Demand Complementarities and Cross-Country Price Differences*

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November 20, 2014

Abstract: This paper presents a two-country model in which consumers’ utility from tradable goods depends on their consumption of complementary goods and services. The model is consistent with the stylized fact that markups are higher in rich countries: In countries with more complementary goods and services consumer demand is less elastic, enabling monopolistically competitive firms to charge higher prices. The paper provides empirical evidence supporting the notion that demand complementarities leads to high prices in rich countries, conditional on the dependence of prices on alternative mechanisms associated with pricing-to-market. The paper explores additional implications for prices of nontradable services and aggregate price indices.

JEL: E31, F12, L11
Keywords: real exchange rates, demand complementarity

* I am grateful to Jagadeesh Sivadasan and Michael Olabisi for sharing the Chinese export data. Thanks also to Raphael Auer, Alan Deardorff, Jonathan Eaton, Yuriy Gorodnichenko, Gordon Hanson, Andrei Levchenko, Lutz Kilian, Pravin Krishna, Bill Lincoln, Andrew McCallum, Philip Sauré, Ina Simonovska, Martin Strieborny, Carlos Vegh, Frank Warnock, Jing Zhang, and seminar participants at Michigan, Dartmouth, Virginia, Federal Reserve Board, Miami, UCSD, UBC, SAIS, and Penn State for helpful comments and discussions.

This paper was previously circulated under the title, “Why are Goods and Services more Expensive in Rich Countries? Demand Complementarities and Cross Country Prices Differences.”

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1. Introduction
The determinants of real exchange rates are a central focus in international economics. While traditional explanations of cross-country price differences are based on cost differences under the assumption that the law of one price holds (e.g. Balassa 1964, Samuelson 1964, Crucini, Telmer, and Zacharides 2005), evidence indicates a strong role for markups of tradable goods that differ by characteristics specific to the destination countries (e.g. Engel and Rodgers 1996; Gopinath, Gourinchas, Hsieh, and Li 2011; Fitzgerald and Haller 2012; Dvir and Strasser 2014). Recent studies of disaggregate data on tradable goods have documented a pattern in the level of markups across countries. For example, Alessandria and Kaboski (2011) find that rich countries pay more for goods leaving U.S. docks, and Simonovska (2013) documents that an online apparel retailer charges higher markups to consumers in rich countries than to consumers in poor countries. In these studies, failure of the law of one price is due to firms charging higher markups to countries with high per-capita incomes.

If high markups in rich countries are behind failures of the law of one price, an open question is why these high markups occur. Understanding the nature of differences in real exchange rates is important for understanding causes of cross-country and sectoral differences in productivity and investment rates (Hsieh and Klenow 2007), and for precisely measuring country-level price indices. I propose a new explanation for high markups in rich countries based on high (and inelastic) demand in rich countries arising from high consumption of goods and services that complement demand for tradable goods.

That demand for one good depends on the availability of another is quite natural. Home entertainment systems can provide substantial utility in a country with reliable access to electricity, but would provide much less utility in a land without reliable electricity. A brand new sedan provides more utility in a country with well-paved roads than in a country with dirt roads. Consumers without electricity (or well-paved roads) get less utility from entertainment systems (or fancy sedans) and thus have lower, more elastic demand for such products.

Many types of goods and services may complement demand for differentiated consumer goods (and differentiated consumer goods could complement demand for each other). To

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1 The underlying causes of real exchange rates also have important implications for trade flows, patterns of competitive advantage, and cross-country differences in income. For example, Krugman (1980) illustrates how preferences determine the location of production, and Krugman and Venables (1995) demonstrate how local demand generates production externalities and income.
distinguish the complementary goods from the consumer goods in the analysis below, I refer to these complementary goods and services as catalyst goods. Often catalyst goods will be durables, such as housing or public infrastructure, but they may also be services or intangibles, such as public safety, other consumer goods, or advertising. The concept of a catalyst captures the notion that some goods and services facilitate consumers’ derivation of utility from other final goods and services. The notion of catalysts is similar to the notion of consumer demand proposed by Lancaster (1966), who suggests that goods and services are not direct objects of utility themselves but rather contain properties and characteristics that consumers combine to generate utility.

Below I embed demand complementarity and pricing-to-market in a two-country general equilibrium model that builds on a class of utility functions that yield demand curves with nonconstant price elasticities of demand. The model features demand complementarity between catalyst goods and differentiated final consumption goods. Specifically, the intercept of the demand curve for a differentiated final good depends on the level of consumption of catalyst goods. In equilibrium, the rich country consumes more catalyst goods and pays more for tradable goods.

The theoretical dependence of prices on catalysts is robust to a wide class of models that deviate from the common CES utility function, but it is nonetheless informative to examine whether support for the theory can be found in the data. A common approach in the literature on differences in tradable prices is to infer a mechanism’s relevance on the basis of a general equilibrium model and data on markup differences (e.g. Alessandria and Kaboski 2011; Simonovska 2014). In the empirical section I propose a direct test of the demand complementarities mechanism. Identification of the mechanism is based on the assumption that some catalysts (e.g. electricity access) exhibit stronger complementarity with some tradable goods (e.g. electric goods) than with others. The demand complementarity hypothesis predicts that prices of complemented tradable goods should depend more on a country’s stock of the relevant catalyst than do prices of other tradable goods.

Even if demand complementarities are responsible for markup differences, a number of challenges may prevent detecting this effect in an empirical test. First, there are few candidate catalysts for which reliable cross-country data exists. Second, country-level catalysts are highly correlated with income per capita in the data (and perfectly correlated in the theory), so a
remaining concern is that high prices may reflect other forms of non-homotheticities. Finally, a common concern in empirical tests of pricing-to-market is that price differences may reflect quality differences rather than markups.

The empirical section addresses these challenges by testing the demand complementarities hypothesis on different catalysts using data on unit values of exports from both the U.S. and China. Each test itself has its limitations, so there is not one unique set of data on unit values and catalysts that offers an ideal test. But considered as a whole body of evidence, the data demonstrate a dependence of prices on catalysts that is consistent with the demand complementarities theory.

A plausible catalyst that is relevant for a large subset of tradable goods is electricity access, which, as discussed in McRae (2010), is an important determinant of demand for electric appliances. I use data on electricity production, which is a proxy for access that is measured across a range of countries, to show that electric goods are sold at higher prices to countries with higher electricity production, conditional on destination country income per capita and conditional on the average dependence of consumer goods prices on country-level determinants.

Although electric goods account for a substantial share of traded goods, accurate data on electricity production is available for a wide range of countries, the empirical test faces a number of limitations. First, electricity is highly correlated with income per capita, which poses the challenge of distinguishing demand complementarities from other pricing-to-market mechanisms associated with high income. Second, electricity may complement demand for retail goods generally (if, for example, reliable electricity supply allows retail stores to keep the lights on and stay open). Therefore much of the dependence of prices on electricity production may be captured by country-level fixed effects. To supplement the evidence on electricity production as a catalyst, I also test two other catalysts that complement a smaller share of traded goods but are more suitable for an empirical test. These catalysts are ski resorts, which complement demand for skis, and golf courses, which complement demand for golf clubs. Each of these catalysts has a relatively low correlation with income per capita and exhibits strong differential demand complementarity. The results demonstrate a strong dependence of prices of skis and golf clubs on ski resorts and golf courses, conditional on the dependence of prices on income per capita. Although the price differences in the test on skis and golf clubs may to some
extent represent quality differences, the results lend support to the body of theoretical and empirical support for the demand complementarities mechanism.2

After presenting the theoretical model and supporting evidence, I then demonstrate additional implications of demand complementarities. First, demand complementarities offer an explanation for the relationship between prices of nontradables and income per capita. A traditional explanation comes from theory developed by Harrod (1933), Balassa (1964), and Samuelson (1964), collectively referred to as HBS: The law of one price holds in tradables, but rich-country productivity is higher in the tradable sector than in the nontradable sector, driving up rich-country wages and causing higher prices in the lower productivity nontradables sector. But it is unlikely that HBS can fully explain the price-income relationship across countries because the difference between tradable-sector productivity and nontradable-sector productivity within rich countries is too small to account for the strong relationship between nontradable prices and incomes across countries (Alessandria and Kaboski 2011). I show that demand complementarities and pricing-to-market offers an explanation for the positive relationship between prices of services and income per capita without relying on sectoral productivity differences.

In addition to the prediction of high service prices in rich countries, the model also suggests that catalyst services are actually less expensive in rich countries. The prediction that some services are cheaper in rich countries may seem contrary to the evidence from the International Comparison Program (ICP) that prices of services are higher in rich countries. However, the ICP data is based on a subset of services that excludes many catalysts. For example, road quality, infrastructure, and advertising are potential catalysts that are not included in country-level price indices. I provide evidence that a number of potential catalysts are indeed more efficient or less costly in rich countries, consistent with the model’s predictions. One implication is that aggregate price indices in rich countries are lower than estimates based on ICP data suggest.

