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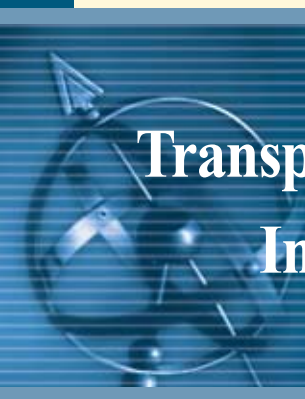

Transport Costs, Relative Prices, and International Risk Sharing

Inkoo Lee and Yonghyup Oh

KIEP Korea Institute for International Economic Policy

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Executive Summary

This paper studies the role of the transport costs in accounting for the puzzling behaviors of relative prices and risk sharing across countries. We show that introducing the transport costs in an otherwise standard competitive model improves its ability to rationalize the deviations from the law of one price and imperfect international risk sharing. Our analysis suggests that the purchasing power parity puzzle and the consumption correlation puzzle can naturally arise in the presence of real frictions, even under the assumption of complete financial markets.

Keywords: Transport cost, relative price, risk sharing, home- bias
JEL classification: F31, F41

국문요약

본 연구는 국가간의 상대가격 결정과 위험공조(risk sharing)에 존재하는 퍼즐을 설명하기 위해 운송비용의 역할이 중요하다는 것을 보여주는 이론 논문이다. 본 논문에서 제시하는 모형을 통해 완전시장과 가격결정의 신축성을 가정하더라도 무역거래의 운송비용을 고려할 때 일물일가법칙과 불완전한 국제위험 공유를 상당한 정도로 설명할 수 있는 것으로 나타났다. 이러한 결과는 완전금융시장하에서도 실물부분에 운송비용과 같은 균열요소가 존재할 때, Rogoff와 Obstfeld(2000)가 제시한 국제거시경제학의 6대 퍼즐 중에서 구매력동일화퍼즐(purchasing power parity puzzle)과 소비의 상관계수퍼즐(consumption correlation puzzle)을 설명할 가능성을 열어주는 결과이다.

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Contents

Transport Costs, Relative Prices, and International Risk Sharing

Inkoo Lee[a] and Yonghyup Oh[b]

I. Introduction

Obstfeld and Rogoff (2000) advanced the hypothesis that trade costs in goods markets in an otherwise neoclassical and competitive environment could resolve the six major puzzles in international macroeconomics, with two exceptions: the purchasing power parity puzzle and the exchange rate disconnect puzzle. They claimed that accounting for these two puzzles would require additional friction: elements of monopoly and sticky nominal prices for goods and labor. However, while useful in addressing international monetary policy questions, recent sticky price models still lack the ability to explain the puzzling behavior of relative prices across countries.

In this paper, we offer an alternative explanation that aids to explain

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the deviations from the law of one price in a framework of flexible prices. In particular, we focus on the role of transport costs which is defined as the cost of moving goods from the location of production to the location of consumption in generating a natural wedge between prices in different locations. Our analysis embodies the notion that traded goods fluctuate in price, but their relative prices are bounded above and below international transaction costs. We explicitly rule out any role of monopoly power or price stickiness to focus on the channels we wish to emphasize. We then show that introducing the transport cost in an otherwise standard competitive model improves its ability to explain the deviations from the law of one price. This finding supports the view that the movements of relative prices are bounded by fixed limits of arbitrage, which are usually treated as proportional transport costs.

This paper also studies the extent to which transport costs can account for the imperfect international risk sharing and the home bias in trade. We find that the imperfect risk sharing and the home bias problem naturally arise in the presence of real frictions such as transport costs. Our finding indicates that the international risk sharing puzzle is virtually a corollary of the home bias puzzle.

The remainder of this paper is organized as follows. In Section 2 and Section 3, we provide a literature review for the purchasing power parity puzzle and the international consumption correlation puzzle, which are two puzzles we address in this study. Section 4 discusses recent developments on the empirical estimates of the transport costs. Section 5 describes the economic environment and develops the base-

line model. In Section 6, we discuss the model's key implications for the relative prices and international risk sharing. Finally, Section 7 presents concluding remarks.

