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**ABSTRACT**

We study the implications for international relative prices of a simple Ricardian model of international trade with imperfect competition and variable markups, providing a tractable account of firm-level and aggregate prices. We show that both trade costs and imperfect competition with variable markups are needed to account for pricing-to-market at the firm and aggregate levels. We also show that international trade costs are essential, but pricing-to-market is not, to account for a high volatility of tradeable consumer prices relative to the overall CPI-based real-exchange rate.

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# Pricing-to-market in a Ricardian Model of International Trade

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Following Marc Melitz (2003) and Andrew Bernard, Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum (2003) (BEJK), recent research on international trade has studied models in which comparative advantage is derived from Ricardian technological differences across firms or plants rather than across countries. These models emphasize the role of trade costs in accounting for trade patterns and allow for imperfect competition with variable markups. In our recent research (see Atkeson and Burstein 2006), we study the ability of a model with technological differences across firms, trade costs, and imperfect competition with variable markups to account quantitatively for several important features of the behavior of fluctuations in international relative prices. In that paper, we present a model that, when parameterized to match some of the main features of the data on trade volumes at both the aggregate and firm level and to have reasonable implications for both the concentration of production among producers in a market and the distribution of markups of price over marginal cost, reproduces many of the main features of the data on the fluctuations in the relative producer and consumer prices of tradeable and traded goods.

In this paper, we present a simplified version of our model based on that presented in BEJK to provide an analytically more tractable account of the role of trade costs and imperfect competition with variable markups in accounting for international relative prices that is useful for classroom discussion. In particular, this model provides a simple and intuitive account of the decision of individual exporting firms to practice pricing-to-market

— that is, to *change* the relative price at which they sell their output at home and abroad in response to a change in the relative costs of production at home and abroad. This simplified model is less appropriate for quantitative work than the model in Atkeson and Burstein (2006) largely because its implications for pricing are not robust to small changes in market structure. In particular, the pricing implications of the model are not continuous with respect to the elasticity of substitution between the output of competing firms — these implications are very different when firms' outputs are perfect substitutes rather than near, but imperfect, substitutes.

In this paper we focus on the implications of our simplified model for two features of the data on international relative prices. The first feature of the data is the observation that, for the major developed economies, the international relative producer price of manufactured (tradeable) goods is roughly twice as volatile as the corresponding terms of trade for manufactured goods (see Atkeson and Burstein 2006 for a full review of these data). In our model, the international relative producer price of tradeable goods moves in response to a change in relative production costs across countries simply because each country specializes in the production of a distinct set of goods. What is more difficult to reproduce in the model is the observation that this change in relative production costs across countries leads to a substantially smaller movement in the terms of trade. Algebraically, this can be the case only if there are systematic fluctuations in the ratio of export prices to home country producer prices and the ratio of import prices to source country producer prices for tradeable goods. Specifically, an increase in the home marginal cost relative to foreign marginal costs leads to an increase in home producer prices relative to export prices. In this model, these fluctuations arise as a result of individual firms' decisions to price-to-market.

The second feature of the data that we study is the finding that for many developed economies there appears to be little or no difference in the magnitude of the fluctuations in the international relative consumer price of the basket of goods that are considered tradeable and the magnitude of the fluctuations in overall consumer price index based real exchange rates (CPI-based RER). This observation that the fluctuations in the international relative consumer price of tradeable goods are nearly as large as fluctuations in CPI-based RER themselves holds both at short and long horizons (see, for example, Charles Engel 1999). This finding has been presented as an important challenge in open economy macroeconomics since it suggests that international arbitrage through international trade plays only a very limited role in mitigating the fluctuations in international relative consumer prices at the macroeconomic level.

We present two main results from our model. First, we show that both trade costs and imperfect competition with variable markups are needed to account for pricing-to-market at the firm and aggregate level. Second, we show that international trade costs are essential, but pricing-to-market is not, to account for a high volatility of tradeable consumer prices relative to the overall CPI-based RER.

## I. Model

We develop a model in which two symmetric countries (indexed by $i$) produce and trade a continuum of goods subject to frictions in international goods markets. Our approach is partial equilibrium in the sense that we take as given movements in the relative cost of production across countries and ask what changes in the consumer and producer prices of goods should result from these changes in costs. We do not address the general equilibrium question of what shocks lead to these large and persistent changes in costs and prices across countries. Compared to the model studied in Atkeson and Burstein (2006), we assume that varieties within a sector are perfect substitutes ($\rho = \infty$, in the notation of that paper), and we also abstract from the fixed costs of exporting, so international trade is only driven by considerations of comparative advantage. We also consider two types of competition: perfect competition and Bertrand competition.