2 It may seem that an alternative to testing for demand complementarities in the data is to infer which goods are catalysts from a calibrated model based on its predictions regarding expenditure shares and elasticities of substitution across goods. It is important to note that theoretically the elasticity of substation between catalysts and consumer goods need not be higher than the elasticity of substitution between subsets of consumer goods. The term ‘demand complementarities’ refers to q-complementarity between catalysts and consumer goods, not to relative elasticities of substitution. Different models that embody demand complementarity and pricing-to-market will have different predictions regarding relative expenditure shares and elasticities of substitution, which suggests that any inference of which goods are catalysts will be heavily dependent on model specifics.
Another recent paper that offers an explanation for high prices of tradables in rich countries by employing nonhomothetic preferences is Simonovska (2014). In that model, high tradable prices in rich countries are due to low demand elasticities (and corresponding high markups) arising from consumption of a larger set of varieties of imported goods. My model differs in that high prices reflect high consumption of catalyst goods, rather than differences in the set of imported goods. One implication of the demand-complementarities model is that the extent to which markups vary across countries should depend on the extent to which the tradable good in question is complementary to other goods and services.

This paper complements work in a number of areas. For example, the demand-side explanation for high prices of consumer goods in rich countries explored here complements a burgeoning literature that examines demand-side explanations for the cross-country relationship between income and quality of imports. Fajgelbaum, Grossman, and Helpman (2011) develop a model featuring complementarity between a homogenous good and quality of vertically differentiated goods. In their model, higher incomes are associated with more purchases of higher quality goods, but not with higher markups paid for those goods. An interesting avenue for future research is to develop models in which high consumption of catalyst goods is associated with purchases of higher quality goods and higher markups for a good of any given quality. This paper’s focus on determinants of levels of real exchange rates also complements the literature documenting the importance of failures of the law of one price for real exchange rate fluctuations (e.g. Engel 1999; Chari, Kehoe, and McGrattan 2002). While a number of theoretical papers offer explanations for high-frequency fluctuations in real exchange rates (e.g. Corsetti and Dedola 2005; Drozd and Nosal 2008; Burstein and Jaimovich 2012), the model I develop offers a complementary mechanism to account for persistent patterns in the level of real exchange rates.

The remainder of the paper proceeds as follows. Section 2 develops a two-country model to explicitly demonstrate that the proposed mechanism can account for the high prices of tradable goods in rich countries. Section 3 presents the empirical evidence that demonstrates the

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3 Hummels and Lugovsky (2009), Alessandria and Kaboski (2011), and Sauré (2012) also propose theoretical explanations for the positive correlation between markups and income per capita.

4 This paper more broadly fits into work that explores the implications of nonhomothetic preferences for patterns of trade, including Bergstrand (1990), Hunter (1991), Matsuyama (2000), Mitra and Trindade (2005) and Fieler (2011), among many others. Markusen (2013) reviews the literature and discusses a range of phenomena for which non-homothetic preferences improve the correspondence between trade models and the data.
dependence of prices on catalyst consumption across countries. Section 4 discusses how extensions of the two-country model can inform the literature on cross-country differences in nontradables prices. Section 5 concludes.

2. Two-Country Model
This section demonstrates that demand complementarities and pricing-to-market can account for the evidence of higher prices of tradable goods in rich countries than in poor countries. The mechanism responsible for high prices of tradable goods in rich countries also generates high prices of nontradable goods, as discussed in Section 4.

Consider a two-country model in which the countries, \( N \) (North) and \( S \) (South), are each endowed with a numeraire good and inelastically supply labor to produce catalyst goods and differentiated final goods. Catalyst goods are not traded across countries. This assumption is for simplicity (the qualitative results are robust to permitting the catalyst to be traded), and because some catalyst goods represent housing and public infrastructure, which are fixed immobile assets. The endowed numeraire is traded and enters the utility function linearly. Following Krugman (1980), each country specializes in a unique set of differentiated final goods. Final goods are produced by monopolistically competitive firms. Firms can move final goods costlessly across international borders and charge country-specific prices, but consumers do not arbitrage because they face large costs of moving goods across international borders; these costs can be the time required to travel across international borders or other transportation costs and information rigidities.

Model Setup. Each country \( j \in \{N, S\} \) produces a mass \( \Omega_j \) of final goods which are consumed at home and abroad. Goods produced in country \( j \) are indexed by \( \omega_j \in \Omega_j \). The utility function of the representative consumer in country \( j \) is

\[
U_j = y_j + \sum_{i \in \{N, S\}} \int_{\omega_i \in \Omega_i} \left[ C_{f_j}(\omega_i) - \frac{Y}{2} \left( f_j(\omega_i) \right)^2 \right] d\omega_i,
\]

(1)

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\(^5\) The setup is based on a variant of the linear demand system developed by Ottaviano, Tabuchi, and Thisse (2002), which is analytically convenient, in part because the marginal utility of income is unity for all levels of income. An extended working paper (Murphy 2013) demonstrates that the results of this section are robust to alternative specifications for which the marginal utility of income varies with income and the numeraire is produced with labor.

\(^6\) The assumption that producing firms can freely move goods across borders is for simplicity only. Price differences will emerge whenever arbitraging price differences is costly, such as in the presence of transportation costs.
where $y_j$ and $C_j$ are consumption of the numeraire and catalyst by country $j$ and $f_j(\omega_i)$ is consumption in country $j$ of variety $\omega_i$ from country $i \in \{N, S\}$. Equation (1) is a simplified version of the utility functions used in Ottaviano et al (2002), Melitz and Ottaviano (2008), and Foster, Haltiwanger, and Syverson (2008), but differs in two ways. First, the marginal utility from consuming any variety $\omega$ is independent of consumption of any other variety $\omega' \neq \omega$. Second, equation (1) features a catalyst good $C$ that acts as a demand shifter for the consumption goods.

The budget constraint of the representative agent in country $j$ is

$$y_j^0 + w_j L_j + \sum_{i=N,S} \int_{\omega_j \in \Omega_j} \Pi_i(\omega_j) = y_j + p_C C_j + \sum_{i=N,S} \int_{\omega_i \in \Omega_i} p_j(\omega_i)f_j(\omega_i), \quad (2)$$

where $y_j^0$ is the endowment of the numeraire in country $j$, $\Pi_i(\omega_j)$ is the profit from sales of variety $\omega_j$ to country $i$, $y_j$ is the amount of the numeraire consumed in country $j$, $p_C$ is the price of the catalyst in $j$, and $p_j(\omega_i)$ is the price of variety $\omega_i$ in $j$.

Consumer optimization with respect to $f_j(\omega_i)$ yields demand for variety $\omega_i$ in country $j$:

$$f_i^d(\omega_i) = \frac{1}{\gamma} \left( C_j - p_j(\omega_i) \right). \quad (3)$$

Similarly, the first order condition with respect to $C_j$ yields

$$F_j = p_C, \quad (4)$$

where $F_j = \sum_{i=N,S} \int_{\omega_i \in \Omega_i} f_j(\omega_i)$ is the total quantity of final goods consumed in country $j$. In equation (4), the marginal benefit of catalyst consumption is total consumption of final goods, reflecting the complementarity between the catalyst and final goods.

**Final Good Sector.** Output in the final goods sector is produced using the technology

$$f(\omega_j) = A_j L_\omega, \quad (5)$$

where $f(\omega_j) \equiv f_N(\omega_j) + f_S(\omega_j)$. Each firm $\omega_j$ charges a country-specific price to maximize the profits $\Pi_i(\omega_j)$ from selling variety $\omega_j$ in country $i \in \{N, S\}$.

Profits from sales of $\omega_j$ in $i$ can be written

$$\Pi_i(\omega_j) = p_i(\omega_j)f_i(\omega_j) - \frac{w_j}{A_j} f_i(\omega_j). \quad (6)$$

The profit-maximizing price charged in country $i$ is
\[ p_i(\omega_j) = \frac{1}{2} \left( C_i^a + \frac{w_j}{A_j} \right). \]  \hfill (7)

Equation (7) can help explain why rich countries pay higher prices for tradable goods: The optimal price of an identical good varies across countries based on the stock of catalyst goods in each country. It remains to be seen that in equilibrium the rich country will produce more of the catalyst good and therefore pay higher prices for final goods.