Ⅱ. Purchasing Power Parity Puzzle

The law of one price (LOP) states that international relative price differentials should be arbitraged away so that identical goods in different locations should sell for the same price, when expressed in a common currency. Purchasing power parity (PPP) is the notion that this should hold on average, across goods: similar baskets of goods should cost the same once expressed in common currency. Translated into observables, it states that the real exchange rate (a ratio of price index in two countries expressed in terms of a single currency) should be unity. Knowing the extent to which data support these propositions is important for understanding nominal exchange rate behaviors, the pricing of international financial assets, and a host of other questions in international economics. Yet the evidence from the empirical literature shows that not only are relative prices quite different across countries, but also such deviations are highly volatile and persistent. These characteristics of the real exchange rates have been the central puzzle in international macroeconomics literature, with the source of the puzzling behavior remaining unclear.

Traditionally, the attempts to address this puzzle were based on the Balassa-Samuelson objection to PPP and centered on the distinction between traded and non-traded goods. The real exchange rates then equal the relative prices of non-traded goods to traded goods. However, these models were shown to be empirically unwarranted. Most not-

ably, Engel (1999) shows that in the U.S. data, no more than 2% of the variation in the real exchange rates can be contributed to the fluctuations in the relative prices of non-traded to traded goods. A number of empirical studies document large, volatile and persistent deviations in the prices of traded goods across countries. Moreover, recent empirical literature emphasizes the finding that deviations from the law of one price behave in a non-linear and heterogeneous way (See Crucini, Telmer & Zachariadis 2005). Therefore, deviations in the prices of traded goods are the empirically relevant cornerstone of the current theoretical approaches.

Several avenues have been explored to motivate the deviations of prices of traded goods from the law of one price. Pricing to market combined with nominal rigidities has been widely used in creating volatile deviations in the real exchange rates (see, for example, Betts & Devereux 2000; Bergin & Feenstra 2001; Chari, Kehoe & McGrattan 2002). In particular, a year-long price stickiness combined with a low degree of intertemporal elasticity of substitution and consumption-leisure separable preferences generates sufficient volatility but not sufficient persistence in the real exchange rates. Such (sticky price) models build microfoundations of the price adjustment process by considering the role of imperfect competition in sustaining price differentials across countries. This approach argues that deviations from the law of one price are generated by the pricing-to-market behavior of monopolistic providers, while nominal price rigidities maintain those deviations. However, in matching and accounting for the observed large, persistent and volatile deviations from the law of one price, this approach

performs worse than expected in the sense that it matches one at the expense of others.

The distribution costs approach (Corsetti & Dedola 2002; Burstein, Neves & Rebello 2001) justifies wedges between the prices of tradable goods, but has to rely on very large costs to product distribution to match the volatility of the real exchange rate.

Differences in preferences across countries have also been used to create deviations from the law of one price (Lapham & Vigneault 2001), but must resort to volatile and highly persistent shocks to the preference parameters in order to match the observed fluctuations in the prices of traded goods.

Finally, models of the costs to arbitrage trade were employed to generate deviations from the law of one price (see Obstfeld & Rogoff 2000; Dumas 1992; Sercu, Uppal & van Hulle 1995; Lee 2008; Lee & Shin 2009). The genesis of such models has derived from the recognition that the sticky price models, while useful in addressing international monetary policy questions, still lack the ability to explain the dynamics of relative prices across countries. In particular, when combined with nontradability of goods, introducing the arbitrage costs in an otherwise standard competitive model appears to dramatically improve its ability to rationalize the observed puzzling behavior of the relative prices. This paper fits into the last strand of literature.

Ⅲ. International Risk Sharing Puzzle

If one believes that both domestic and international capital markets are well approximated by an Arrow-Debreu complete market, then it is a puzzle that international consumption correlations are not higher than expected. In a world of complete financial markets, country-specific output risks should be pooled and thus domestic consumption growth should not depend too much on country-specific output risks. In some sense, the risk sharing puzzle (or consumption correlation puzzle) could be thought of as a corollary of the home equity bias puzzle and the Feldstein-Horioka puzzle. Provided that the most transparent market means of consumption smoothing, which include debt borrowing and equity claims, are less operative across countries than within them, it is not surprising that the degree of international risk sharing is low. However, there are many reasons for thinking about the risk sharing puzzle independently. One is that we have only limited measures of debt and equity trading. The other is that there may be other channels such as direct investment for pooling output risks.