Final consumption, $c_i$, is a composite of final tradeable good consumption, $c_i^T$, and final non-tradeable good consumption, $c_i^N$, given by $c_i = \left(c_i^T\right)^\gamma \left(c_i^N\right)^{1-\gamma}$. The final tradeable and non-tradeable goods are each produced by a competitive firm using a continuum of varieties $j$ subject to a standard CES production function. In each country, those varieties that are used to produce the final tradeable good are indexed by $j \in [0,1]$, and those that are used to produce the final non-tradeable good are indexed by $j \in (1,2]$. The production function for the final tradeable good is given by

$$c_i^T = \left[\int_0^1 \left(y_{ij}\right)^{1-1/\eta} dj\right]^{\eta/(\eta-1)},$$

and likewise for the final non-tradeable good using varieties $j \in (1,2]$. Profit maximization by the final goods producers gives standard CES demand functions with an elasticity of demand determined by $\eta$.

In each country $i$, there are $K$ potential producers of each of these varieties, giving a total of $2 \times K$ potential producers of each variety in the world. These potential producers of each variety have technologies to produce the same good with different marginal costs. Specifically, each potential producer has a constant returns production technology of the form $y = zl$, where $l$ is labor and $z$ is a productivity realization that is idiosyncratic to that producer. Tradeable and non-tradeable varieties are distinguished by the cost of trading them internationally: for tradeable varieties $j \in [0,1]$ there is an iceberg trade cost indexed by $D \geq 1$ to ship these varieties between countries, while for non-tradeable varieties $j \in (1,2]$, international trade is prohibitively costly. Hence, the marginal cost of supplying one unit of a tradeable variety in country 1 for a domestic firm with productivity $z$ is $W_1/z$. The marginal cost for a supplier of country 2 with the same productivity $z$ to sell in country 1 is $DW_2/z$. Note that $D = 1$ corresponds to the case of costless international trade of tradeable varieties.

*A. Perfect Competition*

Under perfect competition, the final goods producers in each country $i$ purchase each variety from the lowest cost supplier of that good to that country, and the price charged for that variety is the marginal cost of that lowest cost supplier. So, the price of sector $j$ in country $i$ is given by $P_{ij} = c^1_{ij}$, where $c^1_{ij}$ is the marginal cost of the lowest cost producer among the $2K$ potential suppliers of this variety $j$ to this country $i$. For imported varieties, this marginal cost is the marginal cost of production scaled up by the international trade cost $D$. Clearly, for the non-tradeable varieties, with $D = \infty$, the lowest cost provider is always domestic and the price is equal to the marginal cost of that producer. With these assumptions, our model is similar to the Rudiger Dornbusch, Stanley Fisher, and Paul Samuelson (1977) Ricardian model of trade with a continuum of goods. The extent to which tradeable varieties are traded depends on the balancing of the trading cost $D \geq 1$ and the dispersion of idiosyncratic productivities $z$.

*B. Bertrand Competition*

Under Bertrand competition, the final goods producer in each country $i$ purchases each intermediate good from the lowest cost supplier of that good to that country, just as under perfect competition, but the price charged is the minimum of the monopoly price for the lowest cost supplier and the marginal cost of the second lowest cost supplier of that good to that country. This is the key distinction between Bertrand and perfect competition: under Bertrand competition there is no fixed relationship between the price of each intermediate good and the marginal cost of the supplier of that good.

To model Bertrand competition, let $c_{ij}^k$ denote the marginal cost of the $k^{th}$ lowest cost supplier ($k = 1$ or 2) of sector $j$ to country $i$. Then, the price is given by $P_{ij} = \min\left\{c_{ij}^2, \frac{\eta}{\eta-1}c_{ij}^1\right\}$.

In defining the term *pricing-to-market*, we consider the prices charged by a single producer of a traded variety $j$ in two different locations. Let $\widehat{P_{ij}}$ be the percentage change in the price of variety $j$ in country $i$. Here a hat on a variable indicates the log change of the variable. Our measure of pricing-to-market at the firm level is $\left(\widehat{P_{1j}} - \widehat{P_{2j}}\right)$. It reflects the extent to which deviations from the law of one price arise from the pricing decision of a single producer supplying different locations as opposed to the pricing decisions of different producers supplying different locations.