Given the price defined by (7), consumer demand in country \( i \) for \( \omega_j \) is

\[ f_i^d(\omega_j) = \frac{1}{2\gamma} \left( C_i^a - \frac{w_j}{A_j} \right). \]  \hfill (8)

The resulting revenues of firm \( \omega_j \) from sales to country \( i \) are

\[ p_i(\omega_j)f_i(\omega_j) = \frac{1}{4\gamma} \left( C_i^{2a} - \frac{w_j^2}{A_j^2} \right), \]  \hfill (9)

and profits are

\[ \Pi_i(\omega_j) = \frac{1}{4\gamma} \left( C_i^a - \frac{w_j}{A_j} \right)^2. \]  \hfill (10)

*Catalyst Sector.* The catalyst in country \( j \) is produced competitively according to

\[ C_j = A_j L_{C_j}, \]

where \( A_j \) is productivity in country \( j \) and \( L_{C_j} \) is labor employed in \( j \)’s catalyst sector. I assume that productivity in country \( j \) is equal across sectors. This is for simplicity and to isolate the role of demand complementarities, rather than within-country productivity differentials, in driving cross-country price differences.\(^7\) The price of the catalyst is \( p_{Cj} = w_j/A_j \), which is derived from cost minimization by the representative catalyst firm. Since the catalyst is not traded across countries, there is no role for comparative advantage and each country will produce some of the catalyst in equilibrium.

*Equilibrium.* Since \( p_i(\omega_j) \) and \( f_i(\omega_j) \) are identical for any variety \( \omega_j \) from country \( j \), it will be helpful to omit variety indices by writing \( p_{ij} = p_i(\omega_j), f_{ij} = f_i(\omega_j), \) and \( \Pi_{ij} = \Pi_i(\omega_j) \ \forall \ \omega_j \in \Omega_j \). Then \( F_j \) becomes \( F_j = \Omega_j f_{jj} + \Omega_i f_{ji} \). The budget constraint in country \( j \) simplifies to

\(^7\) Alessandria and Kaboski (2011) demonstrate that within-country productivity differentials are too small to account for cross-country price differences driven by HBS effects. The assumption in my model that productivity within a country is equal across sectors highlights the independent role of catalyst-driven markups in determining the real exchange rate.
\[ y_j^0 + w_j L_j + \Omega_j (\Pi_{jj} + \Pi_{ij}) = y_j + \rho C_j + \Omega_j p_j f_{jj} + \Omega_i p_{ji} f_{ji} \quad (11) \]

Labor market clearing in \( j \) is \( L = L_{Qj} + L_{Cj} \), where \( L_{Qj} = \int_{\omega_j \in \Omega_j} L_{\omega_j} d\omega_j \) is total labor used in the final goods sector and total labor \( L \) is the same in each country. By substituting in the production functions for final goods and the catalyst, labor market clearing in country \( j \) can be written

\[ L = \frac{1}{A_j} (\Omega_j (f_{jj} + f_{ij}) + C_j). \quad (12) \]

Market clearing for the numeraire is

\[ y_N^0 + y_S^0 = y_N + y_S. \quad (13) \]

Equilibrium is characterized by the first order conditions for catalyst consumption (4), demand for final goods (8), labor market clearing in each country (12), market clearing for the numeraire (13), and the budget constraints (11). By Walras’ Law, one of these equations is redundant. For clarity, the equilibrium conditions are written explicitly as:

\[ F_N = \frac{w_N}{A_N}, \quad F_S = \frac{w_S}{A_S}, \quad f_{NN} = \frac{1}{2\gamma} (C_N - \frac{w_N}{A_N}), \quad f_{NS} = \frac{1}{2\gamma} (C_N - \frac{w_S}{A_S}), \]

\[ f_{SS} = \frac{1}{2\gamma} (C_N - \frac{w_N}{A_S}), \quad f_{SN} = \frac{1}{2\gamma} (C_N - \frac{w_S}{A_S}), \]

\[ L = \frac{1}{A_N} [\Omega_N (f_{NN} + f_{SN}) + C_N], \quad L = \frac{1}{A_S} [\Omega_S (f_{SS} + f_{NS}) + C_S], \]

\[ y_N^0 + y_S^0 = y_N + y_S, \quad y_N^0 - y_N + \Omega_N p_{SN} f_{SN} = \Omega_S p_{NS} f_{NS}, \]

where the last equilibrium equation is a simplified version of the budget constraint for country \( N \).

The ten equations above yield a unique solution for the endogenous variables \( w_N, w_S, y_N, y_S, C_N, C_S, f_{NN}, f_{NS}, f_{SS}, \) and \( f_{SN} \). To see this note that we can reduce the system to four linear equations in four unknowns by substituting demand for final goods into the first order conditions for catalyst consumption and the labor market clearing conditions:

Catalyst First Order Condition:

\[ \text{Catalyst First Order Condition:} \]
\[ \Omega \frac{1}{2\gamma} \left( 2C_S - \frac{w_N}{A_N} - \frac{w_S}{A_S} \right) = \frac{w_S}{A_S}, \quad \Omega \frac{1}{2\gamma} \left( 2C_N - \frac{w_N}{A_N} - \frac{w_S}{A_S} \right) = \frac{w_N}{A_N} \quad (14) \]

Labor Market Clearing:
\[ L = \frac{\Omega}{2\gamma A_N} \left( C_S + C_N - 2 \frac{w_N}{A_N} \right) + \frac{C_N}{A_N}, \quad L = \frac{\Omega}{2\gamma A_S} \left( C_S + C_N - 2 \frac{w_S}{A_S} \right) + \frac{C_S}{A_S}. \quad (15) \]

Uniqueness of the equilibrium follows from a non-zero determinant of this system. Given \( C_N, C_S, w_N, \) and \( w_S, \) one can solve for \( y_N \) and \( y_S \) from numeraire market clearing and the trade balance condition.

**Prices and Income.** The price of a final good in the North relative to the South is
\[ \frac{p_{Nj}}{p_{Sj}} = \frac{C_N + w_j/A_j}{C_S + w_j/A_j}, \quad (16) \]
where \( w_j/A_j \) is the cost of production in origin country \( j. \) The North is characterized by its higher productivity, \( A_N > A_S. \) According to equation (16), a sufficient condition for higher prices in the North is that \( C_N > C_S. \) Intuitively, this result follows from the fact that \( N \) has more effective labor and thus can produce more catalyst goods. To derive the conditions under which this intuition prevails in the model, we can subtract the catalyst first order condition in \( S \) from that in \( N \) and collect terms to yield
\[ \frac{\Omega}{2\gamma} (C_N - C_S) = \left( \frac{w_N}{A_N} - \frac{w_S}{A_S} \right), \quad (17) \]
Likewise, the labor market clearing conditions can be combined and simplified to yield
\[ C_N - C_S = L(A_N - A_S) + \frac{\Omega}{2\gamma} \left( \frac{w_N}{A_N} - \frac{w_S}{A_S} \right), \quad (18) \]
Solving equation (17) for the cost difference and substituting into (18) yields
\[ (C_N - C_S) \left( 1 - \left( \frac{\Omega}{\sqrt{2\gamma}} \right)^2 \right) = L(A_N - A_S). \quad (19) \]
Equation (19) implies that the necessary and sufficient condition for higher prices in \( N \) is \( \sqrt{2\gamma} > \Omega. \) The intuition behind this result is that a large mass of firms causes sufficiently high demand for final goods that equilibrium catalyst consumption falls with wealth. High marginal utility from final goods consumption (low \( \gamma \)) has a similar effect. Under the assumption of sufficiently declining marginal utility of final goods consumption, the higher income country produces more of the catalyst good and therefore pays higher prices for final goods. As
discussed in the empirical section, the relevant case is when rich countries produce more catalysts, consistent with the assumption in the model that $\gamma$ is high.

3. Empirical Evidence

The dependence of prices of consumer goods on complementary goods is a general result, as discussed in Appendix A. Here I provide evidence that prices and markups of subsets of tradables depend on countries’ stock of relevant catalysts. I use disaggregated export data from U.S. and Chinese datasets. The U.S. dataset—the U.S. Exports Harmonized System data, available on Robert Feenstra’s webpage—contains unit values and quantities of bilateral exports leaving U.S. docks for each Harmonized System (HS)-10 product category for years prior to 2006. As discussed by Alessandria and Kaboski (2011), there are two advantages of using this data to study the extent of pricing-to-market for tradable goods. First, the unit values are free-alongside-ship values, which exclude transportation costs, tariffs, and additional costs incurred in the importing country. Thus, the unit values capture the actual price of the good, rather than the price of taking the good to retail. Second, the disaggregated nature of the data mitigates potential concerns that different unit values may reflect differences in quality. The Chinese dataset—customs export data—contains free-alongside-ship values and quantities of goods at the HS-8 level of disaggregation. Despite the lower level of disaggregation, the Chinese dataset has the advantages that it contains identifiers for firms and firm locations, which help control for quality variation within a product category, and that China exports far more consumer goods to a broader range of countries, which permits a more precise estimate of the determinants of cross-country price differences.

