Violating Purchasing Power Parity*

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August 2005

Abstract

This paper demonstrates that deviations from the law of one price are an important source of violations of absolute PPP across countries. Using highly disaggregated U.S. export data, we document evidence of systematic international price discrimination based on the local wage of consumers in the destination market. We show that most violations from absolute PPP can also be explained by international differences in wages. We find very little additional explanation is due to differences in income per capita. Developing and calibrating a model of pricing-to-market based on search frictions and international productivity differences, we show that pricing-to-market of the form considered here accounts for at least 25 percent of the relationship between national price levels and income and 50 percent of the deviations from the law of one price. In contrast, the textbook Harrod-Balassa-Samuelson effect accounts for approximately 39 percent of the relationship between national price levels and income.

JEL classifications: E31, F12. **Keywords:** PPP, Pricing-To-Market, Law of One Price.

*The authors thank Andy Atkeson, Patrick Kehoe, Bruce Weinberg, and Kei-Mu Yi for helpful comments. Virgiliu Midrigan provided excellent research assistance. All remaining errors are our own.

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1. Introduction

Absolute purchasing power parity (PPP) is one of the best known and most easily rejected ideas in economics. Across countries, there are substantial differences in the general price level so that the same basket of goods sells for a different price depending on the country in which it is sold.[1] A well-documented feature of this dispersion in prices is that price levels are strongly positively correlated with real per capita GDP, so that agents in low-income countries pay considerably less for the same basket of goods than agents in high-income countries.[2] In this paper, we explore the determinants of this relationship.

This price-income relationship is often attributed to international differences in productivity in the tradable sector. According to Harrod (1933), Balassa (1964), and Samuelson (1964) (HBS hereafter), rich countries are relatively more productive in tradables than nontradables. If the law of one price (LOP) holds in the tradable sector, then international relative wages are determined by the large productivity differences in tradables. Since wage differences are large but productivity differences are relatively small in the nontradable sector, both nontradables and the common basket of goods are less expensive in low-income countries. The implications of the HBS model extend beyond just understanding PPP. Eaton and Kortum (2001) and Hsieh and Klenow (2003) demonstrate that relative productivity differences across countries are important in explaining cross country variation in capital stocks and income levels. Hence, Hsieh and Klenow (2003) argue that understanding why technical change is characterized by relatively higher productivity growth in the tradable sector is of central interest.[3]

[1] For instance, in over half (60 out of 115) of the countries in the Penn World Tables in 1996, a common basket of goods was less than one-half as expensive as in the United States, when prices are converted using nominal exchange rates. These substantial departures from PPP are quite persistent. Of these 60 countries, we have data for 32 of them in 1985. Over 80 percent, (26 out of 32) also had price levels less than one half that of the United States in 1985. Countries with low price levels also have very low income, with GDP per capita on average fourteen percent that of the U.S. level in 1996.

[2] See Kravis and Lipsey (1983, 1987, and 1988). Rogoff (1996) provides a review of PPP.

[3] A few existing theories present alternatives to HBS in explaining the systematic deviations from absolute PPP. Kravis and Lipsey (1983) and Bhagwati (1984) attribute these deviations to substantial differences in factor endow-

There are two important reasons to question HBS as a complete explanation, however.[4] A first reason is that while we lack direct international evidence on relative productivities of tradables and non-tradables across countries, the time series data on productivity growth rates in tradables and non-tradables indicates only a small bias toward tradables. With the trade share observed in the data, the HBS model requires that non-tradable productivity growth be only 10 percent of tradable productivity growth, but data from 1958-1996 in the U.S. show that non-tradable productivity growth was about sixty percent, or six times the required number. (Jorgensen and Stiroh, 2000). Given this smaller difference in relative productivity growth rates, the HBS model predicts trade flows should be substantially smaller, only 38 percent of what is observed in the data. Thus, the HBS model fails to quantitatively account for this price-income relationship.

The second problem with the HBS explanation is its assumption that the LOP holds for tradable goods, which is clearly violated in the data. Using highly disaggregated data, Heston, Atten, and Nuxoll (1995) and Crucini, Telmer, and Zachariadis (2001) find that international deviations from the LOP for tradables and nontradables are of nearly the same magnitude. Using data from the U.N. International Comparison Programme, Eaton and Kortum (2001) document substantial dispersion in the price of highly tradable investment goods across countries. They also find evidence that low-income countries pay less than high-income countries for investment goods. Pharmaceutical drug prices provide a striking example of the dispersion in international prices for identical goods, as well as evidence of international price discrimination based on income (Danzon and Furukawa 2003).

In this paper, we document evidence of pricing-to-market behavior in traded goods, and show that a modified version of HBS which incorporates pricing-to-market does a better job in matching

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ments. Linder (1961), Dornbusch (1988) and Neary (1988) focus on differences in tastes across countries. Bergstrand (1991) explains price levels in a model with nonhomothetic preferences in which nontraded goods are luxuries and traded goods are necessities. Along with the HBS theory, these competing theories assume that the law of one price holds for tradables and therefore cannot account for the large and persistent deviations from the law of one price in traded goods.

[4] Engel (1993, 1999), Asea and Mendoza (1994), and Chari, Kehoe, McGrattan (2002), show that the HBS model cannot account for fluctuations in real exchange rates at business-cycle frequencies. Alessandria (2002) shows that pricing-to-market of the form considered here increases the volatility of international relative prices over the business cycle.

the price-income relationship in the data. Our empirical work uses highly disaggregated data on exports from the United States to different countries. These data are well suited to isolating the role of this type of pricing-to-market because they measure export income received at the U.S. border before any local nontraded inputs are added. The data demonstrate that exporters systematically charge higher prices for comparable goods when exporting to high-income countries. This relationship is substantial, with the richest country paying, on average, 49 percent more than the poorest country for the same good. Furthermore, the data hint that it is wages, and not income per capita, that drive this pricing market behavior.

Next, we develop a model to motivate the pricing-to-market behavior found in the data.[5] The model is based on search frictions and international productivity differences similar to Alessandria (2002). Since search costs are measured in units of time, consumers in high productivity/high wage countries have relatively high search costs and are therefore less willing to search and less price elastic. Firms take this into account and set relatively high prices in these high-income countries. This produces a tight link between the price of tradables and the local wage.

Using plausible parameters values, the calibrated model is able to match much of the pricing-to-market relationship observed in the export data. Given this pricing-to-market relationship, the model is able to reproduce nearly two-thirds of the PPP-income relationship using the observed share of tradables among OECD countries and the small tradable-nontradable relative productivity differentials observed in the time series data. Basically, pricing-to-market makes all goods, not just non-tradables, more expensive in rich countries. Since tradables are more expensive too, the relative price of nontradables to tradables does not need to be as high as in the standard HBS, and so the relative productivity in non-tradables need not be as low. Pricing-to-market plays an

[5] Our explanation for deviations from absolute PPP complements previous theories based on supply and demand considerations. In our model, high-income countries have a comparative advantage in the production of market goods relative to search services. Since search services are not traded, they are less expensive in low-income countries, and this makes demand by low-income consumers more elastic. To consume goods, consumers must produce nontraded search services. As in HBS then, the true cost of a final good includes a nontraded search component. However, unlike in HBS, because consumers have imperfect information on where to buy goods inexpensively, firms can price discriminate internationally so that the price of the traded good differs across countries.

important quantitative role in the PPP-income relationship and accounts for at least 25 percent of the violations of absolute PPP, while the traditional HBS relative productivity channels explains approximately 39 percent of the price-income relationship.

The paper is organized as follows. The next section discusses the aggregate and disaggregate data relationship between prices, income, and wages. In section 3, we introduce a two-country, three-good model of international price discrimination. Section 4 discusses and evaluates the quantitative implications of the model in relation to the empirical findings of section 2. Section 5 concludes.

2. Empirics

In this section, we review some of the evidence of the price-income relationship. We show this relationship is large in the aggregate data. Then, using highly disaggregated data on exports from the U.S. by destination, we document evidence that U.S. firms systematically price discriminate based on the income of the destination market. We show that this price discrimination is not due to unobserved quality differences. Finally, a simple calculation shows that the amount of pricing-to-market we observe accounts for almost one-half of the aggregate price-income relationship.

A. Aggregate Data

The data show a strong positive relationship between the price levels of tradables and the income levels of countries, both at the aggregate level and in the micro data. Aggregate macro evidence is presented in Figures 1 and 2. Figure 1 shows a strong positive relationship between PPP price levels and income levels in the cross-section of countries using data from Penn World Table 6.1, where prices are based on ICP benchmark data on final prices of goods.[6] A linear regression of the relationship in Figure 1 produces a significant elasticity estimate of 0.43. Although nontradables contribute to this relationship, the price of tradables also play a substantial role. For example, Figure 2 shows a positive relationship between tradable prices and income per capita in the cross-section of 1996 benchmark countries. A linear regression of the relationship in Figure 2 produces a

[6] These results are for the 115 countries which participated in the 1996 benchmark study.

significant elasticity estimate of 0.26.

These aggregate data suffer from two important problems for evaluating the source of the relationship between prices and income. The first shortcoming is that the ICP data are based on a representative basket of goods and so do not include all tradables. The second problem is that the ICP data use final goods prices. Thus, these prices include variations in shipping costs, tax structures, and costs of nontradable components (e.g., distribution, retailing, etc.) Shipping costs (Clark, Dollar and Micco, 2004) and tariffs (Easterly and Rebelo, 1993) tend to be larger for exports to poorer countries. Thus, if firms price discriminate, the aggregate data may underestimate the amount of price discrimination. Eaton and Kortum (2001) and Hsieh and Klenow (2003) have conjectured that inexpensive nontradable distribution costs lead to lower final prices of tradables in low-income countries. However, large productivity differences in distribution, retailing, etc. between rich and poor countries may actually make distribution services, the relevant nontradables, relatively more expensive in poor countries. For example, Burstein, Neves, and Rebelo (2003) find that distribution costs amounted to an additional 64 percent of the price of goods in Argentina compared to just 45 percent in the U.S. In any case, the measured price-income relationship could be distorted by differing costs included in final goods prices.

B. Export Data

The micro data we analyze, U.S. Exports Harmonized System (1989-2001) data (see Feenstra et al. (2002)) yields a similar price-income relationship and so suggests that international deviations of the LOP follow a similar pattern as deviations from PPP. These micro data have significant advantages over the aggregate data in the two problematic dimensions mentioned above.

First, the data are comprehensive of all U.S. domestic exports (i.e., excluding re-exports) and therefore include only tradable goods, and a much broader range of tradables. We have annual totals of the quantities and value of commodities exported to all 182 destination countries. We can link these export data to GDP per capita for all 115 countries with 1996 benchmark data in the Penn

World Table 6.1. We focus primarily on 28 of these countries for which also have manufacturing wage data from the U.S. Bureau of Labor Statistics.

Second, export prices are based on free-along-side ship values,[7] and so they do not include transportation costs, tariffs, and nontradable components such as distribution and retailing costs in the importing country. One complication, however, is that we do not directly observe prices. Instead, the data include the total value and quantity sold, and so we calculate unit values. Numerous important studies of deviations of the LOP and pricing-to-market are based on unit values (see Isard 1977, Feenstra 1989 and Knetter (1989, 1993)). Unit values have the advantage of providing a measure of destination-specific prices for a large number of products.

Although the data is not at the good level, the issue of quality is mitigated in the data. The data include 10,741 commodities classified using the 10-digit Harmonized System product codes, and so it is extremely disaggregated. We drop any commodity with a description containing words like "other,"[8] "not elsewhere specified or included," "NESOI," and "parts" because they are likely to be heterogeneous groups. We also drop commodities containing "$" (e.g., goods categorized by their price level) and goods that are unitless. This reduced set of 6,012 detailed product groups is more likely to be homogeneous goods.[9] (Appendix A provides the names of 30 randomly selected goods from the dataset as an example of the level of detail.)

We present three essential findings from the data: 1) rich countries typically pay higher prices for the same exports than poor countries and the relationship is strong, sizable, and significant; 2) this relationship is linked more closely to the destination countries' levels of wages than their income per capita levels; and 3) this relationship is not likely driven by unobserved variation in

[7] The free-alongside-ship value is the selling price or cost if not sold, including inland freight, insurance, and other charges to the U.S. port of export, but excluding unconditional discounts and commissions. It is essentially the price received by the exporting country before shipment.

[8] We allow the phrase "other than" because it specifies a higher level of detail.

