Why are Goods and Services more Expensive in Rich Countries?

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Abstract: Empirical studies show that tradable consumption goods are more expensive in rich countries. This paper proposes a simple yet novel explanation for this apparent failure of the law of one price: Consumers' utility from tradable goods depends on their consumption of complementary goods and services. Monopolistically competitive firms charge higher prices in countries with more complementary goods and services because consumer demand is less elastic there. The paper embeds this explanation within a static Krugman (1980)-style model of international trade featuring differentiated tradable goods. Extended versions of the model can account for the high prices of services in rich countries, as well as for several stylized facts regarding investment rates and relative prices of investment and consumption across countries.

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1. Introduction

There is abundant evidence that tradable consumption goods are more expensive in countries with high per-capita incomes.[1] In particular, recent studies of disaggregate data show a failure of the law of one price due to firms charging higher markups for goods sold to rich countries than for goods sold to poor countries. For example, Allesandria and Kaboski (2011) find that rich countries pay more for goods leaving U.S. docks, and Simonovska (2011) documents that online apparel retailers charge higher markups to consumers in rich countries.[2]

This paper proposes a simple explanation to account for this evidence: The utility a consumer derives from traded consumer goods depends on the consumer's level of consumption of other goods and services that complement the tradable goods. Higher utility from tradable goods lowers the price elasticity of demand for tradables, causing monopolistically competitive firms to charge a higher markup in markets with high consumption of complementary goods and services. Since consumers in rich countries can afford more complementary goods and services, they have a lower price-elasticity of demand for tradable consumer goods and are charged a higher price for tradables.

One example of such a complementary good is housing, which complements the demand for consumer tradables such as a home entertainment system. In the U.S., 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. Firms can therefore charge a higher price in the U.S. than in Ecuador for identical entertainment systems.

Demand for new consumer goods also depends on public infrastructure, including roads and public safety. The value of a car, for example, depends not only on features specific to the vehicle, but also on the environment in which the car is driven. Paved roads increase the utility from owning a nice car, as does a safe environment with low probability of the car being stolen, while owning the same car may provide far less utility in an area with dirt roads or in an area that is insecure.

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[1] See, for example, Balassa (1964), Samuelson (1964), Baghwati (1984), Summers and Heston (1991), Barro (1991), Hsieh and Klenow (2007), and Allesandria and Kaboski (2011), among many others.

[2] Additional empirical work corroborates this evidence of a failure of the law of one price for tradables. Gopinath, Gourinchas, Hsieh, and Li (2011) demonstrate that wholesalers charge different markups in the U.S. market than in the Canadian market. Fitzgerald and Haller (2012) and Burstein and Jaimovich (2008) also find that wholesale prices differ substantially across destinations, even when the products are made in the same plant. Their evidence suggests that cross-country price differences are driven by characteristics specific to the destination countries.

Many types of goods and services may complement demand for differentiated consumer goods (and differentiated consumer goods could complement demand for each other). To 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, or other consumer goods.[3] The concept of a catalyst captures the notion that some goods and services facilitate consumers' derivation of utility from other final goods and services. For example, a house (or some form of shelter) facilitates enjoyment from watching television; it would be quite unpleasant to watch TV while standing outside in the cold. The notion that some goods serve as catalysts in consumers' production of utility is conceptually 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.

This explanation based on *demand complementarity and pricing-to-market* is simple, but to my knowledge has not been explored to date.[4] Below I embed this explanation within a general equilibrium model that builds on a class of utility functions developed in the trade literature which feature demand curves with nonconstant price elasticities of demand. The baseline model features demand complementarity between catalyst goods and differentiated final consumption goods. Specifically, the intercept of the demand curve for differentiated final goods depends on the level of consumption of catalyst goods. To keep the model as simple as possible, I assume that labor is the only factor of production, and that catalyst goods are not traded across international borders. Section 2 develops the basic intuition within a closed economy. Section 3 extends the analysis to two countries with the aim of explaining the relevant empirical facts with respect to prices of tradable goods across countries.

There are two sources of wealth in a country: productivity in the consumer-goods sector (which is assumed to be identical across firms within a country), and the level of catalyst goods. A high level of catalyst goods may be due to a high endowed stock or to high productivity in a sector that produces catalyst goods. Both sources of wealth lead to high real wages in that

[3] The baseline model below is static, and so durability in the standard sense plays no role. Section 5 incorporates long-lived capital as a factor of production, and in this setup catalysts are permitted to be long-lived.
[4] The term *pricing-to-market* refers to general price discrimination across countries. Krugman (1987) defines pricing-to-market as price discrimination in response to nominal exchange rate movements. A number of authors since then, including Allesandrai and Kaboski (2011), refer to the term more generally.

country and high prices of tradables in that country relative to the prices of tradables in other countries. High productivity in the catalyst sector, for example, increases the production of catalysts, which increases demand for final goods.

Sections 4 and 5 extend the model to demonstrate that the mechanism responsible for the high tradable prices in rich countries can also account for a number of other stylized facts in the trade and growth literatures. Section 4 incorporates nontraded services into a two-country model and shows that complementarities between catalyst goods and nontraded services also generate high prices of nontraded services. The typical explanation for the observed correlation between country per-capita income and nontradable prices is based on the theory developed by Harrod (1933), Balassa (1964), and Samuelson (1964), collectively referred to as HBS. The HBS model postulates that the law of one price holds in tradables, and that rich-country productivity is higher in the tradable sector than in the nontradable sector. High productivity in the tradable sector drives up wages in rich countries, which causes higher prices in the sector with lower productivity (nontradables).

As recently noted by Allesandria and Kaboski (2011), there are at least two strong reasons to doubt that the HBS model can fully explain the price-income correlation across countries. First, the law of one price does not hold for tradables, violating a key assumption of HBS (indeed, this observation is the motivation for this paper). Second, the rise in relative productivity of tradables within countries appears too small to account for the strong relationship between prices and incomes across countries.

In contrast to HBS, the explanation proposed in Section 4 for the high price of nontradables in rich countries does not rely on sectoral productivity differentials. Rather, the driving mechanism is complementarity between catalyst goods (e.g., housing, roads, public safety, or any other complementary good) and final goods and services, which causes monopolistically competitive firms in the tradable and nontradable sectors to charge higher markups when a country has more catalyst goods.

The model extensions in Sections 2 through 4 are static and thus abstract from differences in the durability of different goods, and from the accumulation of capital for production. Nonetheless, some of the goods that are considered catalysts (e.g. housing and roads) are, in reality, more durable than final goods (e.g. electronics). Furthermore, while housing and roads are fixed assets that are not traded, they are produced using traded investment goods. Sections 2

through 4 abstract from these complications for the sake of simplicity and because doing so has no bearing on the basic mechanism driving the model. Section 5 demonstrates that an extended version of the model that incorporates these additional dimensions of reality can explain a number of additional stylized facts in the trade and growth literatures relating to the relative prices of consumption and investment goods across countries.

Hsieh and Klenow (2007) show that (1) investment goods are no more expensive at international prices in poor countries, and (2) real investment as a fraction of GDP per capita is positively correlated with income per capita. Based on these observations, and on the fact that consumption is more expensive in rich countries, Hsieh and Klenow conclude that poor countries must have lower productivity in their investment sector than in their consumer goods sector. This conclusion leads them to declare a "productivity puzzle": Why are poor countries even worse at producing investment goods than they are at producing other goods and services? Hsieh and Klenow challenge the literature to explain this apparent productivity differential in poor countries.[5]

The extended model in Section 5 matches the empirical regularities highlighted by Hsieh and Klenow without relying on sectoral productivity differences in poor countries. The mechanism driving the results, *demand complementarity and pricing-to-market*, is the same mechanism responsible for the high price of consumption goods in rich countries in Sections 3 and 4. Furthermore, in the same way that demand complementarity and pricing-to-market provides an alternative to the HBS-based conclusion that rich countries must have a sectoral productivity differential, it also provides an alternative to Hsieh and Klenow's hypothesis of a poor country productivity differential.

An important question is whether the explanation proposed in this paper fits the micro data. Section 6 of the paper provides independent empirical evidence that prices of consumer goods depend on a country's consumption of the relevant catalyst goods and services. Specifically, I use U.S. export data to investigate whether certain consumer goods are sold at higher prices to countries with higher stocks of relevant catalysts. I show that household goods and electronic goods are sold at higher prices to countries with more housing and electricity,

[5] Buera, Kaboski, and Shin (2011) suggest that one reason for the productivity differential in poor countries is that manufacturing requires economies of scale, which must be supported by a well-developed financial sector. Poor countries face financial frictions which disproportionately lower manufacturing productivity (and hence productivity in the investment good sector).

conditional on country level fixed effects. Also, new cars are sold at higher prices to countries with higher percentages of paved roads.

To summarize, *demand complementarity and pricing-to-market* provides a unified explanation for the following regularities:

1) The prices of tradable consumer goods are positively correlated with income-per-capita.
2) The prices of nontradable goods and services are positively correlated with income-per-capita.
3) Investment goods are no more expensive in poor countries.
4) Real investment rates are positively correlated with income-per-capita.

It also explains the dependence of the prices of household goods, electric goods, and new cars on a country's housing stock, electricity availability, and road quality.

2. Closed Economy Model

This section illustrates in a closed-economy setting how prices of consumer goods increase with a country's wealth due to markups that increase with the country's stock of catalyst goods. The closed economy features a representative consumer with preferences over differentiated final goods, a homogenous catalyst good, and a homogenous numeraire good. The final goods represent appliances, household items, and cars, among other consumer goods. The homogenous catalyst good represents housing and public infrastructure such as roads, energy supply, safety, and any other good that may complement demand for the final goods.

The catalyst is produced under perfect competition by a representative firm, while the consumer goods are produced by monopolistically competitive firms. Both sectors use labor, which is supplied inelastically, as the only factor of production. The numeraire is endowed to the economy and enters the consumer's utility function linearly. This particular setup is based on a variant of the linear demand system developed by Ottaviano, Tabucci, and Thisse (2002), and is chosen to demonstrate in the simplest possible setting how *demand complementarities and pricing-to-market* cause prices of final consumer goods to rise with a country's wealth. The Ottaviano et al (2002) demand system is analytically convenient, in part because the marginal utility of income is unity for all levels of income. Appendix A demonstrates that the results of this section are robust to alternative functional forms for which the marginal utility of income varies with income and the numeraire is produced with labor.

Model Setup. The representative agent's utility function is defined over the catalyst good C, the mass Ω of final goods, and a numeraire y:

$$U = y + C^{\alpha} \int_{\Omega} f_{\omega} d\omega - \frac{1}{2}\gamma \int_{\Omega} f_{\omega}^{2} d\omega, \tag{1}$$

where f_{ω} is consumption of final good $\omega \in \Omega$. The numeraire y is endowed to the economy, and could represent any commodity, such as gold or wheat. Agricultural commodities are perhaps the most intuitive interpretation of the numeraire because, among other reasons, agriculture is often considered to be endowed to the economy due to its heavy reliance on immobile factors of production.[6]

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). The utility function here differs from their utility functions in two ways. First, the marginal utility from consuming any variety ω is independent of consumption of any other variety $\omega' \neq \omega$. This is for analytical convenience only. Second, equation (1) features a catalyst good C that acts as a demand shifter for the consumption goods.

The agent inelastically supplies L units of labor to the market. The agent also owns the firms in the economy and receives profit income from the mass Ω of firms that produce differentiated consumption goods. The budget constraint is

$$y + wL + \int_{\Omega} \Pi_{\omega} d\omega = y + p_C C + \int_{\Omega} p_{\omega} f_{\omega} d\omega, \tag{2}$$

where w is the wage, p_C is the price of the catalyst, and p_{ω} is the price of variety ω.

Maximizing (1) subject to (2) yields demand for final good f_{ω}:

$$f_{\omega}^{d} = \frac{1}{\gamma}(C^{\alpha} - p_{\omega}), \tag{3}$$

which is increasing in C. This simple linear demand function captures the notion that demand for consumption goods is less elastic when the economy has a higher stock of housing and public infrastructure. For example, a consumer's willingness to pay for a fancy new oven is higher (and his price-sensitivity lower) if he has a nice kitchen and house that can accommodate dinner guests.

[6] See, for example Ottaviano et al (2002), and, more recently, Allen (2012) for models with an endowed agricultural commodity. The baseline model features an endowed numeraire and a linear demand system for analytical convenience. As Appendix A demonstrates, the qualitative predictions of the model are robust to alternative, but more analytically complicated, setups in which the numeraire is produced with labor.

Demand for the catalyst is likewise increasing in consumption of final goods:

$$C^d = \left(\frac{\alpha F}{p_C}\right)^{\frac{1}{1-\alpha}}, \tag{4}$$

where $F \equiv \int_0^\Omega f_\omega d\omega$. The larger the mass of goods Ω, and the more of each good consumed, the higher is the demand for the catalyst. For example, demand for a mansion is high if a consumer has access to artwork, furniture, and appliances with which to fill the mansion. Otherwise a large, empty house is of little value.

Final Good Sector. Final good firms employ labor in a linear production function to produce output according to

$$f_\omega = AL_\omega, \tag{5}$$

where A is labor productivity, which is identical across firms, and L_ω is the amount of labor employed by firm ω. Each firm chooses its output price to maximize profits. Firm ω's profit function is

$$\Pi_\omega = p_\omega f_\omega - \frac{w}{A} f_\omega. \tag{6}$$

The profit-maximizing price is derived by substituting (3) into (6) and maximizing with respect to p_ω:

$$p_\omega = \frac{1}{2}\left(C^\alpha + \frac{w}{A}\right). \tag{7}$$

Prices are increasing in C because demand is less elastic when C is high. Equation (7) captures the intuition that (a) monopolistically competitive firms charge a price that is proportional to consumer utility, and (b) catalyst goods increase utility from consumer goods. The two-country counterpart to (7) in Section 3 derives the central result that rich countries pay higher prices for identical goods. Note that linearity of the demand curve (3) is sufficient but not necessary for the price elasticity of demand to be decreasing in the catalyst. Appendix B derives the necessary and sufficient conditions under which the price elasticity of demand is decreasing in C.

Given the price, demand for variety ω is

$$f_\omega^d = \frac{1}{2\gamma}\left(C^\alpha - \frac{w}{A}\right), \tag{8}$$

which is derived by substituting (7) into (3). Firm ω earns profits given by

$$\Pi_\omega = \frac{1}{4\gamma}\left(C^\alpha - \frac{w}{A}\right)^2.$$

I permit profits to be positive because incorporating a zero-profit condition would simply complicate the model by adding an equilibrium equation and an extra endogenous variable (the mass of final goods firms). Also, abstracting from fixed costs and increasing returns permits a clear comparison of productivity across sectors to demonstrate that demand complementarities, rather than productivity differentials, drive the price differences in the two-country models in sections 3 through 5. Nonetheless, the positive relationship between final goods prices and economic wealth derived below is robust to incorporating zero profits as a long-run equilibrium condition.

Since productivity is identical across firms, so are prices and quantities: $f_\omega = f$ and $p_\omega = p \ \forall \ \omega \in \Omega$. Total demand over all final consumption goods is derived by integrating (8) across varieties:

$$F = \frac{\Omega}{2\gamma}\left(C^\alpha - \frac{w}{A}\right). \tag{9}$$

Given total demand for final goods, we can write demand for labor in the final good sector as $L_Q \equiv \int_0^\Omega L_\omega d\omega$, or

$$L_Q = \frac{1}{A}F. \tag{10}$$

Catalyst Sector. Catalysts are produced competitively using the technology

$$C = A_C L_C, \tag{11}$$

where A_C and L_C are productivity and labor in the catalyst sector. Cost minimization yields the price of catalysts, $p_C = w/A_C$.

Equilibrium. Equilibrium is characterized by demand for catalysts (4), demand for consumer goods (9), and labor market clearing,

$$L = \frac{F}{A} + \frac{C}{A_C}. \tag{12}$$

The endogenous variables are $F, C,$ and w.