I proceed by first showing that a positive price-income relationship exists in the export data, and the price-income relationship holds even among goods with limited quality variation, which suggests that high prices reflect high markups. I then present tests of the theory of demand complementarity and pricing-to-market.

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8 Despite the disaggregated nature of the data, there is still room for quality variation within a product category. Therefore, as discussed below, I take a number of steps to help condition on quality, such as normalizing prices by their with-product standard deviation and dropping goods with long quality ladders from the sample.

9 I am grateful to Jagadeesh Sivadasan and Michael Olabisi for sharing the 2005 Chinese Export data.
3.1 Pricing-to-Market

In this subsection I show that in the U.S. and Chinese datasets prices depend positively on income per capita, a relationship that has been found in other studies (e.g., Simonovska 2014, Alessandria and Kaboski 2011). Because high prices may reflect high quality or high markups, I will also condition on quality so that price-income relationship may be interpreted as reflecting high markups in rich countries.

I start by estimating the following specification on exports of consumer goods (end-use category 40000-50000):

\[
\ln p_{ch} = \gamma_h + \beta \ln y_c + \epsilon_{ch},
\]

(20)

where \( p_{ch} \) is the unit value of product \( h \) sold to country \( c \), \( \gamma_h \) represents product-specific fixed effects that capture product-specific cost parameters, and \( y_c \) is income per capita in country \( c \). Unit values for each country-product pair in the U.S. data are averages of the values between 2004 and 2006 (the three most recent years available).\(^{10}\) The Chinese data are only available in 2005. To prevent nonrepresentative products from driving the results, the samples are limited to products that are exported to at least 10 countries and to country-product pairs with over 100 units sold and over $1,000 in value.\(^{11}\)

The elasticity of prices with respect to income per capita in the U.S. data is 0.076 (Table 1, column 1). However, it is possible that there is quality variation within a product category in the U.S. data. Indeed, much prior work on cross-country differences, including Hallak (2006), Baldwin and Harrigan (2011), and Manova and Zhang (2011), infer that high prices reflect high costs associated with high quality. One way to condition on quality in the U.S. data is to drop from the sample goods with high potential variation in quality. Khandelwal (2010) estimates quality ladder lengths for HS-10 products. Refrigerators, for example, have a long quality ladder (and high potential quality variation), while TV antennas have a short quality ladder. I use Khandelwal’s estimates and drop all U.S. export products with ladder lengths above the median ladder estimate for which ladder estimates exist.\(^{12}\) The results (column 3) are nearly identical.

The similar results are robust to various ladder restrictions, including dropping all goods but

\(^{10}\) Averaging unit values across time has the advantage of averaging out the noise in the yearly data while preserving the ability to identify \( \beta \) based on the cross-sectional variation across destination countries.

\(^{11}\) The quantity restriction excludes high-priced products that are clearly unrepresentative (e.g. 17 fans sold to Macau for $66,000, etc). The results are robust to different quantity and value thresholds.

\(^{12}\)Khandelwal’s estimates are based on the assumption that goods with high market share reflect high quality. In the theoretical framework analyzed in this paper, high market share may also result from high demand complementarity with catalyst goods.
those in the lowest quartile of ladder lengths. Thus, the dependence of prices of U.S. exports on destination country income appears to reflect primarily variation in markups. To the extent that some of this relationship may nonetheless reflect variation in quality, the results in Section 3.2 below can be considered to provide a deeper microfoundation for the complementarity that is assumed to exist in models of trade and product quality (e.g. Fajgelbaum et al).

The elasticity of prices with respect to income per capita in the Chinese data (0.025) is lower than in the U.S. data. The lower estimate in the Chinese data may reflect that the firm identifiers more appropriately condition on quality than do the product identifiers in the U.S. data or that pricing-to-market is less prevalent among Chinese exports. The lower dependence of markups on income in the Chinese data implies that we should expect to see lower estimates of demand complementarity and pricing-to-market in the empirical specifications based on Chinese data in Section 3.2.

Finally, one may wonder whether costs (for a given quality) are constant across destinations. For example, large sales volumes may be associated with bulk discounts; an appropriate measure of the markup would condition on these quantity-related lower costs. One way to attempt to condition on these unobserved cost parameters in the framework of monopolistic competition is to condition on quantity. Since price and quantity are functions of underlying demand and cost determinants, quantity can serve as a proxy for these parameters. Appendix B formally discusses how including quantity can reduce bias in pricing-to-market estimates. Columns (2) and (5) show the results from the following specification:

$$\ln p_{ch} = \gamma_h + \psi \ln q_{ch} + \beta \ln y_c + \epsilon_{ch}$$  \hspace{1cm} (21)

where $q_{ch}$ is the quantity of good $h$ sold to country $c$. The estimate for $\psi$ is negative, consistent with a bulk discounts for countries that purchase large quantities. The resulting estimates of pricing-to-market are higher, implying that cost savings are correlated with income per capita.

To summarize, Table 1 confirms the existence of a price-income relationship in the export data. It also demonstrates that the price-income relationship holds even among goods with limited quality variation, which suggests that high prices reflect high markups.

3.2 Testing Demand Complementarities and Pricing-to-Market

In this subsection I provide evidence consistent with the theory of demand complementarity and pricing-to-market. The evidence in this subsection can be considered a test of the theory in the
following sense: The theory offers predictions that can be rejected by the data and there are no competing theories (of which I am aware) that would offer the same predictions.

There are a number of challenges in testing the theory. First, it is necessary to isolate the effect of catalyst-based demand from other factors that are associated with income per capita. Indeed, income and catalyst consumption are perfectly correlated in my theoretical models, and if the same were true of reality it would be impossible to distinguish between demand complementarities and other potential explanations for the price-income relationship. In reality, however, catalyst consumption is imperfectly correlated with income per capita, which permits me to test the dependence of prices on the component of catalyst consumption that is not correlated with income. Different catalysts are likely to have different degrees of correlation with income, and the challenge is to identify a catalyst with (a) reliable cross-country-data, and (b) sufficient variation in the component that is orthogonal to income per capita.

A second challenge is to identify a catalyst that is a strong demand complement for a subset of identifiable consumer goods relative to other goods. This differential demand complementarity is necessary to test the dependence of prices of relevant catalyzed goods on catalyst consumption while conditioning on the average dependence of prices on factors related to income and catalyst consumption. One such catalyst that should exhibit differential demand complementarity is access to electricity, which complements demand for electric goods. McRae (2010), for example, shows that access to reliable electricity in developing countries is associated with a higher likelihood of purchasing electronic appliances.

Data on access to electricity is available from World Development Indicators for only a limited subset of countries, and only starting in 2009, a year past the dates for which I have export price data. As a proxy for electricity access I use a measure that is both available and consistently measured in multiple years for a broad range of countries: International Energy Agency (IEA) data on electricity consumption, defined as total electricity production less any power used by power plants or lost in transmission and distribution.

---

13 There are many potential reasons for the imperfect correlation between catalyst consumption and income. I do not suggest any particular reason, but assume that these reasons are exogenous to prices of consumer imports. In the closed-economy and two-country models, it is straightforward to introduce imperfect correlation between catalyst consumption and income by assuming that productivity in the catalyst sector has a random component.

14 I also test a number of other catalysts that are less suitable for testing due to lack of accurate data across a range of countries (or a lack of exports of relevant tradables), including paved roads as a catalyst for new cars and housing as a catalyst for household goods. The dependence of prices on catalysts in these tests is consistent with the results presented below.
The IEA proxy is most appropriate for countries with low levels of electricity access. There is a mass of countries for which access is nearly 100% of the population and electricity consumption is unrelated to access because everyone has access (Figure 1). But for low values of electricity consumption, access is strongly correlated with electricity consumption. Above the electricity consumption per capita of South Africa (approximately 5 MWH), consumption and access are nearly independent and access is nearly 100%. Therefore I limit the sample of countries to those with less than level of consumption in South Africa (ZAF). The results presented below are slightly stronger for lower thresholds, consistent with the notion that electricity consumption is a stronger proxy for access among countries with low levels of access.\footnote{It may seem that an alternative to using data on electricity production is to use data on electricity prices. As discussed below, price data is available for only approximately 50 countries. For many of these countries, access to electricity is unreliable for many consumers, so the listed price of electricity does not accurately capture the true cost to consumers of obtaining reliable electricity. As discussed in McRae (2010) and McRae (2013), consumers’ desire to own durables depends on whether reliable electricity is available. Therefore production of accessible electricity is the relevant catalyst and a more accurate proxy for the true cost of obtaining reliable electricity.}

Despite a number of features of electricity production that are amenable to an empirical test, there are other features that present challenges. First, electricity is highly correlated with income per capita (correlation coefficient of 0.85 among countries in the sample), which poses the challenge of distinguishing demand complementarities from other pricing-to-market mechanisms associated with high income. Second, electricity may complement demand for retail goods generally (if, for example, reliable electricity supply allows retail stores to keep the lights on and stay open). Therefore much of the dependence of prices on electricity production may be captured by country-level fixed effects. To supplement the evidence on electricity production as a catalyst, in Section 3.3 I test two other catalysts that complement a smaller share of traded goods but are more suitable for an empirical test. These catalysts are ski resorts, which complement demand for skis, and golf courses, which complement demand for golf clubs. Each of these catalysts has a relatively low correlation with income per capita (<0.80) and exhibits strong differential demand complementarity (e.g. ski resorts complement demand for skis more so than they complement demand for other consumer goods).