## II. Aggregate Prices

We consider aggregate shocks to the marginal cost of production, $\widehat{W_i}$, as the driving force behind fluctuations in international relative prices.[1] We measure changes in aggregate price indices in our model using the same methodology used by Bureau of Labor Statistics (BLS) accountants in constructing consumer, producer, and export and import price indices. Specifically, we consider expenditure weighted averages of price changes for individual varieties and use expenditure shares from the symmetric equilibrium (i.e. $W_1 = W_2 = 1$). In this section, we derive expressions for the change in aggregate price indices in response to a small change in relative wages across countries using a first order approximation. Because there are a finite number of potential producers of each variety ($K$), each with distinct productivities, the identities of the firms that produce and sell in each country do not change in response to a sufficiently small change in relative wages, under both perfect and Bertrand competition. Later, when we compute the changes in prices numerically, we account for the switches in the identities of producing firms using the methodology used by the BLS to construct price

[1] We can think of them as arising from a productivity shock or from a change in the nominal exchange rate in a model with sticky nominal wages. In our model we do not need to specify the underlying source of the aggregate shock to relative costs across countries to compute the change in prices.

indices.[2]

The first-order approximations to the change in aggregate price indices in response to a small change in relative wages are as follows. The change in logarithm in the export price index in country 1 (import price index for country 2), covering prices that domestic firms charge for foreign sales, is denoted by $\widehat{EPI}_1$ and is given by

$$\widehat{EPI}_1 = \frac{1}{s_M} \int_{\{\text{tradeable } j \text{ exported by } 1\}} s_{2j} \widehat{P_{2j}} dj. \tag{1}$$

Here $s_{ij}$ denotes the symmetric equilibrium expenditure share of variety $j$ over total tradeable consumption in country $i$, and $s_M$ is the share of tradeables expenditure on imports. This import share $s_M$ is given by the integral of $s_{2j}$ across all varieties $j$ imported by country 2 from country 1, and symmetry makes it equal in both countries. The definition of the import price index $\widehat{IPI}_1$ for country 1, covering prices that foreign firms charge for domestic sales, is symmetric.

Let $\widehat{PPI}_1^T$ denote the change in the producer price index of tradeable goods in country 1. It covers prices that domestic producers of tradeable goods charge for all sales, including sales to foreigners (exports), and is thus given by

$$\widehat{PPI}_1^T = \int_{\{\text{tradeable } j \text{ produced by } 1\}} s_{1j} \widehat{P_{1j}} dj + s_M \widehat{EPI}_1. \tag{2}$$

The producer price for tradeable goods in country 2, $\widehat{PPI}_2^T$, is defined symmetrically.

The change in the consumer price index for tradeable goods in country 1, $\widehat{CPI}_1^T$, covering prices of domestically consumed tradeable goods including domestically produced and imported goods, is given by

$$\widehat{CPI}_1^T = \widehat{PPI}_1^T + s_M \left( \widehat{IPI}_1 - \widehat{EPI}_1 \right), \tag{3}$$

and symmetrically for country 2.

[2] In particular, in constructing the consumer price index, if the identity of the firm selling a particular variety in a particular country changes in response to the change in relative wages, we substitute the price charged by the new firm for that of the old (using the logic that the BLS looks for close substitutes if the original good is not available). On the other hand, in constructing the producer and export price indices, varieties for which the identity of the producer changes in response to the change in relative wages are not included in the relevant price index (or equivalently, we attribute to this variety the rate of change in the overall price index).

The change in the price of the final consumption good in country $i = 1$ , 2 is a weighted average of the change in the price index for tradeable goods and the price index of non-tradeable goods and is given by

$$\widehat{CPI}_i = \gamma \widehat{CPI}_i^T + (1 - \gamma)\widehat{CPI}_i^N. \tag{4}$$

The change in the CPI-based RER is given by $\widehat{RER} = \widehat{CPI}_1 - \widehat{CPI}_2$.