Comparative Statics. The central message of this section is that in general equilibrium, prices of final goods are increasing in the economy's wealth. To gain insight into how this result arises in the model, it is useful to examine how market outcomes respond to the two sources of wealth in the economy (productivity in the catalyst sector and final goods sector). Figure 1 shows how market outcomes vary with productivity in the catalyst sector for the following parameterization:

$$L = 1, \qquad A = 1, \qquad \Omega = 1, \qquad \alpha = 0.3, \qquad \gamma = 0.3.^{7} \tag{13}$$

As A_C increases, the price of the catalyst falls and the quantity of the catalyst increases. The increase in C shifts out the demand curve for final goods, lowering the price-elasticity of demand. Firms charge a higher markup, causing a higher price of final goods. The positive effect of C on demand for final goods outweighs the counteracting effect of w on the price, so overall demand for final goods increases.

Figure 2 shows how market outcomes depend on productivity in the final goods sector. The parameters are as above, and productivity in the catalyst sector is held constant at unity ($A_C = 1$). The effect of A on F and C is similar to the effect of A_C in Figure 1. However, the effect of A on prices is different from the effect of A_C because a higher A lowers the marginal cost of producing final goods, which lowers their price. When productivity in both sectors increases, the net effect is an increase in the price of final goods. Thus, even in a closed economy, prices of final goods rise with economy-wide productivity due to high demand from the consumption of more catalyst goods.

3. Two-Country Model

This section extends the model of Section 2 to incorporate trade between two countries N (North) and S (South). The purpose of this exercise is to demonstrate 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. In the model, each country is endowed with the numeraire and inelastically supplies labor to produce catalyst goods and differentiated final goods. Catalyst goods are not traded across countries. This assumption is for simplicity, and because some catalyst goods represent housing and public infrastructure, which are fixed immobile assets. The numeraire is endowed to each country and is traded. Following Krugman (1980), each country specializes in a unique set of differentiated final goods. As in Section 2, final goods are produced by monopolistically competitive firms. Firms can move final goods costlessly across international borders. Consumers, however, face large costs of moving goods across international borders. Therefore even though firms charge country-specific prices, consumers do not arbitrage because there are prohibitive costs associated with doing so. These

[7] The qualitative results are robust to all parameter values. A proof based on total differentiation of the equilibrium equations is available from the author upon request.

costs could represent the time required to travel across international borders, as suggested in Gopinath et al (2011), as well as other transportation costs and information rigidities.

Model Setup. Each country $j \in \{N, S\}$ produces a mass Ω_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

$$U_j = y_j + \sum_{i=N,S} \int_{\omega_i \in \Omega_i} \left[C_j^{\alpha} f_j(\omega_i) - \frac{\gamma}{2} \left(f_j(\omega_i) \right)^2 \right] d\omega_i, \tag{14}$$

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 ω_i from country $i \in \{N, S\}$. As in the previous section, the numeraire good y simplifies the analysis.

The budget constraint of the representative agent in country j is

$$y_j^0 + w_j L_j + \sum_{i=N,S} \int_{\omega_j \in \Omega_j} \Pi_i(\omega_j) = y_j + p_{Cj} C_j + \sum_{i=N,S} \int_{\omega_i \in \Omega_i} p_j(\omega_i) f_j(\omega_i), \tag{15}$$

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

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

$$f_j^d(\omega_i) = \frac{1}{\gamma} \left(C_j^{\alpha} - p_j(\omega_i) \right). \tag{16}$$

Similarly, the first order condition with respect to C_j yields

$$C_j^d = \left(\frac{\alpha F_j}{p_{Cj}} \right)^{\frac{1}{1-\alpha}}, \tag{17}$$

where $F_j \equiv \sum_{i=N,S} \int_{\omega_i \in \Omega_i} f_j(\omega_i)$ is the total quantity of final goods consumed in country j.

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

$$f(\omega_j) = A_j L_{\omega_j}, \tag{18}$$

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

$p_S(\omega_S) \neq p_N(\omega_S)$, the costs to consumers in country $\{i: p_i(\omega_S) < p_j(\omega_S)\}$ of purchasing good ω_S in i are sufficiently high to prevent arbitrage. Likewise, costs to consumers of transporting good ω_N across international borders are sufficiently high to prevent arbitrage when $p_S(\omega_N) \neq p_N(\omega_N)$.

Profits from sales of ω_j in i can be written

$$\Pi_i(\omega_j) = p_i(\omega_j) f_i(\omega_j) - \frac{w_j}{A_j} f_i(\omega_j). \tag{19}$$

The profit-maximizing price charged in country i is

$$p_i(\omega_j) = \frac{1}{2}\left(C_i^{\alpha} + \frac{w_j}{A_j}\right). \tag{20}$$

Equation (20) states that the optimal price of an identical good varies across countries based on the stock of catalyst goods in each country. This is the key result of the paper, and it explains why rich countries pay higher prices for tradable goods. Of course, it remains to be seen that rich countries have more of the catalyst in equilibrium, a task to which we now turn.

Given the price defined by (20), consumer demand in country i for ω_j is

$$f_i^d(\omega_j) = \frac{1}{2\gamma}\left(C_i^{\alpha} - \frac{w_j}{A_j}\right), \tag{21}$$

The resulting revenues of firm ω_j from sales to country i are

$$p_i(\omega_j) f_i(\omega_j) = \frac{1}{4\gamma}\left(C_i^{2\alpha} - \frac{w_j^2}{A_j^2}\right), \tag{22}$$

and profits are

$$\Pi_i(\omega_j) = \frac{1}{4\gamma}\left(C_i^{\alpha} - \frac{w_j}{A_j}\right)^2. \tag{23}$$

Catalyst Sector. As in Section 2, the catalyst in country j is produced competitively according to $C_j = A_{Cj} L_{Cj}$, where A_{Cj} is productivity in the catalyst sector in country j and L_{Cj} is labor employed in j's catalyst sector. The price of the catalyst is $p_{Cj} = w_j / A_{Cj}$, 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 ω_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

$$y_j^0 + w_j L_j + \Omega_j(\Pi_{jj} + \Pi_{ji}) = y_j + p_{Cj} C_j + \Omega_j p_{jj} f_{jj} + \Omega_i p_{ji} f_{ji} \qquad (24)$$

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

$$L_j = \frac{\Omega_j(f_{jj} + f_{ji})}{A_j} + \frac{C_j}{A_{Cj}}. \qquad (25)$$

Market clearing for the numeraire is

$$y_N^0 + y_S^0 = y_N + y_S. \qquad (26)$$

Equilibrium is characterized by demand for the catalyst in each country (17), demand for final goods (21), labor market clearing in each country (25), market clearing for the numeraire (26), and the budget constraints (24). By Walras' Law, one of these equations is redundant. For clarity, the equilibrium conditions are written explicitly as:

$$C_N = \left(\frac{A_{CN}\alpha(\Omega_N f_{NN} + \Omega_S f_{NS})}{w_N}\right)^{\frac{1}{1-\alpha}}, \qquad C_S = \left(\frac{A_{CS}\alpha(\Omega_N f_{SN} + \Omega_S f_{SS})}{w_S}\right)^{\frac{1}{1-\alpha}},$$

$$f_{NN} = \frac{1}{2\gamma}\left(C_N^\alpha - \frac{w_N}{A_N}\right), \quad f_{NS} = \frac{1}{2\gamma}\left(C_N^\alpha - \frac{w_S}{A_S}\right),$$

$$f_{SS} = \frac{1}{2\gamma}\left(C_S^\alpha - \frac{w_S}{A_S}\right), \quad f_{SN} = \frac{1}{2\gamma}\left(C_S^\alpha - \frac{w_N}{A_N}\right),$$

$$L_N = \frac{\Omega_N}{A_N}(f_{NN} + f_{SN}) + \frac{C_N}{A_{CN}}, L_S = \frac{\Omega_S}{A_S}(f_{SS} + f_{NS}) + \frac{C_S}{A_{CS}},$$

$$y_N^0 + y_S^0 = y_N + y_S,$$

$$y_N^0 - y_N + \Omega_N p_{SN} f_{SN} = \Omega_S p_{NS} f_{NS},$$

where the last equilibrium equation is a simplified version of the budget constraint for country N (see equation 24). 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}.

Results. Figure 3 shows how market outcomes vary with catalyst productivity in N under the following baseline parameterization:

$$A_N, A_S, A_{CN}, A_{CS} = 3, \qquad L_N, L_S, y_N^0, y_S^0, \Omega_N, \Omega_S = 1, \qquad \alpha, \gamma = 0.3.$$ [8]

As A_{CN} rises, N produces and consumes more of the catalyst. Higher catalyst consumption shifts out the demand curves of final goods, which causes firms from both countries to charge higher markups for goods sold in N. The resulting quantities of final goods demanded by N increase because the outward shift of the demand curves caused by higher catalyst consumption outweighs the movement along the demand curves caused by higher prices. Therefore a rise in A_{CN} causes higher catalyst and final good consumption in N, as well as higher prices of final goods.

The rise in f_{NS} requires S to devote more labor resources to its export sector and less resources to production for domestic consumption, causing a fall in f_{SS} and C_S. How is this optimal for S? Since exports from S are sold at a higher markup, the value of exports f_{NS} increase relative to the value of the numeraire. S therefore reallocates labor to the export sector to exchange for the numeraire, leading to an increase in welfare in S. Note that S does not import more consumer goods from N, despite the increase in the price S charges for exports. This is because the increase in A_{CN} increases wages in N, which increases marginal costs in N's final goods sector. Higher marginal costs in N cause an increase in p_{SN} that is greater than S's marginal benefit from additional consumption of f_{SN}.

The wage falls in S because the value of labor falls relative to the value of the numeraire. As C_S falls, the value of final goods produced for domestic consumption in S also falls. Welfare is increasing in S due to imports of the numeraire (Figure 4). However, welfare need not increase in general in S, and it is possible that, depending on the parameterization, welfare in S falls with an increase in A_{CN}. This is because the productivity increase complements labor in N and is specific to the good that N consumes. See Murphy (2011) for an explanation of why welfare may fall under such circumstances.

Figure 5 shows relative prices in N and S of identical goods. The left-hand graph shows the ratio of prices relative to the numeraire, while the graph on the right shows the ratio of PPP-adjusted prices.[9] According to Figure 5, the model predicts that as a country gets richer, it pays

[8] Baseline productivity is set to 3 to ensure that utility from consumption of final goods and catalyst goods is sufficiently high to ensure positive demand for imports from N and S. In other words, the productivity parameters are chosen such that the equilibrium is at an interior solution given by the ten equilibrium equations above.

[9] In Figure 4, $p_{ij}^R \equiv p_{ij}/P_i$, where P_i is the consumer price index. P_i is normalized to unity under the initial calibration in which productivity is equal across countries. Note that PPP holds when N and S are equal because the

higher prices for identical goods than does its poorer counterpart, consistent with the evidence across countries cited in the introduction.

The effects of a productivity increase in N's final goods sector are nearly identical to the effects of A_{CN} with respect to relative prices but differ slightly in other respects. Figure 6 shows the comparative statics for an increase in productivity in the final good sector in N. As A_N increases, N increases its production and consumption of all goods. The increase in C_N increases the markups all firms charge N for consumer goods, which puts upward pressure on prices in N. While p_{NS} increases due to the higher markup, p_{NN} actually falls due to the fall in marginal costs that corresponds to the increase in A_N.

The fall in N's marginal cost of producing final goods also causes the price of its exports, p_{SN}, to fall. This is the main difference between the comparative statics with respect to A_{CN} and those with respect to A_N. The fall in p_{SN} causes S to import more final goods rather than importing more of the numeraire when the price of S's exports increases.

Figure 7 shows the effect of increases in A_N on relative prices. As with the effect of A_{CN}, prices of identical goods are higher in N than in S, consistent with the empirical evidence cited in the Introduction.

Summary of the Two-Country Model. The sources of relative wealth in the rich country, N, are productivity in the catalyst sector and productivity in the final good sector. As productivity in either sector increases, N can afford to produce more catalyst goods, which shifts out its demand for final goods by increasing the price-intercept of the demand curve. N's resulting lower price elasticity of demand causes firms to charge a higher markup in N than in S, which increases relative prices in N.

As we will see in Section 4 below, this simple explanation of *demand complementarity and pricing-to-market* can explain not only high prices of traded consumer goods in rich countries, but also high prices of nontradables in rich countries.

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exact same bundles are purchased at identical costs in each country. When productivity is not equal across countries (e.g. at any point in Figure 4 to the right of the y-axis), P_i is the current price in country i of the bundle of goods consumed when PPP held (the Laspeyres Index):

$$P_i = \frac{y_i^0 + p_{Ci}C_i^0 + p_{ij}\Omega_j f_{ij}^0 + p_{ii}\Omega_i f_{ii}^0}{y_i^0 + p_{Ci}^0 C_i^0 + p_{ij}^0\Omega_j f_{ij}^0 + p_{ii}^0\Omega_i f_{ii}^0},$$

where the superscript 0 indicates the price or quantity that prevails when PPP holds (productivity is equal across countries).

4. Two-Country Model with Nontradables

This section extends the model of Section 3 to incorporate nontradables that are produced and sold domestically by monopolistically competitive firms. The purpose of this simple extension is to demonstrate that the mechanism emphasized above to account for the comparatively high prices of tradables in rich countries can also account for the comparatively high prices of nontradables in rich countries.[10]

The typical explanation for the observed correlation between country income and nontradable prices is based on the theory developed by Harrod (1933), Balassa (1964), and Samuelson (1964). The HBS model assumes that the law of one price (LOP) holds in tradables, and that rich-country productivity is higher in the tradable sector than in the nontradable sector. High productivity in the tradable sector drives up wages in rich countries, which causes higher prices in the sector with lower productivity (nontradables).

As recently noted by Allesandria and Kaboski (2011), there are at least two strong reasons to doubt HBS as a full explanation of the price-income correlation across countries. First, the LOP does not hold for tradables, violating a key assumption of HBS. Second, the rise in relative productivity of tradables within countries appears too small to account for the strong relationship between prices and incomes across countries.

The model extension below provides an alternative explanation to account for comparatively high prices of nontradables in Rich countries (as well as comparatively high tradable prices). In contrast to HBS, the new explanation does not rely on sectoral productivity differentials. Rather, the driving mechanism is complementarity between catalyst goods and final goods, as in Section 3. Rich countries can afford to produce more catalyst goods, which in turn increases demand for nontradable goods and services.

Consider, for example, purchasing car rental services in Ecuador, which has unpaved roads and a generally unsafe environment for driving. Even if a car rental agency can provide a vehicle to rent at low cost, customers will have low preference for this service simply because there are characteristics specific to Ecuador (poor driving conditions) which may not affect the cost to the firm of providing the service, but which reduce customers' utility from the service. Likewise, consumers may require a haircut once a month, but the utility from a haircut at a

[10] This high price of nontradables in rich countries is well-documented. See, for example, Allesandria and Kaboski (2011, p.92).

barber shop relative to cutting one's own hair depends on the convenience of traveling to the barber, which in turn depends on public infrastructure such as roads, safety, and reliable energy supply to ensure the barber shop will be open for business. It may also 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 the cultural norm. Notice that in this last example, the complementary *catalyst* is itself a service.

Utility from nontradable services also depends on durables, such as housing. 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.

The model below captures this intuition by incorporating nontradable services into the model from Section 3. For simplicity, productivity is assumed to be identical across sectors within a country. As we will see, high service prices will rely on demand complementarities, rather than on sectoral productivity differentials.