[9] Several variations of standards for determining "homogeneous" goods (i.e., dropping goods based on the detailed product description only, dropping goods based on the abridged production description only, and dropping goods that lacked units) as well as several methods for dealing with the role of outliers (i.e., dropping low value observations, dropping low quantity observations, dropping commodities whose price variation was deemed unrealistic, and robust regression) were examined. While their magnitudes vary somewhat, the fact that coefficients were quantitatively important and significant was robust to these different specifications.

quality. Indeed, any unobserved variation in quality may very well understate the relationship. It should also be noted that all of these data are from the U.S., and so the goods are likely to be more homogeneous in quality than goods coming from all countries (including the destination country). Even, the ICP prices which are good level prices for identical goods (in theory) suffer from the problem that goods may come from different countries (see Hsieh and Klenow, 2003). We do not view unobserved quality variation as a major problem, but examine the issue in more detail.

C. Results

For expositional purposes, consider the case of a monopolist selling an identical good i in different markets (e.g., countries) j. Given a common cost but different demand, the firm will, in general, charge price p equal to a market-varying markup μ over a common marginal cost c. Hence, marginal costs may vary across goods, and markups will vary across goods and destination markets:

$$\ln p_{ijt} = \ln c_{it} + \mu_{ijt}$$

The purpose is to examine whether μ_{ijt}, the markup charged on good i at time t to destination country j is related to the level of income per capita or wages of that country. We focus on the 28 countries for which both wage and income per capita data are available, which nonetheless constitute 76 percent of all exports in the full sample. These 28 countries include most long-term members of the OECD plus Hong Kong, Israel, South Korea, Mexico, Singapore, Sri Lanka and Taiwan. Results using GDP per capita for a broader range of countries for which GDP per capita data also show a sizable and significant relationship and are presented in Appendix B.

Table 1 presents the estimated coefficients from regressions of log price level on log income and/or log wages, where variation in $\ln c_{it}$ is controlled through fixed effects for each commodity-year combination. We measure incomes in prices in both PPP and exchange rate terms. The first row of the table gives the estimates using all the (homogeneous good) data and measuring log incomes and wages in PPP terms. The "GDP per Capita Only" estimate, from a regression where log GDP per capita is the only regressor (in addition to the fixed effects), yields an elasticity estimate of 18.2 percent. The "Wage Only" estimate is somewhat smaller at 16.6 percent. Though both estimates are highly significant, when we include log wages and log GDP per capita together in the same regression, log wages win the horse race hands down. These estimates are presented in the right-most two columns. The estimated coefficient on wages remains at nearly the same level (15.5 percent) and is highly significant, while the GDP per capita coefficient estimates become much smaller (2.1 percent) and is much less significant.[10]

The second and third rows of the uppermost table show that these results do not hinge on outliers. If we drop observations where the total value exported to a given country is less than 1 percent or 5 percent of the total value of the commodity exported to all countries in a given year, many observations are dropped but the quantitative estimates remain similar and highly significant.

The lower table presents analogous results except that income and wages have been converted to a common currency using nominal exchange rates for these regressions. In these estimates, the pattern between log wages and log income per capita is unchanged, but all of the measured elasticities are smaller in exchange rate terms (13.6 percent for income per capita and 12.6 percent for wages) than the estimates using PPP-based measures.

Based on the estimates in Table 1, the magnitude of the price-wage relationship is potentially large. In 2000, the difference in log wages between the richest and poorest countries in the data set (Germany and Sri Lanka, respectively) was 3.9 measured in exchange rate terms (2.4 in PPP terms). Hence, the implied price differences in U.S. exports to these countries would be 49 percent (40 percent using PPP).

[10] Nevertheless, the estimate of this coefficient usually (the lower table in Table 1 shows an exception) remains statistically significant. Since our data is for manufacturing wages, it may be that the data are an imperfect proxy for the average wage overall and so some of the average wage variation that is independent of our proxy is captured by income per capita.

D. Quality

Although the data is extremely disaggregated, as stated above, one might still suspect that the positive relationships uncovered are driven by unobserved quality variation, with wealthy countries importing higher quality (and higher priced) goods within the 10-digit commodity categories.

To formalize this argument, assume without loss of generality that goods can be classified individually using an $N+1$ digit classification scheme, but only average prices at an N-digit level classification are observed. We model prices as depending on characteristics in a Lancasterian sense, where each level of aggregation (e.g. 1...N digit) involves a certain set of common characteristics.

Ideally, we would estimate β from a relationship based on completely disaggregated (i.e., $(N+1)$-level) individual good price data:

$$\ln P_{ijk}^{N+1} = \sum_{n=1}^{N+1} \alpha_{n,ij} + \beta \ln Y_k + \varepsilon_{ijk}$$

where i indicates a product group, j indicates the individual good within the product group, and k indexes the destination country.

Assume instead, however, that the unit values for group i (going to country k) we observe are actually geometric[11] trade-weighted averages of the prices of j heterogeneous goods:

$$(1) \quad P_{ik}^{N} = \prod_{j} \left(P_{ijk}^{N+1}\right)^{q_{ijk}}$$

where q signifies the trade share. The relationship between these average prices and log income can be expressed:

$$\ln P_{ik}^{N} = \sum_{n=1}^{N} \alpha_{n,i} + \sum_{j} q_{ijk}\alpha_{(N+1),ij} + \beta \ln Y_k + \varepsilon_{ijk}$$

[11] The analysis is much easier to express using geometric averages instead of arithmetic averages. Regressions analogous to those in Table 2 but using arithmetic averages have the nice interpretation of answering "What would the regressions look like if the data were truly less disaggregate?", however, and produce the same qualitative (and similar quantitative) conclusions.

Given the i-specific fixed effects, we can rewrite this equation in deviation form using $\hat{X}_{ik}$ notation to represent the deviations of X_{ik} from mean values $\overline{X}_i$ for group i:

$$\ln \hat{P}_{ik}^N = \beta \ln \hat{Y}_{ik} + \sum\nolimits_j q_{ijk} \hat{\alpha}_{(N+1),ij} + u_{ik}$$

The quality argument claims that $cov \left[\sum q_{ij} \hat{\alpha}_{(N+1),ij}, \ln \hat{Y}_{ik} \right] > 0$, since:

$$\hat{\beta} \to \beta + \frac{cov(\sum_j q_{ij} \hat{\alpha}_{(N+1),ij}, \ln \hat{Y})}{var(\ln \hat{Y})}$$

Interpreting the expression, $\hat{\alpha}_{(N+1),ij}$ is the quality of an individual good j relative to the average in the product category i. Since q_{ijk} is the fraction of product group i purchases in country k that are on good j, the weighted average $\sum_j q_{ijk} \hat{\alpha}_{(N+1),ij}$ is the average relative quality purchased by country k. Thus, if countries with relatively high incomes, $\ln \hat{Y}_{ik}$, tend to purchase relatively high quality goods on average, then this covariance bias will make $\hat{\beta}$ positive even if $\beta = 0$.

Now consider the geometric average price of product group h at an $(N-1)$-digit aggregation:

$$\begin{aligned}
\ln P_{hk}^{N-1} &= \sum\nolimits_{n=1}^{N-1} \alpha_{n,h} + \sum_i q_{hik} \left(\alpha_{N,hi} + \sum_j q_{ijk} \alpha_{(N+1),ij} \right) + \beta \ln Y_k + \varepsilon_{ijk} \\
&= \alpha_h + \sum_i q_{hik} \alpha_{N,hi} + \sum_{i,j} q_{hik} q_{ijk} \alpha_{(N+1),ij} + \beta \ln Y_k + \varepsilon_{ijk} \\
\ln \hat{P}_{hk}^{N-1} &= \beta \ln \hat{Y}_{ik} + \sum_i q_{hik} \hat{\alpha}_{N,hi} + \sum_{i,j} q_{ijk} \hat{\alpha}_{(N+1),ij} + u_{ik}
\end{aligned}$$

Regressions using the more aggregate $(N-1)$-digit unit values suffer from two factors confounding the estimate $\hat{\beta}$:

$$\hat{\beta} \to \beta + \frac{cov(\sum_i q_{hi} \hat{\alpha}_{N,hi}, \ln \hat{Y})}{var(\ln \hat{Y})} + \frac{cov(\sum_{i,j} q_{ijk} \hat{\alpha}_{(N+1),hi}, \ln \hat{Y})}{var(\ln \hat{Y})}$$

The first bias comes from any quality bias on characteristics at level N, while the second term is the quality bias from unobserved characteristics at level $N+1$.

Although we cannot get an estimate of the $(N+1)$-digit quality bias that comes from unobserved $N+1$ quality variation, we can get an estimate of the quality bias at other levels by producing more aggregate average prices. We compare the $\hat{\beta}$ estimates from regressions using these more aggregated data (at the 9-, 7-, and 5- digit levels of the Harmonized System) to estimates using the less aggregate 10-digit coded data.

These results are presented in Table 2. Interpreting Table 2, in the 9-digit case, all categories that are identical up to the first nine digits are used together to construct 9-digit price data according to equation (1). Only 399 commodities are unique up to all ten digits and these are combined into 170 heterogenous 9-digit categories. As more digits are dropped, the categories become broader and more heterogeneous, more goods are combined into groups, and more observations can be included in the regressions. For example, at five digits artificial Christmas trees are simply artificial Christmas trees, while at seven digits these are subdivided into plastic and non-plastic artificial Christmas trees, one of which may have higher average prices and therefore be considered higher quality. (Appendix C shows how a random selection of categories are combined.)

For all of these aggregations, the estimates in Table 2 are systematically lower using the more aggregated categories. Hence, we conclude that, in terms of observable characteristics, *poorer countries import higher quality (i.e. higher priced) goods from the U. S.* on average. If the unobservables follow a similar pattern then our estimates would in fact be *smaller* than the true relationship.

The relationship is so surprising that the claim bears further explaining. The data is not implying that poor countries tend to consume higher quality goods on average than wealthy countries do, only that they tend to *import* (from the U. S.) higher quality goods. Perhaps, this is a result of high-income countries producing high quality domestic substitutes for some goods, so they do not always import the highest quality variety from the U.S. Hence, imports from the U.S. are weighted toward low quality goods. That is, the U.S. may have a stronger comparative advantage in high quality goods relative to poor countries than relative to other high-income countries. However, explaining the source of this effect is outside the scope of this paper.

E. Summary

The estimated elasticities will be used as benchmarks for quantitatively evaluating the explanatory power of the model developed in the next section. We therefore summarize our main findings:

- The macro data yield an elasticity of violations of PPP with respect to PPP income per capita levels of 43 percent.
- The elasticity of deviation in the LOP with respect to PPP income per capita is about 20 percent.
- The corresponding LOP elasticity is slightly smaller with respect to wages (17 percent in PPP terms), but the relationship is stronger.
- The elasticities are smaller (14 percent for income per capita and 13 percent for wages) if exchange-rate conversions are used.

We can get an idea of the potential contribution of pricing-to-market for the price-income relationship with a simple calculation. Suppose that the type of pricing uncovered by U.S. exporters is common to all firms, everywhere. In this case, the average price difference between the same good being sold in two different countries will equal 20 percent of their income difference. Since this affects all goods equally, pricing-to-market generates an elasticity of violations of PPP with respect to income of 20 percent. This is nearly half of the relationship uncovered at the aggregate level.

Now any model of pricing-to-market which generates the amount of price discrimination we've uncovered, will account for a large share of the price-income relationship. We present a model which generates pricing-to-market and is consistent with the important role the data assigns to wages in pricing-to-market. In thinking about a model of pricing-to-market, the fact that wages are the important driving factor points toward a model where variations in time costs yield differences in the price elasticity of demand across countries (as in a model of consumer search), rather than a model where nonhomothetic preferences and income effects drive these differences in the elasticity of demand.

3. Model

This section develops a two-country, three-good model in which there is a positive relationship between disaggregate and aggregate international relative prices, wages and income as a result of pricing-to-market. In this model, firms charge higher prices on average in those countries where wages are higher. Consumers in these high wage countries accept these higher prices because they have a high opportunity cost of time and are thus less willing to search repeatedly.

There are three imperfectly substitutable goods $j = \{1, 2, 3\}$ and two countries denoted $i = \{1, 2\}$. Goods 1 and 2 are tradables with good 1 produced exclusively in country 1 and good 2 produced exclusively in country 2. Both countries can produce good 3, but it is not tradable. Including both tradables and nontradables allows us to distinguish between pricing-to-market and the traditional HBS effect.