Under either perfect or Bertrand competition, $\widehat{P_{ij}} = \widehat{W_i}$ for all non-tradeable varieties since all competitors producing these varieties are domestic. This implies that the price of non-tradeable varieties moves one-to-one with change in the producer's marginal costs. Thus, the change in the CPI-based RER for tradeable goods relative to the overall CPI-based RER is

$$\frac{\widehat{CPI}_1^T - \widehat{CPI}_2^T}{\widehat{CPI}_1 - \widehat{CPI}_2} = \frac{\frac{\widehat{CPI}_1^T - \widehat{CPI}_2^T}{\widehat{W}_1 - \widehat{W}_2}}{\gamma \frac{\widehat{CPI}_1^T - \widehat{CPI}_2^T}{\widehat{W}_1 - \widehat{W}_2} + (1 - \gamma)}. \tag{5}$$

We examine what perfect and Bertrand competition imply for pricing-to-market at the firm level, for pricing-to-market at the aggregate level as measured by the ratio of $\left(\widehat{EPI}_1 - \widehat{IPI}_1\right)$ and $\left(\widehat{PPI}_1^T - \widehat{PPI}_2^T\right)$, and for the fraction of overall CPI-based RER fluctuations accounted for by movements in the CPI-based RER for tradeable goods as given by (5).

*A. Perfect Competition*

Under perfect competition, prices are set equal to the marginal cost of the lowest cost producer. So, $\widehat{P_{1j}} = \widehat{W_1}$ for all nontradeable varieties consumed in country 1 and also for those tradeable varieties $j$ that are produced and consumed in country 1. Similarly, $\widehat{P_{2j}} = \widehat{W_1}$ for all those tradeable varieties produced in country 1 and exported to country 2. Symmetrically, $\widehat{P_{ij}} = \widehat{W_2}$ for all varieties produced in country 2 and consumed in country $i$, and $\widehat{P_{1j}} = \widehat{W_2}$ for all varieties imported in country 1. Hence, there is no pricing-to-market since $\widehat{P_{1j}} = \widehat{P_{2j}}$ for all varieties that are actually traded.

Aggregate prices are given by $\widehat{EPI}_1 = \widehat{PPI}_1^T = \widehat{W_1}$ and $\widehat{IPI}_1 = \widehat{PPI}_2^T = \widehat{W_2}$. Hence, we have our aggregate measure of pricing-to-market, $\left(\widehat{EPI}_1 - \widehat{IPI}_1\right) / \left(\widehat{PPI}_1^T - \widehat{PPI}_2^T\right)$, equal to 1, and

$$\frac{\widehat{CPI}_1^T - \widehat{CPI}_2^T}{\widehat{W}_1 - \widehat{W}_2} = 1 - 2s_M. \tag{6}$$

Given these results and a choice of the share of tradeables in overall consumption $\gamma$, one can compute the movement in the relative consumer price of tradeable goods as a fraction of the overall movement in the CPI-based RER using (5).

*B. Bertrand Competition*

The logic of pricing under Bertrand competition is quite different from that under perfect competition because pricing is determined by the costs of the second lowest cost supplier of a good. We refer to this second lowest cost supplier as the latent competitor. For all non-tradeable varieties, the latent competitor is domestic, so $\widehat{P_{ij}} = \widehat{W_i}$ as under perfect competition. For tradeable varieties, however, the latent competitor can be local or located abroad.

To understand pricing under Bertrand and perfect competition, it is useful to group tradeable varieties purchased in each country into four categories: (1) varieties that are produced locally and priced at the marginal cost of a local latent competitor (we denote the symmetric equilibrium share of this category of goods in tradeable goods consumption by $s_{LL}$), (2) varieties that are produced abroad and priced at the marginal cost of a latent competitor that is also located abroad (share $s_{MM}$), (3) varieties produced locally but priced at the cost of a latent competitor abroad (share $s_{LM}$), and (4) varieties produced abroad but priced at the cost of a local latent competitor (share $s_{ML}$). Locally produced products priced at the monopoly markup of $\eta/(\eta-1)$ are included in $s_{LL}$ while imported varieties priced at this markup are included in $s_{MM}$. Using these shares, we can express the import share as $s_M = s_{MM} + s_{ML}$, and the expenditure share on local goods as $1 - s_M = s_{LL} + s_{LM}$. Note that, in a symmetric equilibrium, these shares do not vary across countries.