\textit{Electricity Consumption and Prices of Electric Goods.} The electricity consumption data permit a test of whether prices of electric goods depend on electricity consumption, conditional on their dependence on income, and conditional on the average dependence of prices on country-
level factors. As mentioned above, the challenge is to isolate the effect of electricity consumption on prices from the effect of other factors related to income per capita. Electricity consumption and income per capita are strongly correlated with a correlation coefficient of 0.85 among the 71 countries in the sample.

I estimate the following empirical specification:

\[
p_{ch} = \gamma_h + \beta_0 \ln y_c + \psi \ln q_{ch} + \beta_1 \ln MwH_c \times Egood_h + \beta_2 \ln y_c \times Egood_h + \epsilon_{ch},
\]

(22)

where \( MwH_c \) is the per capita electricity consumption in country \( c \) in 2005, \( Egood_h \) indicates whether good \( h \) is electric, and \( \epsilon_{ch} \) denotes the regression error. Other definitions and sample specifications are the same as in (20). I classify as ‘electric’ any consumer good that is labeled as electric and not battery-powered, as well as electric goods such as TVs, stereos, and associated parts. The coefficient \( \beta_1 \) captures the extent to which the markup for electric goods depends on electricity access, conditional on the dependence of prices on income per capita. Since electricity consumption is strongly correlated with income, and since electric goods may have an above average dependence on income per capita, \( \beta_2 \ln y_c \times Egood_h \) is included to isolate the dependence of prices of electric goods on electricity from their dependence on income per capita. The average dependence of prices on all factors related to income per capita (including demand complementarities) is captured by \( \beta_0 \). Therefore \( \beta_1 \) is a lower-bound estimate of the dependence of prices of electric goods on catalyst consumption.

\( \beta_1 \) can be interpreted as representing a causal effect of catalyst consumption on prices if electricity consumption is exogenous to the product price. Electricity consumption is indeed likely to be exogenous with respect to the price of a single imported product. If there is any endogenous response to electric prices, electricity consumption should respond negatively to high import prices of complementary goods. In this case, high electricity consumption is associated with low prices of electric goods, and \( \beta_1 \) will underestimate the causal effect of access to electricity on electric goods prices. In other words, the estimate of \( \beta_1 \) is biased downward in the presence of endogenous electricity consumption.\(^{16}\)

\(^{16}\) As a robustness check, I used 2002 values of electricity consumption as an instrument and obtained nearly identical results to those presented below. This is unsurprising given that electricity consumption in 2005 is nearly perfectly correlated with electricity consumption in prior years.
Table 2 shows estimates using the U.S. export data. A 100% increase in per capita electricity consumption is associated with a 13.9% increase in the price of electric goods (column 1). The coefficient is larger (0.174) and statistically significant at the 1% level when conditioning on quantity (column 2), which permits an interpretation of $\beta_1$ as the partial effect on the price of an increase in catalyst consumption, conditional on a country’s position on its demand curve. In column (4) I drop electric goods with long quality ladders from the sample. The estimate of the dependence of prices on electricity consumption increases to 19.2%, which suggests that the estimates are not driven by quality differences among goods with long quality ladders.

I also estimate a version of (22) in which I replace income per capita with country fixed effects $\alpha_c$:

$$p_{ch} = \gamma_h + \alpha_c + \psi \ln q_{ch} + \beta_1 \ln MwH_c \times Egood_h + \beta_2 \ln y_c \times Egood_h + \epsilon_{ch}. \quad (23)$$

This specification conditions on country-level determinants of prices in addition to income per capita. Here a positive estimate of $\beta_1$ suggests that prices of electric goods have an above-average dependence on electricity consumption, conditional on the average dependence of prices on electricity consumption and other country-specific covariates; and conditional on the dependence of prices of electric goods on income per capita. Electric goods have an above-average dependence on electricity consumption and a below-average dependence on income per capita, consistent with the notion that electricity is a stronger demand complement for electric goods than for other consumer goods, but the estimates are imprecisely measured (column 3). The imprecision in the estimates when both country and product fixed effects are included could reflect the limited sample of exports of U.S. consumer goods, noise in the price data, and/or the strong correlation between electricity consumption and income per capita.

The Chinese export data are likely to offer a cleaner test due to the larger volume of consumer goods exports, and due to firm identifiers that help condition on quality. The results from the Chinese export data are qualitatively similar to the results from U.S. export data but are more precisely estimated (Table 3). A 100% increase in electricity consumption is associated with a statistically significant 2% to 4% increase in prices of electric goods. To the extent that the product-firm-location dummies effectively condition on quality, the positive estimate of $\beta_1$ from the Chinese data can be interpreted as evidence of pricing-to-market. Column (3) shows
that the estimate of $\beta_2$ is negative and insignificant, while the estimate of $\beta_1$ is positive and significant. This suggests that any dependence of electric good prices on income is similar to the dependence of consumer goods prices on income as captured by the country-level fixed effects.

**Tests on Disaggregated Goods Categories.** The results in Tables 2 and 3 suggest that prices of electric goods have an above-average dependence on electricity consumption, consistent with the demand complementarity hypothesis. One may wonder whether other non-electric consumer good categories display a similar dependence on electricity consumption, implying that the estimated dependence is due some other artifact of the data rather than demand complementarity. In other words, would placebo goods generate the same result as electric goods? One way to address this question is to estimate the dependence of placebo goods prices on electricity, and then see whether the dependence of electric goods exceeds the average dependence of placebos on electricity consumption. The estimates in Table 3 do exactly this by capturing the average dependence of prices of electric goods on electricity in the country-level fixed effects.

While the results based on averages over placebos are informative, it is nonetheless useful to see whether the dependence on electricity is large for particular subsets of nonelectric goods, and to see which electric goods are driving the results. Table 4 shows the results from interacting electricity consumption with subsets of nonelectric goods (textiles, furniture, and luxury sport equipment) and electric goods (dishwasher and refrigerators, vacuums, and smaller kitchen appliances). The electric goods for which the demand complementarities hypothesis implies positive estimates are in bold. Prices of textiles and luxury sporting equipment tend to have a negative (and often precisely estimated) conditional dependence on electricity consumption. Furniture prices have a positive but insignificant dependence on electricity consumption. Thus prices of nonelectric goods do not appear to display a systematic or strong dependence on electricity consumption.

Among subsets of electric goods, the smaller household appliances that tend to have lower per-unit purchase prices (kitchen appliances and vacuums) are the goods with prices that depend on electricity consumption. Dishwashers and refrigerators generally do not have an above-average dependence on electricity consumption, primarily reflecting the fact that few of these energy-intensive products are destined for countries with low electricity production. Of U.S. exports of dishwashers, for example, only 4% are destined for the low-income countries for
which there is variation in electricity access (in contrast, 44% of U.S. exports of small kitchen appliances are destined for low-income countries). The few consumers in these countries who purchase dishwashers and refrigerators are likely to differ from the average consumer in their appliance demand, and hence the price charged to these consumers is not based the demand curve of a representative consumer.

Also, examining energy-intensive appliances as a group masks important heterogeneity among goods that causes a differential dependence on electricity access and price. A number of electronic goods in the sample exhibit varying energy intensity that can be identified based on their product descriptions. These appliances are refrigerators, combined refrigerators/ freezers, and air conditioning units. Electricity prices determine which level of energy intensity consumers choose to purchase. Table 5 shows that prices of high-energy appliances have a more positive dependence on electricity production and a more negative dependence on electricity prices than do prices of their low-energy counterparts. Here I include all countries for which data exist in the sample, since few low-income countries have data on electricity prices, and since these appliances are imported overwhelming by rich countries. The electricity price data is from the Energy Information Administration.

The general message from Tables 4 and 5 is consistent with the demand complementarities hypothesis. Prices of electric goods depend on electricity consumption. The exception is appliances which have energy intensive substitutes and are primarily sold to countries in which most consumers have access to reliable energy.