In each country, there are many stores, each specialized in the sale of a single good. For simplicity we assume that the measure of each type of store in each country is the same. Households do not know the price charged at any store and must physically visit a store to discover its price. As in Diamond (1971), because search takes time and is imprecise, stores have some monopoly power over consumers and thus may charge different prices for the same good.[12] We assume that these stores are owned and operated by the firm producing output, but require no additional inputs. In Appendix D we show that our results are robust to including a separate retail and distribution sector.

Households must send out shoppers to search for the lowest price quotes and purchase goods. Each shopper can buy at most one unit of the good. Shopping therefore takes time away from work and is imperfect in the sense that consumers do not simultaneously receive price quotes from all the stores in the market. We model search as noisy, as in Burdett and Judd (1983), so that a fraction q of shoppers receive a single price quote while the remaining shoppers $(1 - q)$ receive two

[12] In principle one could allow for more heterogeneity in the types of tradable goods produced in each country, but this would complicate the analysis without changing our result: the price charged would still depend on the opportunity cost of search of consumers.

price quotes. The probability a shopper receives a single price quote is random and equals q. After receiving either one or two price quotes, the shopper must decide whether to purchase a single good at the lowest price quote received or return home empty-handed.

Although without searching, agents do not know the price charged at a specific store, they do have perfect information about the distribution of prices in the economy. The distribution of prices p set by stores selling good j in country i is denoted by $G_{ij}(p)$. Search is directed in the sense that a shopper from country j looking for good i receives only domestic price quotes for good j, i.e., price quotes from the distribution $G_{ij}(.)$. Since the shopper can buy at most one unit of the good, only the lowest price quote received by a shopper is relevant to the shopper's purchase decision. The distribution of lowest price quotes received by shoppers is then

$$H_{ij}\left(p\right) = qG_{ij}\left(p\right) + (1-q)\left[1-\left(1-G_{ij}\left(p\right)\right)^2\right].$$

From the firm's perspective, noisy search makes the consumers heterogenous in that some shoppers will only have one price quote, while others will have multiple price quotes. Consumers with multiple price quotes will differ in their second price quote. As firms cannot distinguish between these different customers, the price they charge will influence both the profit per sale and the share of shoppers with multiple price quotes that they attract.

A. Consumer's Problem

The structure of the consumer's problem is similar to that in Alessandria (2002). In each country, there are many identical families. We use lower case variables to denote the decision rules of individual households and upper case variables to denote aggregate decision rules. Each family is composed of a large number of agents, normalized to a continuum of measure one.[13] The problem of a family is to divide between shoppers and workers and to give shoppers instructions on which prices to accept. A household in country i must choose the number of agents n_{ij} to send out shopping

[13] We assume each family is comprised of only agents from the same country.

for each good j and the number of agents l_i to send out working, which generates the following constraint:

$$(2) \quad \sum_j n_{ij} + l_i = 1,$$

Alessandria (2002) shows that it is optimal to send each agent shopping for good j with a reservation price rule to purchase only if the lowest price quote is below some reservation level, r_{ij}. The consumption of good j by country i consumers depends therefore on both the reservation price and the measure of shoppers. Because there are many shoppers sent out for each good, there is no uncertainty in the amount of goods consumed, which equals:

$$(3) \quad c_{ij} = n_{ij} H_{ij} \left(r_{ij} \right).$$

Given the reservation price, the average purchase price is evaluated from the truncated distribution of lowest prices:

$$(4) \quad p_{ij} \left(r_{ij} \right) = \frac{\int_0^{r_{ij}} p dH_{ij} \left(p \right)}{H_{ij} \left(r_{ij} \right)},$$

which is clearly increasing in reservation price.

The representative home family chooses reservation prices and shoppers for each good to solve the following problem:

$$\begin{aligned} U_i &= \max_{\{r_i, c_i\}} U \left(c_{i1}, c_{i2}, c_{i3} \right) \\ \text{subject to} &: \begin{cases} \sum_j p_{ij} \left(r_{ij} \right) c_{ij} = w_i l_i + \Pi_i, \\ \text{equations (2), (3), (4)} \end{cases} \end{aligned}$$

where U_i is the utility function in country i and Π_i is the profits earned by country i firms.

In this framework, consumers can adjust consumption along two margins, either by changing the number of shoppers or the price they will accept. If there is an interior solution, the problem generates the following first order conditions:

$$
\begin{aligned}
(5) \quad r_{ij} &= \frac{w_i}{H\left(r_{ij}\right)} + p_{ij}\left(r_{ij}\right), \qquad j = 1,2,3 \\
(6) \quad \frac{U_{i1}}{U_{ij}} &= \frac{r_{i1}}{r_{ij}}, \qquad j = 2,3
\end{aligned}
$$

where U_{ij} is the marginal utility of good j.

Equation (5) is an arbitrage condition that implies, at the margin, the family is indifferent between increasing consumption by purchasing at the reservation price or sending out additional shoppers, whose opportunity cost of search is measured in terms of the forgone wage, and purchasing at the average price of the good in the market. With a reservation price of r_{ij}, the family expects to send out $1/H\left(r_{ij}\right)$ shoppers to purchase a single unit. Since the reservation price is linked to the true cost of the good, it is this cost that matters at the margin; therefore, the family chooses consumption so that the marginal rate of substitution between any two goods equals the ratio of their reservation prices as in equation (6).

Our focus is on the difference in prices across countries with different incomes and therefore we have focused on a representative consumer in each country. However, it is straightforward to extend the model to permit heterogeneity in wages. In this case, we see from equation (5) that within countries, consumers with relatively high wages will search less intensively than consumers with relatively low wages. McKenzie and Schargrodsky (2004) find evidence of precisely this behavior. Using a unique dataset on consumer purchasing behavior in Argentina, they find that consumers in the 10th percentile of income spend about 30 percent more time shopping per purchase than consumers in the 90th percentile of income.

B. Firm's Problem

There are many firms in each country specialized in the production of either the country's tradable or nontradable good. The firms within a country are *ex ante* identical. Labor is the only input into production, and one unit of labor in country j produces a_j^T units of the tradable good (good j) and and a_j^{NT} units of the nontradable good (good 3). To focus on international price discrimination, we assume that firms can costlessly sell their goods in either country through the pre-established outlets.

We focus on the problem of a representative firm in country j selling the tradable good (good j) in country i. Even though firms produce the same good, the search frictions give each firm some monopoly power and leads firms to behave as monopolistic competitors.[14] Each firm takes the distribution of prices charged by other firms selling the same good, G_{ij}, the number of price quotes that it delivers, the reservation price of consumers, R_{ij}, and the unit cost of production, w_i/a_i^T, as given. Given the constant returns to scale production, the amount of sales does not influence a firm's unit cost. Thus, the firm's problem becomes one of maximizing profits per customer that receives a price quote. The representative firm from country 1 selling in country i solves:

$$\pi_{ij} = \max_p \left(p - \frac{w_j}{a_j^T} \right) Q_{ij}(p),$$

where $Q_{ij}(p)$ is defined as the probability that a firm makes a sale when charging a price p and equals:

$$Q_{ij}(p) = \begin{cases} \frac{q}{2-q} + \frac{2(1-q)}{2-q}\left[1 - G_{ij}(p)\right] & \text{for } p \leq R_{ij}, \\ 0 & \text{otherwise.} \end{cases}$$

Because each shopper expects to receive $2-q$ price quotes, the probability that a customer has a single price quote is $q/(2-q)$. As long as the firm's price is below the reservation price, the firm will sell to all customers with one price quote. By increasing its price, the firm increases its revenue per sale but decreases the likelihood of a sale, since it increases the probability that those customers

[14] Our model is similar in spirit to the traditional macro model with monopolistic competition and Dixit-Stiglitz preferences. The main difference is that the elasticity of substitution between varieties depends endogenously on the search structure.

with two price quotes have a second price quote that is lower than the firm's price.

Burdett and Judd (1983) have shown that given a reservation price and cost of production, a unique distribution of prices exists and that firms choose their price by randomizing over the support of the distribution. The following proposition summarizes features of the distribution of prices.

Proposition 1: Given R_{ij} and $\frac{w_j}{a_j^T}$, $\exists\ G_{ij}(p), \pi_{ij}$ and $\underline{P}_{ij}$ so firms are indifferent charging $p \in \left[\underline{P}_{ij}, R_{ij}\right]$ where

$$G_{ij}(p) = \begin{cases} 0 & p < \underline{P}_{ij} \\ 1 - \frac{q}{2(1-q)} \frac{R_{ij}-p}{p-w_j/a_j^T} & p \in \left[\underline{P}_{ij}, R_{ij}\right] \\ 1 & p > R_{ij} \end{cases}$$

$$\underline{P}_{ij} = \frac{2(1-q)\, w_j/a_j^T + qR_{ij}}{2-q}$$

Firms earn the same profit by charging any price on the support of the distribution. Firms that charge relatively high prices primarily sell to those consumers with a single price quote, while those with relatively low prices attract more of those shoppers with multiple price quotes. Because firms are indifferent between any price, they can use G_{ij} to choose prices by randomizing on the support of the distribution

C. Equilibrium

The total demand for labor by firms producing tradables in country i is:

$$L_i^T = \frac{N_{1i} + N_{2i}}{a_i^T},$$

and the demand for labor in the nontradable sector is:

$$L_i^{NT} = \frac{N_{i3}}{a_i^{NT}}.$$

The labor market clearing condition is:

$$L_i^T + L_i^{NT} = L_i$$

A symmetric equilibrium is then a distribution of prices, G_{ij}, and wages, w_j; consumer decision rules $\{l_j, n_{ij}, r_{ij}\}$ and aggregate decision rules $\{L_j, N_{ij}, R_{ij}\}$ in each country $j = \{1, 2\}$ for each good $i = \{1, 2, 3\}$ such that: (1) Given prices, wages, and profits, consumer's decision rules solve the household's problem in each country; (2) Given prices and wages, each firm chooses a price to solve each firm's problem; (3) Goods and labor markets clear; and (4) Individual and aggregate decisions are consistent so that all households from the same country behave identically.

Alessandria (2002) shows that the highest price in the market equals the reservation price. This upper bound on prices is an equilibrium because the highest priced firms have no incentive to charge a price above the reservation price, as they would lose all sales.[15] As no shopper returns empty-handed, the marginal cost of each good in each country is the average price paid for it plus the opportunity cost in wage income from shopping for it. At the margin the consumer is indifferent between increasing consumption by using more shoppers or a higher reservation price so that:

$$r_{ij} = w_i + p_{ij}\left(r_{ij}\right)$$

This implies that the true cost of the good is equal to the nontraded search cost plus the actual market price.

Our focus is on the relationship between prices, income and wages. Even though there are many prices charged in each country, we focus only on the mean transaction price as this most closely corresponds to the measure used by the national statistical agencies. By substituting the equilibrium reservation price into the distribution of prices, we can use equation 4 to solve for the

[15] This would not necessarily be true if consumers from both countries could search in the same market. Some firms would choose to sell only to those consumers from the country with the high reservation price.

mean transaction price for tradables of good j (from country j) sold in country i as:

$$(7) \quad p_{ij} = \frac{w_j}{a_j^T} + \frac{qw_i}{1-q}.$$

For nontradables, the mean transaction prices is:

$$(8) \quad p_{i3} = \frac{w_i}{a_i^{NT}} + \frac{qw_i}{1-q}.$$

The average price for good j paid by a consumer in country i, is equal to a markup over the marginal cost of the firm from country j. The markup depends on both the information structure of search and the physical cost of search. Anything that leads the search cost to differ across countries will lead to differences in the mean transaction price. Holding the information structure constant, which is summarized by q, we see that agents in a country with a low wage will, on average, purchase goods at a lower price than agents in a country with a relatively high wage. Consequently, the model predicts a strong relationship between prices and local wages.

Equation (7) also points out the critical differences between our model and the HBS model. In both models, tradables may sell for different prices across countries. In HBS, the price of tradables may differ internationally when there is a nontraded input, such as wholesale or retail distribution, to get the good to the final consumer. Suppose, for instance, that in each country it takes η_i unit of local labor to get a product to a local consumer. Under perfect competition the retail price of a good from country j sold in country i will equal $p_{ij}^{retail} = \frac{w_j}{a_j} + \frac{w_i}{\eta_i}$, but the price at the border is still $p_{ij}^{border} = \frac{w_j}{a_j}$. Thus, HBS generates deviations from the LOP in tradables because consumers must purchase a nontraded good along with the traded good. In our model of pricing-to-market, the search cost is similar to the nontraded retail or distribution costs in HBS. Unlike the case in HBS, this search cost is borne by the consumer and through the search frictions is incorporated into the price charged at the border.

