WORKING PAPERS
RESEARCH DEPARTMENT

WORKING PAPER NO. 07-29
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September 2007

RESEARCH DEPARTMENT, FEDERAL RESERVE BANK OF PHILADELPHIA
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Pricing-to-Market and the Failure of Absolute PPP*

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Abstract

We show that deviations from the law of one price in tradable goods are an important source of violations of absolute PPP across countries. Using highly disaggregated export data, we document systematic international price discrimination: at the U.S. dock, U.S. exporters ship the same good to low-income countries at lower prices. This pricing-to-market is about twice as important as any local non-traded inputs, such as distribution costs, in explaining the differences in tradable prices across countries. We propose a model of consumer search that generates pricing-to-market. In this model, consumers in low-income countries have a comparative advantage in producing non-traded, non-market search activities and therefore are more price sensitive than consumers in high-income countries. We present cross-country time use evidence and evidence from U.S. export prices that are consistent with the model.

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

*This paper is a substantially revised version of the working paper, "Violating Purchasing Power Parity." The authors thank Andy Atkeson, Ariel Burstein, Mario Crucini, Marvin Goodfriend, Patrick Kehoe, Fabrizio Perri, Kim Ruhl, 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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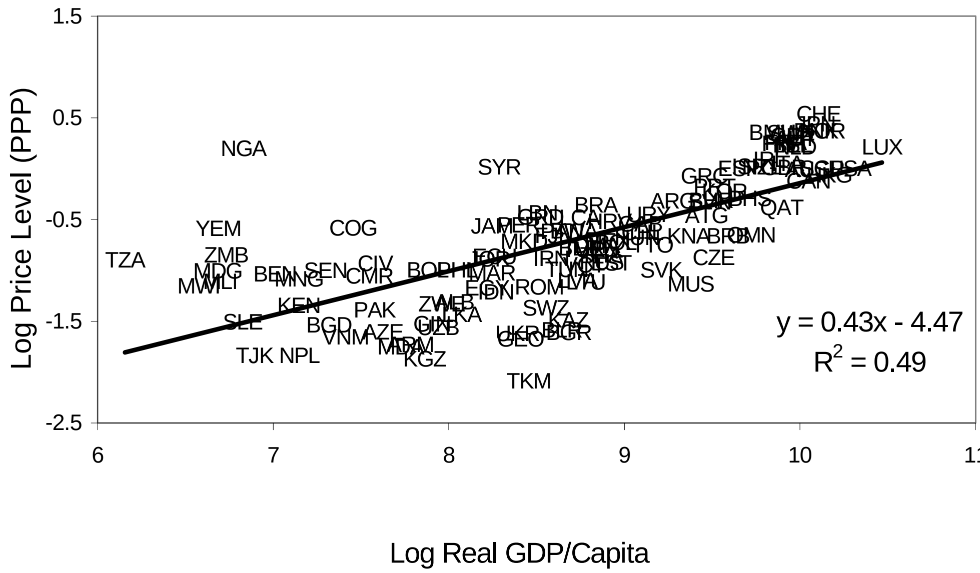
Figure 1: Price Levels and Real GDP per capita



(Source: Penn World Tables 6.1, ICP 1996 Benchmark Price Data)

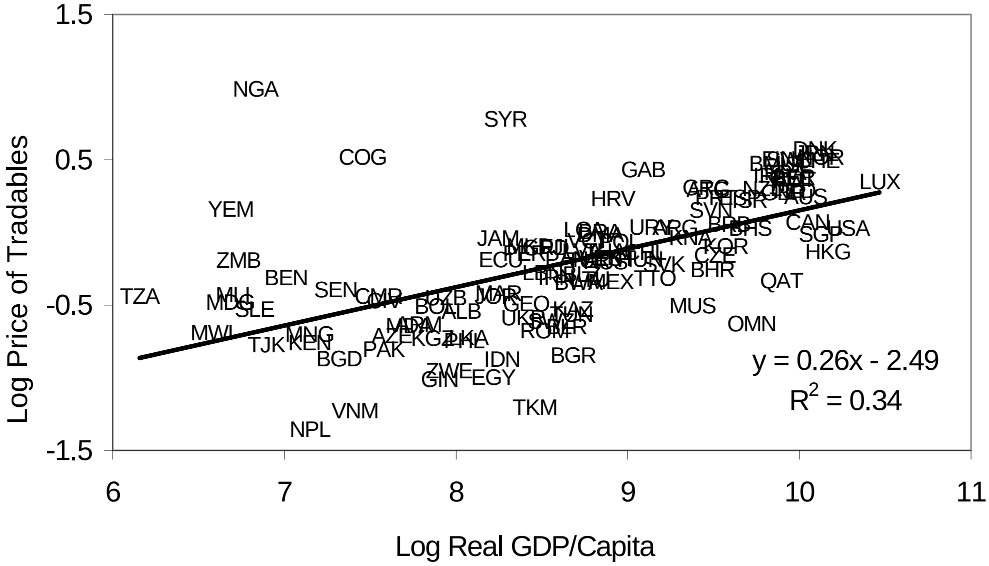
1. Introduction

Figure 1 plots income per capita against the price level and draws a line with the estimated magnitude of this relation. This picture raises two questions: First, why are there large differences in price levels? Absolute PPP states that the same basket of goods should sell for the same price everywhere, yet for instance, the price level in Mexico is 70 percent below the price level in the United States.[1] Second, why are price levels so strongly related to income per capita? A doubling of income per capita is associated with a 43 percent higher price level. The conventional explanation for these two observations is the model of Harrod (1933), Balassa (1964), and Samuelson (1964), the HBS model hereafter. In HBS, differences in price levels are driven solely by non-tradable goods, for which the law of one price (LOP) doesn't hold. Since the LOP holds for traded goods, international relative wages are determined by the large productivity differences in tradables. Large differences in wages lead to differences in the price of non-tradables, a sector in which productivity differences are much smaller across countries. The model therefore rests on the assumption that cross-country productivity

[1] Rogoff (1996) provides a review of PPP.

differences are much smaller in non–tradables than in tradables, and that the LOP holds in tradables.[2]

Figure 2: Tradable Prices and Real GDP per capita



(Source: Penn World Tables 6.1, ICP 1996 Benchmark Price Data)

There are two good reasons to doubt HBS as a full explanation of these observations. First, we see from Figure 2, which plots the tradable price levels against income per capita, that the LOP for tradables is clearly violated in the data. As in Figure 1, the relationship between prices and income is positive and significant, and the estimated elasticity in tradables (0.26) is over 50 percent of the overall elasticity (0.43).[3] Deviations from the LOP are clearly substantial. Second, to explain the magnitude of the relation in Figure 1, the rise in relative productivity of tradables with income across countries (in the cross-section) would have to be much bigger than what we observe within countries (in the time series).

One aim of this paper is to estimate the role of systematic price discrimination across countries, what Krugman (1987) calls pricing-to-market, in the pattern of tradable and overall price levels in

[2] A few existing theories present alternatives to HBS. Kravis and Lipsey (1983) and Bhagwati (1984) focus on differences in factor endowments. Linder (1961), Dornbusch (1988), Neary (1988) and Bergstrand (1991) focus on differences in preferences. All of these theories assume that the LOP holds for tradables.

[3] These deviations from PPP are quite persistent. Of the 115 countries in the 1996 PWT data, 60 countries had a price less than one-half of the U.S. price for a common basket of final goods. 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 U.S. in 1985. Countries with low price levels also have very low income, with GDP per capita on average 14 percent of the U.S. level in 1996.

Figures 1 and 2. The evidence on tradables in Figure 2 could be interpreted as direct evidence of pricing-to-market, but a potential problem with such an interpretation is that the tradable prices are measured using final goods prices. These differences in retail prices may be driven by non-traded components, such as transportation and distribution, instead of differences in the actual price of tradables earned by the producer. In Section 2, we overcome this measurement problem using highly disaggregate data on exports by destination market and show that the tradable price vs. income per capita relationship from Figure 2 primarily reflects pricing-to-market rather than the non-traded content of tradable goods.

The data we study are well-suited for isolating this pricing-to-market because they measure the export income received at the U.S. border before any local non-traded inputs are added. The data show that exporters systematically charge higher prices for comparable goods when exporting to high-income countries. On average the richest country in our data set pays 40 percent more for the same good than the poorest country. We perform robustness checks that support our interpretation of this as true price discrimination, and not the result of quality differences or transfer pricing of related party trade. The estimated elasticity of price with respect to GDP per capita is 0.17, indicating that about two-thirds of deviations in the LOP in final tradables could be due to pure pricing-to-market.

What characteristics of consumers or markets might lead firms to price discriminate based on income? The second aim of this paper is to propose a strong candidate for a micro-level explanation for higher elasticities of demand from consumers in low-wage countries. In Section 3, we develop a model based on consumer search frictions and international productivity differences. Search requires time, which consumers in high-productivity/high-wage countries value at a premium. They are therefore less willing to search and less price elastic shoppers. Firms take this into account and set relatively high prices (and therefore markups) when selling to high-wage countries. Thus, there is a tight (endogenous) link between the local wage and prices, both tradable prices *and* non-tradable prices. Our consumer search story parallels and complements the HBS story. That is, we too rely on small differences in the productivity of a non-traded good. The search friction story requires that productivity in shopping rises less rapidly with income than productivity in market production.

