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ABSTRACT

Armington Elasticity (AE) is the elasticity of substitution among varieties of the same product produced by different countries. AE is part of standard methodology for representing region-specific preferences in international trade. The contribution of this paper is to systematically model the role of technological and economic progress in evolution of AE and consumer preferences. A model is constructed to account for 1) technological progress influencing AE, as substitution becomes easier when varieties embody equally developed technology and 2) steadier demand for technology intensive products as the economy develops and incomes rise. Our model yields a framework where technology, market shares, and consumers' demand for technologically advanced products are linked. Our simulations present the implications for the competitiveness of the domestic variety over the course of economic development. This framework has theoretical, practical, and policy applications in international trade. We provide illustrations of how the framework can be used to analyze the conditions for successful government policy interventions in trade.

JEL CLASSIFICATIONS: F11

KEYWORDS: Armington elasticity; trade policy; economic development; technological progress.

Armington (1969) presents a theory to extend the concept of price elasticity of demand for products to the demand for *varieties* of each product. The varieties of a product are differentiated based on the producing country. Each country produces a different variety. The Armington theory yields tractable solutions for the own and cross price elasticity of demand for each variety, j, of every product i. This turns out to be a function of the price elasticity of product i, the elasticity of substitution among varieties of i^{th} product (the Armington Elasticity), and the market share of variety j. Armington argues that distinguishing varieties of the same product based on the country of production is realistic.

So, an interesting question is what causes the differences among varieties of the same product produced by different countries? It is an important question as well, given the wide use of the Armington approach in CGE models, where it is the standard methodology for representing region-specific preferences for goods in international trade.

Our paper is novel because so far all the causes of Armington-type imperfect substitution, between varieties of a product, explored in the literature are immediate or lagged outcomes of trade/investment/labor policy, physical distance and have little or nothing to do with the intrinsic characteristics of the product itself. By contrast, we focus on intrinsic characteristics of the product stemming directly from the technological capability of the producing country. This approach seems to be supported by the availability of extremely detailed trade data has made it possible to investigate if there is measurable difference among products based solely on their country of origin. For example, Schott (2004) finds that countries export the same product (at the 10 digit level of the Harmonized System of product classification, therefore they are listed as "identical" products) at vastly different unit-values depending on their per capita incomes. This raises the possibility that countries specialize in different quality levels (varieties of the same product) based on their technological capabilities.

The theoretical contribution of this paper is to consider the possibility of genuinely different quality of production based on available technology (Romer (1994) and Mukerji (2009 and 2013)). In this paper we consider long term technological development causing and changing Armington-type imperfect substitution among varieties of a product. The only other work that addresses production processes which lead to intrinsically different product characteristics is Welsch (2006) which attributes the falling AE in France in the 1990's to the evolution of a more specialized production structure that ceased production of close substitutes for many imports. Even there the outcome is studied as a lagged response to trade liberalization policy.

Armington (1969) found that price elasticity of a *variety* of a product is a function of the AE and the overall product price elasticity, both of which are assumed fixed. In this paper we extend the Armington (1969) model so that both these parameters are allowed to change with development and technological progress. Specifically, technological progress influences AE on the supply side by improving the quality of skill/capital/technology intensive production in an economy, making the domestic variety a closer substitute for the imported variety. And on the demand side, improvement in technology is associated with rising per capita income (Schott 2004, Balassa 1979, Romalis 2004, Hallak 2006, Barro 1991, Linder 1961), which leads to steadier demand for skill/capital/technology products. We utilize a modified version of the Markusen (2013) model to reflect this in the second parameter, the overall product price elasticity. Bringing together these developments on the supply and demand side, along with market shares of each variety, our paper yields a relationship between price elasticity of demand for domestic and imported varieties of each product and the level of economic development of a given country. We use numerical simulation to derive the form of this relationship.