3.3. Additional Tests of the Demand Complementarities Hypothesis

Here I test whether prices of skis depend on the number of ski resorts per capita in a country, and whether prices of golf clubs depend on the number of golf courses per capita in a country. Although golf clubs and skis are a small share of trade, they are very suitable for a test of the demand complementarities hypothesis because the catalysts exhibit a relatively low correlation with income per capita and because the catalysts exhibit strong differential demand complementarity. Data on the number of golf courses is obtained from the World Golf Foundation (http://www.worldgolffoundation.org), and country-level data on ski resorts is

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17 The corresponding statistics for China are the following: 10% of exports of dishwashers are destined for low-income countries, and 11% of small kitchen appliance exports are destined for low-income countries.
provided by Snow-forecast.com (http://www.snow-forecast.com/countries). These data were collected in 2013. 53 countries have nonmissing data on golf courses, and 85 countries have nonmissing data on ski resorts. The correlations of catalysts with income per capita are 0.70 for ski resorts and 0.79 for golf courses.

Table 6 shows the results from the test of the demand complementarities hypothesis under a specification analogous to equation (23). Since China exports nearly zero skis or golf clubs, the results are based on U.S. export unit values. The results strongly support the demand complementarities hypothesis. Column (1) shows that a percent increase in ski resorts is associated with a 24.8% increase in the price of skis, and column (2) shows that a percent increase in golf courses is associated with a 10.7% increase in the price of golf clubs, conditional on the average dependence of prices on country-level fixed effects and conditional on the dependence of prices of skis and golf clubs on income per capita.

Thus catalysts seem to be a strong determinant of prices, conditional on the dependence of prices on other mechanisms associated with income per capita. The estimated price elasticities with respect to catalysts in Table 6 are much larger than the typical estimates of pricing-to-market (e.g. Simonovska 2014). The high estimates may reflect quality variation since the data does not distinguish between golf clubs and skis of different quality levels. Despite this caveat, the results document a strong dependence of unit values on catalysts, and a below-average dependence of unit values on income per capita. The below-average dependence of prices of skis and golf clubs on income per capita is especially striking considering that skis and golf clubs are luxury goods for which expenditure shares rise sharply with income. The large negative coefficients on income per capita suggest that demand complementarities, rather than other nonhomotheticities, are responsible for variation in prices of skis and golf clubs.

4. Additional Implications of Demand Complementarities and Pricing-to-Market
Evidence in the previous section supported the notion that demand complementarities can help determine cross-country price differences. This section shows how demand complementarities can help resolve puzzles in the trade and growth literatures. In particular, in this section I demonstrate that the mechanism that leads to comparatively high prices of tradables in rich countries in my model can also account for the comparatively high prices of nontradables in rich countries. While the correlation between income and prices of nontradables is well documented,
a remaining question is: what are the nontradable catalysts that are cheaper/more accessible in rich countries? I provide examples of a number of potential catalysts that are cheaper in rich countries.

4.1 Demand Complementarities and Prices of Nontradables
A prominent explanation for the observed correlation between country income per capita and nontradable prices is that the law of one price (LOP) holds in tradables but rich-country productivity is higher in the tradable sector than in the nontradable sector (Harrod (1933), Balassa (1964), and Samuelson (1964)). High productivity in the tradable sector drives up wages in rich countries, which causes higher prices in the sector with lower productivity (nontradables). A difficulty for the HBS explanation, as recently noted by Alessandria and Kaboski (2011), is that the rise in relative productivity of tradables within rich countries appears too small to account for the strong relationship between prices and incomes across countries: Differences in prices of services across countries cannot be solely attributed to differences in costs; and markups for nontradables are higher in countries with high per capita income.

A theory based on demand complementarities helps explain how markups of nontradables increase with income per capita. The model that formally demonstrates the dependence of prices of nontradables on catalyst consumption is a straightforward extension of the theoretical model in Section 2 and is presented formally in a prior version of this paper (Murphy 2013). The results of such a model are very similar to those from Section 2: As productivity in $N$ increases, $N$’s production and consumption of catalyst and final goods increases, as does the price of tradables in $N$. In addition, the relative price of services is higher in $N$ because the increase in $C_N$ lowers the price elasticity of demand for services, causing service-sector firms in $N$ to charge a higher markup than service-sector firms in $S$.

Complementarity between catalysts and nontradables are likely to be relevant in a number of situations. For example, the value of services such as window-washing, carpet-cleaning, and lawn mowing all depend on whether consumers have homes that can accommodate windows, carpets, and lawns. In Quito, Ecuador, these services are of little value because few homes there are suitable for windows and nice carpets, and few households own lawns. Likewise, the utility from a haircut may depend on the prevalence of other goods and services for
which one might need a haircut to fully enjoy. Salon services are more valuable, for example, when consumers attend formal events in which a certain style of appearance is required.

4.2. Examples of Catalyst Goods.
The theory predicts that catalysts are less expensive in rich countries, which may seem contrary to the conventional wisdom that nontradables are more expensive in rich countries. The evidence that nontradables are more expensive in rich countries is based on the International Comparison Program’s survey of prices across countries. However, the ICP analysis excludes a range of goods that may be considered catalysts, or fails to adjust for quality due to the lack of appropriate data. Here I present further examples of the types of goods and services that can be identified as catalysts due to complementarity with other consumer goods and due to their cost advantages in rich countries.

One of the primary examples of catalysts goods is infrastructure such as roads, which complements demand for a range of goods and services by permitting consumers to travel to service establishments and retail outlets. Infrastructure and government services are types of services that the ICP considers to be comparison-resistant areas due to the lack of comparable data across countries (Rao 2013). Therefore it is not possible to identify potential catalysts by examining price dispersion across countries. Instead, I identify a list of potential candidates for catalysts that broadly complement demand for consumer goods and services. Table 7 shows that each of these goods or services are either higher quality, more available (less costly to obtain), or more efficient in rich countries, consistent with the theory’s predictions.

Public Infrastructure. Roads complement demand for goods by facilitating consumers’ access to retail services. Lagakos (2014) suggests that transportation complements demand for retail services, which helps rationalize why retail sectors in poor countries are slow to adopt new technologies. Transportation quality may also cause pricing to market if it shifts consumers’ demand curves. The measure of a country’s road quality is the percentage of roads that are paved, provided by the World Development Indicators. Another form of public infrastructure that acts as a catalyst is public safety, which increases the ability of consumers to travel to retail outlets to obtain goods and services. Table 7 includes two measures of public safety, ‘Political Stability and the absence of Violence’, and ‘Rule of Law’, which captures the public’s faith in
the police. Each measure is provided through the World Databank by the Worldwide Governance Indicators at Brookings.

**Housing.** Housing complements demand for a range of consumer goods, including home entertainment systems and furniture. In the U.S., for example, consumers have relatively inelastic demand for home entertainment systems because they also have spacious TV rooms in their homes and a reliable supply of energy. In Ecuador, in contrast, the average consumer has less space in his home and an unreliable power supply, and thus lower demand for home entertainment systems. As discussed above, housing also complements demand for housing services. Comparable measures of the housing stock are not available across countries. Therefore the housing data is based on the ICP’s measure of the housing stock for European countries in 2005.

**Advertising and Marketing.** One can consider marketing/advertising (either informative or persuasive) to be a catalyst good. Arkolakis (2010) demonstrates that marketing and advertising, which account for as much 7.7% of GDP in the U.S., costs less in larger markets. Arkolakis’ evidence is based on a small subset of countries, and primarily reflects the price of placing an ad with television, radio, or newspaper outlets in European and Caribbean markets. However, the cost of reaching consumers depends not only on the cost of an ad, but also the efficiency of the ad in reaching consumers. Table 7 shows that consumers in rich countries have greater access to the media through which ads are delivered, including television, radio, telephone, internet, and computers; thus generating greater efficiency in the delivery of ads to consumers. The data are provided by the United Nation’s International Telecommunication Union.

**Urbanization.** Cities are associated with high consumer demand due to proximity between consumers and retail and service establishments (e.g. Glaeser, Kolko, and Saiz 2001; Gollin, Jedwab, and Vollrath 2014; Murphy 2014). Living near malls and shopping centers increases demand for tradable goods sold there, and living near service establishments increases demand for services. The data on urbanization rates are provided by the World Development Indicators at the World Bank.

5. Conclusion

The high price of consumption in rich countries is a well-documented empirical regularity. Understanding the nature of this regularity is important for understanding cross-country
differences in income, investment rates, aggregate price indices, and sectoral productivity. This paper proposes a new explanation—the utility consumers derive from consumer goods depends on their consumption of complementary goods—to account for the high prices of tradable and nontradable consumer goods in countries with high per capita incomes. Rich countries can afford more complementary goods, which generates high (and inelastic) demand for other consumer goods. As a result, monopolistically competitive firms charge higher markups in rich countries.