In country 1, for varieties in categories (1) or (4) (with latent competitors in country 1), $\widehat{P_{1j}} = \widehat{W_1}$, and for varieties in categories (2) and (3) (with latent competitors in country 2), $\widehat{P_{1j}} = \widehat{W_2}$. By symmetry, in country 2, for varieties in categories (1) or (4), $\widehat{P_{2j}} = \widehat{W_2}$, and for varieties in categories (2) and (3), $\widehat{P_{2j}} = \widehat{W_1}$.

Pricing-to-market at the firm level under Bertrand competition can be understood as follows. Consider the pricing of a variety $j$ that is produced in country 1 and exported to country 2. For a portion of such varieties, the producer will face the same latent competitor as the second lowest cost supplier in both markets. If that latent competitor is located in country 1, then $\widehat{P_{1j}} = \widehat{P_{2j}} = \widehat{W_1}$, while if that competitor is in country 2, then $\widehat{P_{1j}} = \widehat{P_{2j}} = \widehat{W_2}$. In either of these cases, there is no pricing-to-market at the firm level since $\widehat{P_{1j}} = \widehat{P_{2j}}$.

For the remainder of those varieties that are produced in country 1 and actually traded, the producer faces a local latent competitor when selling in country 1 and a foreign latent competitor when selling in country 2. Hence, $\widehat{P_{1j}} = \widehat{W_1}$ and $\widehat{P_{2j}} = \widehat{W_2}$. For these varieties, there is pricing-to-market at the firm level since $\widehat{P_{1j}} - \widehat{P_{2j}} = \widehat{W_1} - \widehat{W_2}$. Similar arguments apply for exporters located in country 2.

Import and export prices are then given by

$$\widehat{EPI}_1 = \frac{1}{s_M}\left(s_{MM}\widehat{W_1} + s_{ML}\widehat{W_2}\right) \text{ and } \widehat{IPI}_1 = \frac{1}{s_M}\left(s_{MM}\widehat{W_2} + s_{ML}\widehat{W_1}\right). \tag{7}$$

These results imply that producer and consumer prices are given by

$$\widehat{PPI_1^T} = (s_{LL} + s_{MM})\,\widehat{W_1} + (s_{ML} + s_{LM})\,\widehat{W_2}\ , \tag{8}$$

$$\widehat{CPI_1^T} = (s_{LL} + s_{ML})\,\widehat{W_1} + (s_{MM} + s_{LM})\,\widehat{W_2}\ , \tag{9}$$

and symmetric expressions for $\widehat{PPI_2^T}$ and $\widehat{CPI_2^T}$. With these results, we have

$$\frac{\widehat{EPI}_1 - \widehat{IPI}_1}{\widehat{PPI_1^T} - \widehat{PPI_2^T}} = \frac{1 - 2s_{ML}/s_M}{1 - 2\left(s_{LM} + s_{ML}\right)}\ \text{, and} \tag{10}$$

$$\frac{\widehat{CPI_1^T} - \widehat{CPI_2^T}}{\widehat{W_1} - \widehat{W_2}} = 1 - 2\left(s_M + s_{LM} - s_{ML}\right). \tag{11}$$

Again, one can compute the movement in the relative consumer price of tradeable goods as a fraction of the overall movement in the CPI-based RER using (5).

## III. Discussion

With this model, we establish two main results. The first is the analytical result that *both* imperfect competition with variable markups and trade costs are required for pricing-to-market at the firm and aggregate levels. If either element of the model is missing, then there is no such pricing-to-market. The second result is a quantitative result that, under Bertrand competition, pricing-to-market does not contribute substantially to the relative volatility of tradeable consumer prices and the overall CPI-based RER.

Consider first the result that both imperfect competition with variable markups and trade costs are required for pricing-to-market. It is clear that imperfect competition with variable markups is required for pricing-to-market at the firm level. Moreover, our aggregate measure of pricing-to-market is always equal to 1 under perfect competition — so there is no aggregate pricing-to-market, and it is less than 1 under Bertrand competition, from (10), as long as $s_{ML}(1-s_M) < s_{LM}s_M$.