Model Setup. The representative consumer in country j has utility over the numeraire, tradable goods, and a mass Ψ_j of nontradable services:

$$\begin{aligned} U_j = y_j &+ \int_{\psi_j \in \Psi_j} \left[C_j^{\alpha} f_j(\psi_j) - \frac{\gamma}{2} \left(f_j(\psi_j) \right)^2 \right] d\psi_j \\ &+ \sum_{i=N,S} \int_{\omega_i \in \Omega_i} \left[C_j^{\alpha} f_j(\omega_i) - \frac{\gamma}{2} \left(f_j(\omega_i) \right)^2 \right] d\omega_i, \end{aligned} \tag{27}$$

where ψ_j indexes the services in country j and $f_j(\psi_j)$ is consumption of variety ψ_j in j. Unless otherwise stated, the notation and variable names are the same as in Section 3 above.

Country j's budget constraint is

$$\begin{aligned} y_j^0 + w_j L_j + \int_{\psi_j \in \Psi_j} \Pi(\psi_j) + \sum_{i=N,S} \int_{\omega_j \in \Omega_j} \Pi_i(\omega_j) \\ = y_j + p_{Cj} C_j + \int_{\psi_j \in \Psi_j} p_j(\psi_j) f_j(\psi_j) + \sum_{i=N,S} \int_{\omega_i \in \Omega_i} p_j(\omega_i) f_j(\omega_i), \end{aligned} \tag{28}$$

where $\Pi(\psi_j)$ are profits from sales of service ψ_j at price $p_j(\psi_j)$ and quantity $f_j(\psi_j)$. Consumer optimization with respect to $f_j(\psi_j)$ yields demand for variety ψ_j in country j:

$$f_j^d(\psi_j) = \frac{1}{2\gamma}\left(C_j^\alpha - p_j(\psi_j)\right). \tag{29}$$

Demand for tradable goods is given by (16) above, and demand for catalyst goods is given by (17), where total consumption of final goods and services in country j is

$$F_j \equiv \int_{\psi_j \in \Psi_j} f_j(\psi_j) + \sum_{i=N,S} \int_{\omega_i \in \Omega_i} f_j(\omega_i).$$

Consumption Sector Firms. Optimization by firms in the tradable sector is identical to that in section 3. As above, prices and quantities are independent of the variety, so we can write

$$p_{ji} = \frac{1}{2}\left(C_j^\alpha + \frac{w_i}{A_i}\right), \tag{30}$$

$$f_{ji} = \frac{1}{2\gamma}\left(C_j^\alpha - \frac{w_i}{A_i}\right), \tag{31}$$

where p_{ji} and f_{ji} are the price and quantity of any variety produced in country $i \in \{N, S\}$ and sold in $j \in \{N, S\}$.

Service Sector Firms. Services are produced using the same technology as that used by consumer goods:

$$f_j(\psi_j) = A_j L_{\psi_j}, \tag{32}$$

where L_{ψ_j} is labor used to produce service variety ψ_j. Profits of firm ψ_j are

$$\Pi_j(\psi_j) = p_j(\psi_j) f_j(\psi_j) - \frac{w_j}{A_j} f_j(\psi_j). \tag{33}$$

Profit maximization yields the price

$$p_j(\psi_j) = \frac{1}{2}\left(C_j^\alpha + \frac{w_j}{A_j}\right). \tag{34}$$

The resulting quantity demanded is

$$f_j(\psi_j) = \frac{1}{2\gamma}\left(C_j^\alpha - \frac{w_j}{A_j}\right). \tag{35}$$

Catalyst Sector. Productivity in the catalyst sector is assumed to be identical to productivity in the final goods and services sectors within a country. The production function for catalyst goods is $C_j = A_j L_{Cj}$. As in Sections 2 and 3, the catalyst sector is perfectly competitive.

The price of the catalyst is $p_{Cj} = w_j/A_j$, which is derived from cost minimization by the representative catalyst firm. Also, as in Sections 2 and 3, the catalyst is not traded across countries.[11]

Equilibrium. Since $p_j(\psi_j)$ and $f_j(\psi_j)$ are identical for any variety ψ_j from country j, it is helpful to omit variety indices by writing $p_j = p_j(\psi_j)$ and $f_j = f_j(\psi_j)\ \forall\, \psi_j \in \Psi_j$. Total consumption of goods and services in country j can be written $F_j = \Psi_j f_j + \Omega_j f_{jj} + \Omega_i f_{ji}$.

Equilibrium is characterized by demand for the catalyst in each country (17), demand for final goods in each country (31), demand for nontradables in each country (29), labor market clearing in each country,

$$L_N = \frac{1}{A_N}[\Psi_N f_N + \Omega_N(f_{NN} + f_{SN}) + C_N],$$

$$L_S = \frac{1}{A_S}[\Psi_S f_S + \Omega_S(f_{NS} + f_{SS}) + C_S],$$

numeraire market clearing

$$y_N^0 + y_S^0 = y_N + y_S,$$

and the budget constraint for N, which simplifies to

$$y_N^0 + \Omega_N p_{SN} f_{SN} = y_N + \Omega_S p_{NS} f_{NS}.$$

By Walras' Law, the budget constraint in S is redundant.

Results. The initial parameter values are $\alpha = 0.3,\ \gamma = 0.3$; the initial productivity paramaters are set to unity, and the mass of goods and services in each country is unity ($\Psi_j + \Omega_j + \Omega_i = 1$). Figure 8 shows market outcomes as productivity in N increases. The results are very similar to those from Section 3: 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.

[11] The assumption that catalysts such as housing and roads are nontraded is for convenience, but it is also realistic. Nonetheless, in reality factor inputs for housing and roads are traded, a fact from which the model in this section abstracts. Section 5 improves the realism of the model by incorporating tradable investment goods. As we will see, this extension delivers more than just extraneous realism; it also helps explain stylized facts in the trade and growth literatures.

Summary of Two-Country Model with Services. The value of services within a country rises with that country's stock of catalyst goods. A rich country can afford to produce more of the catalyst, which lowers the price elasticity of demand for tradable final goods and nontradable services within the country. As a result, monopolistically competitive firms in the final good and service sectors charge a higher markup, causing higher prices of tradable goods and nontradable services in the rich country.

Note that the simple mechanism of demand complementarity and pricing-to-market was initially proposed in Sections 2 and 3 to account for the high prices of tradable goods in rich countries. Section 4 showed how the same mechanisms can account for another stylized fact in international trade (the high prices of services in rich countries) by adding a degree of realism to the baseline model. Of course, even the extended model of Section 4 abstracts from many dimensions of reality. One of the most obvious abstractions is the absence of traded investment goods. As we will see in Section 5, incorporating traded investment goods and capital as a factor of production permits the model to explain additional stylized facts in the trade and growth literatures.

Section 5: Incorporating Capital and Tradable Investment into the Two-Country Model. Hsieh and Klenow (2007) propose an explanation for five empirical regularities in the growth literature. Three empirical regularities are well-established and well-known:

1) The price of consumption is high when income per capita is high.
2) The price of capital (relative to consumption) is low when income per capita is high, and
3) Real investment rates are positively correlated with income per capita.

The first fact, which is typically attributed to HBS, has already been discussed at length. Facts (2) and (3) date back to Barro (1991) and are often attributed to policies in poor countries that distort savings and investment decisions.

Hsieh and Klenow emphasize two other stylized facts that are likewise well-established but perhaps less well-known:

4) Investment rates measured in domestic prices are no lower in poor countries, and
5) Prices of investment goods are no higher in poor countries.

Facts (4) and (5) have strong implications for the set of plausible mechanisms responsible for facts (1) through (3). To see this, let I_j, C_j, and p_j stand for investment per capita, consumption per capita, and the price of nontradable consumption in country $j \in \{N, S\}$. Let p_I stand for the price of investment that prevails in both countries (consistent with fact 5). The investment rate in country j measured at domestic prices is

$$i_{dom}^{j} = \frac{p_I I_j}{p_j C_j + p_I I_j},$$

and the real investment rate is

$$i^{j} = \frac{p_I I_j}{p_N C_j + p_I I_j}, \tag{36}$$

where p_N is the price of consumption prevailing in the rich country.[12] Fact (3) can be written as $i^N > i^S$:

$$\frac{p_I I_N}{p_N C_N + p_I I_N} > \frac{p_I I_S}{p_N C_S + p_I I_S}, \tag{37}$$

and fact (4) can be written as $i_{dom}^{N} = i_{dom}^{S}$:

$$\frac{p_I I_N}{p_N C_N + p_I I_N} \approx \frac{p_I I_S}{p_S C_S + p_I I_S}. \tag{38}$$

Note that equation (38) follows from equation (37) and fact (1), given that investment prices are equal across countries (fact 5). Also, fact (2) follows from facts 1 and 5. Therefore, facts 2 and 4 are redundant and the five facts can be restated in the following condensed set of three facts:

1*) The price of consumption is positively correlated with income per capita.

2*) Prices of investment goods are no higher in poor countries.

3*) Real investment rates are positively correlated with income.

Hsieh and Klenow (2007) provide a unified explanation for these stylized facts and conclude,

> "*Poor countries* appear to have low investment rates in PPP terms primarily because they have either *low productivity in producing investment goods* or low productivity in producing tradables to exchange for investment goods…Our results thus imply…a deeper productivity puzzle. The challenge is to explain not only low overall productivity in poor countries, but

[12] The PPP price of consumption as measured by the Penn World Tables (from which Hsieh and Klenow derive their facts) is essentially the price prevailing in rich countries. See Hsieh and Klenow (2007), p. 566.

also low productivity in investment goods (or in providing consumption goods to trade for investment goods) relative to consumption goods" (p. 564, emphasis mine).

To understand Hsieh and Klenow's inference of a productivity puzzle, note that for a rich country N and a poor country S, facts (1*) and (2*) can be written

$$\frac{p_N}{p_I} > \frac{p_S}{p_I} \tag{39}$$

Assuming perfect competition and factor intensities that are the same across sectors, we can write $p_j/p_I = A_{Ij}/A_j$, where A_{Ij} and A_j are productivity in the investment sector and consumption sector in country j. Then (39) becomes

$$\frac{A_{IN}}{A_N} > \frac{A_{IS}}{A_S}.$$

If productivity in N is the same in the investment sector as in the consumption sector, it follows that $A_{IS} < A_S$. Note that A_{IS} could represent productivity in S's investment sector, or in another sector that produces exports to be exchanged for investment goods.

Alternative Explanation. This section provides an alternative unified explanation for these stylized facts that does not rely on poor countries having low productivity in the investment goods sector relative to productivity in the consumption goods sector. My explanation instead builds on the mechanisms developed above under a framework that features pricing-to-market in the final goods sector and complementarity between catalyst goods and final goods.

More concretely, in the model below goods are produced using labor, which is inelastically supplied, and capital, which is accumulated through investment. Rich countries have a high stock of catalyst goods, which causes the value of final consumer goods to be higher in rich countries than in poor countries and causes higher markups for goods sold to Rich countries (Fact 1*).

Fact (2*) is an immediate consequence of any assumption on the market structure for investment goods such that prices of investment goods equalize across countries. In the simplest case, investment goods are produced under perfect competition (as in Hsieh and Klenow 2007) and are traded costlessly. An alternative assumption is that differentiated investment goods are produced by monopolistically competitive firms. If the differentiated goods are aggregated into the investment good through a CES aggregator, then firms will charge the same markup over

marginal cost for their investment good in each country and the price of the final investment good will equalize across countries.

Hsieh and Klenow note that under some empirical specifications, investment goods are slightly more expensive in rich countries. A model in which the investment aggregator function gives rise to price-dependent investment demand curves can generate a positive relationship between investment prices and income, as demonstrated in Appendix D. The properties of such a model are more complicated than is necessary to demonstrate that the focal mechanism, *demand complementarity and pricing-to-market*, can resolve Hsieh and Klenow's productivity puzzle. The model in this section presents the simplest case of perfect competition in the investment goods sector, consistent with the analysis in Hsieh and Klenow (2007). Appendix C demonstrates the case in which a final investment good is produced from differentiated intermediate investment goods using a CES aggregator.

In the two-country model below, the homogenous investment good is traded costlessly, causing the price of the investment good to equalize across countries. This implies that the rental rate of capital also equalizes across countries. The equalization of capital prices across countries causes the capital price-to-wage ratio to be high in poor countries relative to the ratio in rich countries. In response to the difference in factor prices, firms in poor countries demand a lower capital/labor ratio than do rich countries, which lowers real investment in poor countries relative to investment in rich countries (Fact 3*).

All goods are produced using a Cobb-Douglas technology that employs labor and capital as factor inputs. The homogenous investment good is traded, as are differentiated final goods. The catalyst (e.g. housing and infrastructure) is not traded. Since the catalyst represents durables such as housing and roads, as well as nondurables that may complement consumer goods, the catalyst is permitted to be long-lived in the model.

The price of investment is equalized across both countries, so the country with a comparative advantage in the investment sector will produce the investment good, while the other country will trade final consumer goods for the investment good. This assumption approximates reality: Eaton and Kortum (2001) show that poor countries import most of their capital equipment. Finally, the model abstracts from production of nontradable final goods and services for the sake of simplicity only.

Model Setup. The representative consumer in country $j \in \{N, S\}$ maximizes

$$\sum_{t=0}^{\infty} \beta^t U_{jt}$$

subject to

$$K_{j,t+1} = (1-\delta)K_{jt} + I_{jt},$$

$$C_{j,t+1} = (1-\delta)C_{jt} + X_{jt},$$

$$y_{jt}^0 + R_{jt}K_{jt} + w_{jt}L_{jt} + \sum_{i=N,S} \int_{\omega_j \in \Omega_j} \Pi_{it}(\omega_j)$$
$$= p_{Ijt}I_{jt} + y_{jt} + p_{Xjt}X_{jt} + \sum_{i=N,S} \int_{\omega_i \in \Omega_i} p_{jt}(\omega_i) f_{jt}(\omega_i),$$

where U_{jt} is the within-period utility function given by (14), K_{jt} is the capital stock in period $t \in \{0,1,2,\ldots\}$, R_{jt} is the rental price of capital, I_{jt} is capital investment by j in period t, p_{Ijt} is the price of capital investment, X_{jt} is the addition to j's catalyst stock in period t, p_{Xjt} is the price of X_{jt}, and δ is depreciation of capital and the catalyst. The remaining variables are as defined in Section 3.

The analysis carried out here is in steady state, so from now on time subscripts will be omitted. Consumer optimization with respect to K yields the steady-state rental price of capital:

$$R = p_I(r + \delta), \tag{40}$$

where $r = \frac{1-\beta}{\beta}$ is the real interest rate. Since investment is traded at no cost, its price equalizes across countries ($p_{Ij} = p_I$), as does the rental price of capital.

Steady-state demand for the catalyst in country j is

$$C_j = \left[\frac{\beta\alpha F_j}{p_{Xj}\big(1-\beta(1-\delta)\big)}\right]^{\frac{1}{1-\alpha}}, \tag{41}$$

where

$$F_j \equiv \sum_{i=N,S} \int_{\omega_i \in \Omega_i} f_j(\omega_i).$$

Demand for consumer good variety ω_i in country j is given by (16).

Consumption Good Sector. Output in the consumption goods sector is produced using the technology

$$f(\omega_j) = A_j L_{\omega j}^{\eta} K_{\omega j}^{1-\eta}, \tag{42}$$

where $f(\omega_j) \equiv f_N(\omega_j) + f_S(\omega_j)$. As in the baseline model, each firm ω_j charges a country-specific price to maximize the profits $\Pi_i(\omega_j)$ from selling variety ω_j in country $i \in \{N, S\}$. Also, costs to consumers of transporting goods across international borders are sufficiently high to prevent arbitrage.

The profit-maximizing price charged in country i is

$$p_i(\omega_j) = \frac{1}{2}\left(C_i^{\alpha} + \frac{c_j}{A_j}\right), \tag{43}$$

where

$$c_j = \frac{1}{\eta^{\eta}(1-\eta)^{1-\eta}}\, w_j^{\eta} R^{1-\eta}$$

is the cost-minimizing price of a unit of output at unit total factor productivity.
Equation (43) is the Section 5 counterpart to equation (20), and it accounts for the high price of consumer goods in rich countries.