Section 4 provides a quantitative analysis of the search model, which can account for two-thirds of the observed pricing-to-market relationship, and 57 percent of the PPP-income relationship, or about twice as much as the HBS model alone explains. The existence of pricing-to-market augments the HBS explanation in two ways. It helps reconcile the smaller observed differences in the relative price of tradables to non-tradables, and it also helps reconcile large differences in average price levels with the evidence that relative productivity in the tradable sector does not increase nearly as much with income (in the time series) as the HBS explanation would require (in the cross-section of countries).

Corroborating evidence, which we review, supports the consumer search model as a strong candidate explanation for the pricing-to-market we observe. First, we show, using cross-country time-use studies, that the ratio of shopping time to work time increases substantially with income, which indicates that shopping productivity does not increase as rapidly as income (and overall productivity). Second, within countries, time-use studies find that poorer consumers, and retired consumers with lower opportunity cost of time, spend relatively more time shopping per purchase (McKenzie and Schargrodsky, 2005, and Aguiar and Hurst, 2005). Furthermore, these studies find that shopping time is negatively related to purchase price, a direct implication of the search model. Third, our U.S. export evidence shows that the opportunity cost of time (wage) is more robustly associated with prices than with income, and that pricing-to-market is strongest for consumer goods. Finally, quantitatively, numerical examples indicate that the search model can potentially generate pricing-to-market of the order observed in the U.S. export data.

In addition to its contribution to the study of absolute PPP, this paper relates to two other literatures. Our emphasis on pricing-to-market in tradables as an important source of violations from absolute PPP is consistent with the prevailing view in the literature on relative PPP. Engel (1999) and Chari, Kehoe and McGrattan (2002) show that deviations from the LOP in tradables account for nearly all of the fluctuations in real exchange rates among developed countries.[4] Theoretical explanations of this pricing-to-market take two forms. The first approach focuses on the role of sticky prices set in local currencies, while the second emphasizes that local market conditions differ across countries and time so

[4] Asea and Mendoza (1994) show that the HBS model is inconsistent with real exchange rate and output fluctuations.

that firms have incentive to systematically price discriminate internationally.[5] Since we are looking at absolute PPP and long term deviations, we follow the approach of focusing on local market conditions. This paper also relates to the literature on the role of relative prices and productivities in capital accumulation and growth. Eaton and Kortum (2001) and Hsieh and Klenow (2007) demonstrate that relative price differences across countries are important in explaining cross-country variation in capital stocks and income levels. Hsieh and Klenow therefore argue that understanding the origins of these relative price and productivity differences is essential. We argue that pricing-to-market, and not only relative productivities, plays a role in the prices (of investment, for example) that countries face.

2. Pricing-to-Market: Empirics and Importance

In this section, we document evidence, using highly disaggregated data on U.S. exports, that U.S. firms systematically price discriminate based on the income of the destination market. We show that this price discrimination is not likely due to unobserved quality differences or transfer pricing issues, and that it provides some evidence for a search model where the elasticity of demand varies with the opportunity cost of search. Finally, using a modified version of Engel's (1999) decomposition of real exchange rates, we find that pricing-to-market accounts for 40 percent of the aggregate price-income relationship and the non-traded component of final goods accounts for 20 percent.

A. Export Data

The micro data we analyze, U.S. Exports Harmonized System data (see Feenstra et al., 2002), have significant advantages over the aggregate data in identifying pricing-to-market in tradables.

First, the data are comprehensive of all U.S. domestic exports (excluding re-exports) and therefore include only tradable goods, and a much broader range of tradables. We have annual data on the total value and quantity of all commodities exported by destination country. We link these data to income per capita data from the Penn World Tables 6.1 for the years 1989-2000 and to hourly (manufacturing) wage data available from the BLS. These wages are reported in nominal local currency,

[5] Starting with Krugman (1987), the local market condition models have sought to explain differences in elasticities of demand across countries from first principles without resorting to differences in tastes. A variety of local market condition models exist and emphasize both supply considerations, such as differences in industry structure (Dornbusch, 1987), and demand considerations, such as the decisions of firms to build market shares (Alessandria, 2004b).

which we convert to international Gheary-Khamis dollars using the PWT PPP price level.[6]

Given our emphasis on search and the opportunity cost of time, we focus on countries for which both hourly wage and income per capita data are available. These 28 countries include most long-term members of the OECD plus Hong Kong, Israel, South Korea, Mexico, Singapore, Sri Lanka and Taiwan. Over the 12 years of data, we have 1.1 million good-year observations for these countries, constituting 78 percent of the value of U.S. exports.

The second crucial advantage of this export data is that they are collected "at the dock" of the U.S., and so exclude local non-traded inputs in the destination market. That is, our export prices are based on free-alongside-ship values,[7] so they do not include transportation costs, tariffs, or distribution and retailing costs in the importing country. One complication, however, is that we do not directly observe prices. Instead, we calculate unit values from data on the total value and quantity sold. Numerous important studies of deviations of the LOP and pricing-to-market are based on unit values (see Isard, 1977, Feenstra, 1989, and Knetter, 1993). Unit values have the advantage of providing a measure of destination-specific prices for a large number of products.

Although the data are not at the individual good level, the issue of quality is also mitigated in the data. The data include 10,741 products classified using the 10-digit Harmonized System product codes, and so it is extremely disaggregated. (Appendix A provides the names of 30 randomly selected goods from the dataset as an example of the level of detail.)

B. Pricing-to-Market Evidence

For exposition, consider a monopolist selling an identical good in different markets (e.g., countries). Facing different demand in each market, the firm will, in general, charge price p equal to a market-varying markup μ over a common marginal cost c. Hence, while marginal costs and markups

[6] Converting to U.S. dollars using exchange rates produces nearly identical results, except that estimated elasticities of prices are smaller with respect to exchange rate-based income per capita, given their larger variance. We also deflate all price and income values to 1996 equivalents, though this is not strictly necessary as common price levels will be picked up in the fixed effects introduced below.

[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.

may vary across goods, i, and time, t, markups also vary across destination market, j:

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

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 estimate the following regression equation:

$$\text{(1)} \quad \ln p_{ijt} = \alpha_{it} + \beta \ln y_{jt} + e_{ijt},$$

in which y_{jt} is a measure of destination country income (either GDP per capita, wage, or a vector of both). The intercepts, α_{it}, capture variation in $\ln c_{it}$. They are estimated as fixed effects for each good-year combination. We use the "within" estimator, so that the identification of β comes from variation in the income of destination countries within good-year cells.[8] We report White robust standard errors that allow for heteroskedasticity in e_{ijt}, and also allow for country-year clustering.[9]

Table 1 presents the estimated $\hat{\beta}$ coefficients on log income and/or log wages from these fixed-effect regressions. 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 17.0 on PPP income/capita. The "Wage Only" estimates are slightly smaller at 16.2.

Though both sets of estimates are highly significant, when we include log wages and log GDP per capita together in the same regression, log wages wins the horse race hands down. These estimates are presented in the two right-most columns. The estimated coefficient on wages remains at nearly the same level (15.6) and is highly significant, while the GDP per capita coefficient estimate becomes much smaller (1.2) and insignificant.

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

[8] Marginal costs are made both good- *and* year-specific to avoid problems with changing quality over time and issues of non-stationarity in income and prices. Making marginal cost only good-specific while adding time-dummies common to all goods produces very similar estimates, but suffers from the quality change and non-stationarity issues.

[9] Clustering on good-year has a negligible effect on standard errors given the nearly 40,000 good-year combinations.

(Germany and Sri Lanka, respectively) was 2.4 measured in PPP terms. Hence, the implied price differences in U.S. exports to these countries would be 40 percent.

C. Alternatives to Pricing-to-Market

We interpret the price-income relationship we observe as pricing-to-market. We show here that the evidence does not favor alternative explanations. The two alternatives we consider are that the price differences we observe are driven by 1) differences in quality, or 2) related party trade and transfer pricing concerns.[10] The explanation of methodology and results here is heuristic, but details are given in Appendix B.

Quality

Although the data are extremely disaggregated, one might still suspect that the positive relationships uncovered are driven by unobserved heterogeneity within product categories. That is, perhaps there is no price discrimination, but wealthy countries simply tend to import higher quality (and higher priced) goods within the 10-digit commodity categories. We address this result in two ways.

The first approach is quite simple and involves dropping those product categories viewed as potentially most heterogeneous. Panel B of Table 1 shows the results from running our regressions on a sample in which we dropped any commodity with descriptions containing words like "other,"[11] "not elsewhere specified or included," "NESOI," and "parts." The elasticity estimates are quite similar to the full sample. For instance the "GDP per Capita Only" estimate fails very slightly from 17.0 to 16.5 and the "Wage Only" elasticity estimate falls from 16.2 to 15.0. We tried multiple approaches[12] to determine heterogeneous categories and they all yielded similar results.

Our second approach is to examine the biases stemming from heterogeneity directly, by aggregating the data into even more heterogeneous product categories (9-, 7-, and 5-digit levels of the

[10] In addition to these two non-PTM explanations, we also considered a PTM alternative: whether pricing might be driven by intellectual property protection and local competition from pirated goods. Our results were robust to inclusion of indexes of intellectual property protection.

