting finding is that, in 3SLS estimation, 8 exporters from 7 markets (i.e., Korea and U.K. in wall paper market, Japan in benzene market, Japan in polybutadiene

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rubber market, Germany in Motor vehicle pumps market, Japan in front-ends loaders market, Sweden in chainsaws market, and Japan in relays market) did not show pass-through behaviors for own exchange rate but show significant pass-through behaviors for rival's exchange rate. This finding is more obvious from reduced form estimation which indicates 11 exporters from 11 markets (i.e., Canada in beer, Japan in benzene, Germany in hydroxide, Japan in polybutadiene rubber, Japan in steel pipe, Germany in diesel engine, Germany in motor vehicle pump, Japan in front-end loaders, Sweden in chainsaws, Japan in relay, and Korea in grand piano) are affected by rival's exchange rate but not by own exchange rate. The more interesting thing is the fact that these exporters have relatively small market shares and are affected by the exchange rate of exporters who have the largest market shares. These exporters may have a strong tendency to follow a rival price. To match with a market leader price, these firms may try to offset price changes in the local currency induced by own cost shock (e.g., exchange rate fluctuation). This finding may reveal that own exchange rate passthrough tends to be related positively with a market share. Also, this finding emphasizes the importance of the game structure in studying exchange rate pass-through.

Finally, this study gives an interesting implication to import pass-through studies in both aggregated data and disaggregated data. In the import pass-through study, most previous studies used a trade weighted exchange rate. However, this study shows that, with the 3SLS estimation, 10 product markets' (i.e., wall paper, benzene, polybutadiene rubber, electrodes, motor vehicle pumps, front-end loaders, chainsaws, relays, ag. tractors, and grand pianos) prices are affected by only the exchange rate of the country which has the largest market share. Meanwhile, trade weighted exchange rates may be used as a good proxy in

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only 6 markets (i.e., beer, hydroxide, steel pipe, shavers, spark plugs, and power cable), considering that all exchange rates affect prices . Reduced form estimations also indicate that 13 product markets' (i.e., wall paper, benzene, hydroxide, polybutadiene rubber, electrodes, steel pipe, motor vehicle pumps, front-end loaders, chainsaws, shavers, relays, ag. tractors, and grand pianos) prices are affected by only the exchange rate of the country which has the largest market share while trade weighted exchange rates seem to work in only 2 markets (i.e., beer and power cable). Only, if all firms have considerable market powers, passthrough estimations with a trade weighted exchange rate may be unbiased.

IV.6 Conclusion

This study which tests a simultaneous system with aggregated data at the finest level incorporated the strategic behaviors between firms in a market. The evidences across two estimations (3SLS and reduced from) indicate that price adjustment tends to pass through to the local currency price in the destination market, and that the pass-through rate are significantly different across countries and products. The study results confirm quite well to other research on traded good prices and exchange rates. However, this study manifests the importance of rival exchange rate. While the own exchange rate pass-through tends to be related inversely with market share, firms which have small market shares often pass through for the fluctuation of rival exchange rate. Particularly, some exporters who have small market shares pass through the change of rival exchange rate but not the change of own exchange rate. This study also gives some implications at the macro-level. First, in the export price pass-through studies, an export price is affected by not only own trade weighted

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exchange rate across destination countries but also rivals' exchange rate in each destination market. This study also shows that, in many markets, prices are affected by only the exchange rate of the country which has the largest market share, rather than the trade weighted exchange rate. It tells that import pass-through studies using trade weight exchange rate may have a specification problem.

The value added of this research is the approach to manifest strategic interaction and the level of industry detail. The next step of this study is to link with other destination markets to incorporate exporter's price discrimination behaviors across destination markets. For example, in the beer market, Netherlands exports not only to U.S. but also to Japan, Korea etc. Then the cost function will be inter-linked across destination markets. Knetter (1989) studied the price discrimination behaviors across destination markets for U.S and Canada firms. If the broad data sample are available, the study of this line can be developed tremendously. Another interesting extension is to incorporate the exchange rate uncertainty issue. The variability of exchange rate may also affect on exchange rate pass-through. In incorporating the exchange rate uncertainty into empirical studies, the calculation of expected exchange rates and exchange rate variabilities may be a major step and obstacle.