The result that trade costs ($D > 1$) are also required for pricing-to-market under Bertrand competition is more subtle. Without trade costs ($D = 1$), every tradeables firm that produces also exports and faces the same latent competitor both on domestic sales and on exports. Hence, $\widehat{P_{1j}} = \widehat{P_{2j}}$ for all tradeable varieties $j$, and there is no pricing-to-market at the firm level. Moreover, our aggregate measure of pricing-to-market in (10) is equal to 1 just as under perfect competition.[3]

It is worth noting, however, that with Bertrand competition we do not need trade costs to have imperfect pass-through of costs to traded goods prices. If $s_{ML} > 0$, i.e., some exporting firms face foreign latent competitors and hence do not pass through changes in their domestic production costs, we see from (7) that export and import prices each reflect both domestic and foreign costs, even without trade costs. The extent of pass-through under Bertrand competition depends on the extent of national comparative advantage as measured by the share of exporters with latent competitors that are located in the same country. When national comparative advantage is strong in the sense that all exporters face a latent competitor in their home country, so that $s_{ML} = 0$, then from (7) we have that export and import price indices move just as they do under perfect competition. In contrast, when national comparative advantage is weak relative to the magnitude of trade costs in the sense that all exporters face latent competitors abroad, so that $s_{MM} = 0$, then export and import prices move in exactly the opposite direction as under perfect competition. In general, under Bertrand competition, our model predicts higher pass-through of costs to import prices if exporters to a country do not face much local competition (low $s_{ML}/s_M$).

Note that in our model, prices are set optimally every period and not fixed by assumption. Thus, our model illustrates that the evidence of persistent pricing-to-market and persistent deviations of relative PPP can be rationalized under flexible prices if the underlying movements in international relative costs are sufficiently persistent.

[3] This aggregate result can be seen as follows. In this case, all tradeable goods firms face the same latent competitor and set equal prices on domestic sales and on exports, which implies $s_{MM} = s_{LL}$. Under $D = 1$ we also have $s_M = 0.5$, which, combined with the definitions $s_M = s_{MM} + s_{ML}$ and $1 - s_M = s_{LL} + s_{LM}$, implies $s_{LM} = s_{ML}$. We therefore have $s_{ML}/s_M = 2s_{ML} = s_{LM} + s_{ML}$ and using (10) we obtain the result.

We now consider the model's implications for the movement in the consumer prices for tradeable goods relative to the movement in the overall CPI-based RER. We begin with an analytical result. If the expenditure share on imported goods priced at the cost of a domestic latent competitor is equal to the expenditure share on domestically produced goods priced at the cost of a foreign latent competitor ($s_{ML} = s_{LM}$), then the fraction of movements in the CPI-based RER accounted for by changes in the relative consumer price of tradeable goods is the same under perfect or Bertrand competition despite the different logic of pricing. Under perfect competition, the movement in the CPI for tradeable goods is a weighted average of the movements in underlying domestic and foreign marginal costs with the weights given by the share of imports in final consumption. Under Bertrand competition, foreign costs impact the domestic CPI for tradeable goods to the extent that some consumption goods have foreign latent competitors. If $s_{ML} = s_{LM}$, then the share of consumption goods with foreign latent competitors ($s_{MM} + s_{LM}$) is equal to the import share ($s_{MM} + s_{ML}$). So, in this case, the fraction of the CPI-based RER fluctuations accounted for by movements in the relative consumer price of tradeable goods is equal under either form of competition. Equivalently, in this case we can say that pricing-to-market and imperfect pass-through play no role in accounting for the fraction of the CPI-based RER fluctuations accounted for by movements in the relative consumer price of tradeable goods.

This analytical result can be understood as follows, thinking about the pricing of each individual tradeable variety. The deviations from relative PPP for those varieties that are actually traded that occur under Bertrand competition contribute to the fluctuations in the relative price of tradeable goods. Bertrand competition introduces an offsetting effect not present with perfect competition, however, for the prices of tradeable varieties that are not traded. Under perfect competition, for all tradeable varieties that are produced in country 1 and not exported, $\widehat{P_{1j}} = \widehat{W_1}$, while for those produced in country 2 and not exported, $\widehat{P_{2j}} = \widehat{W_2}$. Hence, for all tradeable varieties that are not traded $\widehat{P_{1j}} - \widehat{P_{2j}} = \widehat{W_1} - \widehat{W_2}$. Under Bertrand competition, the pricing of tradeable varieties that are not traded is still determined by the cost of the latent competitor, and this competitor can be located in either country. Hence, for those varieties produced in country 1 and not exported, a fraction face local latent competition and hence have $\widehat{P_{1j}} = \widehat{W_1}$, while the remainder face foreign latent competition and have $\widehat{P_{1j}} = \widehat{W_2}$. Applying the same argument to producers in country 2 who do not export, we get that, on average, the fluctuations in the relative price of those tradeable varieties that are not actually traded is smaller under Bertrand competition than it is under perfect competition. The pricing of tradeable varieties that are not actually traded contributes to smaller fluctuations in the relative price of tradeable goods under Bertrand competition. To the extent that $s_{LM} \simeq s_{ML}$, the effects of Bertrand competition on pricing-to-market of tradeable varieties that are actually traded and on the pricing of tradeable varieties that are not actually traded offset when aggregated to determine the fluctuations in the overall relative consumer price of tradeable goods.