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

[12] We also tried several variations of standards for determining "heterogeneous" 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) and dropping commodities whose price variation was deemed unrealistic. The results were very robust to exclusion of these categories, and are available upon request.

Harmonized System). Though the bias that comes from heterogeneity within 10-digit categories is still unobservable, we can get an estimate of the quality bias at other levels by producing more aggregate average prices. We do this by comparing the $\hat{\beta}$ estimates from regressions using these more aggregated data to estimates using the less aggregated 10-digit coded data. A formal justification of this approach, based on a Lancasterian model where each Harmonized System digit represents a characteristic with a given price, and an explicit statement of the potential quality bias are developed in Appendix B.

The results of this approach 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 (10). Only 878 commodities are unique up to all ten digits and these are combined into 349 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 B also 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. 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.

This finding may appear surprising, and so it bears further explanation. First, the finding does not imply 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. In contrast, poor countries may have only low-quality domestic substitutes and therefore tend to import predominantly high-quality goods from the U.S. 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.[13] In any case, explaining the source of this effect is outside the scope of this paper, but our results are not likely driven by unobserved quality biases.

Transfer Pricing of Related Party Trade

Approximately 30 percent of U.S. exports are between related parties.[14] We explore whether the pricing of these trade flows influences our results. In theory, and legally, firms are supposed to use market prices for intrafirm trade so that export prices on intrafirm and cross-firm transactions should not systematically differ, ceteris paribus. However, in practice, firms have reasons to price intrafirm transactions differently than arm's-length transactions. Such pricing allows multinationals to shift profits from high- to low-tax countries, and so we explore whether these considerations influence our main finding.

To get at this idea, we collect data on corporate tax rates from the University of Michigan's World Tax Database.[15] We also collect data on related party trade by country and 2-digit industry from 1989 to 2000 from the BEA.[16] We construct two measures of the importance of related party trade. The first is the fraction of exports to a country that is between related parties (i.e., exports to related parties in country j/total exports to country j), and the second is the fraction of exports in an industry that is between related parties (i.e., exports in industry i to related parties/total exports in industry i).[17]

At 0.21, the unconditional correlation between log wages and corporate tax rates is not particularly strong. Nevertheless, we examine whether prices are systematically higher when trade is to related parties located in countries with high corporate tax rates. The exact regression equation and results are

[13] This comparative advantage interpretation of our result for U.S. exports is consistent with Schott's (2004) result for U.S. imports. Using similar data, Schott reported that U.S. imports coming from higher income countries tended to be more expensive. In Schott's study, there is good reason to believe these higher prices reflect higher quality. He examines imported goods from producers in different countries all imported into the same market. The variety of source countries allows for more heterogeneity, while the single destination market precludes a pricing-to-market interpretation. Again, if the U.S. has a stronger comparative advantage in high quality goods production relative to poor countries, then one would expect U.S. imports from poor countries to be lower quality goods, while its exports are higher quality.

[14] http://www.census.gov/foreign-trade/aip/index.html#relparty

[15] http://www.bus.umich.edu/OTPR/otpr/default.asp

[16] http://www.bea.gov/bea/uguide.htm#_1_24

[17] The country measure of related party trade varies from year to year, while the industry specific data are constant over the sample and based on available 1998 data.

given in Appendix B, but essentially, we do this by including the interaction between the intensity of related party trade and the corporate tax rate as a right-hand-side variable (measuring whether related party trade is priced substantially higher when sold to countries with high corporate tax rates). The industry-specific measure of related party trade produces estimates of this interaction term that are negligible and not significantly different from zero. The country-specific measure produces a significant estimate, but the magnitude is negligibly small and actually perverse. More important, using both measures, the size of the price-wage elasticity does not fall with inclusion of these controls, but actually rises slightly. Thus, transfer pricing does not appear to be driving the results.

D. Importance of Pricing-to-Market

Our first aim was to estimate the importance of pricing-to-market for deviations from absolute PPP. To do so, we modify Engel's, now standard, decomposition of fluctuations in real exchange over time to take into account differences in price levels across countries by income,[18]

$$\frac{p_i - \bar{p}}{y_i - \bar{y}} = \frac{p_i^T - \bar{p}^T}{y_i - \bar{y}} + (1-\alpha)\frac{\left(p_i^{NT} - p_i^T\right) - \left(\bar{p}^{NT} - \bar{p}^T\right)}{y_i - \bar{y}},$$

$$\Rightarrow \varepsilon_{PPP} = \varepsilon_{LOP} + (1-\alpha)\,\varepsilon_{N/T}, \tag{2}$$

where ε_{PPP} is the elasticity of the overall price level (with respect to income per capita), ε_{LOP} is the elasticity of deviations from the LOP (in tradables), $\varepsilon_{N/T}$ is the elasticity of the relative price of non-tradables, and α is the share of tradables. This decomposition shows that the aggregate price level and income relationship we seek to explain, ε_{PPP}, depends one-for-one on the deviations from the LOP and income relationship, ε_{LOP}, and only partly on how the relative price of non-tradables to tradables varies with income across countries, $\varepsilon_{N/T}$.

The traditional HBS story assumes $\varepsilon_{LOP} = 0$ so that the 100 percent of deviations from PPP come from the relative price of non-tradables to tradables. But the data tell us there are sizeable deviations from the LOP. The PWT data on the price of tradables indicate that $\varepsilon_{LOP} = 0.26$, so that

[18] This assumes that the log price index is approximated by a geometric average $p = \alpha p^T + (1-\alpha)\,p^{NT}$ and that all countries have the same basket.

deviations from the LOP account for about 60 percent of the aggregate price-income relationship. The more modest estimates of pricing-to-market from the export data of $\varepsilon_{LOP} = 0.17$ would still account for 40 percent, a substantial share, of the PPP income relationship. These findings are consistent with Engel's finding that about 45 percent of U.S. long-run real exchange rate fluctuations are due to movements in the relative price of traded goods.[19] We interpret the difference between the two values for ε_{LOP} (0.26 and 0.17) as measuring the 20 percent contribution of local non-traded distribution costs to differences in price levels across countries.

3. Search as a Theory of Pricing-to-Market

This section develops a search-driven theory of pricing-to-market, in which firms charge higher prices on average in countries where wages, and hence the opportunity costs of search, are high. Consumers in high-wage countries are less willing to spend time searching for lower prices. The theory produces a positive relationship between prices, wages, and income. We first discuss evidence in support of such a theory and then present a formal model.

A. Corroborating Support for Search

There are a number of reasons to favor the search-based story over a direct preference story in which consumers become less price sensitive with income. First, there is substantial evidence within countries that prices are dispersed and that consumers alter their shopping behavior to take advantage of this dispersion of prices. For instance, Aguiar and Hurst (2006), using scanner data on consumer expenditures and diary data on time use, find that a doubling of shopping time lowers the average purchase price by 7 to 10 percent.[20] Second, within countries there is evidence that shopping effort, measured as time spent shopping per dollar spent, is decreasing in the wage of shoppers. Third, cross country evidence on time-use suggests that low-income countries have a comparative advantage in producing non-traded search services. Fourth, empirically, the evidence from our U.S. export pricing-to-market estimates are consistent with the search story. A final methodological reason is that the search

[19] Engel (1999) attributes approximately 95 percent of *short-run* real exchange rate fluctuations to movements in the relative price of traded goods.

[20] Shopping with uncertainty, either due to the availability of the goods or time of the shopping trip, is isomorphic to a model with no uncertainty over search time but uncertainty over prices.

story offers a true explanation of this relationship, rather than just assuming it through preferences.

Time-Use Evidence

Time-use studies provide evidence that time spent shopping is related to income in a way consistent with the search model. Many studies have examined the relationship between the opportunity cost of time and shopping behavior for consumers within a given economy, i.e., facing a given distribution of prices. For example, McKenzie and Schargrodsky (2005) study the behavior of Argentinian shoppers and find a strong relationship in the cross-section of consumers between consumer search and income. After controlling for quantity purchased, they find that consumers in the 10th percentile of the income distribution spend 30 percent more time shopping than consumers in the 90th percentile. Low-income consumers also visit a greater variety of stores. McKenzie and Schargrodsky also show that the 2002 Argentine economic crisis, which lowered the wages of workers, led to increases in both these measures of consumer search. Still, financial crises presumably affect both income/wealth and the distribution of prices, in addition to the opportunity cost of time. Aguiar and Hurst (2006) have cleaner evidence of the effect of opportunity cost of time. They document an increase in shopping time per purchase experienced upon retirement, which affects the opportunity cost of time, but should not affect the lifetime budget constraint nor the distribution of prices. Both of these studies also find that search effort is negatively related to purchase price. This evidence of dispersion in prices even within countries provides further support for our search story over one based on tastes.

The cross-country time-use data are also consistent with our theory. Since the distribution of prices is not the same over the cross-section of countries, the search story does not (necessarily) imply that consumers in poor countries shop more per unit purchased than consumers in rich countries. (Indeed, in the model, the response of firm pricing behavior exactly cancels out the increased willingness to search in poor countries, and search time per unit is constant across countries. All differences in search effort work through the reservation price consumers are willing to accept.) However, our story hinges on the cost of shopping rising with country income, which requires productivity in the production technology to rise faster than the productivity in the shopping technology. Since income (and purchases) rises faster than shopping productivity, a crucial implication of the theory is that people in rich countries spend more total hours shopping per hour of work than people in poor countries.