Given the price defined by (43), consumer demand in country i for ω_j is

$$f_i^d(\omega_j) = \frac{1}{2\gamma}\left(C_i^{\alpha} - \frac{c_j}{A_j}\right). \tag{44}$$

Catalyst Investment Sector. Catalyst investment in country j is produced under perfect competition according to

$$X_j = A_{Xj} L_{Xj}^{\eta} K_{Xj}^{1-\eta}, \tag{45}$$

where A_{Xj} is productivity in the catalyst investment sector. The price of catalyst investment is $p_{Xj} = c_j / A_{Xj}$. Since the catalyst investment good is not traded across countries, there is no role for comparative advantage and each country will produce some catalyst investment in equilibrium.

Capital Investment Sector. Capital investment is produced in country N under perfect competition according to

$$I = A_I L_I^{\eta} K_I^{1-\eta}, \tag{46}$$

where A_I is productivity in the durable investment sector. The price of capital investment is $p_I = c_N / A_I$. Country N purchases some of the investment good and exports the rest. Market clearing implies

$$I = I_N + I_S, \tag{47}$$

The capital investment good is not produced in S because productivity in S is assumed to be low enough in the investment sector (as in all sectors) that S is better off exchanging consumption goods for I_S.

Equilibrium. I solve for fifteen unknowns,

$$w_N, w_S, y_N, y_S, C_N, C_S, f_{NN}, f_{NS}, f_{SS}, f_{SN}, p_{NS}, p_{SN}, R, K_N, K_S,$$

using the following fifteen equilibrium conditions:

$$C_N = \left[\frac{\alpha A_{XN}(\Omega_N f_{NN} + \Omega_S f_{NS})}{c_N(r+\delta)}\right]^{\frac{1}{1-\alpha}} \qquad C_S = \left[\frac{\alpha A_{XS}(\Omega_S f_{SS} + \Omega_N f_{SN})}{c_S(r+\delta)}\right]^{\frac{1}{1-\alpha}}$$

$$L_N = \left(\frac{R}{w_N}\frac{\eta}{1-\eta}\right)^{1-\eta}\left[\frac{\Omega_N(f_{NN}+f_{SN})}{A_N} + \frac{X_N}{A_{XN}} + \frac{I_N + I_S}{A_{IN}}\right].$$

$$L_S = \left(\frac{R}{w_S}\frac{\eta}{1-\eta}\right)^{1-\eta}\left[\frac{\Omega_S(f_{SS}+f_{NS})}{A_S} + \frac{X_S}{A_{DS}}\right]$$

$$y_N^0 - y_N + \frac{c_N}{A_{IN}} I_S + \Omega_N p_{SN} f_{SN} = \Omega_S p_{NS} f_{NS}$$

$$y_N^0 + y_S^0 = y_N + y_S$$

$$R = w_N\left(\frac{1}{A_I}\frac{r+\delta}{\eta^\eta(1-\eta)^{1-\eta}}\right)^{\frac{1}{\eta}}$$

$$f_{NN} = \frac{1}{2\gamma}\left(C_N^\alpha - \frac{c_N}{A_N}\right) \quad f_{SN} = \frac{1}{2\gamma}\left(C_S^\alpha - \frac{c_N}{A_N}\right) \quad f_{SS} = \frac{1}{2\gamma}\left(C_S^\alpha - \frac{c_S}{A_S}\right) \quad f_{NS} = \frac{1}{2\gamma}\left(C_N^\alpha - \frac{c_S}{A_S}\right)$$

$$p_{NS} = \frac{1}{2}\left(C_N^\alpha + \frac{c_S}{A_S}\right) \qquad p_{SN} = \frac{1}{2}\left(C_S^\alpha + \frac{c_N}{A_N}\right),$$

$$K_N = \frac{w_N}{R}\frac{1-\eta}{\eta}L_N \qquad K_S = \frac{w_S}{R}\frac{1-\eta}{\eta}L_S$$

where

$$c_N = \frac{w_N}{\eta}L_N \qquad c_S = \frac{w_S}{\eta}L_S$$

$$I_N = \delta K_N \qquad I_S = \delta K_S. \tag{48}$$

Results. Figure 9 shows prices and consumption under the following initial parameter values:

$$A_N, A_{XN}, A_I = 4, \qquad A_S, A_{XS} = 2, \qquad y_N^0, y_S^0 = 3, \qquad L_N, L_S, \Omega_N, \Omega_S = 1, \qquad \alpha, \gamma = 0.3,$$

$$\beta = 0.99, \qquad \delta = 0.3.$$

Note that productivity in S is identical across sectors, which excludes the possibility discussed in Hsieh and Klenow (2007) of productivity differentials in S driving the results. Even though S does not produce the investment good in equilibrium, it is assumed to have access to the technology to produce the investment good using the same labor productivity as prevail in the other sectors.

As in the Section 3, the rich country, N, pays more for final goods due to a lower price elasticity of demand stemming from higher consumption of the catalyst. N also purchases more of the investment good because its ratio of the capital price to the wage is lower than the corresponding ratio in S. This is because high productivity in N causes w_N to be high relative to w_S. Demand for capital in each country is given by (48). Since labor supply is equal across countries, and $\frac{w_N}{R} > \frac{w_S}{R}$, demand for capital (and investment goods) is higher in N. As shown in Figure 10, actual investment and the real investment rate are higher in N than in S.

Summary of Model with Investment. Hsieh and Klenow (2007) infer from facts (1*) through (3*) above that poor countries must be worse at producing investment goods (which are primarily tradable) than at producing consumption goods (which include a substantial nontraded component). Their hypothesis of a productivity differential in poor countries is a corollary of the Harrod-Balassa-Samuelson hypothesis in the sense that, under their proposed explanation, poor countries have lower productivity in a primarily tradable sector (investment) than in a primarily nontraded sector (consumption).

This section proposes an alternative explanation for the facts based on demand complementarities and pricing-to-market: High levels of catalysts in the rich country cause a high real wage and high consumption prices there. Since investment prices equalize across countries (due either to perfect competition, constant markups in a monopolistically competitive investment sector, or to complete cross-country capital markets), the rental rate on capital also equalizes across countries. The high wage-to-rent ratio in the rich country causes high demand for capital goods there.

Implications. A shortcoming that is shared by the Harrod-Balassa-Samuelson hypothesis and the Hsieh-Klenow hypothesis is that it is not intuitively clear why productivity should differ across sectors within a country to the extent required to explain the observed price patterns. The mechanism I propose, pricing-to-market and demand complementarities, is based on intuitive consumption patterns and the realistic assumption that firms have market power. That a single intuitive mechanism can provide a unified explanation for a number of puzzles in the trade and growth literatures is attractive from a modeling point of view, but we also need to ask how compatible this mechanism is with the micro data. The next section provides independent empirical evidence in support of this mechanism's relevance for observed price patterns.

6. Empirical Evidence

So far I have emphasized the ability of a single mechanism, *demand complementarity and pricing-to-market*, to account for a number of cross-country stylized facts. This section presents direct evidence from micro data that prices of tradable goods depend on a country's consumption of *catalyst* goods. The challenge in the empirical work is to distinguish the effect of demand complementarities from other mechanisms that may cause a positive correlation between consumer prices and income across countries.[13]

The analysis in this section examines three catalyst goods in particular: housing, electricity, and roads. Each of these catalyst goods is an imperfect correlate with GDP per capita, and each is expected to be a strong complement for a different subset of consumer goods. Houses complement demand for household goods (e.g. televisions and furniture), electricity complements demand for electric goods, and roads complement demand for new cars. Therefore, the model predicts the following, conditional on country-level fixed effects:

1) Household goods are sold at higher prices in countries with more housing per capita.
2) Electric goods are sold at higher prices in countries with a more reliable power supply (or superior energy infrastructure).
3) New cars are more expensive in countries with better roads.

[13] Allesandria and Kaboski, for example, propose a model in which consumers in low-wage countries have a comparative advantage in searching for price discounts.

To explore these predictions, I obtain prices of goods sold to different countries from disaggregated US export data. The US Exports Harmonized System data, available on Robert Feenstra's webpage, contains unit values and quantities of highly disaggregated bilateral exports leaving US docks. As discussed by Allesandria and Kaboski (2011), there are two advantages to using this data to study the extent of pricing-to-market for tradable goods. First, the disaggregated nature of the data mitigates potential concerns that different unit values may reflect differences in quality. Second, the unit values are free-alongside-ship values, which exclude transportation costs, tariffs, and additional costs incurred in the importing country. I classify each Harmonized System (HS)-10 category in the export data as a 'household good', 'electric good', or 'new car'. Household goods are identified based primarily on their end-use code. All furniture, glassware, chinaware, cookware, cutlery, tools, rugs, TVs, VCRs, and stereo equipment (end-use codes 41000, 41010, 41020, 41040, 41200, and 41210) are considered household goods; so are most appliances (end-use 14030), with the exception of air conditioners and radiators, the demand for which I assume depends more on weather than on housing. Finally, I include towels, linens, bedding, curtains, as well as most 'other household goods' (end-use 41050). I exclude personal items such as shavers and hair dryers.

Any item labeled as "electric" and not battery-powered is identified as electric; so are a number of clearly electric goods, including TVs, stereos, and associated parts that are not explicitly labeled 'electric'. New cars include only new passenger vehicles. I trimmed the sample of goods by excluding any observation in which the quantity sold is missing, zero, or unity.

Country-level data on the catalyst goods are from the International Comparison Program (ICP) and the World Development Index at the World Bank. The ICP provides direct measures of the housing stock for Europe in 2005 (Heston 2011 provides the 2005 data and discusses measurement issues). The measure of the housing stock in Europe is based on a survey of rental rates, from which the ICP assigned countries an index of their per capita housing volume. Measures of housing volume in other regions are either unreliable, or are not comparable to the measure of housing in Europe (see Heston 2011 for a discussion).

I use electricity consumption as a proxy for a country's energy infrastructure. Country-level data on electricity consumption per capita are from the World Development Index at the World Bank. The measure of a country's road quality is the percent of roads that are paved, also

available from the World Development Index. Most countries do not have data on road quality for more than a single year between 2002 through 2006, so I pick the most recent year for which data is available as a country's measure of road quality.

I test the three hypotheses outlined earlier separately in the following subsections.

6.1 Housing Volume and Prices of Household Goods

First, I assess whether prices of U.S. exports of households goods depend on European countries' stock of housing. Europe is an especially suitable region for such an investigation because its countries have low levels of within-country inequality, mitigating potential concerns that housing volume of the average resident may differ from housing volume of the consumer driving demand for household goods. Furthermore, housing volume is generally high in Europe, so a marginal increase in volume, such as an additional room, is likely to increase demand for furnishings of those rooms.[14]

The empirical specification is

$$p_{ch} = \alpha_c + \gamma_h + \psi q_{ch} + \beta \mathrm{Vol}_c \mathrm{HHgood}_h + \epsilon_{ch}, \tag{49}$$

where p_{ch} is the log of the unit value of good h exported to country c, normalized by its within-good standard deviation. α_c represents country fixed effects, γ_h represents fixed effects for each HS-10 good category, and q_{ch} is the log quantity of good h sold to country c, normalized by its within-good standard deviation. $\mathrm{Vol_c}$ is the measure of the housing stock in country c, $\mathrm{HHgood_h}$ indicates whether the good is classified as a household good, and ϵ_{ch} denotes the regression error. All data are 2005 values, the only year for which data on Europe's housing stock is available.

The coefficient β captures the extent to which the markup for household goods depends on housing volume. I include quantity as a regressor in (49) to capture the dependence of firms' costs on the quantity they sell to a given destination. A negative estimate for ψ may reflect bulk discounts, or other cost savings from repeated transactions between U.S. sellers and foreign buyers. Omitting quantity would bias downward β to the extent that higher housing-related demand for household goods is associated with higher quantities sold and lower marginal costs.

[14] In less developed regions, differences in volume are less likely to translate into marginal increases in demand for household goods; rather, in less developed countries, higher volume may imply an increase in personal space but not an increase in demand for furnishing.

Table 1 shows that a standard deviation increase in a European country's housing volume index is associated with a 4.4% increase in the price of household goods (normalized by the standard deviation of its log), conditional on country and product fixed effects. This estimate is significant at the 95% confidence level. This result supports the hypothesis that housing is a catalyst for deriving utility from household goods, and that higher housing stocks are associated with a low price elasticity of demand for household goods within a country.

Consumer goods, of course, are not a primary export of the U.S. Therefore it is informative to examine more closely which consumer good exports are driving the results in Table 1. Table 2 shows the results from alternative specifications of the sample of household goods. The specification in column (1) removes from the sample all household products that were sold to less than 10 countries around the world in 2005. It also removes product-country pairs for which less than 100 units were sold in 2005. The purpose of this restriction is to prevent nonrepresentative products from driving the result. The sample restriction removes approximately a quarter of the product-country observations.

According to Column 1.1 in Table 2, a standard deviation increase in a European country's housing volume index is associated with a 3.8% increase in the price of household goods. This estimate is significant at the 90% confidence level. To determine which goods are driving this strong relationship, I reclassify goods into subcategories of household goods (e.g. dishwashers, kitchen appliances, etc.), and rerun the regression by interacting housing volume with each subcategory. Column 1.2 reports the results for subcategories with statistically significant (or nearly significant) estimates. Television-related goods and refrigerators are the most important contributors to the observed relationship between a country's housing stock and the price it pays for household goods.[15] This result does not imply that housing does not complement demand for other household goods; rather, it is a reflection of the relatively high quantity of U.S. exports of television and refrigerator-related goods. Housing may complement

[15] The importance of television-related goods is striking, given that the U.S. is not a renowned producer of televisions. Closer examination, however, reveals that U.S. exports of television-related goods are primarily in antennas and other signal receptors, such as satellite dishes. Thus demand for televisions complements demand for U.S. television-related exports, and a country's housing stock complements demand for televisions.

demand for dishwashers, but U.S. exports of dishwashers to Europe are insufficient to provide a precise estimate of this relationship.[16]

A typical concern in empirical work studying the determinants of export prices is that high prices reflect higher-quality goods. While the disaggregate nature of the data mitigates this concern to some extent, there is still room for quality variation within an HS-10 category (see the discussion in Allesandria and Kaboski 2011). To address this concern, Specification 2 in Table 2 drops from the sample all household goods with long quality ladders. Specifically, I use the quality ladder estimates from Khandelwal (2010), and I drop all household goods with ladder estimates above the median estimate.[17] The sample retains other consumer goods with long ladder estimates. Therefore, the regression will, if anything, understate the dependence of prices of household goods on housing volume. This is because, to the extent that high export prices reflect high quality consumer goods sold to rich countries, the regression will estimate a high value of the country fixed-effect for rich countries.[18] Since housing volume is positively correlated with per capita income, some of the dependence of prices on housing will be captured by the high fixed effect estimates in rich countries.

The estimates in Columns 2.1 and 2.2 in Table 2 are nearly identical to the estimates from Subsample 1, which suggests that the estimated relationship between prices of household goods and a country's housing stock does *not* reflect high quality consumer goods being sold to countries with high housing volumes. Rather, the relationship reflects primarily a failure of the law of one price for household goods such that identical household goods are more expensive in countries with more housing per capita.

6.2 Electricity Infrastructure and Prices of Electric Goods

[16] One reason that the U.S. exports so few washing machines (for example) is that European consumers require washing machines with features (e.g voltage requirements) that are horizontally differentiated from the features required by U.S. consumers.

[17] Approximately half of the HS-10 categories have nonmissing ladder estimates. Those with missing ladder estimates are kept in the sample. Note that long quality ladder estimates for a final good may reflect strong complementarity with catalyst goods, rather than high quality. This is because the estimates of ladder length in Khandelwal (2010) are based on the assumption that high market share (conditional on price) reflects high quality. In the models above, goods with high degrees of complementarity also have high market share. Thus dropping goods with long estimated quality ladders may remove some goods that are strong complements with catalyst goods, thus biasing downward the estimated relationship between catalysts and the price of final goods.