The international risk sharing puzzle has given rise to sub-puzzles. Backus, Kehoe & Kydland (1992) find that output growth rates are more correlated than consumption growth rates across countries. Backus & Smith (1993) show that, in the presence of non-traded goods, efficient risk sharing calls for giving higher consumption growth rates to countries that experience relative falls in the real prices of consump-

tion. Crucini (1999), comparing the provinces of Canada, the states of the United States, and the G-7 countries, find similar degrees of risk sharing within regions of Canada and the U.S. that exceed the risk sharing that occurs across countries. Specifically, more than two-thirds of the fitted annual variations in regional consumption are found to be common to all regions compared to less than one-third in the case of G-7 countries. Lewis (1999) points out that if a substantial share of output is nontradable, international consumption correlations will be significantly reduced. However, Stockman & Tesar (1995) find that international consumption correlations for apparently tradable goods are not much higher than those for nontradable goods. This supports the view that the dichotomous distinction between tradable goods and nontradable goods is overdrawn and suggests that there are significant impediments to international risk sharing in tradable goods. On the other hand, Sorensen, Wu, Yosha & Zhu (2007) document that international home bias in debt and equity holdings declined during the period 1993–2003 at the same time as international risk sharing increased. In particular, using panel-data regressions for OECD countries, they demonstrate that less home bias is associated with more international risk sharing, and that more financial integration is associated with more risk sharing when financial integration is measured as the ratio of foreign assets to gross domestic products. Oh (2009) using a gravity type model for a large set of countries in the world finds that English speaking countries show higher consumption risk sharing than other language or geographical groups. Obstfeld & Rogoff (2000), in their seminal work, argue that risk sharing is more impaired internationally

than domestically due to international trade. Following the spirit of Obstfeld & Rogoff (2000), this paper analyzes the effect of transport cost on international consumption correlations.

Ⅳ. Transport Costs

The most natural measure of the transport costs from a theoretical point of view is the difference between imports evaluated at a price which includes freight and insurance (CIF) and exports evaluated free on board (FOB). For example, Hummels (2001) estimates transport costs based on direct measurement of the freight rate, which is defined as the ratio of transportation expenditure to the value of imports exclusive of freight and insurance charges. The all-commodities trade-weighted average freight rate ranges from 3.8% for the US to 13.3% for Paraguay. Across commodities in the US, the freight rate ranges from a low of 0.9% for transport equipment to a high of 27% for crude fertilizer. In their extensive survey of the measurement of the trade costs, Anderson and van Wincoop (2004) show that the 170% of the 'representative' trade costs in industrialized countries breaks down into 21% of the transportation costs, 44% of border-related trade barriers, and 55% of retail and wholesale distribution costs. However, as Anderson and van Wincoop point out, there are numerous problems when one attempts to implement such a measure due to inconsistencies across countries in bilateral value and quantity data for trade, cross-hauling of goods, and aggregation bias. Hummels & Lugovskyy (2006) also find that IMF CIF/FOB ratios are dramatically different from explicitly collected data on shipping costs, and conclude that it would be unwise to use the direct measure of trade costs in exercises where the level of the

costs is an important issue. Motivated by the difficulties of the standard method in measuring the trade costs, Obstfeld & Taylor (1997) estimate the trade costs in the threshold autoregressive model (TAR) by searching for the optimal threshold value that maximizes the log-likelihood ratio. This approach basically emphasizes that price differentials decay slowly within the arbitrage bands, but grow rapidly outside the bands as international trade takes place. They show that the optimal thresholds are below average in the U.S. and Canada (between 0.5% and 8%) and higher elsewhere. Thresholds are found to be lower between the U.S. and Asia (2%~8%) than between the U.S. and Europe (9%~19%). Lee (2008) also shows that, with Belgium being the numeraire country, implied trade costs estimated from the BAND-TAR model range from a low of 0.6% between Belgium and Netherlands to a high of 57.1% between Belgium and Indonesia. He also finds that implied trade costs are lower between Belgium and other European countries (0.6%~13.5%) than they are between Belgium and countries outside Europe (4.4%~57.1%).

In this paper, we offer an alternative measure of the trade cost by considering the cost as the units of time, which is the fraction of an hour needed for individual to transport good from its location of production to the location of that individual's consumption. The underlying idea is that each consumer is required to spend time to transport goods that are sold in the retail market. In this sense, this cost is related to transformation cost associated with bringing the internationally traded consumption good from the point of production to its final destination.