In Table 3 we report the relationship between time use and income per capita from two separate cross-country time-use datasets. The first line reports the results from the recently completed European Harmonized Time-Use Survey (EHTUS). The second line reports the results from the Multinational Time-Use Survey (MTUS). In general, cross-country time-use comparisons are difficult owing to definitional and sampling differences. The EHTUS was designed with these comparability issues in mind, while the MTUS is a collection of mostly individual country surveys that have been recoded to be more comparable ex-post. Despite these differences, we find that both surveys generate a similar relationship between the ratio of shopping to work time and income per capita. From the EHTUS we find a 10 percent increase in income per capita generates a 3.4 percent increase in the ratio of shopping to work time (3.2 percent in the MTUS).

Export Pricing Evidence

Two pieces of evidence from the U.S. export data are consistent with the search explanation. First, it is the wage level rather than income per capita that drives the pricing relationship, when both explanatory variables are included. In the search story, the elasticity is driven by the opportunity cost of time (i.e., the wage) rather than non-labor income or differences in income per capita arising from demographic differences. Admittedly, it is possible that the significance of wages could be driven by other factors, such as measurement quality or coverage of the wage data (which is strictly the manufacturing wage).

Second, pricing-to-market is stronger for goods in which search is likely to most important. We measure the importance of search for a good in two dimensions. First, we show pricing-to-market is strongest for consumer goods. After separating the data by their end-use category (1-digit codes), consumer goods have the highest estimated income elasticity at 21.8. The other four categories (we exclude re-exports and "other") are all positive but lower than consumer goods, averaging just 14.9.[21] The opportunity cost of search might also be a consideration to firms in their decisions to search, but

[21] Industrial supplies also have relatively high coefficients (16.8 percent), while large products like capital goods (14.6 percent) and autos (11.3 percent), or products with presumably little market power like food/feeds/beverages (9.1 percent), have smaller elasticities.

we model consumer search, and the story applies most naturally to consumers. Finally, we also find that pricing-to-market is relatively stronger for goods sold in relatively more decentralized transactions. To test the role of search frictions on trade flows, Rauch (1999) classifies goods into three methods of sale:[22] 1) Organized exchange, 2) Reference priced and 3) Differentiated goods. The differentiated category includes all goods not sold on organized exchanges or with reference prices. We should note that the Rauch classification is not absolute, in the sense that each category may include goods sold in all three manners and so we can only say that the organized exchange category contains relatively more goods sold on organized exchanges. Table 4 presents the estimates of pricing-to-market by a good's mode of sale. We find the highest wage elasticity for differentiated goods of 16.0 percent and the lowest for goods sold on organized exchanges of 8.0 percent.

B. Model

There are three imperfectly substitutable goods $i = \{1, 2, 3\}$ and two countries denoted $j = \{1, 2\}$. 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 non-tradables along with tradables allows us to incorporate, and distinguish between, the traditional HBS effect and pricing-to-market.

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. Because search takes time and is imprecise, stores have some monopoly power over consumers and thus may charge different prices for the same good.[23] We assume stores are owned and operated by the firm producing output, but require no additional inputs. We abstract from wholesale, retail, and international trade costs since we found them to be only half as important as pricing-to-market for tradable prices.[24]

[22] The Rauch classification is based strictly on the dominant method of sale for goods within a product category. It is not based on the similarity of goods within a product category and therefore not a measure of quality differences within product categories.

[23] 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 consumers' opportunity cost of search.

[24] In Appendix C we show that our results are robust to the inclusion of a separate retail and distribution sector, where

Households 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 price quotes. The probability that 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 know the distribution of prices in the economy. A shopper from country j looking for good i receives (domestic) price quotes for good i from the known 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 is then

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

From the firm's perspective, noisy search makes the consumers heterogeneous in that some shoppers will have only one price quote, while others will have multiple price quotes. Consumers with multiple price quotes will differ in their second price quote. Since 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 purchase from them.

Consumer's Problem

The consumer's problem is similar to that in Alessandria (2004a). In each country, there are many identical families. Lowercase variables denote individual decision rules and uppercase variables denote aggregate decision rules. Each family is composed of a large number of agents, normalized to a continuum of measure one. The problem of a family is to divide its agents between working and

consumers search among retailers rather than producers.

shopping and to give shoppers instructions on which prices to accept. In country j the number of agents n_{ij} shopping for good i and the number of agents l_j working satisfy the time constraint:

$$(3) \quad \sum_i n_{ij} + l_j = 1,$$

It is optimal to send each agent shopping for good i with a reservation price rule to purchase only if the lowest price quote is below some reservation level, r_{ij}. Consumption of good i by country j consumers depends on both the reservation price and the measure of shoppers. With many shoppers for each good there is no uncertainty in consumption, which equals:

$$(4) \quad c_{ij} = n_{ij} H_{ij}(r_{ij}).$$

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

$$(5) \quad p_{ij}(r_{ij}) = \frac{\int_0^{r_{ij}} p dH_{ij}(p)}{H_{ij}(r_{ij})},$$

which is clearly increasing in reservation price.

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

$$\begin{aligned} U^j &= \max_{\{r_{ij}, c_{ij}\}} U(c_{1j}, c_{2j}, c_{3j}), \\ \text{subject to} &: \begin{cases} \sum_i p_{ij}(r_{ij}) c_{ij} = w_j l_j + \Pi_j, \\ \text{equations (3), (4), (5),} \end{cases} \end{aligned}$$

where U^j is the utility function in country j and Π_j is the profits earned by country j firms.

If an interior solution exists the first-order conditions satisfy:

$$(6) \qquad r_{ij} = \frac{w_j}{H(r_{ij})} + p_{ij}(r_{ij}), \qquad i = 1, 2, 3,$$

$$(7) \qquad \frac{U_1^j}{U_i^j} = \frac{r_{1j}}{r_{ij}}, \qquad i = 2, 3,$$

where U_i^j is the marginal utility of good i.

Equation (6) is an arbitrage condition that implies, at the margin, the family is indifferent between (1) increasing consumption by purchasing at the reservation price, or (2) 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 $1/H(r_{ij})$ shoppers to purchase a single unit. Since the reservation price is linked to the true cost of the good, this is the 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 (7).

We focus on the difference in prices across countries with different incomes and therefore only consider a representative agent in each country. However, it is straightforward to extend the model we present to permit heterogeneity in wages. In this case, we see from equation (6) that within countries, consumers with relatively high wages will have high reservation prices, and search less intensively, than consumers with relatively low wages, consistent with the within-country evidence.

Firm's Problem

There are many firms in each country that specialize in the production of either the country's tradable or non-tradable good. 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 a_j^{NT} units of the non-tradable good (good 3). To focus on international price discrimination, firms can costlessly sell their goods in either country through the pre-established outlets.

To fix ideas, consider the problem of a representative firm in country 1 selling the tradable good (good 1) in country j. A similar problem exists for non-tradable and country 2 firms. Even though many firms produce the same good, the search frictions give each firm some monopoly power and lead firms to behave as monopolistic competitors.[25] Each firm takes as given the distribution of prices charged by other firms selling the same good, G_{1j}, the number of price quotes that it delivers, the reservation price of consumers, R_{1j}, and the unit cost of production, w_1/a_1^T. 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 j solves:

$$\pi_{1j} = \max_p \left(p - \frac{w_1}{a_1^T}\right) Q_{1j}(p),$$

where $Q_{1j}(p)$ is the probability that a firm makes a sale when charging a price p and equals:

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

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

Burdett and Judd (1983) show that given a reservation price, R_{ij}, and cost of production, w_i/a_i^T, a unique distribution of prices exists, $G_{ij}(p)$, where

$$G_{ij}(p) = \begin{cases} 0 & p < \underline{P}_{ij} \\ 1 - \frac{q}{2(1-q)} \frac{R_{ij} - p}{p - w_i/a_i^T} & p \in \left[\underline{P}_{ij}, R_{ij}\right] \\ 1 & p > R_{ij} \end{cases} \quad \text{and} \quad \underline{P}_{ij} = \frac{2(1-q)\, w_i/a_i^T + qR_{ij}}{2-q}$$

Any price on the support of the distribution yields firms the same profits, and firms will randomize. Firms with relatively high prices primarily sell to those consumers with a single price quote, while

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

those with relatively low prices attract more of those shoppers with multiple price quotes.