Our model has widespread practical application. We focus on the intersection between market shares, technological innovation and consumers' evolving preference for technology intensive products. A commonplace example is of governments over time and in economies at all stages of development attempting to influence market shares as well as technological innovation. For example, before the trade liberalization of 1991 the Indian government encouraged import substitution through prohibitive tariffs and import licenses. The government's policy ensured large market shares for domestic producers and was supposed to encourage home grown technological innovation (Bhagwati and Desai, 1970). The unintended side effect was often technological stagnation, perhaps driven by lack of competition and limited exposure to emerging technologies through imports (Bhagwati and Srinivasan, 1975). For instance in the consumer automobile market, cars were limited largely to just two vehicles – Hindustan Ambassador and Premier Padmini - both manufactured domestically with the original design licensed/bought from British Motor Corp. and Fiat respectively (Sumantran, 1993). The cars and the technology behind them remained practically unchanged throughout their reign of the Indian market from the 1960's and 1970's to when they finally lost practically all their market shares once Indian trade was liberalized. In our model we present one scenario (Section 3.4) where only demand side forces act and the supply side is held constant, this could be a framework to analyse situations like the Indian economy's example that we just presented.

Another example of the practical application of this model is in instances where technological innovation and market shares come into play in counterintuitive ways, with technologically advanced countries scrambling to catch up with less advanced nations. An example is the market for electric cars where an area of intense competition is the European market for lithium-ion car batteries. The European Commission is seeking to advance local companies in battery production in Europe (Onstad, et.al., 2018). While Asian manufacturers, who currently lead in market share, are seeking to locate production facilities in Europe where electric car manufacturing has accelerated and buying batteries from abroad is now less feasible. For now it appears to be a losing battle for the European companies, as European governments are unlikely to match the huge production subsidies that Asian governments provide (Stanway, 2018). The best hope for European companies is to invest in the next generation "solid state" batteries where they will not be encumbered by the pre-existing market leadership of Asian rivals. Our model, in the case where both supply and demand side forces act (Section 3.5) but one variety has a very large market share, presents a framework to analyse such cases as this example.

We can see from the above examples that technology, market shares and consumers' demand for advanced products are closely linked in practice, with market shares sometimes trumping even technological prowess. At other instances, like the case of India outlined above, market share is not enough to ensure dominance and the entry of superior technology changes the competitive landscape quickly.

The rest of the paper is laid out as follows. Section I contains a literature review, Section II presents the theoretical model and Section III, the simulation results. Section IV concludes.

I. LITERATURE REVIEW

The literature has produced a large range of estimates of AE (for example see, Goldstein & Khan (1985), Panagariya et al. (2001), Gallaway, et al. (2003)). Furthermore, in contrast to this paper, the extant literature has explored, for example, that imperfect substitutability may arise due to price distortion (such as from trade barriers) or trade costs (such as due to physical distance). In these cases products sourced from different countries need not necessarily be differentiated due to their intrinsic characteristics. Examples include, Welsch (2006) recording a rise in AE after trade liberalization in France in the 1980's as the reduction in tariffs made imports more competitive with the domestic variety. Similarly, Yilmazkuday (2009) explores trade costs as the cause of imperfect substitutability. Other literature proposed causes of imperfect substitutability are: political processes/foreign ownership which make consumer perception of products become more or less dependent on the product's country of origin. Foreign ownership might lead to more openness, and rising AE of imported inputs (Blonigen & Wilson (1999)). Likewise, unionization might lead to falling AE due to political movements that encourage people to buy domestic, for example, in an attempt to protect domestic jobs (Blonigen & Wilson (1999)).

II. THEORETICAL MODEL

II.1 Supply Side: Technology impacts skill/capital/technology intensive production

We use a modified version of the Armington (1969) model. Our model's novel contribution on the supply side is that unlike extant literature, which assumes fixed AE, we allow AE to be a function of technology. Technology is an important determinant of product quality, especially in developing countries. For instance Romer (1994) and Mukerji (2009 and 2013) argue quality improvement eases substitution between imports and domestic produced varieties in skill/capital/technology intensive products. Thus in our model AE is directly proportional to the level of existing production technology. This represents the increasing ease of substitution between home and imported varieties as the home technology progresses towards the world technology frontier.

This contribution is also very timely in today's technology driven competitive landscape, where ignoring the differences in technology content of the varieties of a given product misses a fundamental basis of quality and competitiveness. Consider commonplace products of everyday use like cellular phones and electric cars – each have varieties that compete based on a constant race for technological superiority. This is also in keeping with the large theoretical and empirical literature on the international competitiveness of product varieties originating from countries at different levels of technological progress (Mukerji (2009, 2013), Schott (2002, 2004)).