Ⅴ. The Model

In this section, we present a model of two countries and two goods. The home and foreign country, each specializing in the production of a single good using only labor as an input, are similar in two respects. First, they are assumed to be populated by a large and equal number of infinitely –lived consumers with identical utility functions. Second, their financial markets are perfectly integrated, complete, and friction-less. The factor that distinguishes one economy from another is the transport cost. Individuals must transport each of the goods from a location of production to their location of consumption. The cost is measured in units of time, which is the fraction of an hour needed for individual to transport good from its location of production to that individual's consumption location. The use of time in this process is what allows for alternative interpretations of the differences between the price in a centralized market and the economic value at the point of consumption. Therefore, in our model, the transport cost could be thought of as time needed to transform the good in some way that is specific to the good, the location, or the individual.

Consumers in each country choose consumption of the home-produced tradable goods (C_{1t}), the foreign-produced tradable goods (C_{2t}), and the leisure (L_t) to maximize:

$$E(U) = E_0 \sum_{t=0}^{\infty} \beta^t U(C_{1t}, C_{2t}, L_t) = E_0 \sum_{t=0}^{\infty} \beta^t (\gamma_1 \log C_{1t} + \gamma_2 \log C_{2t} + \kappa L_t)$$

in the case of the home country, and

$$E(U) = E_0 \sum_{t=0}^{\infty} \beta^t U(C_{1t}^*, C_{2t}^*, L_t^*) = E_0 \sum_{t=0}^{\infty} \beta^t (\gamma_1 \log C_{1t}^* + \gamma_2 \log C_{2t}^* + \kappa L_t^*)$$

in the case of the foreign country.

A single representative agent allocates market time across the hours worked (N) in the marketplace, hours of leisure, and hours of transportation (τ) subject to the constraint that these three activities exhaust total hours available:

$$1 - N_t - L_t - \tau_1 C_{1t} - \tau_2 C_{2t} \geq 0$$

The foreign country faces an analogous constraint:

$$1 - N_t^* - L_t^* - \tau_1^* C_{1t}^* - \tau_2^* C_{2t}^* \geq 0$$

We assume that the financial markets of the two countries are complete and perfectly integrated, so that the goods' market clearing conditions are given by

$$Y_{1t} - C_{1t} - C_{1t}^* \geq 0$$
$$Y_{2t} - C_{2t} - C_{2t}^* \geq 0$$

where Y_{1t} and Y_{2t} are the outputs of the home-produced tradable goods and the foreign-produced tradable goods respectively. Output is

produced using labor and is affected by the productivity variables (A): $Y_{1t} = A_t N_t$ and $Y_{2t} = A_t^* N_t^*$.

Finally a social planner that allocates goods, "production" effort, and "transformation" effort to individuals would solve the following problem:

$$Max\ E_0 \sum_{t=0}^{\infty} \beta^t \left[U(C_{1t}, C_{2t}, L_t) + U(C_{1t}^*, C_{2t}^*, L_t^*) \right]$$

subject to

$$1 - L_t - N_t - \tau_1 C_{1t} - \tau_2 C_{2t} \geq 0$$
$$1 - L_t^* - N_t^* - \tau_1^* C_{1t}^* - \tau_2^* C_{2t}^* \geq 0$$
$$(10)\quad AN_t - C_{1t} - C_{1t}^* \geq 0$$
$$(11)\quad A_t^* N_t^* - C_{2t} - C_{2t}^* \geq 0$$

To solve the model, we specify the following Lagrangian problem and then solve the resulting system of first-order conditions:

$$Max\ L = E_0 \sum_{t=0}^{\infty} \beta^t \left[U(C_{1t}, C_{2t}, L_t) + U(C_{1t}^*, C_{2t}^*, L_t^*) \right]$$
$$+ w_t (1 - L_t - N_t - \tau_1 C_{1t} - \tau_2 C_{2t})$$
$$+ w_t^* (1 - L_t^* - N_t^* - \tau_1^* C_{1t}^* - \tau_2^* C_{2t}^*)$$
$$+ p_t (AN_t - C_{1t} - C_{1t}^*)$$
$$+ p_t^* (A_t^* N_t^* - C_{2t} - C_{2t}^*)$$