Without further assumptions, there is no presumption in our model that $s_{LM} \simeq s_{ML}$. We now explore the implications of a simple quantitative example.

*A. Quantitative Example*

We consider an example in which the share of tradeable goods in overall consumption is $\gamma = 0.4$, the elasticity of substitution between varieties is $\eta = 3$, and the number of potential competitors per variety in each country is $K = 20$. Firm productivities $z$ within each variety are independently drawn from a lognormal distribution with variance $\theta^2$. The parameters $K$ and $\theta$ control the dispersion of idiosyncratic productivities $z$ within a variety. Given $D$, a higher $K$ or a lower $\theta$ leads to a smaller number of exporters. In this example, we calibrate $\theta$ for an arbitrary choice of $K$. Atkeson and Burstein (2006) calibrate $K$ and $\theta$ to match facts on industry concentration. We choose the parameters $\theta$ and $D$ so that, in a symmetric equilibrium, the trade share is $s_M = 16.5$ percent,[4] and the fraction of tradeable firms that export is 25 percent.[5] The choice of these two parameters under Perfect and Bertrand competition are $D = 1.503$, $\theta = 0.66$, and $D = 1.7$, $\theta = 0.875$, respectively. Under Bertrand competition, expenditure shares by latent competitor are $s_{LL} = 75.1$ percent , $s_{LM} = 8.4$ percent, $s_{ML} = 7.5$ percent, and $s_{MM} = 9.0$ percent.

The following table reports the results to changes in the wage rate in country 1 of various sizes (the results for $\widehat{W}_1 = 0.001$ percent also correspond to those using the expressions from the first-order approximation). Two results emerge from this example. First, the model

[4] This is roughly the average of US manufactured imports and exports as a ratio of manufactured gross output between 1987 and 2003 (see Atkeson and Burstein 2006).

[5] This is roughly the fraction of exporters in total plants in the US manufacturing sector between 1987 and 1992 (see Bernard and Jensen 2004).

produces substantial aggregate pricing-to-market under Bertrand competition. Note that pricing-to-market is less pronounced after a larger increase in $W_1$. This is because after a large shock to wages in country 1, it is more likely that those firms in $s_{ML}$ and $s_{LM}$ — those facing latent competitors from abroad — switch export status. But note that even after a shock as large as 40 percent, we still get substantial aggregate pricing-to-market. Second, the fraction of the movement in the CPI-based RER accounted for by a change in the relative consumer price of tradeable goods does not vary substantially with the form of competition.[6] This is because, in our quantitative example, $s_{LM}$ is quite close to $s_{ML}$.[7]

**Table 1: Quantitative Example**

| | **Numbers in percent** | | | | | |
|---|---|---|---|---|---|---|
| | $\widehat{W}_1 = 0.001$ | | $\widehat{W}_1 = 20$ | | $\widehat{W}_1 = 40$ | |
| | **Perfect** | **Bertrand** | **Perfect** | **Bertrand** | **Perfect** | **Bertrand** |
| $\frac{\widehat{EPI}_1 - \widehat{IPI}_1}{\widehat{PPI}_1^T - \widehat{PPI}_2^T}$ | 100 | 13.0 | 100 | 36.7 | 100 | 54.2 |
| $\frac{\widehat{CPI}_1^T - \widehat{CPI}_2^T}{\widehat{CPI}_1 - \widehat{CPI}_2}$ | 77.1 | 75.7 | 76.8 | 75.6 | 76.1 | 75.1 |

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[6] The model produces larger movement in the relative consumer price of tradeable goods, closer to the US data, if we include non-tradeable distribution costs that are half the cost of the consumer price of tradeable goods.

[7] The difference between $s_{LM}$ and $s_{ML}$ is even smaller if we instead assume that $z$ is exponentially distributed.

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