4. Quantitative Results

In this section we compare the quantitative properties of the model to the observed deviations from the LOP documented for U.S. exports as well as the observed violations in absolute PPP from the Penn World Tables. We first show that the model generates large deviations from the LOP and violations in absolute PPP when productivity differences across countries are the same in tradables and nontradables. Moreover, we find that our model closely matches the observed relationship between wages and tradable prices. We then use our framework to quantify the importance of pricing-to-market relative to the traditional HBS effect arising from productivity differences that are biased toward tradables. Given a productivity gap between tradables and non-tradables across countries that matches the U.S. time series evidence, we find that the model explains approximately 64 percent of the price-income relationship in the data. Moreover, pricing-to-market accounts for 25 percent of the price-income effect and the HBS channel accounts for 39 percent.

A. Calibration

The demand side of the economy is chosen to be consistent with the standard textbook presentation of the HBS model (see Obstfeld and Rogoff 1996). Agents in each country are assumed to have the following symmetric utility function:

$$u\left(c_{i1}, c_{i2}, c_{i3}\right) = \left(c_{i1}^{\rho} + c_{i2}^{\rho}\right)^{\frac{\alpha}{\rho}} c_{i3}^{1-\alpha}.$$

Preferences over tradables and nontradables are Cobb-Douglas so that they are not very substitutable. On the other hand, tradables are often assumed to be perfect substitutes because this eliminates wealth effects from changes in the terms of trade (see Hsieh and Klenow (2003)). We make a minor departure from this case and set $\rho = 0.99$, which makes tradables very close substitutes.[16]

[16] As our focus is on the long-run differences in price levels our calibration of ρ differs substantially from models focused on short-run fluctuations.

The size of the tradable sector is set to match the median import and export share of GDP of a subset of OECD countries. We use those OECD countries for which re-exports are not large[17] and for which we have manufacturing wage data from the BLS. Table 3 reports the trade shares of these countries in 2000. The median country imports and exports approximately one-third of GDP.[18] To be consistent with these shares in our two-country model we set $\alpha = 2/3$ so that nontradables account for one-third of output.[19] We find that the openness of a country does not substantially change the amount of pricing-to-market and report sensitivity to the trade share.

The production side of the economy depends on the search (q) and goods $\left(a^T\right)$ technologies. For our baseline case we assume that tradable and nontradable technologies are identical, so that $a_i^T = a_i^{NT} = \overline{a}$. We calibrate our two country model so that one country matches features of the U.S. economy. We vary technology in the second country to match the world income distribution.

We choose $(q, \overline{a})$ to match two observations. First, the American Time-Use Study (2003) finds shopping activities are time intensive activities as the average American spends about 4 times as much time working as purchasing goods and services. From the market clearing conditions and the time constraint we can solve for $\bar{a} = \frac{N}{L}$. Second, labor income in the U.S. is approximately 60 percent of total income (Cooley and Prescott 1996). Using the ratio of labor income to total income, we solve for our competitiveness parameter as $q = \frac{(1-\theta)}{\theta\bar{a}+(1-\theta)}$, where θ is labor's share of income. Given our observed labor income and time spent shopping, we find that $\overline{a} = 1/4$ and $q = 0.\overline{72}$. In all of our experiments, we hold the noisy search parameter constant and allow productivity in the tradable and non-tradable sectors to vary across countries.

We use the model to construct a distribution of prices and income which we then compare to the data. We do this by solving our two country model repeatedly. In each case, the comparison country is the U.S. while productivity in the second country is chosen to match the income of a

[17] This requires dropping the Netherlands, Belgium, and Ireland.

[18] For comparison, the median country in the Penn World Tables imported approximately 38 percent of GDP and exported 42 percent of GDP in 2000.

[19] Stockman and Tesar (1995) use data on a cross-section of OECD countries from 1970 to 1985 and find the tradable sector is nearly 50 percent of output.

different benchmark country. In this way, we construct a distribution of 115 prices and income.

We solve the model first by assuming that the productivity gap between countries is the same in both sectors. We refer to this case as the *Balanced Productivity* gap case. Next, we solve the model assuming that the productivity difference in the non-tradable sector is smaller than in the tradable sector. This is our benchmark model which we refer to as the *Biased Productivity* gap case. While it is commonly asserted that the productivity gap in tradables is relatively large compared to non-tradables, there is little direct evidence of this gap. Studies which do measure this gap assume that the LOP holds for traded goods and use relative prices to infer productivity differences. For instance, Hsieh and Klenow (2003) use the relative price of consumption to investment to infer that productivity in the investment sector increases with output (in the cross-section) at a rate 2.6 times that of the consumption sector. Similarly, using data on relative price levels, Herrendorf and Valentinyi (2005) find that the productivity difference in tradables must be nearly 12 times larger than those in non-tradables.

Rather than use our theory to construct relative productivity differences, we consider the evidence of changes in productivity in tradables and non-tradables in the U.S. Jorgenson and Stiroh (2000) estimate labor productivity growth by sector for the U.S. from 1958 to 1996. We classify these sectors into tradables and non-tradables and then use their sectoral weights to construct a measure of the productivity gap between tradables and non-tradables. Both weighted and simple averages of productivity and labor productivity growth rates are reported in Table 5. We find that non-tradable labor productivity growth has been about 60 percent of tradable labor productivity growth. In the biased productivity case, we take the time-series evidence from the U.S. on the productivity gap and examine the implications of such a gap for the world distribution of income and prices.[20]

[20] Our findings from the U.S. time series are similar in magnitude to Hsieh and Klenow, but not directly comparable. Consumption includes many tradables (e.g., food, clothing), and equipment is an important fraction of tradables (11 percent of U.S. exports) but certainly not all of tradables. Consistent with their results, we do find a much weaker price-income relationship in the ICP data and pricing-to-market relationship in the U.S. export data for equipment. Nevertheless, the relationship for ICP tradables and U.S. exports overall is strong and robust.

B. Measuring Prices and Income

Before evaluating the model, we consider some measurement issues. This discussion is based on the data studied and the statistics computed. To begin with we have computed the elasticity of deviations from the LOP with respect to wages. In our framework we measure the size of deviations from the LOP as the average price differential of the two tradable goods or

$$\ln LOP_i = \frac{1}{2}\left(\ln\left(P_{11}/P_{21}\right) + \ln\left(P_{12}/P_{22}\right)\right).$$

We have also measured elasticities of individual and aggregate prices with respect to income. In this case, we have measured income both at PPP terms and at market exchange rates. To facilitate the discussion, we focus on measuring income at PPP. We follow the convention of the Penn World Tables and compute nominal GDP, Y_i, as the sum of expenditures of domestic production,

$$Y_i = P_{1i}\left(R_{1i}\right) N_{1i} + P_{2i}\left(R_{2i}\right) N_{2i} + P_{i3}\left(R_{i3}\right) N_{i3}$$

To solve for the aggregate price level, P_i, we use a welfare-based price index.[21] This implies:

$$P_i = \left(\frac{P_i^T}{\alpha}\right)^{\alpha}\left(\frac{P_{i3}}{1-\alpha}\right)^{1-\alpha},\ P_i^T = \left(P_{i1}^{\frac{\rho}{\rho-1}} + P_{i2}^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}.$$

Real income, y_i, is nominal GDP deflated by the price index (P_i) or $y_i = Y_i/P_i$.

With these measures of real income and prices, we use the model's data to compute similar

[21] The price index takes into account only the transaction price of the goods, not the search costs that are borne. Deriving price indices that include the costs of search do not noticeably change the quantitative results. Also, measuring output at world prices generates similar results.

statistics,

$$\begin{aligned} \ln P_i &= \varepsilon_{PPP} \ln y_i + \mu_i \\ \ln LOP_i &= \varepsilon_{LOP} \ln y_i + \mu_i \\ \ln LOP_i &= \varepsilon_w \ln w_i + \mu_i \end{aligned}$$

Finally for comparison with the HBS model, we also measure the elasticity of the relative price of non-tradables to tradeables with respect to income as

$$\ln P_i^{NT}/P_i^T = \varepsilon_{NT} \ln y_i + \mu_i.$$

All results are presented in Table 5. The top panel of the table presents our elasticity estimates from various parameterizations of the model. We account for the share of violations from PPP accounted for by the model and the two main channels in the bottom panel.

C. Balanced Technology Gap

In the Balanced Technology case, the productivity gap across countries is the same in both sectors, $a_1^T/a_2^T = a_1^{NT}/a_2^{NT}$. With tradables accounting for two-thirds of consumption, the model generates quantitatively important deviations from the LOP and violations from absolute PPP. The elasticity of deviations from the LOP with respect to income is approximately 10.7 percent at PPP (10.3 percent at market prices). The elasticity of violations from PPP with respect to income is approximately 11.0 percent at PPP (10.0 percent at market prices). Thus, our model can account for 55 percent of the deviations from the LOP and almost 26 percent of the violations of PPP associated with income levels. Moreover, deviations from the LOP depend on wages only slightly less than in the data as the elasticity is 9.9 percent in the model and 13.0 percent in the data.

The size of deviations from the LOP and violations of PPP differ for a couple of reasons. First, for deviations from the LOP, we take an average over the two tradable goods. Because the cost of production of these two goods differs, in general the size of deviations from the LOP will differ. To measure aggregate prices, we use a price index which takes into account the relative price of the two tradables so that consumption is not equally divided between these two goods. Second, because tradables and nontradables are poor substitutes, the deviations from the LOP are larger for tradables so that the HBS effect actually works in reverse in this case.

D. Biased Technology Gap

We now explore the impact on prices when the technology gap across countries is relatively larger in the tradable sector. The column titled *benchmark* in Table 5 summarizes our findings. With a biased productivity gap, we find that the model can now account for 64 percent of the violations of PPP with income. Pricing-to-market accounts for 25 percent of the price-income relationship, while 39 percent is due to the change in the relative price of non-tradables to tradables.

For comparison, from the column titled *HBS model*, we see that the HBS model only generates 35 percent of the price-income relationship. Our benchmark model generates a stronger HBS effect because it generates larger wage differences for any income difference across countries. This occurs because higher productivity in production raises consumption which requires more search, holding search effort per purchase fixed.

E. Sensitivity

We now consider a few modifications of the model. In particular, we consider the role of the trade share, productivity bias, competitiveness in search markets, and time spent shopping for our results. Except where noted, the model is parameterized as in the benchmark case of the biased productivity gap.

Trade share

Figure 3 plots the relationship between the trade share and both pricing-to-market and violations of PPP with balanced productivity. As is clear, the effect of varying the trade share is minor. This is because pricing-to-market affects all goods, traded and non-traded, in the same way. Thus, the trade share only affects pricing-to-market through its influence on the terms of trade and thus the relative wage. However, with highly substitutable goods this effect is small so that the impact on relative prices is also minor.

When the productivity gap is biased, the trade share has a large effect on the size of violations from PPP. With a smaller trade share non-traded goods receive a larger weight in prices. In Table 5, the column titled *Low Trade Share* reports the results of the benchmark model with a trade share of 42 percent. This trade share generates violations from PPP that are consistent with the data in the benchmark model. This lower trade share slightly weakens the amount of pricing-to-market in the model.

For comparison, we also include the size of violations from PPP in the standard model with a low trade of $\alpha = 0.23$. This is the level of trade which is consistent with the aggregate price-income relationship. This tradable share generates trade flows that are only 38 percent of those in the data.

Biased Productivity

We now consider the effect of the size of the productivity gap on relative prices. Figure 4 plots our measures of elasticities against the extent of comparative advantage in nontradables (i.e., the ratio of relative nontradable productivities to relative tradable productivities) which we denote as

$$g_{N/T} = \frac{\ln\left(a_1^{NT}/a_2^{NT}\right)}{\ln\left(a_1^{T}/a_2^{T}\right)}.$$

When $g_{N/T} = 0$, technological differences are completely concentrated in the tradable sector. When $g_{N/T} = 1$, there is no relative bias across sectors in technology levels. For comparison, the elasticity of deviations from PPP in a model without price discrimination is also reported as ε_{PPP}^{STD}.

From figure 5 we see that the violations from PPP are decreasing in $g_{N/T}$ while pricing-to-market is increasing in $g_{N/T}$. To understand these different results, first note that in the model without price discrimination that ε_{PPP}^{STD} is decreasing in $g_{N/T}$ because the relative price of non-tradables is decreasing as the productivity gap diminishes.