where p_t, p_t^*, w_t, w_t^* are the multipliers on the constraints in the Lagrangian problem and have the following interpretations as shadow prices:

p_t, p_t^*: prices of the final good
w_t, w_t^*: wage rates

Letting D_j denote the partial derivative of a function with respect to its *j*th argument, the first-order necessary condition for this Lagrangian problem are

$$
\begin{aligned}
&C_{1t}: D_1U(C_{1t}, C_{2t}, L_t) - w_t\tau_1 - p_t = 0\\
&C_{2t}: D_2U(C_{1t}, C_{2t}, L_t) - w_t\tau_2 - p_t^* = 0\\
&L_t: D_3U(C_{1t}, C_{2t}, L_t) - w_t = 0\\
&N_t: p_t A_t - w_t = 0\\
&C_{1t}^*: D_1U(C_{1t}^*, C_{2t}^*, L_t^*) - w_t^*\tau_1^* - p_t = 0\\
&C_{2t}^*: D_2U(C_{1t}^*, C_{2t}^*, L_t^*) - w_t^*\tau_2^* - p_t^* = 0\\
&L_t^*: D_3U(C_{1t}^*, C_{2t}^*, L_t^*) - w_t^* = 0\\
&N_t^*: p_t^* A_t^* - w_t^* = 0\\
&w_t: 1 - L_t - N_t - \tau_1 C_{1t} - \tau_2 C_{2t} = 0\\
&p_t: AN_t - C_{1t} - C_{1t}^* = 0\\
&w_t^*: 1 - L_t^* - N_t^* - \tau_1^* C_{1t}^* - \tau_2^* C_{2t}^* = 0\\
&p_t^*: A_t^* N_t^* - C_{2t} - C_{2t}^* = 0
\end{aligned}
$$

VI. Results

1. Relative Prices

The relative price of any pair of goods can be read off as the marginal rates of substitution in the optimum. From the first order condition, the relative price of the home-produced goods between the home and the foreign agents is then given by:

$$(12)\quad MRS_{1t} = q_t \lambda_{1t} \quad \text{where} \quad \lambda_{1t} = \frac{A_t \tau_1 + 1}{A_t^* \tau_1^* + q}$$

The relative price of the foreign-produced goods between the home and the foreign agents is given by:

$$(13)\quad MRS_{2t} = q_t \lambda_{2t} \quad \text{where} \quad \lambda_{2t} = \frac{A_t \tau_2 + (1/q_t)}{A_t^* \tau_2^* + 1}$$

The term λ_1 and λ_2 capture the impact of the costs of moving goods from the location of production to the location of consumption on the relative prices faced at the final consumption stage, and q is their relative price before these costs are taken into account. There are two sources of possible asymmetries across countries in these terms. First, there may be asymmetries arising from transport costs differing across countries. However, even if $\tau = \tau^*$ for every goods, the relative

price of the final good still has an asymmetry because the marginal cost of transporting the goods depends on the wages of the agent.

Equation (12) and (13) imply that transport costs play a crucial role in shaping the behavior of the real exchange rates between different locations. It is evident from the equations that deviations from the law of one price are positively associated with the size of the transport costs. This occurs because higher transport costs make goods less likely to be traded and hence limit the opportunity for arbitrage. For example, when the gains from trade are not high enough to offset the transport costs, the implicit relative price is a matter of reading off the appropriate marginal valuations, expressed as the ratio of home and foreign marginal utility evaluated at autarkic output points. The implied price differential is not sufficient at these output levels to justify paying for the transport costs.

It is worthwhile to note that in the absence of the transport costs (that is, $\tau = \tau^* = 0$), the relative prices simply reduce to a unity in which law of one price holds for every good.

2. International Risk Sharing

From the first order condition, the equilibrium consumption of the home-produced goods is given by;

(14) $$C_{1t} = \frac{\gamma_1}{p_t A_t \tau_1 + p_t}$$

$$(15)\quad C_{1t}^{*} = \frac{\gamma_1}{p_t^{*} A_t^{*} \tau_1^{*} + p_t}$$

Similarly, the equilibrium consumption of the foreign-produced goods is given by;

$$(16)\quad C_{2t} = \frac{\gamma_2}{p_t A_t \tau_2 + p_t^{*}}$$

$$(17)\quad C_{2t}^{*} = \frac{\gamma_2}{p_t^{*} A_t^{*} \tau_2^{*} + p_t^{*}}$$

The principal implication of risk sharing is that individual consumption responds to aggregate shocks but not to idiosyncratic shocks. This is because, under the circumstance of complete financial markets, countries effectively insure each other to the maximum extent possible against country-specific output shocks by pooling portfolios. Thus the literature on risk sharing and complete markets predicts positive relationship between consumptions across countries. In our model, this is reflected by the fact that when countries are specialized in production, the price mechanism provides complete insurance for domestic and foreign residents alike as long as $\tau = \tau^{*} = 0$.