Equilibrium

The total demand for labor by firms producing tradables and non-tradables in country j are L_j^T and L_j^{NT}, respectively. The labor market clearing condition is:

$$L_j^T + L_j^{NT} = \frac{N_{j1} + N_{j2}}{a_j^T} + \frac{N_{3j}}{a_j^{NT}} = L_j$$

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 (2004a) 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.[26] 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 of the shopper. This equals the reservation price:

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

We focus only on the average transacted price (which equals the unit value), since this most closely corresponds to the measure used by the national statistical agencies and in our empirical work. By substituting the equilibrium reservation price into the distribution of prices, we can solve for the

[26] 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.

average price for tradables of good i (from country i) and non-tradables sold in country j as:

$$(8) \quad p_{ij} = \frac{w_i}{a_i^T} + \frac{qw_j}{1-q}.$$

$$(9) \quad p_{3j} = \frac{w_j}{a_j^{NT}} + \frac{qw_j}{1-q}.$$

The average price for good i paid by a consumer in country j is equal to a markup over the marginal cost of the firm from country i. The markup depends on both the information structure of search (summarized by q) and the time cost of search w_j. Holding q constant, agents in a country with a low wage will, on average, pay 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.[27]

4. Results

This section evaluates the explanatory power of the model. We first show that the model generates large deviations from the LOP even when productivity differences across countries are the same in tradables and non-tradables. Moreover, we find that our model closely matches the observed relationship between wages and tradable prices. We then examine the importance of pricing-to-market relative to the traditional HBS effect arising from productivity differences that are biased toward tradables.

Given a relative productivity of tradables vs. income relationship that matches the U.S. time series evidence, we find that the model explains 57 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 32 percent.

[27] Equation (8) also points out the difference 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 non-traded input, such as wholesale or retail distribution, to get the good to the final consumer. In our model of pricing-to-market, the search cost is similar to the non-traded retail or distribution costs in HBS. Unlike in HBS, this search cost is borne by the consumer and through the search frictions it is incorporated into the price charged at the border.

A. Calibration

Preferences are consistent with the standard textbook presentation of the HBS model (see Obstfeld and Rogoff 1996). Agents in each country have the following symmetric utility function:

$$U^j = u\left(c_{1j}, c_{2j}, c_{3j}\right) = \left(c_{1j}^{\rho} + c_{2j}^{\rho}\right)^{\frac{\alpha}{\rho}} c_{3j}^{1-\alpha}.$$

Preferences over tradables and non-tradables are Cobb-Douglas.[28] Home and foreign tradables are often assumed to be perfect substitutes. We depart slightly from this case and set $\rho = 0.99$.[29]

The size of the tradable sector is set to match the median trade share of GDP of those OECD countries for which re-exports are not large[30] and for which we have manufacturing wage data from the BLS. The median country[31] imports and exports approximately one-third of GDP in 2000 and so we set $\alpha = 2/3$ and non-tradables account for one-third of output.[32] The openness of a country affects the weight we put on the HBS channel but does not substantially change the amount of pricing-to-market. We report sensitivity to the trade share.

The production side of the economy is calibrated as a symmetric two-country model to match certain features of the U.S. economy. The production parameters are the search, q, and market goods, a^T, productivities. For our baseline case, we assume that tradable and non-tradable technologies are identical,[33] so that $a_j^T = a_j^{NT} = \bar{a}$. Since productivity in market shopping is 1 (each shopper can purchase one unit), $\bar{a}$ captures the relative productivity of market production to shopping. In equilibrium, since all produced goods are purchased: $\bar{a} = \frac{N}{L}$, the ratio of shopping time to market labor. The American Time-Use Study (2003) reports that the average American spends about 4 times as much

[28] The assumption of a unitary elasticity of substition between tradables and non-tradables is consistent with the estimate of 1.24 by Ostry and Reinhart (1991) for a group of developing countries and Mendoza's (1995) estimate of 0.74 for a group of industrialized countries.

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

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

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

[32] 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.

[33] The model is calibrated to the typical good. A more general model would allow for goods to vary in both the noisy search parameter and the time it takes per purchase, while holding these parameters constant across countries.

time working as purchasing goods and services, so $\bar{a} = 1/4$. The labor's share parameter[34] θ is set to 60 percent of total income (Cooley and Prescott 1996), and this pins down $q = 0.727$. In all of our experiments, we hold this noisy search parameter constant across countries but allow tradable and non-tradable productivity to vary.[35]

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, one country is the U.S., and the second country is a PWT benchmark country. Productivity in the second country is chosen to match income per capita relative to the U.S. In this way, we match the world income distribution and have synthetic price data for 115 artificial economies.

With two symmetric countries, our calibration implies an average markup over marginal cost of 66 percent. However, because exporters reduce their markup to low-income countries, in the asymmetric version of the model, the average markup of firms from the richest country is only 60 percent, and 40 percent on average across the 115 countries. Markups are notoriously difficult to measure, yet this level of monopoly power is consistent with those found in structural IO studies of the ready-to-eat cereals market (Nevo 2001), the U.S. minivan market and U.S. automobile market (Berry, Levinsohn and Pakes, 1995, and Goldberg, 1995). Moreover, our pricing-to-market evidence finds on average there is a 40 percent price difference for the same goods between the richest and poorest countries. Such price variation is only possible if markups are of this size.

We start by assuming that the productivity gap between countries is the same in both sectors. This is our *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, 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 cross-country evidence of this gap. Studies that do measure this gap across countries assume that the LOP holds for traded

[34] From the market clearing and income constraint $q = \frac{(1-\theta)}{\theta\bar{a}+(1-\theta)}$, where θ is labor's share of income. Since $q > 0$ is the source of market power, it helps determine $(1-\theta)$, the share of income that goes to profits. In a more general model with capital, this would equal the share of income that covers fixed costs.

[35] The choice of q will determine the markup and will influence the slope of the price-income relation across countries. However, q is calibrated independently of its implications for the slope.

goods and use relative prices to infer productivity differences.[36]

Rather than use our theory to construct relative productivity differences, we consider the evidence on the relationship between income and productivity in tradables and non-tradables, respectively, in the U.S. time series. Jorgenson and Stiroh (2000) estimate labor productivity growth by industry for the U.S. from 1958 to 1996. We classify these industries into tradable and non-tradable sectors and then construct a measure of the productivity gap using each industry's share of sectoral value-added. These weighted averages, along with simple averages, of TFP and labor productivity growth rates[37] are reported in Table 5. We find that non-tradable labor productivity has grown about two-thirds as fast as tradable labor productivity. 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. We also test the sensitivity to the relative size of this gap. For reference, we also present results from the standard HBS model with no pricing-to-market.[38] The parameters for the various models are reported in Table 6.

Prices and income are measured consistently with the empirical data and statistics computed in Section 2. Deviations from the LOP are measured as the log average price of U.S. exports to destination j, or $\ln LOP_j = \ln\left(P_{US,j}/P_{US,US}\right)$. To measure income, we follow the convention of the Penn World Tables and compute nominal GDP, Y_j, as the sum of expenditures of domestic production. The aggregate price level, P_j, is measured using the welfare-based price index.[39] Real income, y_j, is nominal GDP deflated by the price index P_j (i.e., $y_j = Y_j/P_j$).

With these measures of real income and prices, we estimate statistics that correspond to our empirical results.[40] All results are presented in Table 7. The table's top panel presents our elasticity

[36] For instance, Hsieh and Klenow (2007) 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 (2006) find that the productivity difference in tradables must be nearly 12 times larger than those in non-tradables.

[37] We follow Canzoneri et al. (1999) and focus on labor productivity. What really matters for the HBS effect is the change in the marginal product of labor across sectors. For a broad range of production functions this is proportional to the change in average labor productivity. In contrast, measuring TFP growth depends on the assumed structure of the production function and requires measures of capital stocks and materials usage.

[38] Our model converges to the HBS model as $q \to 0$ and a becomes large.

[39] 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.

[40] We compute a single price for each country and then estimate our statistics from the synthetic sample of countries

estimates from various versions of the model. The bottom panel decomposes each model's price-income relation into its main components. The column titled *Data* summarizes our estimates of the price-income relationship from the PWT tables (ε_{PPP} and $\varepsilon_{N/T}$) and the U.S. export data (ε_{LOP} and ε_w), plus evidence from the time-use surveys $\left(\varepsilon_{shop/work}\right)$.

B. Balanced Technology Gap

In the balanced technology case, the productivity gap across countries is the same in both sectors, $a_1^T/a_j^T = a_1^{NT}/a_j^{NT}$. These cross-country productivity differences generate differences in wages, income and prices. In equilibrium, this generates higher prices for all goods, tradable and non-tradable, in higher wage/income countries. With tradables accounting for two-thirds of expenditures, the model generates quantitatively important elasticities of deviations from the LOP (11.4) and violations of absolute PPP (10.7). Thus, our model can account for 67 percent of the deviations from the LOP and almost 25 percent of the violations of PPP associated with income levels.[41] Moreover, the elasticity of deviations from the LOP with respect to wages in the model is only slightly less than in the data (11.5 vs. 16.2).

C. Biased Technology Gap

The column titled *Benchmark* in Table 7 reports the properties of the model when the relative productivity of the tradable sector rises with income as in the Jorgensen-Stiroh data. With a biased productivity gap across countries, the model accounts for 57 percent of the violations of PPP with income. The traditional HBS effect accounts for 32 percent of the price-income relationship, while pricing-to-market accounts for 25 percent. Pricing-to-market is quite similar to the balanced

running the same regressions we ran in the empirical section.