Two factors influence the relationship between pricing-to-market and the productivity gap. First, there is a limit to the amount of pricing-to-market that a firm will undertake as the lowest price it will ever charge is its marginal cost. Thus, pricing-to-market is somewhat non-linear in that among relatively high wage countries, firms will vary prices with their customer's wages, but among relatively low-wage destinations, markups are already quite low, so firms have very little ability to vary their price with the destination wage. Secondly, with a biased productivity gap relative wages differences are much larger than relative income differences. This is because relative wages are determined primarily by the productivity difference in tradables while relative income differences are based on productivity in both sectors. Taken together these two features imply that a biased productivity gap leads to greater pricing-to-market among high-income locations and lower pricing-to-market among low-income locations. Given the world distribution of income, the reduced pricing-to-market to low-income locations has a stronger effect on the estimate of pricing-to-market.

For the model without pricing-to-market to account for the violations from PPP, the model requires the productivity gap in tradables to be ten times the productivity gap in non-tradables.

Markups

We now consider the effect of the labor share on the model's predictions. In Table 5, the column titled *Low Labor Share* reports the results of the model with a labor share of 50 percent. In this case, there are larger violations from PPP and these are entirely due to an increase pricing-to-market. A lower labor share leads to larger markups and gives firms more room to price-to-market. This is particularly important for pricing to low-income countries as firms will never price below marginal cost so that there is a lower bound on their prices.

Search time

Here we consider the effect of reducing the time spent shopping per unit of consumption. In table 5, the column titled *Low Shop Time* reports our measures of elasticities when the ratio of time working to time shopping is doubled to 8. The amount of time shopping primarily affects the level of income which then affects our estimates indirectly by changing the elasticity of income with respect to productivity. However, because search activities are already a small fraction of labor activities in the benchmark case, this effect is quantitatively minor.

F. Relative Prices and Relative Wages

We now reconsider the relationship between international relative prices and relative wages in the data and the model. Pricing-to-market in the model is driven by the opportunity cost of time measured by wages and not income-per-capita. As the model abstracts from important determinants of income-per-capita such as population growth, labor market participation and capital accumulation, focusing on relative wages and prices is a more direct test of the model.

We re-calibrate technology in the model to match the exact distribution of wages in the sample of countries for which we have wage data. Figure 5 plots the relationship between relative price levels and wages from the model and the data.

The data generates an elasticity of price levels with respect to wages, which we denote ε_w^{PPP} equal to 0.4. The model generates $\varepsilon_w^{PPP} = 0.29$ and thus can explain nearly 72.5 percent of the relationship between prices and wages. We find that pricing-to-market is the largest source of the relationship as it accounts for 40 percent and the HBS effect accounts for 32.5 percent. That we find a stronger effect for pricing-to-market when examining wages could be attributed either to wages being more important than income in price setting or price-setting being different toward these 28 countries compared to the full 115 Benchmark countries.

5. Conclusions

This paper provides strong empirical evidence of systematic pricing-to-market based on the wages of consumers in the destination market. Further work needs to be done to determine whether this type of pricing-to-market is common to exports in the rest of the world. We have shown that this pricing-to-market contributes significantly to deviations from absolute PPP in the data. In contrast to previous work, our work finds that wages have substantially more explanatory power for national price levels than income per capita.

We have developed a model of pricing-to-market based on international productivity differences and search frictions. Our model generates a role for local wages in the price-setting behavior of firms. We use our model to differentiate between the traditional explanation of violations of PPP, that is, those due to relatively larger productivity differentials in the tradable sector, and ours based on pricing-to-market. We have shown that pricing-to-market accounts for about 25 percent of the violations from absolute PPP and 50 percent of the deviations from the LOP. In contrast, violations of PPP due to differences in the ratio of the relative price of tradables to nontradables across countries, as emphasized by HBS, account for only 39 percent of the violations of PPP. Thus, we argue that pricing-to-market is central to understanding both international relative price and income differences.

While the findings here address the source of long-run deviations from absolute PPP, they may also have implications for understanding fluctuations in prices and real exchange rates at business-cycle frequencies. If, as in our search model, it is indeed wages that determine the pricing-to-market relationship, we may expect firms to respond to business cycle variations in setting their prices (see Alessandria, 2002, for example). If instead, prices are set based on the value of consumers' lifetime budget constraints (for which wages and income per capita are only proxies), the pricing-to-market we've uncovered may not be important for business-cycle frequencies. Thus, a topic for future research is to distinguish between wages and other measures of wealth or income as the driving force in this pricing-to-market relationship.

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Table 1: Coefficients from Commodity-Year Fixed Effects Regressions of Log Price on Log Income per Capita and/or Log Wages

Using Exchange Rate Income and Wages:						
					Both Together	
	Number of Obs.	**Fraction of Total Value Exported**	**GDP per Capita Only**	**Wage Only**	**GDP per Capita**	**Wages**
All Homogenous* Goods to Benchmark Countries with BLS Wage Data**	626,067	1.000	0.130 (61.3)	0.122 (69.8)	-0.005 (-1.1)	0.126 (33.3)
Dropping Low Value Country-Commodity Observations						
Country Value<1% of Average Country Value for Commodity	576,340	0.999	0.141 (66.0)	0.128 (73.4)	0.013 (2.9)	0.119 (32.1)
Country Value<5% of Average Country Value for Commodity	471,485	0.996	0.148 (68.2)	0.130 (73.6)	0.033 (7.2)	0.106 (28.3)
Using PPP Income and Wages:						
					Both Together	
	Number of Obs.	**Fraction of Total Value Exported**	**GDP per Capita Only**	**Wage Only**	**GDP per Capita**	**Wages**
All Homogenous* Goods to Countries with BLS Wage Data**	626,067	1.000	0.177 (48.8)	0.162 (62.8)	0.026 (4.9)	0.148 (39.7)
Dropping Low Value Country-Commodity Observations						
Country Value<1% of Average Country Value for Commodity	576,340	0.999	0.196 (53.8)	0.168 (65.8)	0.049 (9.4)	0.143 (39.0)
Country Value<5% of Average Country Value for Commodity	471,485	0.996	0.208 (56.6)	0.166 (65.3)	0.071 (13.4)	0.130 (35.1)

*Homogeneous indicates that we have dropped all commodities without units and all commodities that included "other", "NESOI", "not elsewhere specified or included", "parts" and "$" in either the detailed or abridged commodity description.

** These countries include the following Australia, Austria, Belgium-Luxembourg, Brazil, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong, Ireland, Israel, Italy, Japan, South Korea, Mexico, the Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sri Lanka, Sweden, Switzerland, and the total U.S. exports of these goods.

Table 2: Effect of Quality Aggregation on Coefficients from Regressions of Log Unit Value on Log Wages (t-stats in parentheses)

	Number of Commodity Groups	Number of Observations	Exchange Rate	PPP
Commodities Combined at the 9-Digit Level				
Individual (10-Digit) Commodities	399	32,645	0.119 (15.3)	0.168 (14.7)
Aggregated (9-Digit) Commodities	170	22,138	0.094 (10.6)	0.134 (10.1)
Commodities Combined at the 7-Digit Level				
Individual (10-Digit) Commodities	2,065	207,305	0.108 (34.7)	0.150 (32.5)
Aggregated (7-Digit) Commodities	632	101,979	0.090 (21.4)	0.128 (20.3)
Commodities Combined at the 5-Digit Level				
Individual (10-Digit) Commodities	3,988	415,821	0.121 (56.0)	0.161 (50.9)
Aggregated (5-Digit) Commodities	947	178,054	0.101 (31.5)	0.137 (28.4)

Table 3: Imports and Exports as a fraction of GDP (2000)

COUNTRY	Exports	Imports
AUSTRALIA	0.229	0.228
AUSTRIA	0.503	0.509
CANADA	0.461	0.403
DENMARK	0.441	0.381
FINLAND	0.430	0.337
FRANCE	0.285	0.273
GERMANY	0.338	0.334
ITALY	0.283	0.273
JAPAN	0.108	0.094
KOREA	0.448	0.417
MEXICO	0.310	0.330
NEW ZEALAND	0.363	0.345
NORWAY	0.467	0.294
PORTUGAL	0.315	0.428
SPAIN	0.301	0.324
SWEDEN	0.461	0.403
SWITZERLAND	0.456	0.399
TURKEY	0.240	0.315
UNITED KINGDOM	0.281	0.301
UNITED STATES	0.113	0.150
Median	0.327	0.332

From OECD's Annual accounts - measured in national currencies.

Table 4: U.S. Sectoral Productivity Growth (1958-96)

	Average		Weighted Avg	
	Productivity Growth	Labor Productivity Growth	Productivity Growth	Labor Productivity Growth
Tradables*	0.59	1.91	0.68	2.09
Non-Tradables**	0.28	1.51	0.22	1.31
Ratio ($g_{N/T}$)	0.47	0.79	0.32	0.63

*Tradables include: Agriculture; Metal Mining; Coal Mining; Petroleum and Gas; Nonmetallic Mining; Food Products; Tobacco Products; Textile Mill Products; Apparel and Textile; Lumber; Furniture; Paper Products; Printing and Publishing; Chemical Products; Petroleum Refining; Rubber and Plastics; Leather Products; Primary Metals; Fabricated Metals; Industrial Machinery and Equipment; Electronic and Electric Equipment; Motor Vehicles; Instruments; Miscellaneous Manufacturing.

**Non-tradables include: Construction; Transport and Warehouse; Communications,; Electric Utilities; Gas Utilities; Trade; FIRE; Services; Stone, Clay and Glass; Other Transportation.

Table 5: Amount of PPP and LOP Explained by Model Variants

A. Elasticity*	Data	Balanced	Benchmark	Variations on Biased Productivity Economy**				
				HBS	Low Labor Share	Low Shop Time	Low Trade	HBS Low Trade
ε_{PPP}	0.430	0.107	0.276	0.151	0.315	0.276	0.430	0.430
ε_{LOP}	0.200	0.110	0.103	0.000	0.137	0.107	0.102	0.000
ε_{W}	0.130	0.099	0.081	0.000	0.106	0.085	0.072	0.000
ε_{NT}	0.353	-0.021	0.503	0.453	0.509	0.493	0.554	0.561
B. Accounting for violations from PPP								
Fraction of ε_{PPP}		25%	64%	35%	73%	64%	100%	100%
Fraction from PTM		26%	25%	0%	34%	26%	25%	0%
Fraction from HBS		-1%	39%	35%	39%	38%	75%	100%

*ε_{PPP} and ε_{NT} are based on the whole sample of 115 PWT Benchmark countries while ε_{w} and ε_{LOP} are based the 28 benchmark countries for which the BLS provides wage data.

**The variations of the Benchmark economy all include a biased productivity gap. In the HBS economies there is no pricing-to-market and unit labor supply. Low labor share is the Benchmark economy with labor share of income of 1/2. The Low Shop Time economy is the Benchmark economy in which the ratio of time spent working to shopping is 8. The Low Trade Share economy is the Benchmark economy with a lower tradable share of 0.42. The HBS Low Trade is the HBS model with a low trade share of 0.23.