[18] For a model predicting a relationship between quality of imports and income, see Hallack (2006).

A final empirical hypothesis is that prices of electric goods depend on countries' access to electricity. As a proxy for a country's electricity access, I use data on electricity consumption per capita, provided by the World Development Index. This proxy is most appropriate in underdeveloped countries with low average electricity consumption per capita. In developed countries, differences in electricity consumption are more likely to reflect differences in factors other than the population's access to electricity, such as weather. Therefore I limit my attention to countries that consumed less than 4 mega-watt-hours of electricity per person in 2006. This restriction removes most European countries from the sample, as well as other wealthy countries such as Japan and Qatar.

I run the following regression:

$$p_{ch} = \alpha_c + \gamma_h + \psi q_{ch} + \beta \mathrm{MWHpercap}_c \mathrm{Egood}_h + \epsilon_{ch}, \qquad (50)$$

where $\mathrm{MWHpercap_c}$ is the per capita electricity consumption in country c, and $\mathrm{Egood_h}$ indicates whether good h is electric. Unit values and quantities for each country-product pair are averages of the values between 2004 and 2006 (the three most recent years of data).[19] The remaining variables are defined as in Section 6.1. The sample in regression (50) is limited to country-product pairs with over 100 units sold and to products that are exported to at least 10 countries to prevent nonrepresentative products from driving the results.

Column (1) in Table 3 shows that a megawatt-hour increase in per capita electricity consumption is associated with a 7.3% increase in the price of electric goods. This estimate is statistically significant at the 99% confidence level. This relationship holds when electric goods with long quality ladders are excluded from the sample (Column 2), which suggests that higher prices reflect higher markups rather than higher quality.

Of the electric goods in the sample, far more are sold to Latin America than to any other region. Therefore, columns (3) and (4) limit the sample to Latin American exports. The relationship between electricity consumption and prices of electric goods is about twice as strong across Latin American countries than the relationship across all countries in the sample. A percent increase in per capita electricity consumption is associated with a 13.3% increase in the price of electric goods (column 3). When electric goods with long quality ladders are dropped

[19] Averaging unit values across time has the advantage of averaging out the noise in the yearly data while preserving the ability to identify β off of the cross-sectional variation across destination countries. When the regression is run on yearly data (rather than averaged data), the results are similar but with slightly larger standard errors.

from the sample, this relationship weakens only slightly (column 4), again suggesting that the results are driven by pricing-to-market rather than by quality differences.

The positive relationship between electricity consumption and prices of electric consumer goods documented in Table 3 is driven primarily by exports of refrigeration, heating, and air conditioning products across Latin American countries. When regression (50) is modified to

$$p_{ch} = \alpha_c + \gamma_h + \psi q_{ch} + \beta_1 \text{MWHpercap}_c \text{ Refrig}_h + \beta_2 \text{MWHpercap}_c \text{HeatAC}_h + \epsilon_{ch},$$

to incorporate indicator variables, Refrig_h and HeatAC_h, for refrigeration and heat/air conditioning products, the estimates for β_1 and β_2 are 0.46 and 0.17. Both estimates are significant at the 95% confidence level.

6.2 Paved Roads and Prices of New Cars

Data on the percent of paved roads are available across regions for different years between 2003 and 2006. I take the most recent year for which data are available in a country as that country's measure of road quality and estimate the following regression:

$$p_{ch} = \alpha_c + \gamma_h + \psi q_{ch} + \beta \text{Road}_\text{c} \text{Newcar}_\text{h} + \epsilon_{ch}, \qquad (51)$$

where Road_c is the percent of roads that are paved in country c and Newcar_h indicates whether good h is a new car. The remaining variables are defined as above. Unit values and quantities for each country-product pair are averages of the values between 2004 and 2006 (the three most recent years of data).[20]

Results. Table 4 shows the results from regression (51). In columns (1) and (2), the sample includes all exported non-military goods (end use classification 0 through 4). Column (1) states that a percentage point increase in the fraction of roads that are paved is associated with a 0.6 percent increase in the price of new cars. This association applies to new cars but not to automobiles and auto parts in general (end use category 3). Column (2) suggests that the paved roads are not associated with high prices of other automobiles or auto parts. Consistent with the evidence in regressions (1) and (2), regression (3) shows that road quality is associated with high prices of new cars relative to prices of auto-related exports.

[20] The sample does not restrict observations based on the quantity of goods because cars are assumed to be sold in lower quantities on average than are consumer goods. Indeed, using the same cutoff threshold of 100 units in Sections 6.1 and 6.2 would remove almost two-thirds of the new car observations from the sample.

The evidence in Table 4 suggests that road quality complements demand for new cars but not demand for automobiles generally and auto parts. One possible explanation for this result is that demand for automobiles (used or new) is driven primarily by the need for transportation, regardless of the quality of the roads. Demand for new cars relative to used cars, however, depends on the enjoyment of driving, in addition to efficient travel. A new Cadillac is not much more effective than an old jeep at transporting an individual over a mile of dirt road. However, a luxury Cadillac may be more effective at transporting someone on paved roads, and it is likely to be a more comfortable experience.

An additional explanation for the negative (but insignificant) relationship between auto parts in general and paved roads is that demand for auto parts may be high when roads are in poor condition. Not only are consumers less likely to purchase new cars (for which new parts are not immediately necessary) when roads are poor, but bad roads cause car damage and thus necessitate constant repair and frequent need for replacement parts.

The general message from Table 4 is consistent with the model's predictions based on demand complementarity and pricing-to-market: road quality is associated with higher prices of new cars. The main caveat is that the results may simply reflect the fact that higher quality cars are sold to countries with higher quality roads. Since new cars have long quality ladders, this concern cannot be addressed as in Sections 6.1 and 6.2 by dropping products with short quality ladders.

In reality, high prices of new cars are likely a result of both sales of high-quality cars and pricing to market for identical models. The standard assumption in the literature has been that price differences reflect quality differences, but recent evidence has demonstrated a strong role for price discrimination across countries for a range of products.[21] Thus it seems reasonable to infer price discrimination in the auto market as well. Precisely identifying the relative importance of pricing-to-market in the auto industry will require price data on identical models.

7. Discussion

The analysis above has referred to complementary goods as *catalysts* to distinguish the complementary goods from other final consumer goods. In many of the examples above, the

[21] See, for example, Allesandria and Kaboski (2011) for evidence across a range of goods and countries and Simonovska (2011) for evidence across a specific category of goods within Europe.

catalyst goods are durables such as housing and public infrastructure. However, demand complementarities are not unique to durables; services and other nondurable goods can also complement demand for final goods.

Demand complementarities are not limited to priced goods and services, either. Customers do not always directly pay for amenities associated with the services they purchase, but the quality of the amenities complements their demand for services. For example, customers may have higher utility from food at a restaurant if the restaurant has nice artwork, good service, and comfortable chairs. The more efficiently a restaurant can produce these complementary goods and services, the more it can charge for food of a given cost. Likewise, the availability of retail stores, and the quality of service at those stores, can complement demand for retail goods. Demand complementarities at the retail level can explain, for example, the finding in Crucini, Telmer, and Zachariadas (2005) that nontraded retail inputs account for much of the price dispersion for goods and services in the European Union. Finally, one could think of marketing and related sales activity as catalyst services. A number of recent papers, including Arkolakis (2010) and Gourio and Rudanko (2011), investigate the implications of marketing and sales activity on firm outcomes. The analysis above suggests that such activity may also contribute to the cross-country differences in prices and real investment rates if such activity reduces consumers' price-elasticity of demand.

The baseline model presented above demonstrates a simple way of incorporating complementarity into general equilibrium models. One of the results emphasized is that, with markups that depend on demand complementarities, prices and quantities of consumer goods will be positively related, both within a country over time and across countries. The commonly used constant-elasticity-of-substitution (CES) framework is a limiting case in which demand complementarities do not cause higher markups. While CES functions are widely used because of their analytical simplicity, they do not permit the types of effects emphasized above.

Simonovska (2011) is perhaps the most closely related paper in that it suggests that nonhomotheticities in the utility function and price discrimination are responsible for the failure of LOP for tradable consumer goods. In Simonovska's model, high tradable prices in rich countries are due to markups arising from consumption of lager varieties of imported goods. In the models above, high prices reflect high consumption of catalyst goods, rather than differences in the set of imported goods. Furthermore, the mechanism highlighted above causes high

markups in a closed economy setting as well as an open economy setting and can account for a number of empirical regularities in the trade and growth literatures. One implication of the demand-complementarities explanation 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. Whether or not the markup Simonovska identifies for apparel goods is representative of the markup on other tradables, therefore, depends on whether the degree of complementarity for apparel products is representative of complementarity for tradable goods in general.

8. Conclusion

A well-established empirical regularity is that tradable consumption goods are more expensive in countries with high per-capita incomes. This paper proposes a simple explanation for this relationship based on demand complementarities and pricing-to-market by monopolistically competitive firms: The utility consumers derive from tradable goods depends on their consumption of complementary goods. Rich countries can afford more complementary goods, which generates high (and inelastic) demand for tradables. As a result, monopolistically competitive firms charge higher markups in rich countries.

The paper provides direct empirical evidence that the phenomenon of *demand complementarities and pricing-to-market* is responsible for high prices of specific subsets of tradable goods in countries with high consumption of relevant complementary goods. Specifically, household goods are sold at higher prices to countries with more housing volume per capita; electronic goods are sold at higher prices to countries with superior electricity infrastructure (as proxied by electricity consumption per capita); and new cars are sold at higher prices to countries with a higher percentage of paved roads.

The theoretical models developed in the paper demonstrate that evidence of *demand complementarity and pricing-to-market* also strongly supports the notion that nontradable consumer goods are more expensive in rich countries because demand is higher (and less elastic) there, thus offering an explanation to a longstanding puzzle in the trade literature. In additional, the evidence lends support to the notion that real investment rates are higher in rich countries due to high demand. Understanding why rich countries have higher rates of investment is important for understanding why income disparities persist between rich and poor countries. Economists have typically attributed

differences in investment rates to market distortions (e.g. high taxes and corruption) in poor countries. Hsieh and Klenow (2007) argue that distortionary taxes cannot account for the relationship between investment rates and income per capita and instead prefer an explanation based on sectoral productivity differences. While much work remains to be done to quantify the precise role of demand complementarities in accounting for differences in prices and real investment rates across countries, my results suggest that low investment rates in poor countries may be a result of low demand there, rather than a result of distortionary taxes or within-country productivity differentials.

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Appendix A

The models presented above feature an endowed numeraire that enters the utility function linearly. This setup is chosen for its tractability and because it permits a focus on demand complementarities, rather than the marginal utility of income, as the determinant of consumers' price elasticity of demand for final goods. Here I present an alternative closed-economy setup in which the numeraire is produced by labor, rather than endowed. The utility function is also altered to permit the marginal utility of income to vary with income.[22]

The representative agent's utility function is defined over the catalyst C, the mass Ω of final goods, and a numeraire Y:

$$U = Y^{\eta}\left(C^{\alpha}\int_{\Omega} f_{\omega}d\omega - \frac{1}{2}\gamma\int_{\Omega} f_{\omega}^{2}d\omega\right)^{1-\eta}, \tag{52}$$

where f_{ω} is consumption of final good $\omega \in \Omega$. This utility function is similar to that in Chaney (2008) in that it features Cobb-Douglass preferences over a homogenous numeraire and differentiated consumer goods.

The budget constraint is

$$wL + \int_{\Omega}\Pi_{\omega}d\omega = Y + p_{C}C + \int_{\Omega} p_{\omega}f_{\omega}d\omega, \tag{53}$$

[22] If the model were to feature a numeraire produced by labor and a baseline utility function given by (1), the model solution would be at a corner in which the numeraire is the only good produced and consumed. A derivation of the corner solution to this alternative setup is available upon request.

Consumer optimization with respect to f_ω yields the implicit demand for final good of variety ω:

$$Y^\eta\ (1-\eta)B^{-\eta}(C^\alpha - \gamma f_\omega) = \lambda p_\omega,$$

where λ is the multiplier on the budget constraint (53) and $B \equiv C^\alpha \int_0^\Omega f_\omega d\omega - \frac{1}{2}\gamma \int_0^\Omega f_\omega^2 d\omega$ is the bundle of final and catalyst goods. We can obtain an expression for λ from the first order condition with respect to Y:

$$\eta Y^{\eta-1} B^{1-\eta} = \lambda.$$

Combining the above two equations yields an explicit expression for demand for final good ω:

$$f_\omega = \frac{1}{\gamma}\left[C^\alpha - \frac{\eta}{1-\eta}\frac{1}{Y}Bp_\omega\right]. \tag{54}$$

Production of final goods, catalyst goods, and the numeraire good are linear in labor using labor productivity A, which is assumed to be identical across sectors. The final goods sector is monopolistically competitive, while the catalyst and numeraire sectors are perfectly competitive. Firm ω maximizes $\Pi_\omega = \left(p_\omega - \frac{w}{A}\right) f_\omega$, which implies the optimal price

$$p_\omega = \frac{1}{2}\left[Y\frac{1-\eta}{\eta}B^{-1}C^\alpha + \frac{w}{A}\right]. \tag{55}$$

The price increases with C^α, as in Section 2. It also increases as the marginal utility of income falls. Since λ is decreasing in Y, the price of final goods is increasing in Y.

Given the price the resulting demand for good ω is

$$f_\omega^d = \frac{1}{2\gamma}\left[C^\alpha - \frac{w}{A}\frac{\eta}{1-\eta}\frac{1}{Y}B\right]. \tag{56}$$

Demand for the catalyst is derived from consumer optimization:

$$C = \left[Y\frac{1-\eta}{\eta}\alpha\frac{F}{p_C}B^{-1}\right]^{\frac{1}{1-\alpha}}. \tag{57}$$

Equilibrium is characterized by demand for catalysts, demand for consumer goods, and labor market clearing,

$$L = \frac{1}{A}(\Omega f + C + Y) \tag{58}$$

These conditions can be written as

$$C = \left[Y\frac{1-\eta}{\eta}\alpha f\left(C^\alpha f - \frac{1}{2}\gamma f^2\right)^{-1}\right]^{\frac{1}{1-\alpha}}$$

$$f = \frac{1}{2\gamma}\left[C^{\alpha} - \frac{\eta}{1-\eta}\frac{\Omega}{Y}\left(C^{\alpha}f - \frac{1}{2}\gamma f^{2}\right)\right]$$

$$L = \frac{1}{A}(\Omega f + C + Y),$$

where I've substituted in $w = A$ and $p_C = w/A$. Figure A1 shows market responses to an increase in productivity A. As in the baseline model in Section 2, prices of final goods are increasing in a country's wealth due to markups that increase with consumption of the catalyst good.

Appendix B.

The models in this paper use 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 $\epsilon \equiv \left|\frac{\partial q}{\partial p}\frac{p}{q}\right|$. 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

$$q q_{21} > q_2 q_1. \tag{59}$$

Condition (59) 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, $q = Cp^{-\epsilon}$, these two effects exactly cancel out so that $q q_{21} = q_2 q_1$. 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 sensitive to the price firms charge in a way that is consistent with condition (59).

Appendix C.

This appendix alters the model in Section 6 by assuming that differentiated investments goods are produced under monopolistic competition and aggregated into a final investment good through a CES aggregator. Each country $j \in \{N, S\}$ produces a mass Ψ_j of differentiated investment goods. Each good $\psi_j \in \Psi_j$ is exported and sold domestically. Countries N and S purchase investment goods and costlessly aggregate them into a final investment good.