[41] The difference between ε_{LOP} and ε_{PPP} is due to a small terms of trade effect since tradables are close, but not, perfect substitutes. The low supply of goods from a poor country moves the terms of trade in its favor, which then implies wage differences are smaller than productivity differences, and therefore the higher income country has a lower production cost. The absolute level of markups is based on local shopping costs and therefore fixed within any market (recall equation (8)) which means that lower cost producers charge higher *proportional* markups. With higher markups, firms from rich countries have more room to lower their export price and hence do more pricing-to-market. To match the export data, we measure ε_{LOP} export prices from the higher income country. The terms of trade also affect the relative price of non-traded to traded goods. The price of non-tradables will actually fall with income, since they are locally produced and production costs are lower in richer countries.

productivity case.[42]

For comparison, in the column titled *HBS standard model*, the HBS model generates only 28 percent of the price-income relationship. Thus, given the observed productivity bias in the time-series data, the HBS model alone explains little of the PPP-income relationship. Our benchmark pricing-to-market model exhibits a slightly stronger HBS effect because it generates larger wage differences than income difference across countries. This occurs because higher market productivity raises consumption, which leads to more shopping time and less market labor. As income rises, the ratio of shopping to work time rises faster in our model than the point estimate in the data (0.968 vs. 0.330). Both models generate movements in the relative price of non-traded to traded goods with income that are only slightly higher than the data.

D. Sensitivity

We now consider a few modifications of the model. In particular, we consider the role of the share of tradables, productivity bias, labor share of income, and shopping technology for our results.[43] Except where noted, the model is parameterized as in the benchmark case of the biased productivity gap.

Share of Tradables

Figure 3 plots the relationship between the share of tradables and both pricing-to-market and violations of PPP with balanced productivity. The effect of varying the share of tradables is minor. This is because pricing-to-market affects all goods, traded and non-traded, in the same way. Thus, the tradables share only affects pricing-to-market through its influence on the terms of trade and in turn

[42] Compared to the balanced productivity case, now there is slightly less pricing-to-market, with a larger decline in ε_w. The lower coefficients are a combination of economic forces and our statistical methods. With biased productivity differences, cross-country wage differences exceed income differences, and so the price differences between the richest and poorest countries are larger than with the balanced productivity case. This increases the estimate of ε_{LOP}, holding pricing-to-market on wages constant. But pricing-to-market on wages actually declines because for the poorest countries, which have lower wages than in the balanced case, firms are already charging close to marginal cost and can go no lower. That pricing-to-market with respect to wages tends to flatten out for low-wage/income countries implies that the model is non-linear and with our linear estimatation this shows up as a lower coefficient on ε_{LOP}.

[43] We also explored varying the elasticity of substitution between tradables and non-tradables as well as the elasticity of substitution across tradables. Varying these elasticities primarily affected estimates of $\varepsilon_{N/T}$, but had very little impact on ε_{LOP} or ε_w. We also explored changing the level of shopping time per purchase equally across countries and this had a very minor impact on our estimates.

the relative wage. However, with highly substitutable goods this effect is small.

When the productivity gap is biased, the tradables share has a large effect on the size of violations from PPP. With a smaller share of tradables, non-traded goods receive a larger weight in prices. In Table 7, the column titled *Low Trade* reports the results of the benchmark model with a trade share of 29.5 percent. This is the necessary tradables share for the benchmark model to generate the same violations from PPP as in the data. This lower share of tradables 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 tradables share of $\alpha = 0.108$ in the column titled *HBS Low Trade*. This is the level of trade consistent with the aggregate price-income relationship in the standard HBS model. This tradables share generates trade flows that are only 15 percent of those in the data and requires larger differences in the relative price of tradables to non-tradables than in the PWT data (0.48 vs. 0.35).

Biased Productivity

Figure 4 plots our measures of elasticities against the extent of comparative advantage in non-tradables (i.e., the ratio of relative non-tradable productivities to relative tradable productivities), which we denote as $g_{N/T} = \ln\left(a_1^{NT}/a_2^{NT}\right)/\ln\left(a_1^{T}/a_2^{T}\right)$. When $g_{N/T} = 0$, technological differences are completely concentrated in the tradables 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 4 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, 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, firms face a lower bound on price in their pricing-to-market decision, since they will never charge below marginal cost. Thus, pricing-to-market is somewhat non-linear. Among relatively high-wage countries, firms will vary prices with their customers' 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. Second, with a biased productivity gap, relative wage 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.

From Figure 4, we see that for the model without pricing-to-market to account for the violations from PPP, the productivity gap in tradables must be ten times the productivity gap in non-tradables, or about 6.6 times larger than in the U.S. time series data.

Labor Share

We now consider the effect of the labor share on the model's predictions. In Table 7, the column titled *Low Labor* reports the results of the model with a labor share of 50 percent. In this case, there are larger violations of PPP and these are entirely due to an increase in pricing-to-market. The 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 since firms will never price below marginal cost. With higher markups, the model now accounts for 86 percent of the tradable price-income relationship and 93 percent of the tradable price-wage relationship.

Search Time

Our model relies on relative productivity differences in shopping to be smaller than in market production. As we have seen already, there is some evidence of this from the time-use surveys, but not to the extent we have assumed in the model. To make the model consistent with the time-use data, we now allow the amount purchased per shopping trip to vary across countries with tradable productivity. We assume consumers in country j can purchase κ_j units per shopping trip, and let differences in κ_j

be proportional to the differences in the tradable technology.[44] To match the elasticity of shopping to work time, the model requires the productivity gap in shopping to be 53 percent of the productivity gap in tradables, so that lower income countries continue to have a comparative advantage in shopping.

The column titled *Variable Shopping* reports the results of this modification. The estimates are quite similar to the benchmark model for two reasons. First, because there is less substitution of work for shopping, the model can match the income distribution with smaller wage differences. This tends to weaken the HBS effect. Second, the increased shopping time of lower income countries means that differences in search costs are smaller for a given difference in wages compared to the benchmark model. This leads firms to do less pricing-to-market among richer countries, but also allows them to do more pricing-to-market among poorer countries.[45] The net effect is a higher estimate of ε_{LOP} that counteracts the lower HBS effect, leading to a very small change in the aggregate price-income relationship.

E. Relative Prices and Relative Wages

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. Rather than match the distribution of income per capita, we recalibrate technology 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 generate an elasticity of price levels with respect to wages, which we denote ε_w^{PPP} equal to 0.4. The model generates $\varepsilon_w^{PPP} = 0.30$ and thus can explain nearly 75 percent of the relationship between prices and wages. We find that pricing-to-market is the largest source of the price-wage relationship, since it accounts for 50 percent and the HBS effect accounts for 25 percent. The stronger

[44] As before, we normalize the units per purchase in our base country to be $\kappa = 1$.

[45] This result may seem perverse but is largely due to estimating a linear model on non-linear data. If we plotted the distribution of prices against income in the benchmark model and the variable shopping model, we would find that for each income level the variable search model generates higher prices. However, the variable search model generates an almost linear relationship between income and prices, while the benchmark model generates a non-linear relationship.

pricing-to-market relationship that we find with wages is consistent with our empirical result, in which wages seem to drive the pricing-to-market.[46]

5. Conclusions

Using highly disaggregated data on U.S. exports at the border, we find strong empirical evidence that pricing-to-market accounts for most of the long-run differences in tradable prices across countries. These tradable price differences are an important source of the deviations from absolute PPP, accounting for about 40 percent of the relation between aggregate price levels and income per capita in the data. This is in stark contrast to the conventional view that deviations from absolute PPP are solely due to differences in non-traded goods prices.

Our empirical work suggests that consumers in low-income countries are more price sensitive than consumers in high-income countries. We develop a model with this type of pricing-to-market based on international productivity differences and search frictions. Similar to HBS, our model relies on low-income countries having a comparative advantage in producing non-traded goods. Unlike HBS, these non-traded goods are shopping activities that affect the prices of all goods purchased. Our model generates a role for local wages in the price-setting behavior of firms and is consistent with cross-country differences in shopping activities. The model is also consistent with two features of our data analysis suggesting an important role for search frictions. First, contrary to previous work, we find that wages have substantially more explanatory power for pricing-to-market than income per capita. Second, pricing-to-market appears strongest for those goods for which search frictions are likely to be most important, consumer goods and goods sold in decentralized transactions. This evidence is also consistent with the within-country evidence that consumers can use search to lower their average purchase price.

Naturally, other factors may contribute to the pricing relation we have found, so further empirical work on this topic is necessary. Nevertheless, ours is, to the best of our knowledge, the first investigation to document an important role empirically and theoretically for tradable prices and absolute PPP. It

[46] Of course, it is also true that since wages are our main focus, this may be due to our rather simplistic modeling of income, which ignored leisure decisions, capital income, etc.

is typically assumed in theoretical and empirical work that the law of one price holds for tradables. We have shown that such an assumption may drastically overstate the differences in productivity across sectors across countries and is important for understanding the source of income differences as well.

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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 - Details of Quality and Related Party Trade Analysis

Quality

To formalize the quality 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:

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

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[47] trade-weighted averages of the prices of j heterogeneous goods:

$$(10) \quad P_{ik}^{N} = \prod\nolimits_{j} \left(P_{ijk}^{N+1}\right)^{q_{ijk}}$$

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

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

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 $\beta = 0$. In practice, our estimates of $\hat{\beta}$ decrease with aggregation, as shown in Table 2, indicating that the quality bias is negative. Low -income countries tend to purchase relatively high-quality goods. The table below gives an example of the aggregation of categories in practice.