V. GENERAL CONCLUSION

This dissertation consisted of three essays on exchange rate and price. In the first essay (chapter II), I studied the relationship between price leadership and exchange rate (cost, revenue) uncertainty. The essay investigated the incentives to lead and follow in a model in which exporting firms have the different degrees of exchange rate uncertainty. As exchange rate uncertainty increases, firms take a flexible strategy as a dominant strategy. Over certain ranges of exchange rate variability only one firm has a flexible strategy as its dominant strategy, and the other firm is induced to be a price leader, resulting in a dominant strategy Nash-equilibrium (price leader-follower equilibrium). Which firm will be the price leader depends on the mark-up and substitutability of products. In the general context, this study is also related to cost uncertainty. The particular attention of this research was also given to the implication of exchange rate variability for exchange rate pass-through. Exchange volatility may produce a structural break in the observed pass-through relationship, as the new game structure of the market may not be consistent with the historical rate of exchange rate passthrough. Although the model is the same, the solution differs and the exchange rate passthrough differs as the exchange rate variability changes.

The second essay (chapter III) focused more on brand loyalty. In many markets, consumers who have previously purchased from one firm have (or perceive) costs of switching to a competitor's product, even when the two firm's products are functionally identical. I explicitly analyzed the effect of rival exchange rate for different cases (perfect foresight for exchange rates, imperfect foresight for exchange rates, perfect capital mobility, and imperfect capital mobility). In the case of the perfect foresight, the results added to those of Froot and Klemperer's (1989). First, exchange rate pass-through of greater than unity is possible in some cases. Second, if the change of own exchange rate is in the opposite direction to that of the rival's and is relatively small compared to the rival's, perverse exchange rate pass-through happens even with elastic demands. Also, it is possible that the firm chooses a perverse pass-through strategy even with a permanent exchange rate change. Third, the possibility of perverse PT in terms of a trade weighted exchange rate can not be eliminated either for permanent or for temporary shocks, even in the elastic demand area. In the case of the imperfect foresight, the exchange rate PT is affected by exchange rate uncertainty (covariance and variances of the exchange rates) as well as current own- and rival's bilateral exchange rates and expected future exchange rates. The expected future profit is affected by expected competition situations that depend on the interactive movement of future exchange rates.

The last essay (chapter IV) tested the strategic behaviors between exporting firms with simultaneous estimation techniques (three stage least squares) using 7-digit TSUSA data. Exchange rate pass-through was estimated. The 3SLS and reduced form estimates were compared, and the effect of rival exchange rate was emphasized. Also, I manifested the problem of tests using a trade-weighted exchange rate. The evidences across two estimations (3SLS and reduced form) indicate that price adjustment tends to pass through to the local currency price in the destination market, and that the pass-through rate are significantly different across countries and products. The study results confirm quite well to other research on traded good prices and exchange rates. However, this study manifests the importance of rival exchange rate. While the own exchange rate pass-through tends to be related positively with market share, firms that have small market shares often pass through for the fluctuation of rival exchange rate. Particularly, some exporters who have small market shares may pass through the change of rival exchange rate but not the change of own exchange rate. This study also gives some implications at the macro-level. First, in the export price pass-through studies, an export price is affected not only by own trade weighted exchange rate across destination countries but also by rivals' exchange rates in each destination market. This study also shows that, in many markets, prices are affected only by the exchange rate of the country which has the largest market share, rather than the trade weighted exchange rate. It tells that import pass-through studies using trade weighted exchange rate may have a specification problem.

In this dissertation, firms' strategic interaction and pricing were studied under different conditions. Most importantly, this research emphasized the importance of market structure in exchange rate and price issues. The different specification of market structure changes the analytical form, raising different empirical results and policy implications. Most existing theoretical and empirical studies on exchange rate pass-through did not pay an attention to the competition with goods produced in different source countries.

The analysis developed here has implications not only to the micro-level questions, but also to the macro-level questions related to exchange rate. The existence of a stable relationship between exchange rates and traded goods prices on the various national markets is an essential ingredient in external adjustment processes and a major channel of

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international transmission mechanisms. The role of exchange rate changes in balance-ofpayments adjustment processes is a major concern. In the macro-level, the effect of currency appreciation or depreciation on the trade balance can be analyzed more exactly under better understanding on individual market competition structures. Most literature has been performed on aggregate trade price data: aggregation tends to alter the statistical characteristics of individual price series. Hopefully, the present study will provide future researchers with some useful guidance in the study of some of issues associated with the response of prices to exchange rates.

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IMAGE EVALUATION TEST TARGET (QA-3)







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