The paper presents evidence that supports a role of demand complementarities in driving cross-country price differences. Prices of subsets of exported goods depend on destination countries’ stock of relevant complementary goods, conditional on income per capita and other country-level determinants. The paper also demonstrates that demand complementarities can help explain cross-country differences in prices of nontradable goods. An important implication of the demand complementarities hypothesis is that aggregate price indices may be lower in rich countries than conventional wisdom suggests since rich countries have more efficient access to catalyst goods and services.

Appendix A
The model in this paper uses a simple linear demand curve to illustrate how an increase in complementary goods (catalysts) reduces the price-elasticity of demand for final consumer goods by shifting out the demand curve. Linearity of the demand curve is sufficient for a decrease in the price elasticity of demand in response to an increase in the complementary good, but it is not a necessary condition. This appendix derives the necessary and sufficient conditions on the demand curve under which an increase in complementary goods leads to higher markups for consumer goods.

A generic demand curve can be written \( q = q(C, p) \), where \( C \) is the complementary catalyst and \( p \) is the price of the good. The price-elasticity of demand is decreasing in \( C \) if and only if \( \frac{\partial \epsilon}{\partial C} < 0 \), where \( \epsilon = \left| \frac{\partial q}{\partial p} \right| \). We can write \( \frac{\partial \epsilon}{\partial C} = -q_{21} \frac{p}{q_{(d,p)}} + q_{2} \frac{p}{q_{(d,p)^2}} q_{1} \), in which case the necessary and sufficient condition simplifies to

\[
q_{Q_{21}} > q_{2} q_{1}.
\]  

Condition (24) states that any slope-increasing effects of an increase in \( C \) on the demand curve must be more than compensated by a shift out of the demand curve. In the commonly used case of a constant elasticity demand curve, \( q = C p^{-\epsilon} \), these two effects exactly cancel out so that
\( q_{21} = q_2 q_1 \). As discussed in Nakamura and Zerom (2010), price-independent demand elasticities are difficult to reconcile with the data. Their estimates on coffee demand suggest that the price elasticity of demand is increasing in the price.

**Appendix B**

Here I discuss the justification for including quantity on the right-hand-side of the empirical specification to condition on omitted demand and cost parameters that are correlated with catalyst consumption. Under the framework of monopolistic competition, the firm chooses the price/quantity that maximizes profits. Let the profit-maximizing price for a firm in country \( i \) selling to country \( j \) be \( p^*_j = p(\theta_j, C_j, c_{ji}) \) and the profit-maximizing quantity be \( q^*_j = q(\theta_j, C_j, c_{ji}) \), where \( \theta_j \) are demand shifters other than catalysts, \( C_j \) are catalysts in country \( j \), and \( c_{ji} \) are the costs associated with selling from \( i \) to \( j \) (variation in costs may represent variation in bulk discounts, for example). The demand complementarities hypothesis is that \( \partial p^*/\partial C_j > 0 \), where

\[
p^*_j \sim \theta_j^{\alpha_1} C_j^{\alpha_2} + c_{ji}, \quad q^*_j \sim \theta_j^{\alpha_1} C_j^{\alpha_2} - c_{ji}
\]

If \( c_{ij} \) or \( \theta_j \) are correlated with \( C_j \) in the sample, then the estimated dependence of price on catalysts will be biased. For example, if \( c_{ji} \) is positively correlated with \( C_j \) due to bulk discounts, then a regression

\[
p_{ij} = \alpha + \beta_1 C_j + \epsilon_{ij}
\]

will yield a downward biased estimate of \( \beta_1 \).

One way to overcome this omitted variable problem is to include a proxy for \( \theta_j \) and \( c_{ij} \). Since quantity is a function of the omitted variables, it can serve as a proxy. Of course, it also is a function of \( C_j \), so some of the dependence of the price on \( C \) will be captured by the relationship between price and quantity.

\[
p_{ij} = \alpha + \beta_1 C_j + \beta_2 q_{ij}(\theta_j, C_j, c_{ij}) + \epsilon_{ij}
\]

Substituting in for \( q_{ij} \), this is equivalent to

\[
p_{ij} = \alpha + \beta_1 C_j + \beta_2 [\theta_j^{\alpha_1} C_j^{\alpha_2} - c_{ji}] + \epsilon_{ij}
\]
Note that some of the positive dependence of \( p_{ji} \) on \( C_j \) in (27) is captured by \( \beta_2 \), so in this case \( \beta_1 \) is a downward biased estimate of the true dependence of the price on catalyst consumption. However, this bias may be less than the downward bias caused by omitting \( c_{ji} \). Since the estimated coefficient on \( q_{ji}, \beta_2, \) is negative, this suggests that costs are indeed an important omitted variable in (25). If only demand shifters mattered, then the estimate of \( \beta_2 \) would be positive, contrary to the evidence in Section 3.

References


### Table 1 - Coefficient Estimates from Regressions of Log Unit Values of U.S. and Chinese Exports on Income Per Capita

<table>
<thead>
<tr>
<th>Regressors</th>
<th>US Export Data</th>
<th>Chinese Export Data</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>All Consumer Goods</td>
<td>Goods with Short Quality Ladders</td>
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<tr>
<td>log(GDP per capita)</td>
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<td>0.126*** (0.004)</td>
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<td>Log(quantity)</td>
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<td>-0.071*** (0.004)</td>
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<tr>
<td># products</td>
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<td>1,322</td>
</tr>
</tbody>
</table>

Notes: Data source: World Bank Development Indicators, U.S. Exports by HS-10 classification, and Chinese Exports by HS-8 classification. For the Chinese Data, products are defined by HS-8 category, firm, and firm location. Robust standard errors clustered at the product level in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
### Table 2-Coefficient Estimates from Fixed-Effects Regressions of Log Unit Values of U.S. Exports on PerCapita Electricity Consumption

<table>
<thead>
<tr>
<th>Regressors</th>
<th>Subsample 1</th>
<th>Subsample 2</th>
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</thead>
<tbody>
<tr>
<td>log(GDP per capita)</td>
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<td>0.083***</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>log(MWh per capita) X Electric good</td>
<td>0.139*</td>
<td>0.174***</td>
</tr>
<tr>
<td></td>
<td>(0.057)</td>
<td>(0.049)</td>
</tr>
<tr>
<td>log(GDP per capita) X Electric good</td>
<td>-0.137*</td>
<td>-0.120*</td>
</tr>
<tr>
<td></td>
<td>(0.056)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Log(quantity)</td>
<td>-0.246***</td>
<td>-0.290***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.007)</td>
</tr>
</tbody>
</table>

Country FEs                                      YES
Product FEs                                      YES
R-squared                                       0.00
# observations                                   24,072
# products                                       1,312

Notes: Data source: World Bank Development Indicators and U.S. Exports by HS-10 classification. Subsample 2 drops from Subsample 1 all electric goods with quality ladder estimates greater than the median, where the quality ladder estimates are obtained from Khandelwal (2011). Robust standard errors clustered at the product level in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
Table 3-Coefficient Estimates from Regressions of Log Unit Values of Chinese Exports on Per Capita Electricity Consumption

<table>
<thead>
<tr>
<th>Dependent Variable: Log(price)</th>
<th>Regressors</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log(GDP per capita)</td>
<td>0.020***</td>
<td>0.023***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>log(MWh per capita) X Electric good</td>
<td>0.023*</td>
<td>0.038***</td>
<td>0.020*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.010)</td>
</tr>
<tr>
<td></td>
<td>log(GDP per capita) X Electric good</td>
<td>-0.026*</td>
<td>-0.029**</td>
<td>-0.011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.011)</td>
<td>(0.010)</td>
<td>(0.011)</td>
</tr>
<tr>
<td></td>
<td>Log(quantity)</td>
<td></td>
<td>-0.087***</td>
<td>-0.092***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.006)</td>
<td>(0.006)</td>
</tr>
</tbody>
</table>

Country Fes: YES  
Product FEs: YES  YES  YES  
R-squared: 0.07  0.07  0.07  
# observations: 158,817  158,817  158,817  
# products: 26,298  26,298  26,298