Equation (46) changes to

$$I_j = \left(\sum_{i=N,S} \int_{\psi_i \in \Psi_j} q_j(\psi_i)^{\frac{\sigma-1}{\sigma}} d\omega_i \right)^{\frac{\sigma}{\sigma-1}}, \tag{60}$$

where $q_j(\psi_i)$ is country j's quantity of the differentiated intermediate investment variety ψ_i produced in country i. Demand for good ψ_i in country j is

$$q_j(\psi_i) = \left(\frac{p_{q_j}(\psi_i)}{P_{Ij}} \right)^{-\sigma} I_j,$$

And the optimal price charged by firm ψ_i in country j is

$$p_{q_j}(\psi_i) = \frac{\sigma}{\sigma - 1} c_i. \tag{61}$$

Note that the price is a constant markup over marginal costs, so each differentiated investment good is sold at the same price in both countries. Therefore the cost of final investment goods equalizes across countries, as does the rental rate of capital. As in Section 6, the wage is higher in the rich country (N), which causes higher demand for capital in N.

The equilibrium conditions are altered only slightly relative to those in Section 6. The trade balance condition now accounts for the fact that both countries produce investment goods:

$$y_N^0 - y_N + \Psi_N p_{qSN} q_{SN} + \Omega_N p_{SN} f_{SN} = \Omega_S p_{NS} f_{NS} + \psi_N p_{qNS} q_{NS}, \tag{62}$$

where p_{qij} and q_{ij} are defined analogously to p_{ij} and f_{ij} for $i, j \in \{N, S\}$. Demand for labor also now accounts for investment good production in both countries:

$$L_N = \left(\frac{R}{w_N} \frac{\eta}{1-\eta} \right)^{1-\eta} \left[\frac{\Omega_N (f_{NN} + f_{SN})}{A_N} + \delta \frac{C_N}{A_{CN}} + \frac{q_{NN} + q_{SN}}{A_{IN}} \right],$$

$$L_S = \left(\frac{R}{w_S} \frac{\eta}{1-\eta} \right)^{1-\eta} \left[\frac{\Omega_S (f_{SS} + f_{NS})}{A_S} + \delta \frac{C_S}{A_{CS}} + \frac{q_{SS} + q_{NS}}{A_{IN}} \right].$$

Figure C1 shows how relative final goods prices, real investment, and investment prices depend on wealth in N. As in Section 6, the patterns of prices and investment are consistent with facts (1* through 3*).

Appendix D

This appendix departs from the model in Section 5 by postulating that final investment goods are produced from differentiated investment goods using a quadratic aggregator similar to the utility function, thus permitting price-dependent markups for differentiated investment goods. Specifically, equation (60) is now

$$I_j = L_{Ij} + \sum_{i=N,S} \int_{\psi_i \in \Psi_i} \left[\theta q_j(\psi_i) - \frac{\gamma}{2} \left(q_j(\psi_i) \right)^2 \right] d\omega_i, \tag{63}$$

where L_{Ij} is labor in country j that is allocated to the aggregation of investment goods. Before proceeding, a couple of remarks must be made regarding this particular aggregator function. First, there is a bliss point after which additional units of a given differentiated investment good are actually counterproductive. In the utility function, the bliss point represents the fact that more consumer goods eventually becomes undesirable (consider eating a hundred cheeseburgers in a day). It is less clear what a bliss point represents in the aggregation of investment goods. Thus the CES aggregator may actually be more realistic than the quadratic investment aggregator. Nonetheless, this section presents the quadratic aggregator for completeness.

Second, equation (63) features labor as a substitute for intermediate investment goods. This assumption captures the notion that with sufficient labor input, the aggregate investment good could be produced without any intermediate investment goods. It also simplifies the analysis.

Demand in country j for investment good ψ_i is

$$q_j(\psi_i) = \frac{1}{\gamma} \left[\theta - \frac{1}{w_j} p_{q_j}(\psi_i) \right]$$

The optimal price charged by firm ψ_i for a good sold to country j is

$$p_{q_j}(\psi_i) = \frac{1}{2} \left(\theta w_j + c_i \right),$$

And resulting demand is

$$q_j(\psi_i) = \frac{1}{2\gamma}\left[\theta - \frac{c_i}{w_j}\right].$$

The price of the final investment good in country j is equal to the wage in j, and investment demand in j is proportional to demand for capital in j.

In contrast to the prior models with investment, the price of investment does not equalize across countries; nor does the rental price of capital.[23] To determine relative prices, we must solve for the equilibrium. There are 20 unknowns, $w_N, w_S, y_N, y_S, C_N, C_S, f_{NN}, f_{NS}, f_{SS}, f_{SN}, p_{NS}, p_{SN}, R_N, R_S, K_N, K_S, q_{NN}, q_{NS}, q_{SS}$, and q_{SN}, for which I solve using the following equilibrium equations:

$$C_N = \left[\frac{\alpha A_{CN}(\Omega_N f_{NN} + \Omega_S f_{NS})}{c_N(r+\delta)}\right]^{\frac{1}{1-\alpha}} \qquad C_S = \left[\frac{\alpha A_{CS}(\Omega_S f_{SS} + \Omega_N f_{SN})}{c_S(r+\delta)}\right]^{\frac{1}{1-\alpha}}$$

$$L_N = \left(\frac{R_N}{w_N}\frac{\eta}{1-\eta}\right)^{1-\eta}\left[\frac{\Omega_N(f_{NN}+f_{SN})}{A_N} + \delta\frac{C_N}{A_{CN}} + \frac{q_{NN}+q_{SN}}{A_{IN}} + L_{IN}\right].$$

$$L_S = \left(\frac{R_S}{w_S}\frac{\eta}{1-\eta}\right)^{1-\eta}\left[\frac{\Omega_S(f_{SS}+f_{NS})}{A_S} + \delta\frac{C_S}{A_{CS}} + \frac{q_{SS}+q_{NS}}{A_{IN}} + L_{IS}\right]$$

$$y_N^0 - y_N + \Psi_N p_{qSN} q_{SN} + \Omega_N p_{SN} f_{SN} = \Omega_S p_{NS} f_{NS} + \Psi_S p_{qNS} q_{NS}$$

$$y_N^0 + y_S^0 = y_N + y_S$$

$$R_N = p_{IN}(r+\delta) \qquad R_S = p_{IS}(r+\delta)$$

$$f_{NN}^c = \frac{1}{2\gamma}\left(C_N^\alpha - \frac{c_N}{A_N}\right) \qquad f_{SN}^c = \frac{1}{2\gamma}\left(C_S^\alpha - \frac{c_N}{A_N}\right)$$

$$f_{SS}^c = \frac{1}{2\gamma}\left(C_S^\alpha - \frac{c_S}{A_S}\right) \qquad f_{NS}^c = \frac{1}{2\gamma}\left(C_N^\alpha - \frac{c_S}{A_S}\right)$$

[23] The differences in rental rates across countries hinges on the implicit assumption that markets for capital assets are separate across countries. Permitting cross-country capital ownership would cause rental rates and investment prices to equalize across countries, thus defeating the purpose of the exercise in this section of demonstrating that simple model extensions can generate a positive relationship between investment prices and income per capita. As discussed in Hsieh and Klenow (2007), the evidence of a positive relationship between investment prices and income per capita is limited primarily to prices of investment structures, which are highly nontraded. Thus the models in Section 5 and Appendix C are likely more empirically relevant than the model in this appendix.

$$p_{NS} = \frac{1}{2}\left(C_N^{\alpha} + \frac{c_S}{A_S}\right) \qquad p_{SN} = \frac{1}{2}\left(C_S^{\alpha} + \frac{c_N}{A_N}\right),$$

$$K_N = \frac{w_N}{R}\,\frac{1-\eta}{\eta}L_N \qquad K_S = \frac{w_S}{R}\,\frac{1-\eta}{\eta}L_S$$

$$q_{NN} = \frac{1}{2\gamma}\left[\theta - \frac{c_N}{w_N}\right] \qquad q_{SN} = \frac{1}{2\gamma}\left[\theta - \frac{c_N}{w_S}\right]$$

$$q_{SS} = \frac{1}{2\gamma}\left[\theta - \frac{c_S}{w_S}\right] \qquad q_{NS} = \frac{1}{2\gamma}\left[\theta - \frac{c_S}{w_N}\right]$$

where

$$p_{q_{NN}} = \frac{1}{2}[\theta w_N + c_N] \qquad p_{qNS} = \frac{1}{2}[\theta w_N + c_S]$$

$$p_{q_{SS}} = \frac{1}{2}[\theta w_S + c_S] \qquad p_{qSN} = \frac{1}{2}[\theta w_S + c_N]$$

$$c_N = \frac{w_N}{\eta}L_N \qquad c_S = \frac{w_S}{\eta}L_S$$

Figure D1 shows how market outcomes depend on productivity in country N. Relative prices in N are increasing in productivity in N, and purchases of intermediate investment goods are higher in N, consistent with the stylized facts discussed in Hsieh and Klenow (2007).

Table 1-Coefficient Estimates from Fixed-Effects Regressions of Log Unit Values on Measures of the Housing Stock

Dependent Variable: Log(price)/SD(Log(price))	(1)	(2)
Housing volume X Household good	0.032	0.044**
	(0.023)	(0.017)
Log(quantity)/SD(Log(quantity))		-0.685***
		(0.011)
Product FEs	YES	YES
Country FEs	YES	YES
R-squared	0.01	0.35
# observations	13,021	13,021
# products	1,320	1,320

Notes: Prices and quantities are normalized by their within-product standard deviation. Data source: World Bank Development Index, International Comparison Program, and U.S. Exports by HS classification. Robust standard errors 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 on Measures of the Housing Stock. Alternative Subsamples of Household Goods

Dependent Variable: Log(price)/SD(Log(price))	Subsample 1			Subsample 2		
Regressors	(1.1)	(1.2)	(1.3)	(2.1)		(2.2)
Housing volume X Household good	0.038*			0.037*		
	(0.020)			(0.022)		
Housing volume X Television-related good		0.397***	0.473***		0.426***	0.492***
		(0.087)	(0.096)		(0.052)	(0.080)
Housing volume X refrigerator		0.253	0.373**		0.252*	0.372*
		(0.161)	(0.178)		(0.114)	(0.206)
Housing volume X furnishing		0.102	0.204*		0.212*	0.280**
		(0.100)	(0.110)		(0.116)	(0.114)
Log(quantity)/SD(Log(quantity))	-0.513***	-0.512***		-0.512***	-0.511***	
	(0.017)	(0.012)		(0.017)	(0.012)	
Product FEs	YES	YES	YES	YES	YES	YES
Country FEs	YES	YES	YES	YES	YES	YES
R-squared	0.19	0.19	0.01	0.19	0.19	0.01
# observations	9,893		9,893	9,371	9,371	9,371
# products	1,164		1,164	1,088	1,088	1,088

Notes: Prices and quantities are normalized by their within-product standard deviation. Data source: International Comparison Program, and U.S. Exports by HS classification. Subsample 1 includes all consumer goods which are sold to at least 10 countries, and all product-country observations with at least 100 units sold. Subsample 2 drops from Subsample 1 all household goods with quality ladder estimates greater than the median, where the quality ladder estimates are obtained from Khandewal (2011). Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 3-Coefficient Estimates from Fixed-Effects Regressions of Log Unit Values on PerCapita Electricity Consumption

Dependent Variable: Log(price)/SD(Log(price))	All Regions		Latin America	
	Subsample 1	Subsample 2	Subsample 1	Subsample 2
Regressors	(1)	(2)	(3)	(4)
MWh per capita X Electric good	0.073***	0.078***	0.133***	0.126***
	(0.023)	(0.027)	(0.042)	(0.048)
Log(quantity)/SD(Log(quantity))	-0.615***	-0.616***	-0.620***	-0.623***
	(0.007)	(0.007)	(0.017)	(0.017)
Product FEs	YES	YES	YES	YES
Country FEs	YES	YES	YES	YES
R-squared	0.29	0.29	0.29	0.19
# observations	21,477	21,110	5,399	5,304
# products	1,063	1,043	1,016	996

Notes: Prices and quantities are normalized by their within-product standard deviation. Data source: World Bank Development Index, and U.S. Exports by HS classification. Subsample 1 includes all consumer goods which are sold to at least 10 countries, and all product-country observations with at least 100 units sold. 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 Khandewal (2011). Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Table 4-Coefficient Estimates from Fixed-Effects Regressions of Log Unit Values on Percent of Paved Roads

Dependent Variable: Log(price)/SD(Log(price))	Sample: Non-Military Goods		Sample: Auto Vehicles, Parts, and Engines
Regressors	(1)	(2)	(3)
Percent of roads paved X New car	0.006***		0.005***
	(0.001)		(0.001)
Percent of roads paved X Auto		-0.0001	
		(0.0005)	
Log(quantity)/SD(Log(quantity))	-0.649***	-0.649***	-0.542***
	(0.004)	(0.004)	(0.032)
Product FEs	YES	YES	YES
Country FEs	YES	YES	YES
R-squared	0.33	0.33	0.24
# observations	332,570	332,570	8,155
# products	7,882	7,882	136

Note: Prices and quantities are normalized by their within-product standard deviation. Data source: World Bank Development Index and U.S. Exports by HS classification. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.

Figure 1: Comparative Statics: Market Outcomes as Catalyst Productivity, A_C, Increases.

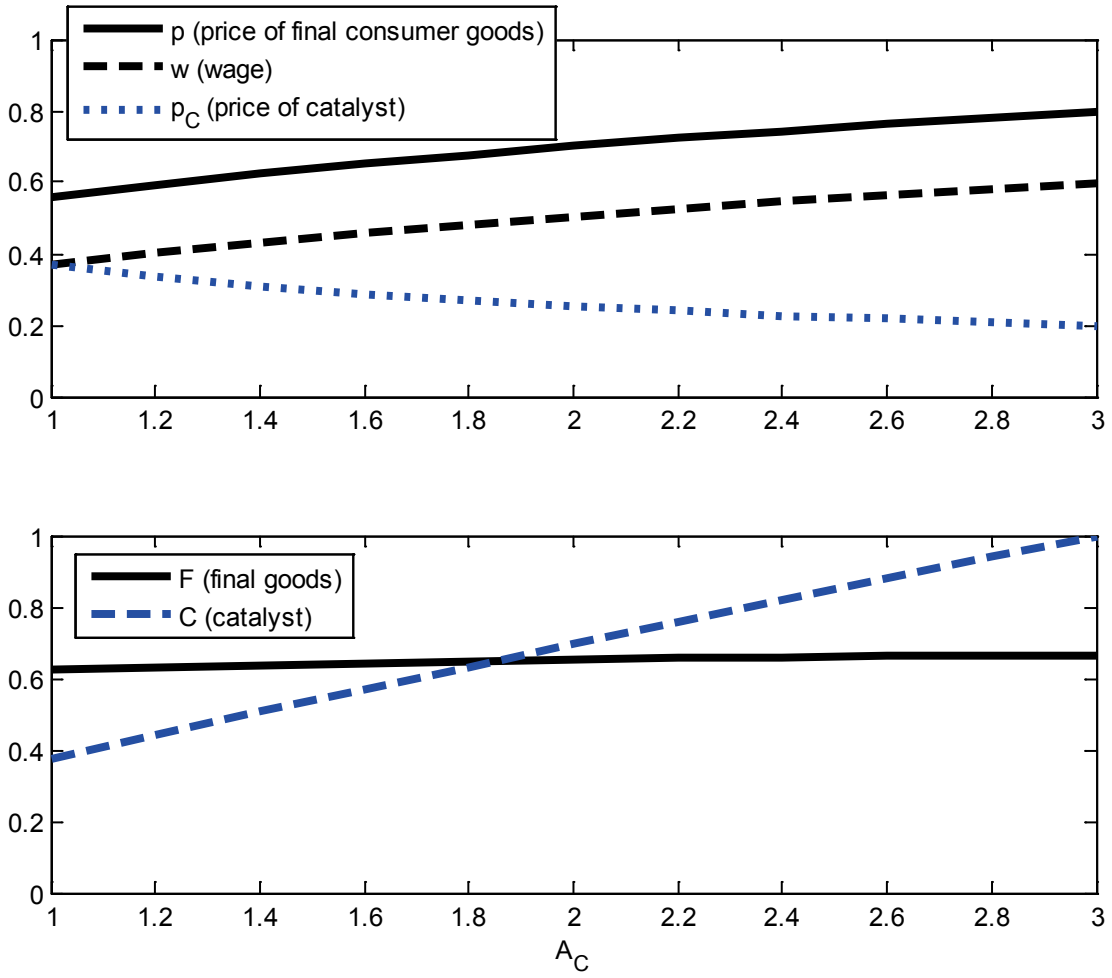


Figure 2: Comparative Statics: Market Outcomes as Final-Good Productivity, *A*, Increases.