Figure 1: Log PPP vs. Log GDP/Capita

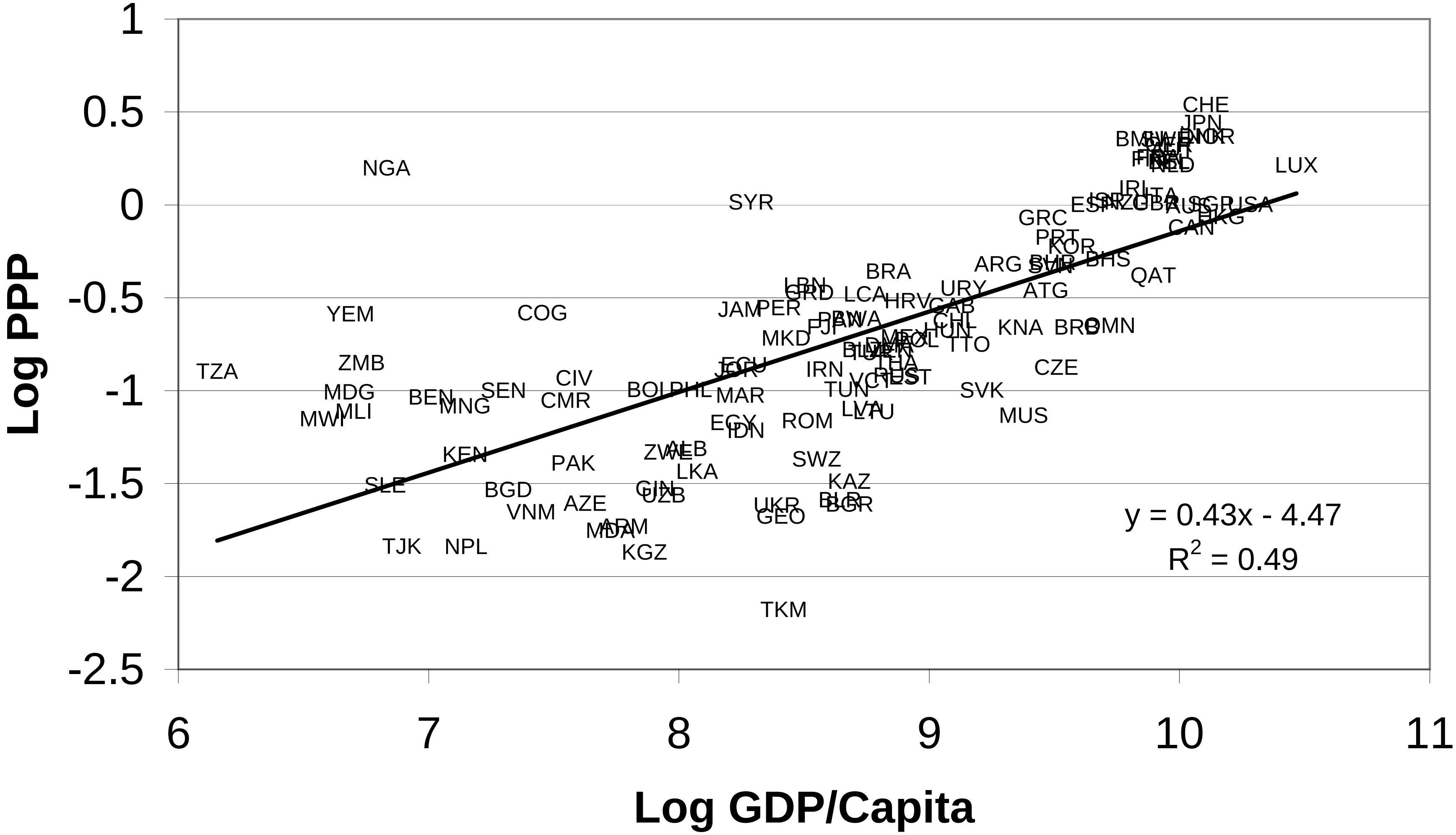


Figure 2: Log Price of Tradables vs. Log GDP/Capita

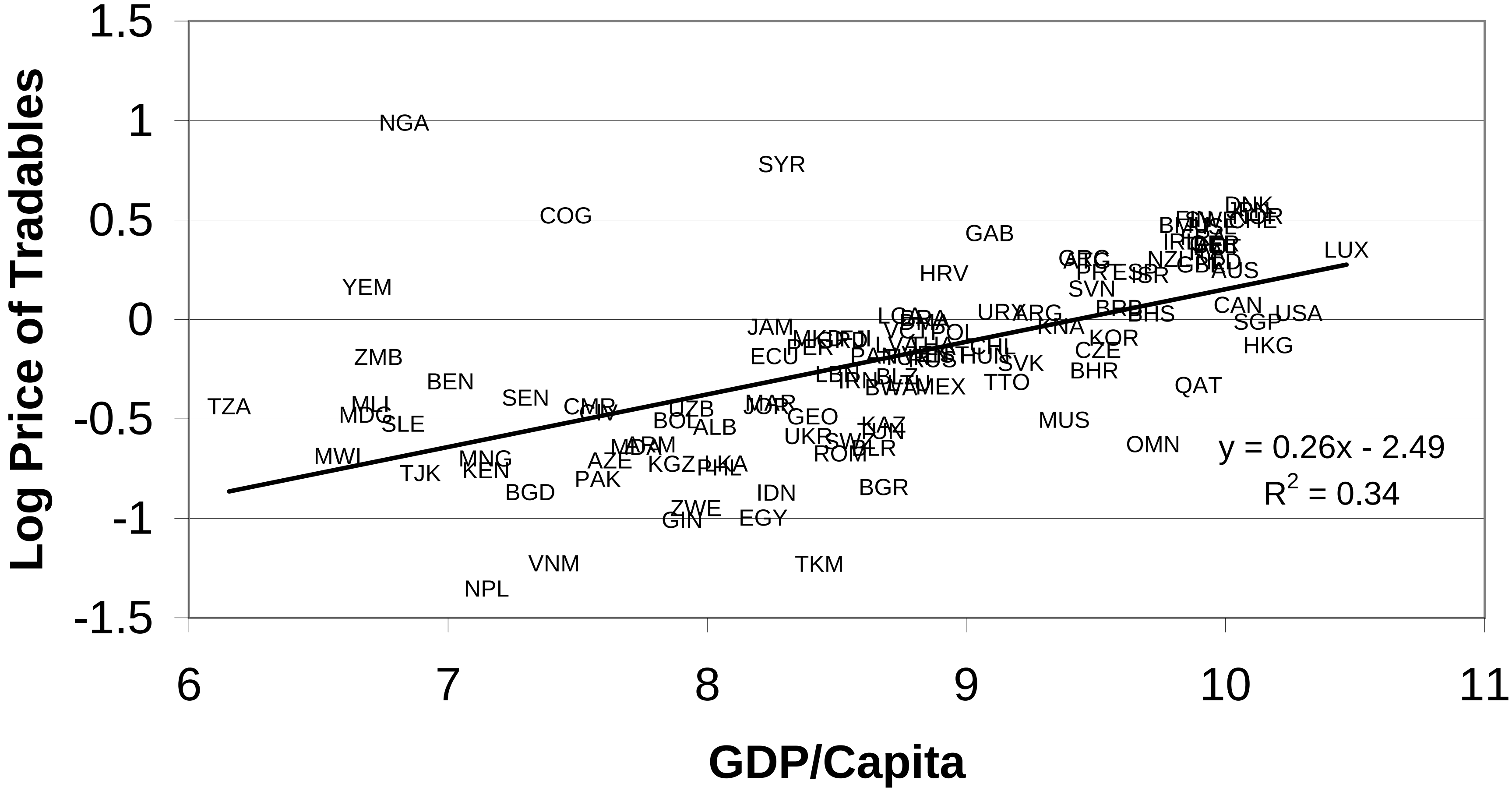


Figure 3: Price Elasticities and Trade Share

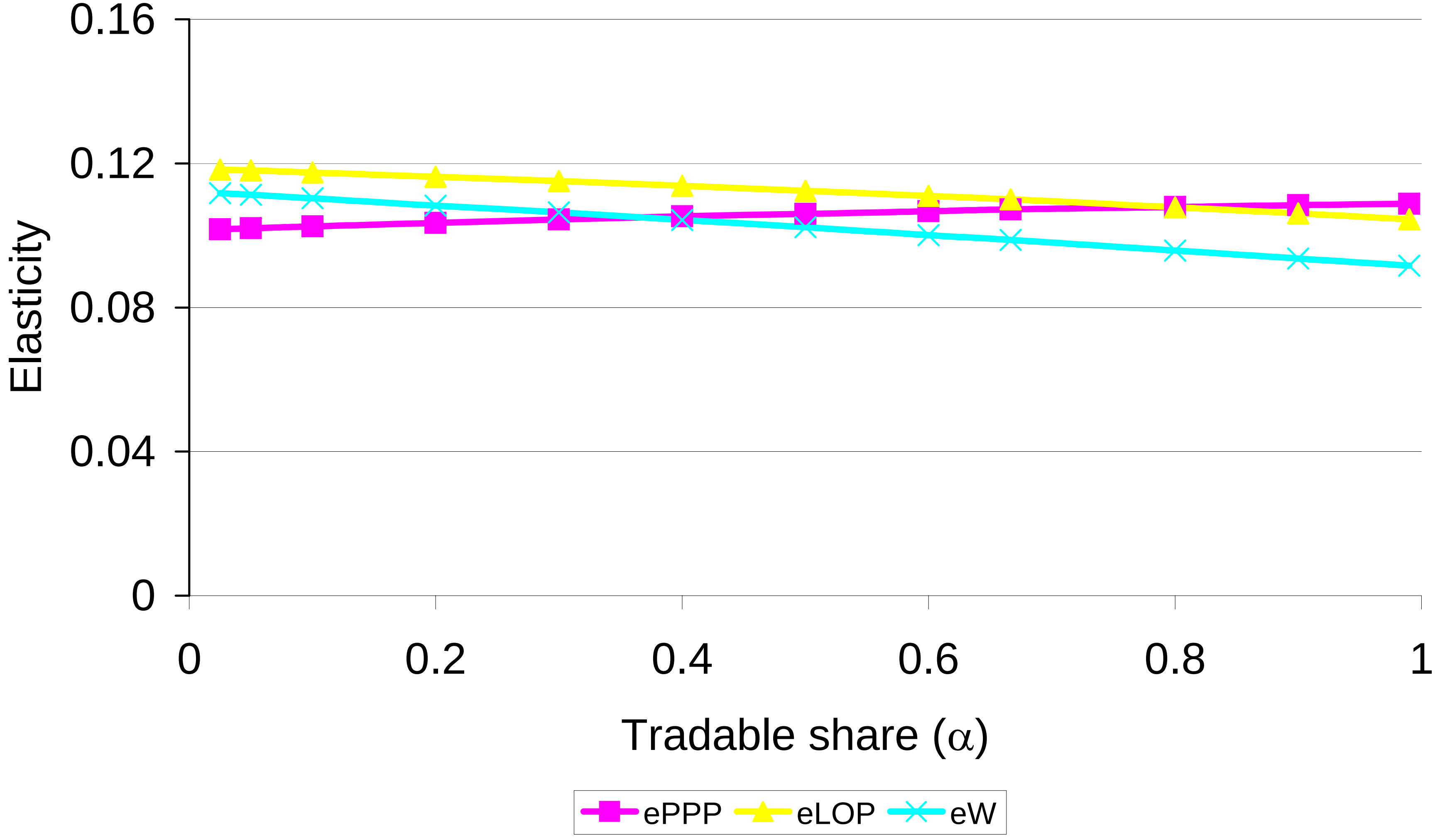


Figure 4: Elasticity and Biased Productivity Gap

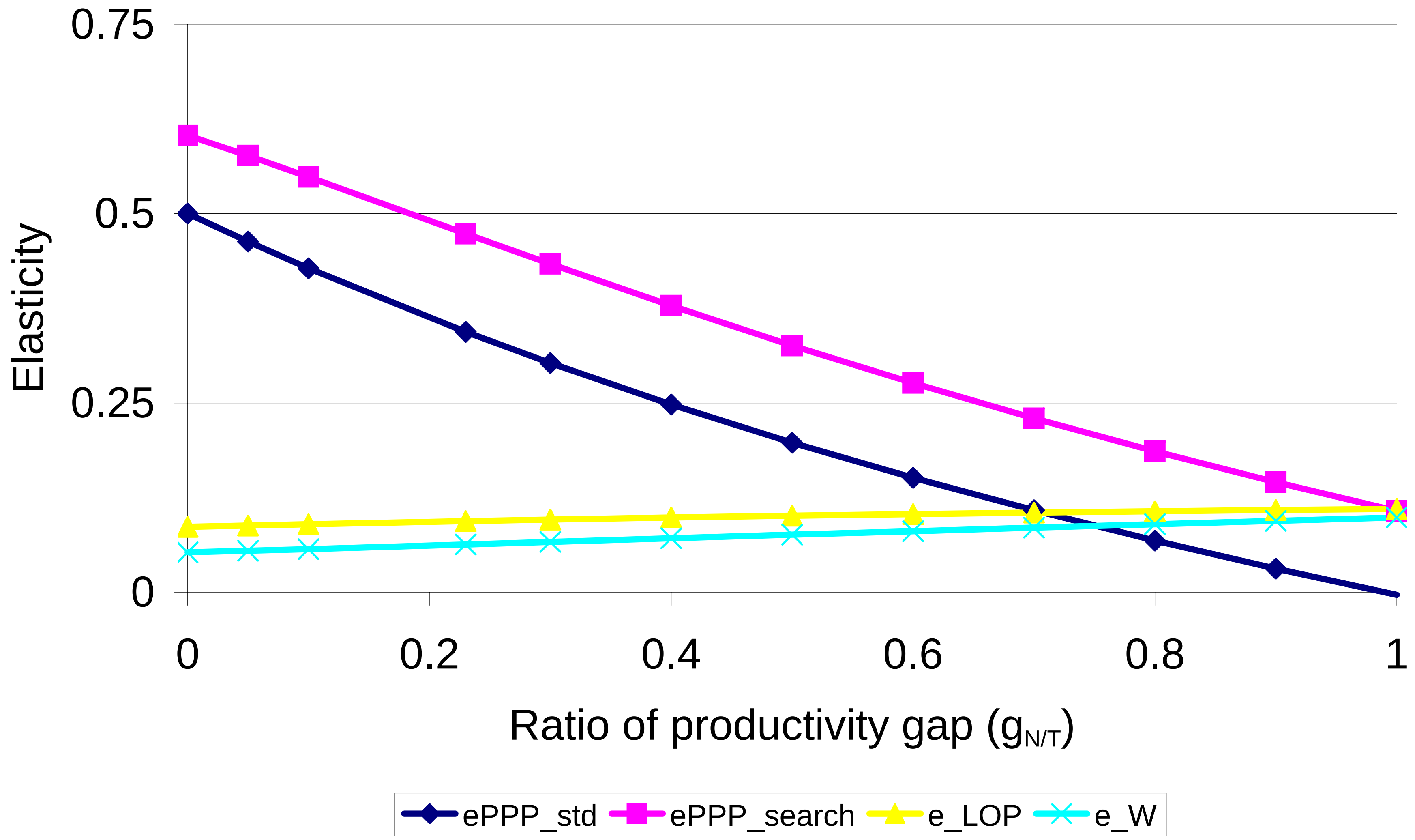
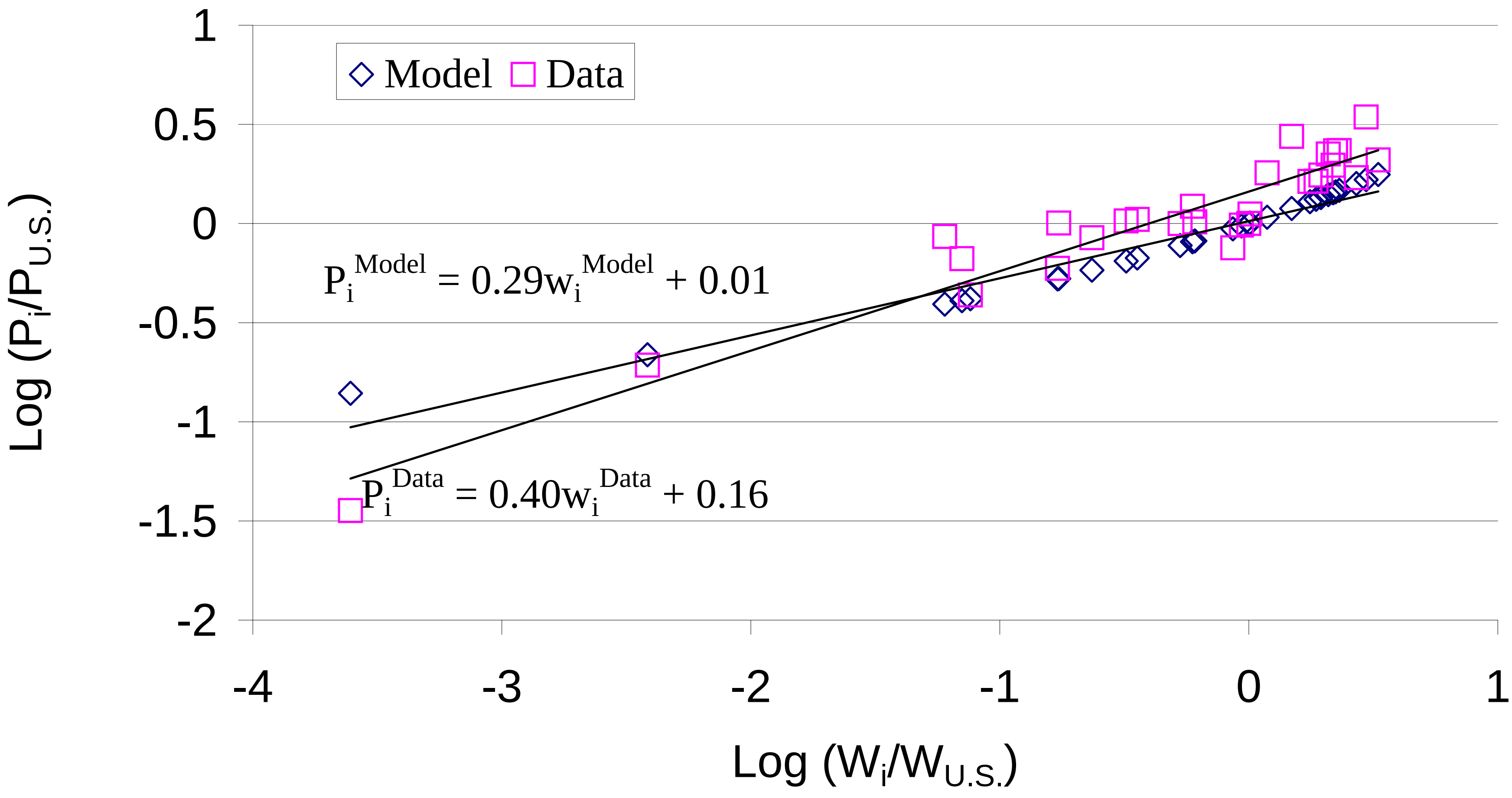


Figure 5: Actual and Predicted Relative Prices and Wages



Appendix A:

Sample of 30 Randomly Selected Goods in Alphabetical Order

1	BARS & RODS OF IRON OR NONALLOY STEEL, HOT-ROLLED, IN IRREGULARLY WOUND COILS, OF CIRCULAR CROSS-SECTION LT 14MM DIAMETER, CONTAINING LT 0.6% CARBON
2	BOVINE LEATHER WITHOUT HAIR ON, PRETANNED EXCEPT VEGETABLE PRETANNED, BUT NOT FURTHER PREPARED
3	BOVINE UPPER LEATHER, WHOLE, WITHOUT HAIR ON, OF A UNIT SURFACE AREA NOT EXCEEDING 28 SQUARE FEET (2.6 M2)
4	CHICKEN CUTS AND EDIBLE OFFAL (EXCEPT LIVERS) FROZEN
5	COPPER POWDERS OF LAMELLAR STRUCTURE; FLAKES
6	DIAMONDS, UNSORTED
7	DIISODECYL ORTHOPHTHALATES
8	ELECTRICAL SPECTROMETERS AND SPECTROGRAPHS USING OPTICAL RADIATIONS (ULTRAVIOLET, VISIBLE, INFRARED)
9	FERROCHROMIUM, 4 PERCENT OR LESS CARBON
10	GRINDERS, POLISHERS AND SANDERS, SUITABLE FOR METAL WORKING, ROTARY TYPE (INC COMBINED ROTARY-PERCUSSION) PNEUMATIC TOOLS FOR WORKING IN THE HAND
11	HOMOGENIZED COMPOSITE FOOD PREPARATIONS (SEE NOTE 3)
12	KRAFT FOLDING CARTON STOCK, CLAY COATED, BLEACHED AND OVER 95% CHEMICAL FIBERS, WEIGHING 150 G/M2 OR LESS, IN ROLLS OR SHEETS
13	METHYLCHLOROFORM (1,1,1-TRICHLOROETHANE)
14	MONOLITHIC I/C'S, DIGITAL, SILICON, (MOS), FIELD EFFECT TRANSISTOR, VOLATILE MEMORY, DYNAMIC READ-WRITE RANDOM ACCESS (DRAM) NOT OVER 300,000 BITS
15	OPTICAL SCANNERS AND MAGNETIC INK RECOGNITION DEVICES, ENTERED WITH THE REST OF A SYSTEM
16	ORIGINAL ENGRAVINGS, PRINTS AND LITHOGRAPHS, FRAMED OR NOT FRAMED
17	PAVERS, FINISHERS AND SPREADERS FOR CONCRETE, FOR PUBLIC WORKS, BUILDING OR SIMILAR USE
18	POCKET LIGHTERS, GAS FUELED, REFILLABLE
19	POLYMERS OF VINYL ACETATE, IN AQUEOUS DISPERSION
20	POWER SUPPLIES FOR ADP, SUITABLE FOR PHYSICAL INCORPORATION INTO AUTOMATIC DATA PROCESSING MACHINES,WITH A POWER OUTPUT NOT EXCEEDING 50W
21	SKINS OF SWINE, EXCEPT LIVERS, EDIBLE, FROZEN
22	SOBUTENE-ISOPRENE (BUTYL) RUBBER (IIR)
23	SWEET CORN, UNCOOKED OR COOKED BY STEAMING OR BOILING IN WATER, FROZEN
24	SWITCHES, PUSH-BUTTON, RATED AT NOT OVER 5 A, FOR A VOLTAGE NOT EXCEEDING 1,000 V
25	SYNTHETIC FILAMENT YARN EXCEPT SEWING THREAD, NOT FOR RETAIL SALE, SINGLE MONO,MULTIFILAMENT, OF POLYESTER UNTWISTED OR WITH A TWIST OF LT 5 TURNS/MTR