Notes: Data source: World Bank Development Indicators and Chinese Exports by HS-8 classification. Products are defined by HS-8 category, firm, and firm location. Robust standard errors clustered at the product level in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
<table>
<thead>
<tr>
<th>Regressors</th>
<th>US Export Data</th>
<th>Chinese Export Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Log(MWh per capita) X textiles</td>
<td>0.037</td>
<td>-0.179***</td>
</tr>
<tr>
<td></td>
<td>(0.030)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Log(GDP per capita) X textiles</td>
<td>0.018</td>
<td>0.132***</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>Log(MWh per capita) X furniture</td>
<td>0.077</td>
<td>-0.054</td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.055)</td>
</tr>
<tr>
<td>Log(GDP per capita) X furniture</td>
<td>-0.113</td>
<td>-0.083</td>
</tr>
<tr>
<td></td>
<td>(0.076)</td>
<td>(0.068)</td>
</tr>
<tr>
<td>Log(MWh per capita) X luxury</td>
<td>-0.147</td>
<td>-0.050</td>
</tr>
<tr>
<td></td>
<td>(0.123)</td>
<td>(0.109)</td>
</tr>
<tr>
<td>Log(GDP per capita) X luxury</td>
<td>0.097</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.081)</td>
<td>(0.099)</td>
</tr>
<tr>
<td>Log(MWh per capita) X dishwasher/refrigerator</td>
<td>-0.020</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(0.101)</td>
<td>(0.090)</td>
</tr>
<tr>
<td>Log(GDP per capita) X dishwasher/refrigerator</td>
<td>0.140***</td>
<td>0.112</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.061)</td>
</tr>
<tr>
<td>Log(MWh per capita) X vacuum</td>
<td>0.169</td>
<td>0.302*</td>
</tr>
<tr>
<td></td>
<td>(0.088)</td>
<td>(0.122)</td>
</tr>
<tr>
<td>Log(GDP per capita) X vacuum</td>
<td>0.186</td>
<td>0.164</td>
</tr>
<tr>
<td></td>
<td>(0.129)</td>
<td>(0.172)</td>
</tr>
<tr>
<td>Log(MWh per capita) X kitchen appliance</td>
<td>0.536***</td>
<td>0.365**</td>
</tr>
<tr>
<td></td>
<td>(0.119)</td>
<td>(0.117)</td>
</tr>
<tr>
<td>Log(GDP per capita) X kitchen appliance</td>
<td>-0.525***</td>
<td>-0.315*</td>
</tr>
<tr>
<td></td>
<td>(0.152)</td>
<td>(0.142)</td>
</tr>
<tr>
<td>Log(quantity)</td>
<td>-0.293***</td>
<td>-0.092***</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.006)</td>
</tr>
</tbody>
</table>

Country Fes                       | YES            | YES                |
Product FEs                       | YES            | YES                |
R-squared                         | 0.04           | 0.29               |
# observations                    | 24,072         | 24,072             |
# products                        | 1,312          | 1,312              |

Notes: Luxury goods include equipment for water sports, skiing, golf, tennis, and adventure sports. Robust standard errors clustered at the product level in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
<table>
<thead>
<tr>
<th>Dependent Variable: Log(price)</th>
<th>US Export Data</th>
<th>Chinese Export Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regressors</td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>log(MWh per capita) X SMALL Refrigerator/Freezer</td>
<td>-0.184*** (0.014)</td>
<td>-0.010 (0.006)</td>
</tr>
<tr>
<td>log(MWh per capita) X LARGE Refrigerator/Freezer</td>
<td>-0.063*** (0.014)</td>
<td>0.042*** (0.006)</td>
</tr>
<tr>
<td>log(Electricity Price) X SMALL Refrigerator/Freezer</td>
<td>-0.256*** (0.016)</td>
<td></td>
</tr>
<tr>
<td>log(Electricity price) X LARGE Refrigerator/Freezer</td>
<td></td>
<td>-0.043*** (0.006)</td>
</tr>
<tr>
<td>log(MWh per capita) X SMALL Refrigerator</td>
<td>-0.130*** (0.017)</td>
<td>-0.052*** (0.004)</td>
</tr>
<tr>
<td>log(MWh per capita) X LARGE Refrigerator</td>
<td>0.186*** (0.014)</td>
<td>0.007 (0.006)</td>
</tr>
<tr>
<td>log(Electricity Price) X SMALL Refrigerator</td>
<td>0.735*** (0.017)</td>
<td></td>
</tr>
<tr>
<td>log(Electricity price) X LARGE Refrigerator</td>
<td>-0.464*** (0.015)</td>
<td>-0.041*** (0.005)</td>
</tr>
<tr>
<td>log(MWh per capita) X SMALL Window AC Unit</td>
<td>0.080*** (0.015)</td>
<td></td>
</tr>
<tr>
<td>log(MWh per capita) X LARGE Window AC Unit</td>
<td>0.177*** (0.017)</td>
<td></td>
</tr>
<tr>
<td>log(Electricity Price) X SMALL Window AC Unit</td>
<td></td>
<td>-0.033 (0.017)</td>
</tr>
<tr>
<td>log(Electricity Price) X LARGE Window AC Unit</td>
<td></td>
<td>-0.341*** (0.016)</td>
</tr>
<tr>
<td>Country FEs</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Product FEs</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td># observations</td>
<td>45,130</td>
<td>29,373</td>
</tr>
<tr>
<td># products</td>
<td>1,322</td>
<td>1,322</td>
</tr>
</tbody>
</table>

Notes: Size definitions do not correspond in the U.S. and Chinese data. Small refrigerator/freezers are less than 200 Liters (China) and less than 184 Liters (U.S.). Large refrigerator/freezers from China are greater than 200 Liters in size. The U.S. data does not contain exports of refrigerator/freezers greater than 184 Liters. Small refrigerators are less than 50 Liters (China) or 184 Liters (U.S.). Large Refrigerators are greater than 150 L (China) or 382 L (U.S.). Small AC units use less than 2.93 KW/hour of energy. Large units use greater than 4.98 KW/hour. The Chinese data does not identify AC unit power intensity. The specification also includes interactions with income per capita and log(quantity) as regressors. Electricity price data is from the Energy Information Administration and is the average price charged between 2004 and 2008. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
## Table 6-Coefficient Estimates from Regressions of Log Unit Values of U.S. Exports on Ski Resorts and Golf Courses Per Capita

<table>
<thead>
<tr>
<th>Dependent Variable: Log(price)</th>
<th>Regressors</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>log(ski resorts per capita) X ski</td>
<td>0.248***</td>
<td>0.248***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.007)</td>
<td>(0.007)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>log(GDP per capita) X ski</td>
<td>-0.741***</td>
<td>-0.745***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.018)</td>
<td>(0.018)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>log(golf courses per capita) X golf club</td>
<td>0.107***</td>
<td>0.259***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.023)</td>
<td>(0.039)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>log(GDP per capita) X golf club</td>
<td>-0.121**</td>
<td>-0.406***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.045)</td>
<td>(0.082)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Log(quantity)</td>
<td>-0.263***</td>
<td>-0.262***</td>
<td>-0.259***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.007)</td>
<td>(0.006)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Country Fes</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Product FEs</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.23</td>
<td>0.24</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td># observations</td>
<td>19,262</td>
<td>34,269</td>
<td>17,570</td>
<td></td>
</tr>
<tr>
<td># products</td>
<td>1,317</td>
<td>1,319</td>
<td>1,317</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Robust standard errors clustered at the product level in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
### Table 7 - Catalysts and Income Per Capita

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Catalyst Data Source</th>
<th>Correlation between catalyst and log (GDP per capita)</th>
<th>Number of Countries with non-missing Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Paved Roads</td>
<td>WDI</td>
<td>0.58</td>
<td>209</td>
</tr>
<tr>
<td>Absence of Violence</td>
<td>WGI</td>
<td>0.67</td>
<td>208</td>
</tr>
<tr>
<td>Rule of Law</td>
<td>WGI</td>
<td>0.79</td>
<td>210</td>
</tr>
<tr>
<td>Housing Volume</td>
<td>ICP</td>
<td>0.86</td>
<td>31</td>
</tr>
<tr>
<td>Radio Access (percent of population)</td>
<td>ITU</td>
<td>0.21</td>
<td>64</td>
</tr>
<tr>
<td>TV Access (percent of population)</td>
<td>ITU</td>
<td>0.72</td>
<td>104</td>
</tr>
<tr>
<td>Telephone Access (percent of population)</td>
<td>ITU</td>
<td>0.71</td>
<td>83</td>
</tr>
<tr>
<td>Internet Access (percent of population)</td>
<td>ITU</td>
<td>0.88</td>
<td>158</td>
</tr>
<tr>
<td>Computer Access (percent of population)</td>
<td>ITU</td>
<td>0.90</td>
<td>160</td>
</tr>
<tr>
<td>Urbanization Rate</td>
<td>WDI</td>
<td>0.70</td>
<td>210</td>
</tr>
</tbody>
</table>
Figure 1: Electricity Consumption and Electricity Access across Countries

Notes: Data from World Development Indicators.