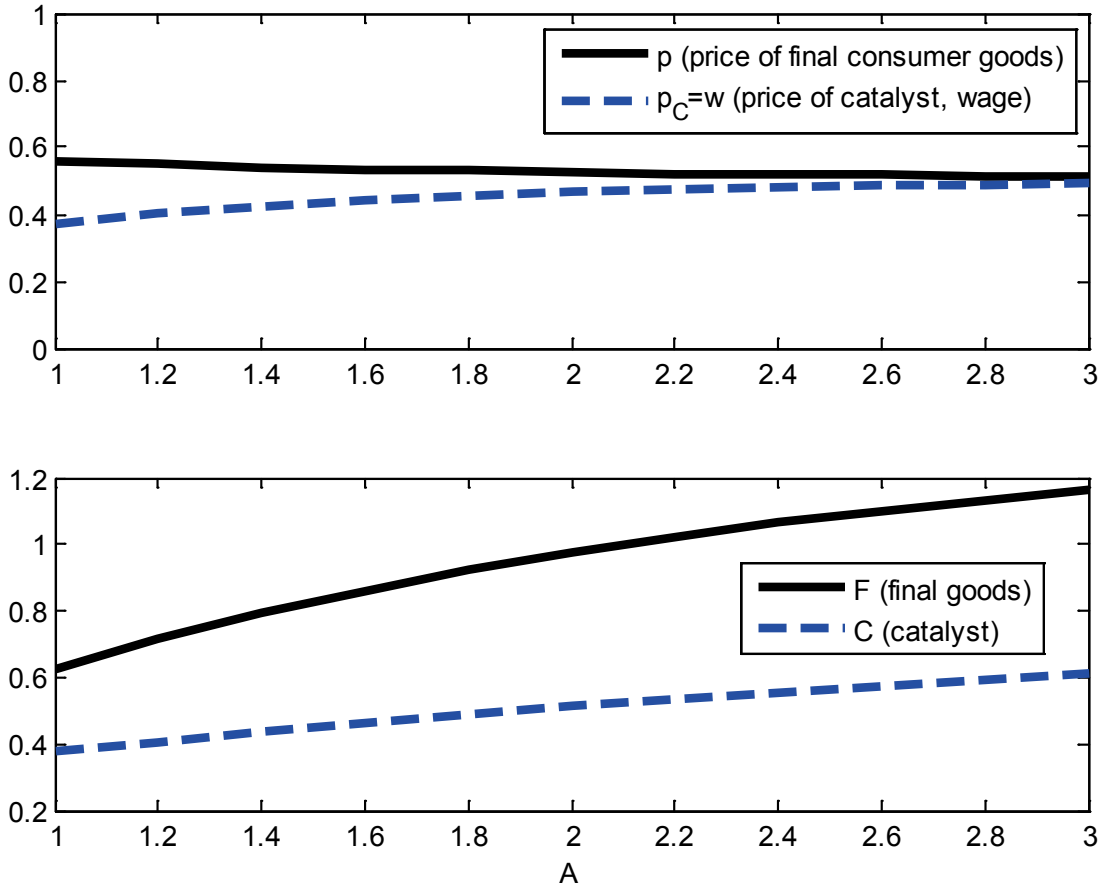


Figure 3: Effect of Productivity in *N*'s Catalyst Sector on Prices and Quantities.

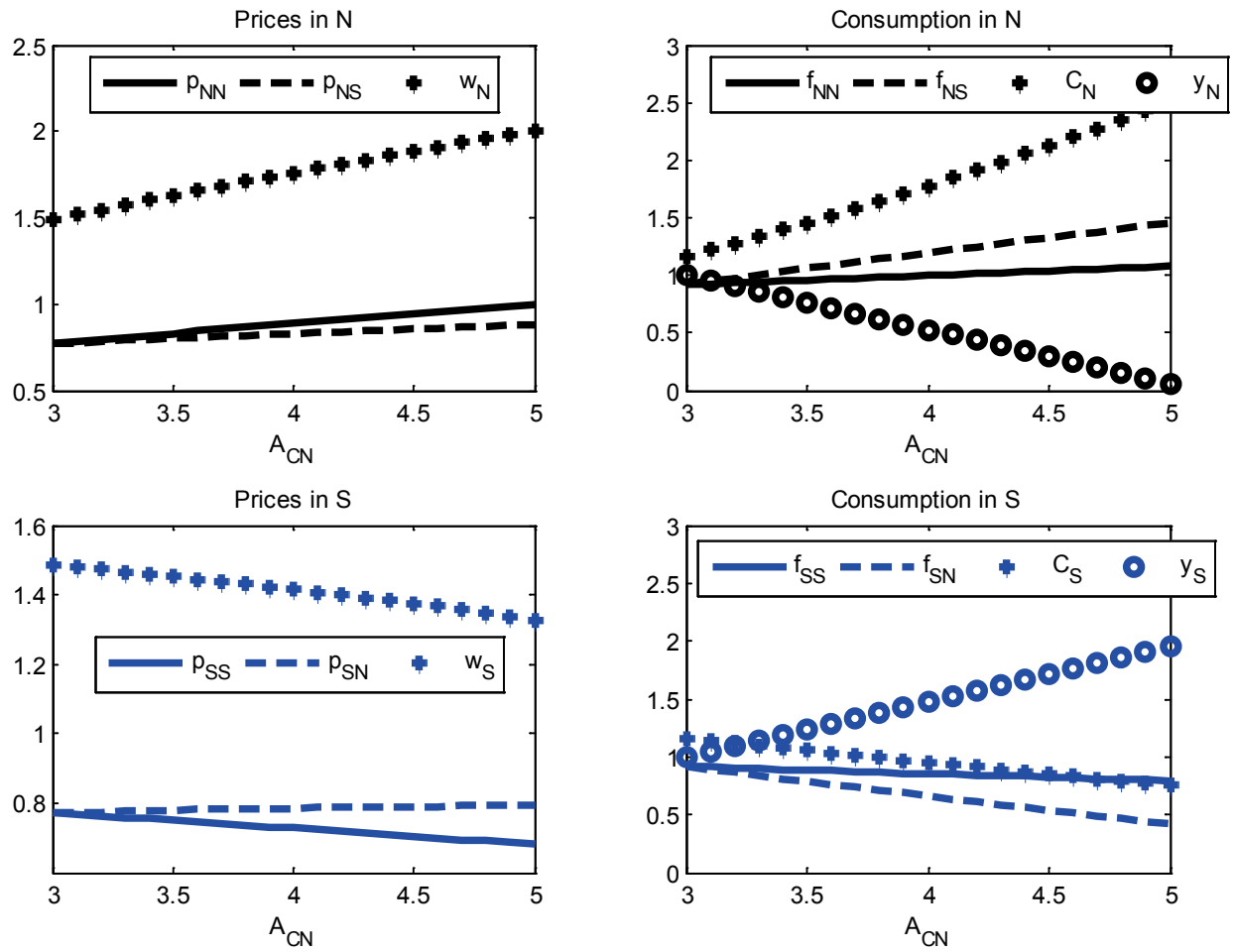


Figure 4: Effect of Productivity in *N*'s Catalyst Sector on Welfare

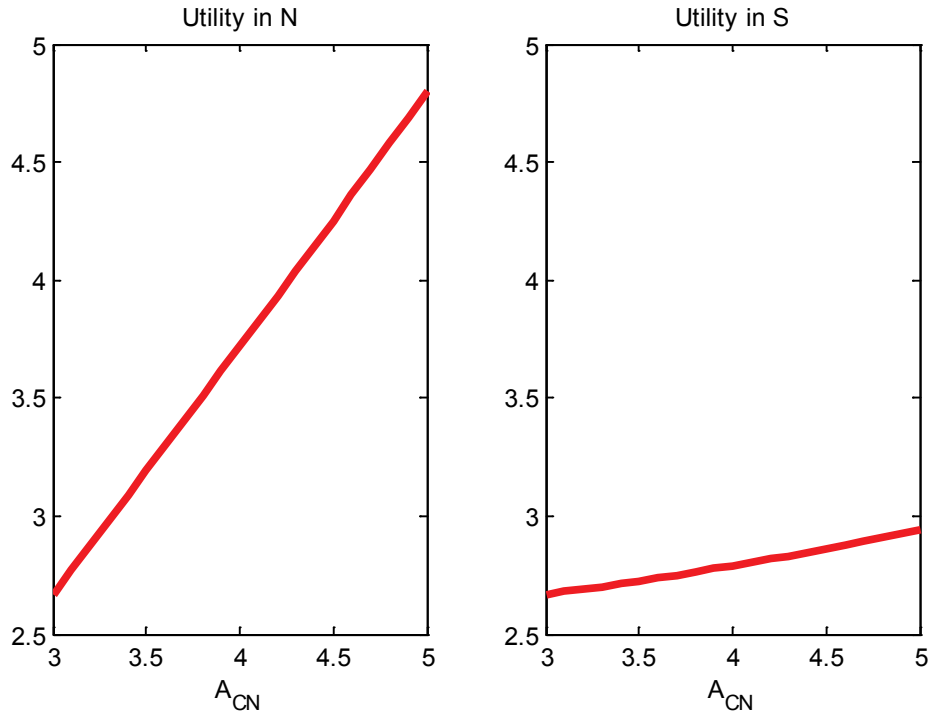
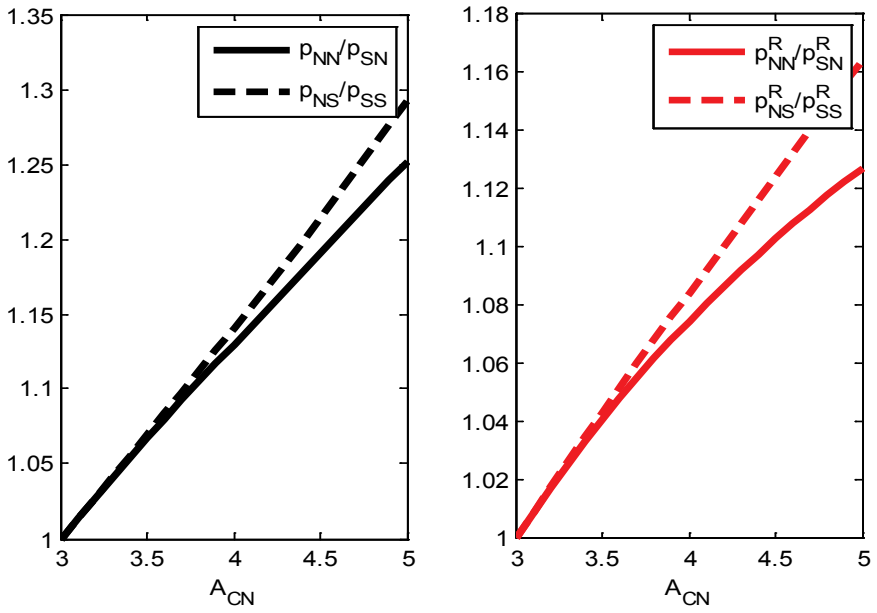


Figure 5: Effect of Productivity in *N*'s Catalyst Sector on Relative Prices.



Note: The graph on the left shows the ratio of prices relative to the numeraire, while the graph on the right shows the ratio of PPP prices. See Footnote 9 for an explanation of how PPP prices are computed.

Figure 6: Effect of Productivity in *N*'s Final Good Sector on Prices and Quantities.

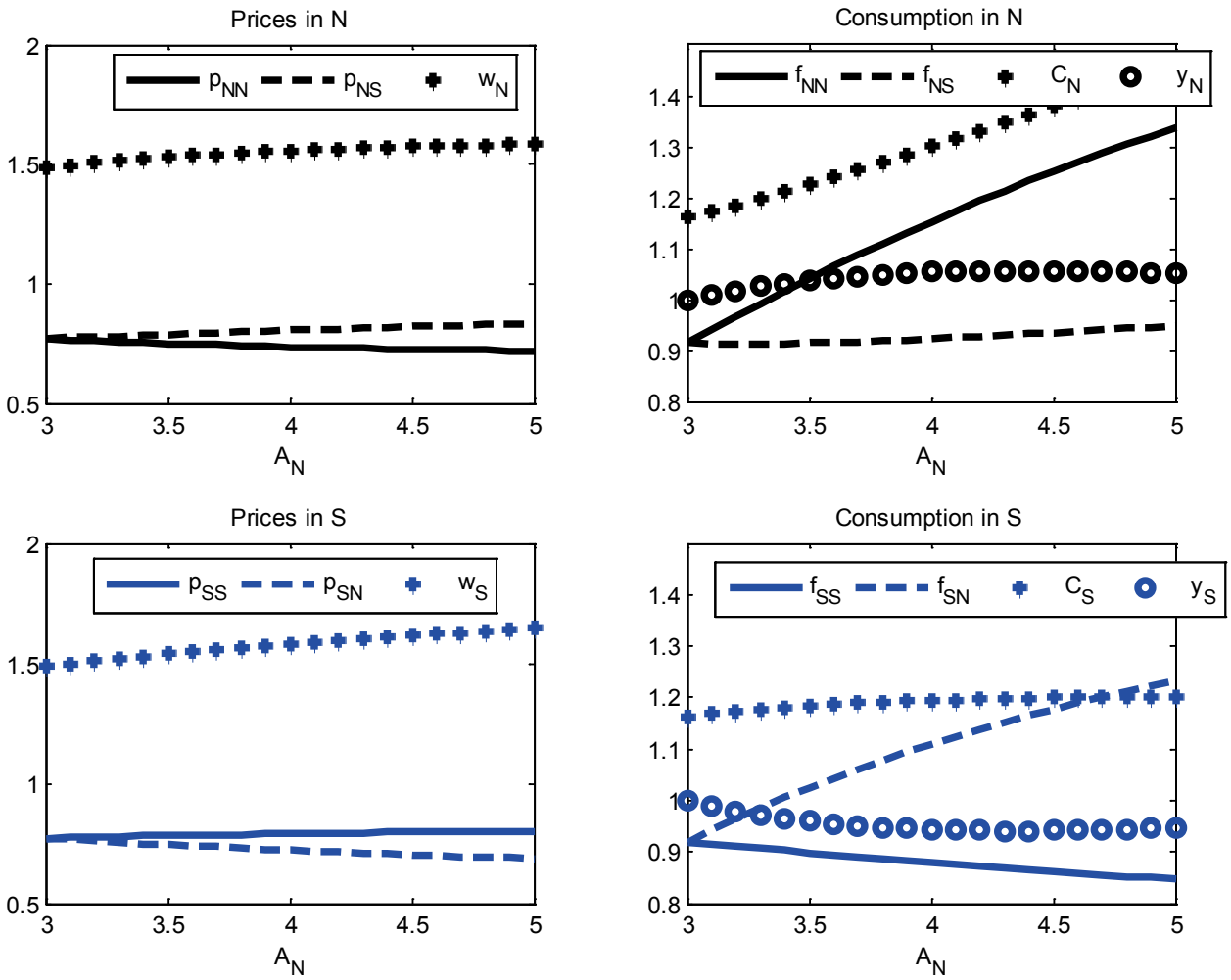
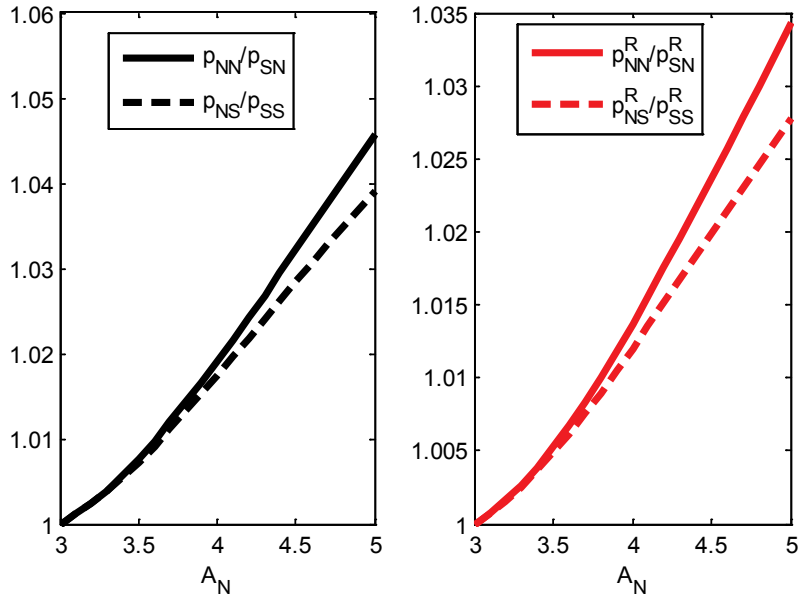


Figure 7: Effect of Productivity in N's Final Good Sector on Relative Prices.