26	SYNTHETIC FILAMENT YARN EXCEPT SEWING THREAD, NOT FOR RETAIL SALE, SINGLE, MULTIFILAMENT, WITH A TWIST OF GE 5 TURNS PER M OF POLYETHYLENE, PROPYLENE
27	TABLE OR KITCHEN GLASSWARE OTHER THAN DRINKING GLASSES, OF LEAD CRYSTAL
28	TILTING ARBOR TABLE SAWS, WOODWORKING, NEW
29	TURNIP SEED OF A KIND USED FOR SOWING
30	WOVEN FABRIC OF COTTON CONTAINING LT 85% BY WEIGHT OF COTTON WEIGHING GT 200G/M2 DYED PLAIN WEAVE POPLIN OR BROADCLOTH MIXED WITH MMF

Appendix B:

Coefficients from Commodity-Year Fixed Effects Regressions of Log Price on Log Income/Capita of Major** U.S. Export Destination Countries

	Number of Obs.	Fraction of Total Value Exported	Exchange Rate	PPP
All Homogenous* Goods to Countries with PWT Income/Capita Data* **	830,552	1.00	0.030 (26.4)	0.042 (22.4)
Dropping Low Value Country-Commodity Observations				
Country Value<1% of Average Country Value for Commodity	776,455	1.00	0.034 (30.2)	0.049 (26.0)
Country Value<5% of Average Country Value for Commodity	638,691	1.00	0.040 (33.4)	0.058 (29.2)

*Homogeneous indicates that we have dropped all commodities that included "other", "NESOI", "not elsewhere specified or included", "parts" and "$" in either the detailed or abridged commodity description. In addition, we have dropped all goods that did not have units listed.

** We include benchmark countries in years in which they import at least 25 percent of the number of goods imported by the country importing the most goods. Mexico imports 4264 of the 5074 commodities exported by the U.S. (out of a total of 6012 in the classification system), thus countries importing at least 1066 commodities were included. For these countries, U.S. exports are deemed a representative sample of export prices overall. The 42 countries satisfying this criteria are varied in their geography and income level: Argentina, Australia, Austria, Belgium, Bahamas, Barbados, Brazil, Canada, Chile, Denmark, Ecuador, Egypt, Finland, France, Germany, Great Britain, Greece, Hong Kong, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Panama, Peru, the Philippines, Russia, Singapore, Spain, Sweden, Switzerland, Thailand, Trinidad and Tobago, Turkey, Uruguay, and Venezuela. These countries constitute 81 percent of all price-income observations and 96 percent of all trade.

***Log incomes in exchange rate terms ranged from 4.7 to 10.7 (6.1 to 10.7 in PPP terms) across the sample. The estimated price elasticity with respect to income in exchange rate (PPP) terms of 0.030-0.040 (0.042-0.058) would therefore imply an 18-24 percent (19-27 percent) price difference across the sample.