However, in the presence of the transport costs $(\tau > 0, \tau^{*} > 0)$, the productivity shocks in common industries are transmitted negatively between countries and thus the price mechanism provides no automatic insurance in this case. This is because when the arbitrage costs are sufficiently large relative to the output differentials between countries,

the gains from trade are not high enough to offset the transport cost leading to a non-trade equilibrium. Note that when $\tau = \tau^* = 0$, the consumptions of each goods are perfectly positively correlated across countries. Our model will degenerate to an autarky economy when the costs of moving goods from the location of production to the location of consumption are sufficiently large, in which risk sharing is prohibited.

Our model also indicates that the transport cost plays an essential role in determining the home bias in trade, even under the assumption of a complete financial market. From the equations above, the consumption ratios between the home-produced goods and the foreign-produced goods faced by each country are given by:

$$(18)\quad \frac{C_{1t}}{C_{2t}} = \frac{\gamma_1}{\gamma_2}\frac{p_t A_t \tau_2 + p_t^*}{p_t A_t \tau_1 + p_t}$$

$$(19)\quad \frac{C_{2t}^*}{C_{1t}^*} = \frac{\gamma_2}{\gamma_1}\frac{p_t^* A_t^* \tau_1^* + p_t}{p_t^* A_t^* \tau_2^* + p_t^*}$$

Suppose that two countries have identical preferences for the home and the foreign goods, and have a common currency. When the transport costs do not exist, the consumption ratio simply equals unity, and consumption expenditures are evenly divided between the home and the foreign goods. However, if consuming imports requires more time in searching for and transporting goods relative to domestic products, then consumers will prefer to purchase domestic products, resulting in a home bias. This finding, in turn, implies that incomplete risk sharing

naturally arises in the presence of real frictions such as transport costs. As noted by Obstfeld & Rogoff (2000), the international consumption correlation puzzle is almost a corollary of the home bias puzzle. This paper supports the view that transport costs play a significant role in the home bias in trade, which is associated with less international risk sharing.

Ⅶ. Conclusions

The law of one price states that international relative price differentials should be arbitraged away, so identical goods in different countries should sell for the same price, when expressed in a common currency. Yet, the evidence from the empirical literature shows that not only are relative prices quite different across countries, but such deviations are highly volatile and persistent. These characteristics of the real exchange rate have been the central puzzle in international macroeconomics, with the source of the puzzling behavior remaining unclear.

In this paper, using a simple two-country model, we show that deviations from the law of one price can naturally arise in the presence of the transport costs, even under the assumption of a flexible price market. This result suggests that it is possible to generate deviations from the law of one price and purchasing power parity within a flexible price framework if a relevant real factor, such as transport costs, is introduced. Our framework complements those that emphasize the role of sticky prices. Our future work should concentrate on assessing the dynamics (e.g. volatility and persistence) of the real exchange rates in the presence of time cost.

We also find that the transport costs lead the consumption correlations to be affected by idiosyncratic output shocks, resulting in the international risk sharing puzzle. A high level of home trade bias is positively related to less risk sharing, indicating that international risk shar-

ing puzzle is virtually a corollary of the home bias puzzle. This suggests that market integration that reduces transport cost between locations should operate in a way that lowers the degree of home bias and promotes international risk sharing.

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Inkoo Lee and Yonghyup Oh

This paper studies the role of the transport costs in accounting for the puzzling behaviors of relative prices and risk sharing across countries. We show that introducing the transport costs in an otherwise standard competitive model improves its ability to rationalize the deviations from the law of one price and imperfect international risk sharing. Our analysis suggests that the purchasing power parity puzzle and the consumption correlation puzzle can naturally arise in the presence of real frictions, even under the assumption of complete financial markets.

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