[47] 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.

Related Party Trade and Transfer Pricing

We ran regressions using the interaction between the intensity of related party trade and the corporate tax rate as a right-hand-side variable. If corporate tax rates in the destination country are high (relative to the U.S.), then prices should also be high in order to lower profits earned in the destination country. But this effect should be stronger, the more important related party trade is. The transfer pricing argument predicts that the coefficient on this variable should be positive. Finally, if transfer pricing is driving the results, then inclusion of this variable ought to dramatically reduce our pricing-to-market estimates.

Using the industry-specific related party trade measure RPT_i as an example, the regression equation is:

$$\begin{aligned} \ln p_{ijt} &= \tilde{\alpha}_{it} + \tilde{\beta} \ln y_{ijt} + \gamma(\tau_{j,t} - \tau_{US,t}) + \delta(\tau_{j,t} - \tau_{US,t}) RPT_i + \tilde{e}_{ijt} \\ &= [\tilde{\alpha}_{it} - \gamma \tau_{US,t}] + \tilde{\beta} \ln y_{ijt} + \gamma \tau_{j,t} - \delta \tau_{US,t} RPT_i + \delta \tau_{j,t} RPT_i + \tilde{e}_{ijt} \end{aligned}$$

The tildas distinguish the fixed effect and income parameters from those in the simpler regression equation (1). The fixed effect now captures both $\tilde{\alpha}_{it}$ and the $\gamma \tau_{US,t}$, which is independent of the destination market. The third term captures the broad effect of the corporate tax rate in the destination market, while time dummies interacted with related party trade capture the fourth term without identifying δ. The δ coefficient is instead identified by the interaction of corporate tax rates and related party trade, and the theory would predict $\delta > 0$. When we control for related party trade by country, the RPT_i is replaced by the country-specific measure $RPT_{j.}$ The available sample changes slightly based on whether we use RPT_i (industry-specific) or RPT_j (country-specific). We keep the samples constant, however, when comparing the results that include the controls to the results that exclude them.

The industry-specific measure of related party trade produces estimates of $\hat{\delta}$ that are negligible and not significantly different from zero. The country-specific measure produces an estimate of -0.008 and is significant, but the magnitude is small and actually perverse. More important, using both measures, the size of the price-wage elasticity does not fall with inclusion of these controls, but actually rises slightly. After controlling with the industry-specific measure of RPT, $\tilde{\beta}$ increases from 0.179 to 0.193 for wages and 0.174 to 0.184 for real income per capita. Using the country-specific measure requires using a slightly different sample because of data availability. Inclusion of this control increases $\tilde{\beta}$ from 0.175 to 0.207 for wages and 0.194 to 0.249 for real income per capita. Thus, transfer pricing does not appear to be driving the results.

Appendix B1:
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 10 digits. In the random sample of five 5-digit groups chosen, none of the goods were unique up to 10 digits in the Harmonized System Code.

Appendix $C-$ Retail and Wholesale Distribution

Assume there is a combined retail and wholesale distribution sector that purchases goods from manufacturers, combines them with labor and then sells the modified product to searching consumers. We show that 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

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

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. [48]

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 relationships 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 no 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 1 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 1 With respect to wages, the elasticity of:

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 $q < \frac{(1-\theta)(1+\tau_D)}{(1+(1-\theta)\tau_D)}$.

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 important, because the producer has some market power it considers how its price affects the reservation price of the consumer.

[48] 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.

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 1

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.