Note: The graph on the left shows the ratio of prices relative to the numeraire, while the graph on the right shows the ratio of PPP prices. See Footnote 9 for an explanation of how PPP prices are computed.

Figure 8: Effect of Productivity, A_N, on Market Outcomes in Two-Country Model with Nontraded Goods and Services.

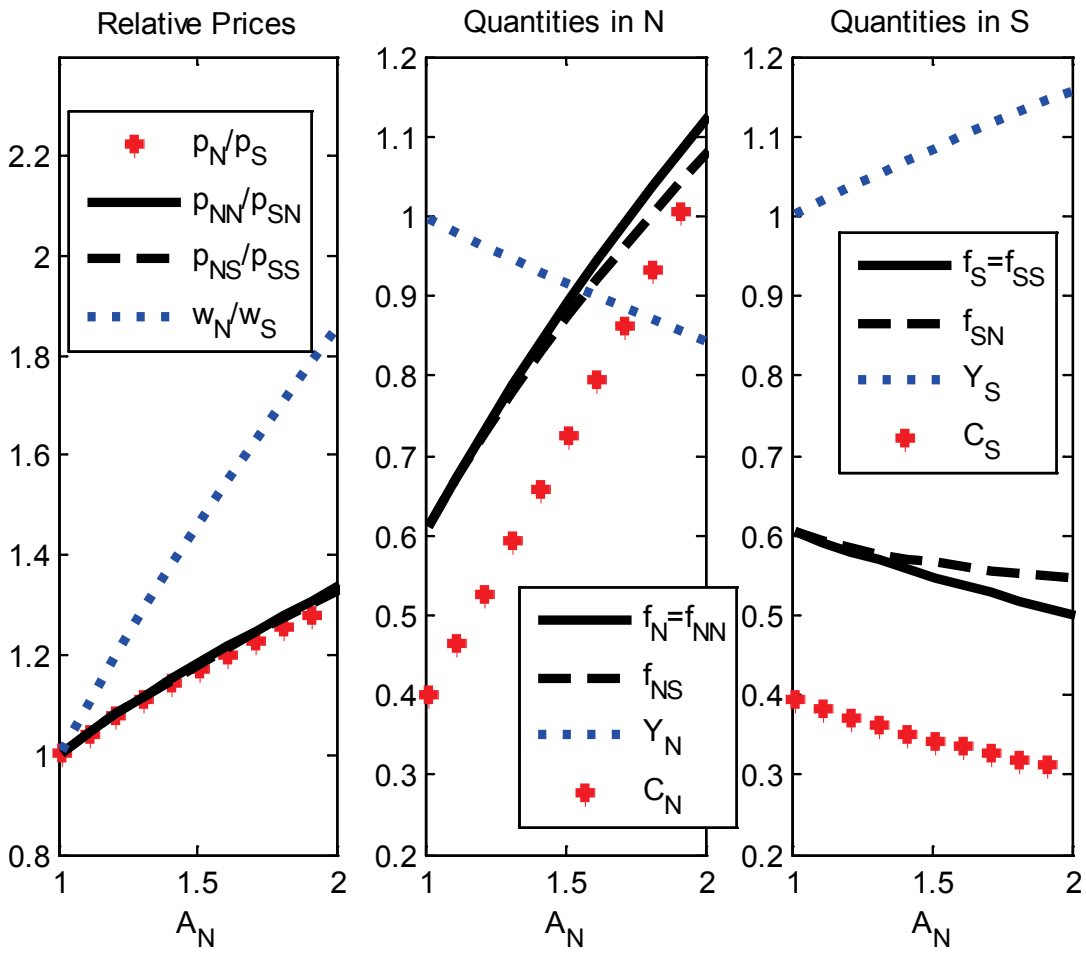


Figure 9: Effect of Increasing Productivity in all Sectors in N in Two-Country Model with Capital.

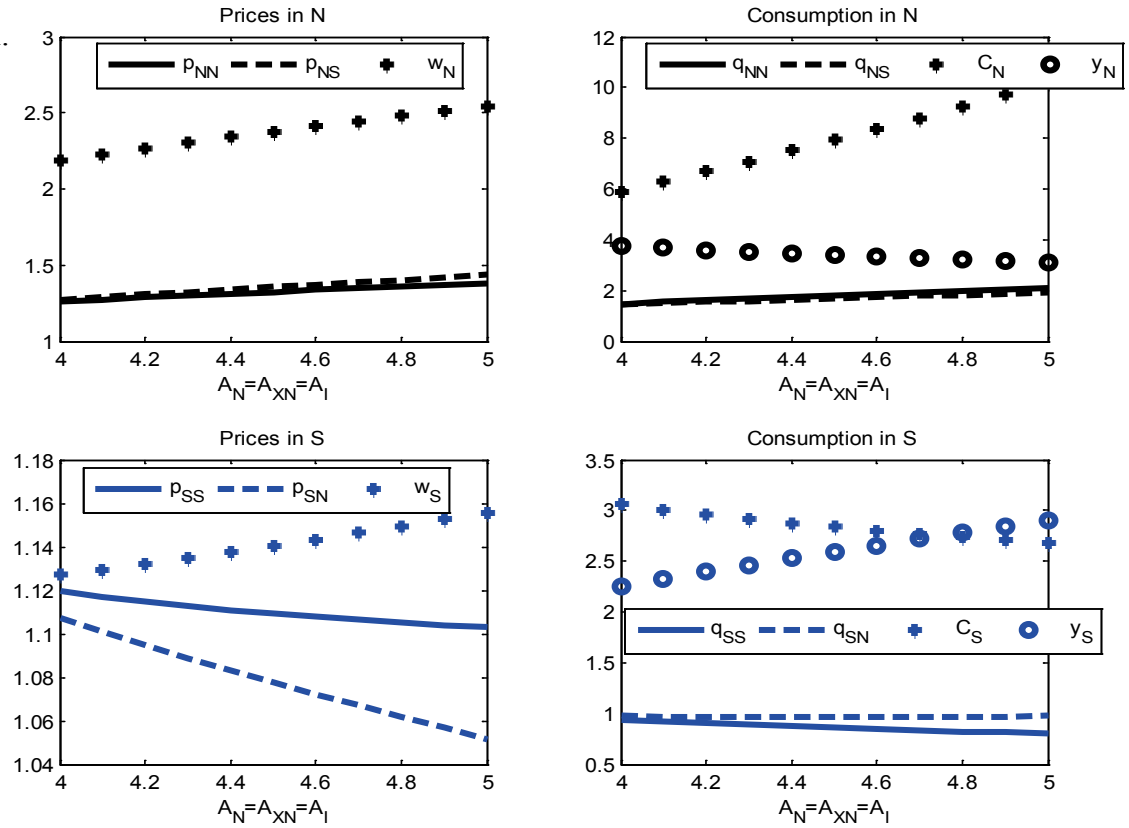
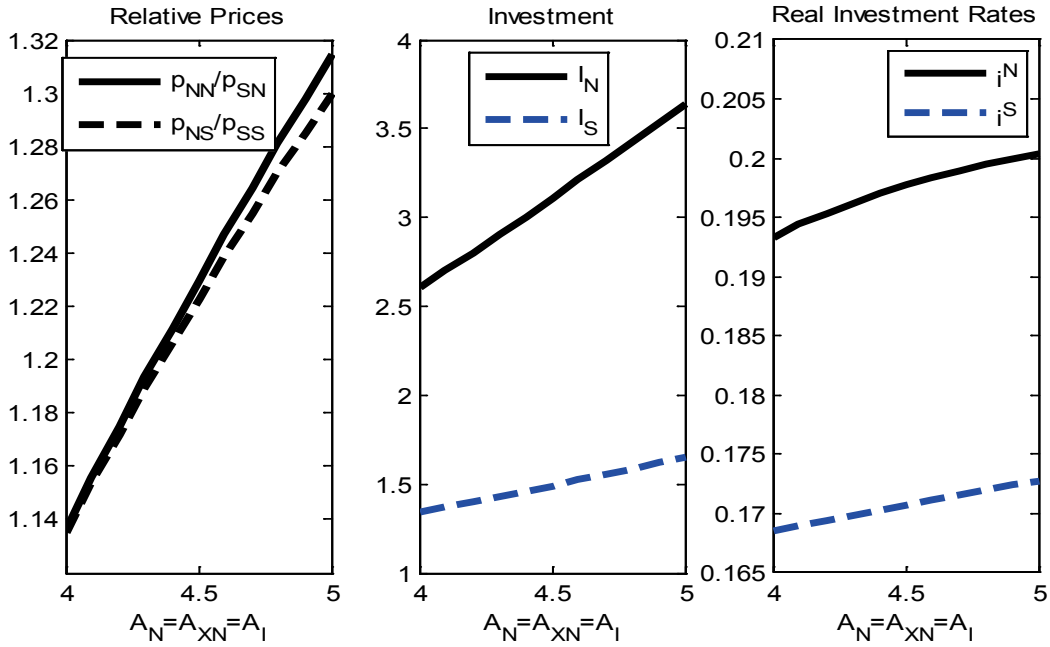


Figure 10: Relative Prices and Real Investment in Two-Country Model with Capital.



Note: The real investment rate in country j is given by Equation (36), where I substitute $y_j + \Omega_N p_{NN} f_{jN} + \Omega_S p_{NS} f_{jS} + p_{Xj} X_j$ for $p_N C_j$ in the denominator.

Figure A1: Market Outcomes as Productivity Increases in Model with Numeraire Produced by Labor.

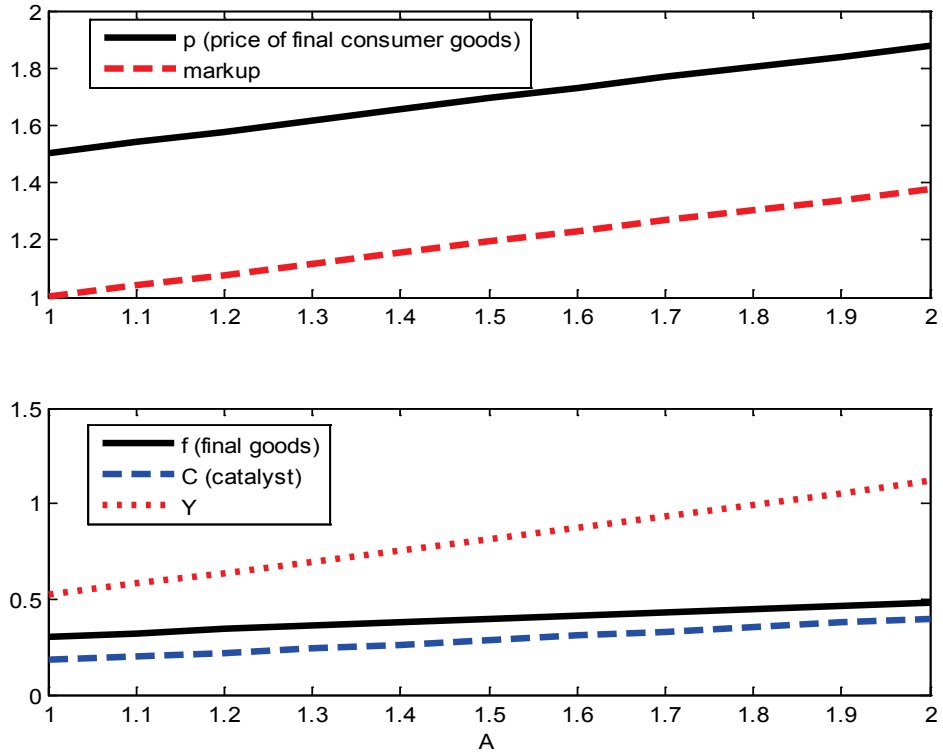


Figure C1: Relative Prices and Real Investment in Alternative Model with Investment Produced by a CES Aggregator over Differentiated Intermediate Investment Goods.

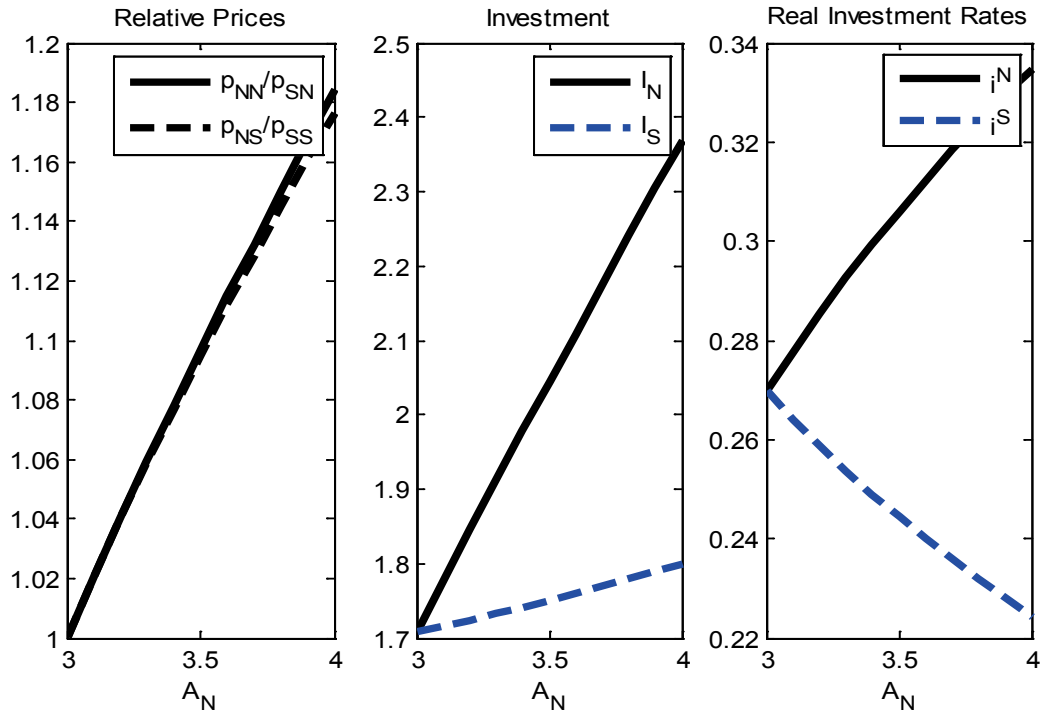


Figure D1: Relative Prices and Purchases of Intermediate Investment Goods in Alternative Model with Investment Produced by a Quadratic Aggregator over Differentiated Intermediate Investment Goods.