Appendix C:
Random Sample of Five Quality Groupings

Harmonized Sytem Code	9-Digit Group*	7-Digit Group	5-Digit Group	Commodity Description
2601110030	A	A	A	IRON ORE NONAGGLOMERATED CONCENTRATES
2601110060	B	A	A	IRON ORE NONAGGLOMERATED COARSE
2601110090	C	A	A	IRON ORE NONAGGLOMERATED NOT COARSE
2601120030	D	B	A	IRON ORE AGGLOMERATED PELLETS
2601120060	E	B	A	IRON ORE AGGLOMERATED BRIQUETTES
2601120090	F	B	A	IRON ORE AGGLOMERATED NOT PELLETS OR BRIQUETTES
7204410020	G	C	B	NO 1 BUNDLES STEEL SCRAP
7204410040	H	C	B	NO 2 BUNDLES STEEL SCRAP
7204410060	I	C	B	BORINGS, SHOVELINGS AND TURNINGS STEEL SCRAP
7204410080	J	C	B	SHAVINGS, CHIPS, MILLING WASTE, SAWDUST, FILINGS, TRIMMINGS, STAMPINGS STEEL SCRAP
7204490020	K	D	B	NO 1 HEAVY MELTING STEEL SCRAP
7204490040	L	D	B	NO 2 HEAVY MELTING STEEL SCRAP
7204490060	M	D	B	CUT PLATE AND STRUCTURAL STEEL SCRAP
7204490070	N	D	B	SHREDDED STEEL SCRAP
9505104010	O	E	C	ARTIFICIAL CHRISTMAS TREES, OF PLASTIC
9505105010	P	F	C	ARTIFICIAL CHRISTMAS TREES, EXCEPT OF PLASTIC
0203210000	Q	G	D	CARCASSES AND HALF-CARCASSES OF SWINE, FROZEN
0203221000	R	H	D	HAMS, SHOULDERS AND CUTS THEREOF, OF SWINE, BONE IN, PROCESSED, FROZEN
0203229000	S	I	D	HAMS, SHOULDERS AND CUTS THEREOF, OF SWINE, BONE IN, EXCEPT PROCESSED, FROZEN
5209413000	T	J	E	WOVEN FABRIC OF COTTON CONTAINING 85% OR MORE BY WEIGHT OF COTTON WEIGHING MORE THAN 200G/M2 OF DIFFERENT COLORS PLAIN WV CERTIFIED HAND-LOOMED FABRIC
5209420030	U	K	E	WOVEN FABRIC OF COTTON CONTAINING 85% OR GT BY WEIGHT OF COTTON WEIGHING GT 200G/M2 OF YARNS OF DIFFERENT COLORS DENIM WEIGHING LE 360G/M2
5209420050	V	K	E	WOVEN FABRIC OF COTTON CONTAINING 85% OR MORE BY WEIGHT OF COTTON WEIGHING 360 G/M2 OF YARNS OF DIFFERENT COLORS DENIM
5209430000	W	L	E	WOVEN FABRICS OF COTTON, 85% OR MORE COTTON BY WEIGHT, WITH YARNS OF DIFFERENT COLORS, 3-THREAD OR 4-THREAD TWILL INCLUDING CROSS TWILL, OVER 200 G/M2

* A relatively small fraction (about five percent) of all goods are unique up to ten digits. In the random sample of five five-digit groups chosen, none of the goods were unique up to ten digits in the Harmonized System Code.

Appendix D

Here we modify the baseline model to allow for a combined retail and wholesale distribution sector. This sector purchases goods from manufacturers, combines them with labor and then sells the modified product to searching consumers. We show this model generates export and retail prices that are similar to the baseline model.

Households: Assume there is a continuum of differentiated goods indexed by their position on the unit interval $i \in [0,1]$. A country j consumer sends shoppers, $n_j(i)$, with reservation prices, $r_j(i)$ for each good $i \in [0,1]$ and agents to work to solve

$$
\begin{aligned}
C_j &= \max_{n_j(i), r_j(i)} \left(\int_0^1 c_j(i)^\theta \, di \right)^{\frac{1}{\theta}} \\
\text{subject to} &: \quad
\begin{array}{l}
\int p(i) \, c_j(i) \, di = w_j l_j + \pi_j \\
c_j(i) = n_j(i) \, H_{ji}(r(i)) \\
p_j(i) = \frac{\int_0^{r_j(i)} p dH_{ji}}{H_{ji}(r_i)} \\
l_j + \int n_j(i) \, di = 1
\end{array}
\end{aligned}
$$

This problem yields the following reservation price and demand equations,

$$
\begin{aligned}
r_j(i) &= w_j + p_j(i). \\
n_j(i) &= \left(\frac{r_j(i)}{R_j} \right)^{\frac{1}{\theta - 1}} C_j,
\end{aligned}
$$

where $R_j = \left(\int r_j(i)^{\frac{\theta}{\theta-1}} \right)^{\frac{\theta-1}{\theta}}$, $P_j = \int p_j(i) \left(\frac{r_j(i)}{R_j} \right)^{\frac{1}{\theta-1}} di$ and $C_j = \frac{w_j l_j + \pi_j}{P_j}$. The term R_j measures the minimum resource cost of a unit of consumption and the term P_j denotes the market price of a unit of consumption. For the sake of exposition, we normalize $R_j = 1$. Given many identical households solving the same problem, the aggregate demand curve is $D_{ji}(r) = n_j(i)$ where $r_j(i) = w_j + p_j(i)$.

Distributor/Retailer: We assume that there are many independent firms that purchase good i at $p_m(i)$ and then incur a cost c_j to deliver the good to the consumer. Given the reservation price of consumers, and the cost of production $p_m(i) + c_j(i)$, this is the standard Burdett and Judd (1983) problem which we have shown generates the following average price

$$
p_j^{retail}(i) = p_m(i) + c_j(i) + \frac{q(i) \, w_j}{1 - q(i)}.
$$

As we have already shown, this problem generates a distribution of retail prices with mean $p_j^{retail}(i)$ and maximum price,

$$
r_j(i) = p_m(i) + c_j(i) + \frac{w_j}{1 - q(i)}.
$$

Producers: Given this retail price and reservation price and the aggregate demand curve, we now can solve the producer's maximization problem. Suppose that the producer's cost is $c_m(i)$, then the producer's problem is

$$\begin{aligned}\Pi(i) &= \max D(r(i))(p_m(i) - c_m(i)) \\ &= \max\left(p_m(i) + c_D(i) + \frac{w_j}{1-q(i)}\right)^{\frac{1}{\theta-1}} C*(p_m(i) - c_m(i)).\end{aligned}$$

The producer charges $p_m(i) = \frac{(1-\theta)\left[c_D(i)+\frac{w_j}{1-q(i)}\right]}{\theta} + \frac{c_m(i)}{\theta}$. The producer's markup depends on both its own costs and the downstream costs including those of the consumer. [1]

Industry prices: Now, we solve for the prices at each level

$$\begin{aligned}p_m(i) &= \frac{c_m}{\theta} + \frac{(1-\theta)}{\theta}\left[c_D(i) + \frac{w_j}{1-q(i)}\right], \\ p^{retail}(i) &= \frac{c_m + c_D(i)}{\theta} + \left[\frac{(1-\theta)}{\theta} + q(i)\right]\frac{w_j}{1-q(i)}, \\ r_j(i) &= \frac{w_j/(1-q(i)) + c_m + c_D(i)}{\theta}.\end{aligned}$$

As before, the price at which the manufacturer sells to the foreign market is increasing in the wage of the consumer. Moreover, it is now also increasing in the distribution cost in the destination market. We show below that the relationship between wages and prices in the baseline model are similar to those in the modified model with a distribution margin.

For comparison we modify the original model to include a local distribution cost and assume it is borne by the manufacturer. The final retail price will include this local cost. With the assumption that the manufacturer distributes its own good, there is not a market price at the border. To derive a price at the border we assume that the gap between the retail price and the price at the border is the difference in costs due to distribution costs. In this case we have

$$\begin{aligned}p^{direct}_{border}(i) &= c_m(i) + \frac{qw_j}{1-q}, \\ p^{direct}(i) &= c_m(i) + c_D(i) + \frac{qw_j}{1-q},\end{aligned}$$

where p^{direct}_{border} measures the price at the border and p^{direct} is the retail price.

Proposition summarizes three results. First, the elasticity of reservation prices with respect to wages is the same in both models. Second, the elasticity of retail prices is stronger with a distribution sector so that there is more pricing-to-market at the retail level. Finally, we find that pricing-to-market at the border can be stronger or weaker in the model with distribution depending on the substitutability of varieties and the search costs. Pricing-to-market at the border is more likely to be stronger when varieties are less substitutable and more consumers have multiple offers.

Proposition 2 With respect to wages, the elasticity of:

PROPOSITION 1. *a. Reservation prices is the same in both models.*
b. Retail prices is larger with distribution, even when there is no resource cost to distribution.
c. Border prices is larger in the model with distribution iff $q < \frac{(1-\theta)(1+\tau_D)}{(1+(1-\theta)\tau_D)}$.

[1] If downstream costs are proportional to upstream costs, then the producer charges a constant markup. For instance, suppose that $c_j(i) = (1+\tau_D)p_m$ and $w_j(i)/(1-q(i)) = (1+\tau_R)c_D$. Then, the optimal price is $p_m(i) = \frac{c_m}{\theta-(1-\theta)(1+\tau_D)[2+\tau_R]}$ and markups are constant.

Even when no resources are used in distributing goods, as in our baseline model, we find that pricing-to-market at the retail level is stronger in the model with a separate distribution channel. This occurs because now both the retailer and producer take into account how the local wage affects the demand for its good. Most importantly, because the producer has some market power it considers how its price affects the reservation price of the consumer.

At the border, we find that pricing-to-market can be stronger or weaker in the model with retail distribution depending on the substitutability of varieties, search costs and distribution costs. Pricing-to-Market in export prices is more likely to be stronger when varieties are less substitutable, more consumers have multiple offers and downstream distribution costs are higher.

Proof of Proposition 2 a. Reservation price is the same, $\frac{\partial r^{retail}}{\partial w}\frac{w}{r^{retail}} = \frac{\partial r^{direct}}{\partial w}\frac{w}{r^{direct}}$: $\frac{\partial r^{retail}}{\partial w}\frac{w}{r^{retail}} = \frac{\frac{1}{\theta(1-q)}}{\frac{c_m+c_D}{\theta}+\frac{1}{\theta}\frac{w}{1-q}} = \frac{1}{(1-q)\frac{c_m+c_D}{w}+1}$, $\frac{\partial r^{direct}}{\partial w}\frac{w}{r^{direct}} = \frac{\frac{1}{(1-q)}}{c_m+c_D+\frac{w}{1-q}} = \frac{1}{(1-q)\frac{c_m+c_D}{w}+1}$

b. PPP effect stronger, $\frac{\partial p^{retail}}{\partial w}\frac{w}{p^{retail}} > \frac{\partial p^{direct}}{\partial w}\frac{w}{p^{direct}}$, $\frac{\partial p^{retail}}{\partial w}\frac{w}{p^{retail}} = \frac{\left[\frac{1-\theta}{\theta}+q\right]\frac{w}{1-q}}{\frac{c_m+c_D}{\theta}+\left[\frac{1-\theta}{\theta}+q\right]\frac{w}{1-q}} = \frac{(1-\theta)+\theta q}{(1-q)\frac{c_m+c_D}{w}+(1-\theta)+q}$, $\frac{\partial p^{direct}}{\partial w}\frac{w}{p^{direct}} = \frac{q\frac{w}{1-q}}{c_m+c_D+q\frac{w}{1-q}} = \frac{q}{(1-q)\frac{c_m+c_D}{w}+q}$ and clearly $(1-\theta)+\theta q > q$

c. Border prices, $\frac{\partial p^{direct}_{border}}{\partial w}\frac{w}{p^{direct}} = \frac{\frac{q}{1-q}}{c_m+\frac{qw}{1-q}} = \frac{q}{(1-q)\frac{c_m}{w}+q}$. Given $c_D = \tau_D w_j$, then $p^{retail}_m = \frac{c_m}{\theta} + \frac{(1-\theta)}{\theta}w_j\left[\tau_D + \frac{1}{1-q(i)}\right]$, and $\frac{\partial p^{retail}_m}{\partial w}\frac{w}{p^{retail}_m} = \frac{\frac{1-\theta}{\theta}\left[\tau_D+\frac{1}{1-q}\right]w_j}{\frac{c_m}{\theta}+\frac{(1-\theta)}{\theta}w_j\left[\tau_D+\frac{1}{1-q(i)}\right]} = \frac{(1-\theta)(\tau_D(1-q)+1)}{(1-q)\frac{c_m}{w}+(1-\theta)(\tau_D(1-q)+1)}$.

Comparing these conditions we see that $\frac{\partial p^{retail}_m}{\partial w}\frac{w}{p^{retail}_m} \geq \frac{\partial p^{direct}_{border}}{\partial w}\frac{w}{p^{direct}}$ iff $\frac{(1-\theta)(1+\tau_D)}{(1+(1-\theta)\tau_D)} > q$. The term on the LHS is increasing in τ_D so that adding a distribution sector leads to more pricing-to-market at the border.