Figure 3: Price Elasticities and Tradable Share

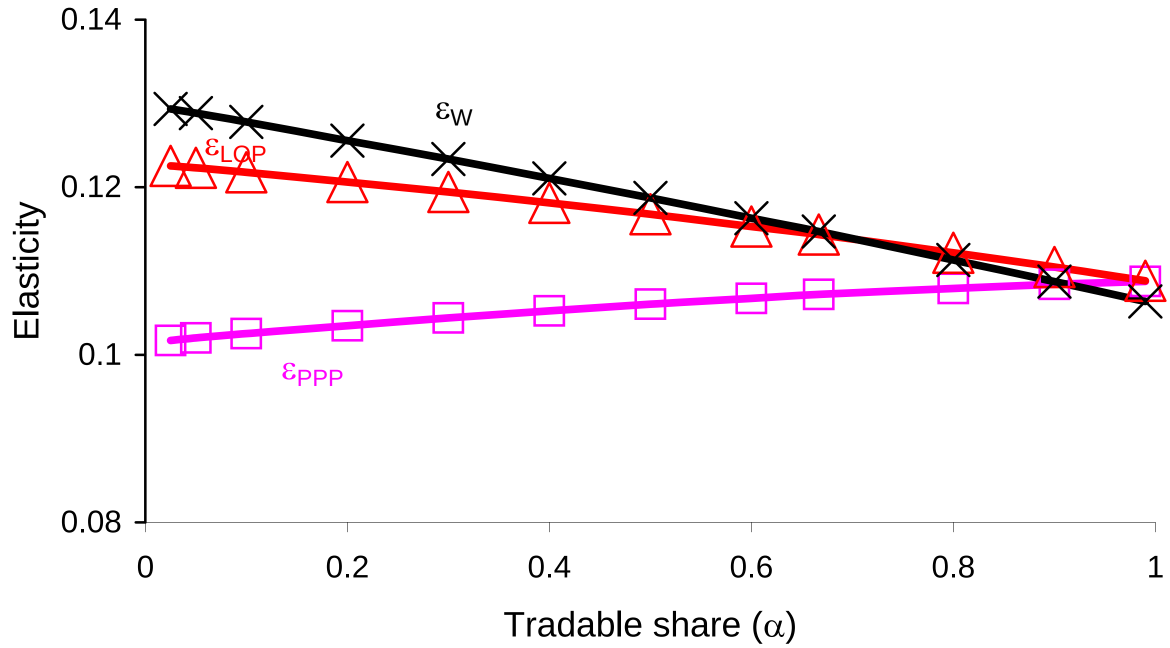

Figure 4: Price Elasticities & Productivity Gap

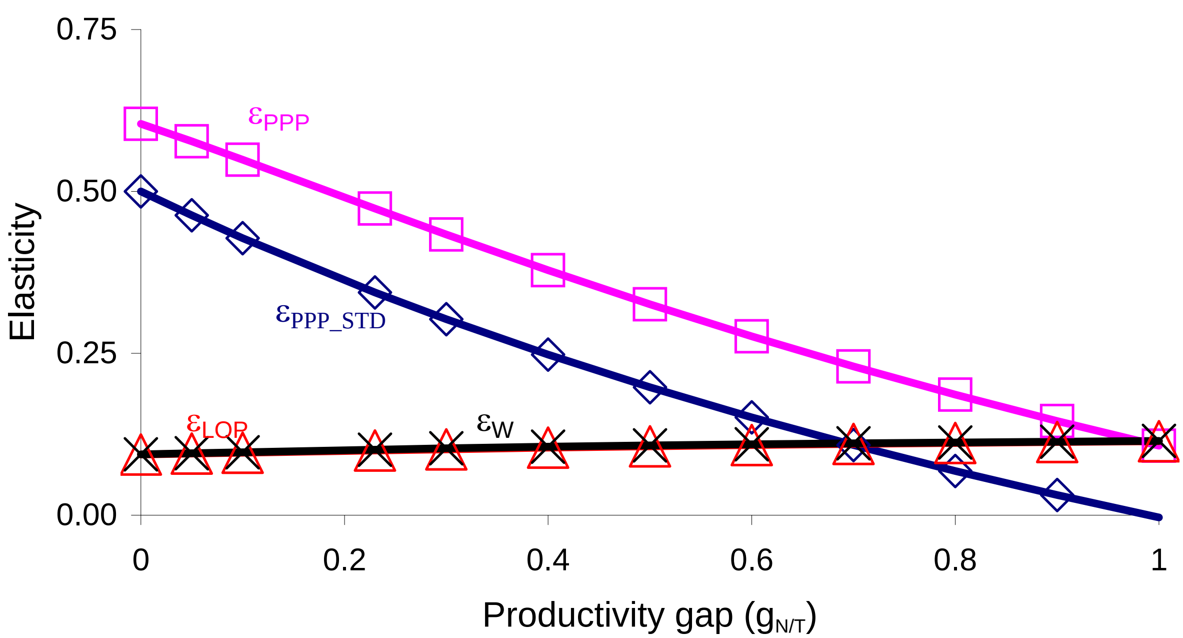

Figure 5: Relative Prices and Wages

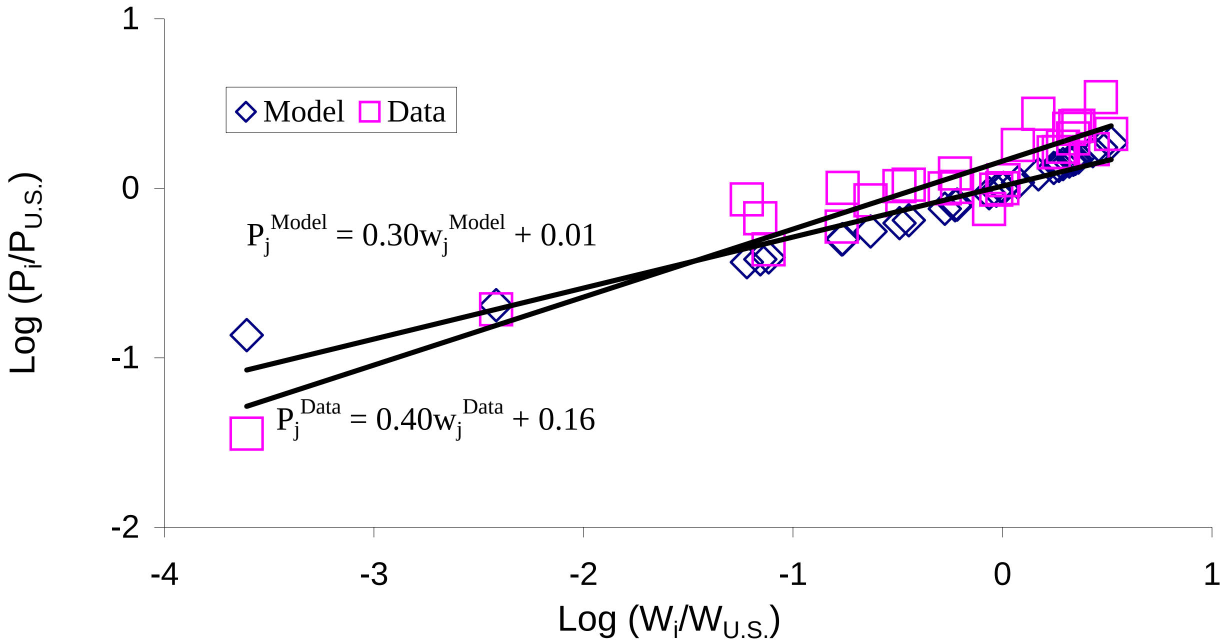

Table 1: Coefficients from Commodity-Year Fixed-effects Regressions of Log Prices on Log real GDP per capita and/or Log Wages (t-statistics in parentheses)*

Coefficient	Share of US Exports (Value)	GDP per Capita only	Wage Only	Both together
Log GDP per capita	0.78	0.170 (3.7)	-	0.012 (0.4)
Log Wage		-	0.162 (5.6)	0.156 (7.3)
Homogenous Sample**				
Log GDP per capita	0.46	0.165 (3.8)	-	0.028 (1.0)
Log Wage		-	0.150 (5.4)	0.135 (7.0)

* t-statistics are based on country-year clustered White robust standard errors. ** Homogenous sample drops goods with descriptions "other,""not elsewhere specified or included," "NESOI," and "parts."

Table 2: Effect of Quality Aggregation on Coefficients from Regressions of Log Prices on Log Wages (t-statistics in parentheses)

	Number of Commodity Groups	Number of Observations	Coefficient
Combined at the 9-Digit Level			
Individual (10-Digit) Commodities	878	77,930	0.187 (6.3)
Aggregated (9-Digit) Commodities	349	51,020	0.158 (4.9)
Combined at the 7-Digit Level			
Individual (10-Digit) Commodities	4,212	481,669	0.152 (5.5)
Aggregated (7-Digit) Commodities	1,156	220,535	0.113 (3.6)
Combined at the 5-Digit Level			
Individual (10-Digit) Commodities	7,388	901,660	0.163 (5.7)
Aggregated (5-Digit) Commodities	1,491	336,432	0.130 (4.1)

Table 3: Coefficient from Regression of Log Time Use on Log GDP per capita
(t-statistics in parentheses)

Group	Observations	Shop/Work Time	Work Time*	Shop Time**
EHTUS	15	0.337 (2.77)	-0.139 (-1.97)	0.198 (2.83)
MTUS	48	0.321 (4.28)	-0.112 (-2.73)	0.208 (3.10)

EHTUS countries: Belgium, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, Norway, Poland, Slovenia, Spain, Sweden, U.K. and sample is 20 to 74 year olds.

MTUS countries: Canada (71, 81, 86, 92, 98), Denmark (64, 87) France (65, 74, 98), Netherlands (75, 80, 85, 90, 95, 00), Norway (71, 81, 90, 00), U.K. (61, 75,83, 87, 95,00), USA (65, 75, 85, 92, 98, 03), Hungary (65, 77), West Germany (65), Poland (65), Belgium (65), Bulgaria (88), Czechslovakia (65), East Germany (65), Yugoslavia (65), Italy (80, 89), Australia (74), Israel (92), Germany (92), Austria (92), S. Africa (00), Slovenia (00) and the sample is 20 to 59 year olds.

* EHTUS work time is measured as paid work in primary and secondary employment. MTUS work time is measured as paid work in first and second job plus paid work at home.

** Shop time is measured as time shopping and receiving personal services plus time travelling to shopping.

Table 4: Coefficients from Commodity-Year Fixed-effects Regressions of Log Prices on Log Wages by Rauch Industry Classification (t-statistics in parentheses)*

Coefficient	Organized Exchange	Reference Priced	Differentiated
Log Wage	0.080 (3.3)	0.135 (4.5)	0.160 (5.3)

* t-statistics are based on country-year clustered White robust standard errors.

Table 5: U.S. Sectoral Productivity Growth (1958-96)

	Average Growth		**Weighted Avg* Growth**	
	TFP	Labor Productivity	TFP	Labor Productivity
Tradables	0.56	1.85	0.67	2.07
Non-Tradables	0.27	1.60	0.26	1.41
Ratio ($g_{N/T}$)	0.48	0.87	0.38	0.68

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; Other Transportation Equipment; Stone, Clay and Glass.

Non-tradables include: Construction; Transport and Warehouse; Communications; Electric Utilities; Gas Utilities; Trade; FIRE; Services.

*The weighted measure weights productivity growth in each sector by its average annual share of value added in either the tradable or non-tradable sector. The productivity data is reported in Jorgenson and Stiroh (2000). Total Factor Productivity Growth (TFP) is measured as a residual using materials, capital stocks, and labor used plus their expenditure shares.

Benchmark Model	
Technology	$\bar{a} = 4, q = 0.727, \ln \frac{a_j^{NT}}{\bar{a}} / \ln \frac{a_j^T}{\bar{a}} = 2/3,$
Preferences	$\alpha = 2/3, \rho = 0.99$
Variations	
Balanced	$\frac{a_j^{NT}}{\bar{a}} / \frac{a_j^T}{\bar{a}} = 1$
Low Trade Share	$\alpha = 0.295$
Low Labor Share	$\bar{a} = 4, q = 0.8, \alpha = 2/3$
Vary Shop	$\frac{\kappa_j^{NT}}{\bar{\kappa}} / \frac{a_j^T}{\bar{a}} = 0.53$
HBS	$q = 0.00005, \bar{a} = 4$
Standard	$\alpha = 2/3$
Low Trade	$\alpha = 0.108$
Measurement	
Nominal Income	$Y_j = P_{j1}(R_{j1}) N_{j1} + P_{j2}(R_{j2}) N_{j2} + P_{3j}(R_{3j}) N_{3j}$
Aggregate Prices	$P_j = \left(\frac{P_j^T}{\alpha}\right)^{\alpha} \left(\frac{P_{3j}}{1-\alpha}\right)^{1-\alpha}, \; P_j^T = \left(P_{1j}^{\frac{\rho}{\rho-1}} + P_{2j}^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}.$
Empirical structure	
	$\ln P_j = \varepsilon_{PPP} \ln y_j + e_j$
	$\ln LOP_j = \varepsilon_{LOP} \ln y_j + e_j.$
	$\ln LOP_j = \varepsilon_w \ln w_j + e_j,$
	$\ln P_j^{NT}/P_j^T = \varepsilon_{N/T} \ln y_j + e_j$

Table 6: Parameter Values

Table 7: Model Results

			Variations on Biased Productivity Economies					
			PTM Model				HBS Model	
A. Elasticity*	Data	Balanced PTM	Benchmark	Low Labor share = 1/2	Variable Shopping	Low Trade α=0.295	Standard	Low Trade α=0.108
ε_{PPP}	0.430	0.107	0.245	0.283	0.232	0.430	0.128	0.430
ε_{LOP}	0.170	0.114	0.109	0.147	0.117	0.110	0.000	0.000
ε_{w}	0.162	0.115	0.111	0.151	0.115	0.115	0.000	0.000
$\varepsilon_{N/T}$	0.353	-0.022	0.406	0.410	0.345	0.453	0.384	0.482
$\varepsilon_{shop/work}$	0.330	1.041	0.968	0.962	0.332	0.987	0.988	1.024
B. Accounting for violations from PPP								
Fraction of ε_{PPP}		24.9%	56.9%	65.9%	54.0%	100%	29.7%	100%
Fraction from PTM		26.6%	25.5%	34.1%	27.2%	25.7%	0.0%	0.0%
Fraction from HBS		-1.7%	31.5%	31.8%	26.8%	74.3%	29.7%	100%

*ε_{PPP} and $\varepsilon_{N/T}$ 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 but consumers do shop for goods. Low labor share is the Benchmark economy with labor share of income of 1/2. The Vary Shop economy is one in which the shopping technology improves along with the tradable technology. The Low Trade Share economy is the Benchmark economy with a lower tradable share of 0.295. The HBS Low Trade is the HBS model with a low trade share of 0.108.