We model AE as a function of the measure of technological development denoted by the index, T, that varies from 0 to 100 -

$$\sigma(T) = \sigma_L e^{rT}$$

Where AE varies from low (σ_L) to high (σ_H) levels depending on the technology available in a particular country and r is a positive constant. We choose an exponential functional form since it yields an intuitively appealing characteristic of steeper response of the elasticity of substitution at higher income/technology levels. We would naturally expect higher levels of technology leading to ever faster convergence towards σ_H. During our simulations, T, the technology index, is taken to be the percentile per capita income of households in the country because of the strong positive relation between per capita income and technological sophistication indicated in the literature (Schott 2004, Balassa 1979, Romalis 2004, Hallak 2006, Barro 1991, Linder 1961).

Let $T_{\min}$ = the minimum technology index which when achieved by a country, makes its domestic product a robust substitute for the imported variety, thus at $T_{\min}$ the AE takes on the high value of σ_H. Thus $\sigma_H = \sigma_L e^{rT_{\min}}$, taking natural logs and solving for r, we get the relationship -

$$\sigma(T) = \sigma_L e^{\frac{T}{T_{\min}} \ln(\frac{\sigma_H}{\sigma_L})} \tag{1}$$

II.2 Demand Side: Per-capita income & skill/capital/technology intensive product demand

Another contribution of our model, within this framework, is that we model the impact of technological progress on the demand side. Specifically, per capita income is typically positively associated with technological development. Furthermore, rising per capita income has been shown to lead to steadier demand for skill/capital/technology intensive products (e.g. Markusen (2013)). Thus to account for the demand side. To reflect this, we incorporate an extended Markusen (2013) model where the Marshallian price elasticity of demand for skill/capital/technology intensive products is falling in per capita income.

Thus on the demand side we use a Stone-Geary utility function. Our model has four products that are consumed in the economy: products x_1 and x_2 are relatively skill/capital/technology intensive, thus we extend the Markusen (2013) model here, to include more than one skill/capital/technology intensive product; product y is a relatively labor intensive product, this product is assumed to require rudimentary technology that all countries possess and z is an endowment product that is non-rival and non-excludable. Each of x_1 and x_2 have n varieties, one domestically produced and the rest are imported from $n-1$ countries respectively. Household utility is -

$$\begin{aligned} &u(x_{11}, x_{12}, x_{13}, x_{14} ..., x_{1n}, x_{21}, x_{22}, x_{23}, x_{24}, ..., x_{2n}, z, y) \\ &= u(x_1, x_2, z, y) = (x_1 + x_2 + z)^{\beta} y^{1-\beta} \end{aligned} \tag{2}$$

The first equality where we collapse the utility function so that x_1 and x_2 each now represent all n varieties of the product, follows from an assumption of functional separability of x_1 and x_2. The second equality presents the Stone-Geary utility function.

Let m^q be the income of household q. We will assume in our model that all households have the same per capita income m and use it to represent the percentile of per capita income to which the country belongs, indexed to range between 0 and 100 internationally. Therefore low, middle and high income countries will be denoted by the percentile of their per capita income. Later, in our simulations the same parameter is used to represent the percentile per capita income m, and the technology index, T. and P_{x_1}, P_{x_2} and P_y be the prices of x_1 , x_2 and y. The household budget constraint is -

$$m^q = P_{x_1}x_1 + P_{x_2}x_2 + P_y y \tag{3}$$

There are L households, $M = \sum_{q=1}^{L} m^q$ and $Z = zL$. Maximizing (2) subject to (3), yields the following first order conditions where λ denotes the Lagrangian multiplier –

$$\beta(x_1 + x_2 + z)^{\beta-1} y^{1-\beta} - \lambda P_{x_1} = 0 \tag{4}$$

$$\beta(x_1 + x_2 + z)^{\beta-1} y^{1-\beta} - \lambda P_{x_2} = 0 \tag{5}$$

$$(x_1 + x_2 + z)^{\beta}(1-\beta) y^{-\beta} - \lambda P_y = 0 \tag{6}$$

Solving for x_1 using equations (4) and (6) yields –

$$x_1 = \frac{\beta(m^q - x_2 P_{x_2})}{P_{x_1}} + (\beta - 1)(x_2 + z) \tag{7}$$

We use the aggregate demand X_i to denote the sum over all households' demand for x_i and write –

$$X_1 = \sum_{q=1}^{L} x_1 = \frac{\beta(M - X_2 P_{x_2})}{P_{x_1}} + (\beta - 1)(X_2 + Z) \tag{8}$$

Defining the price elasticity as positive and by using $\frac{dX_1}{dP_{x_1}} = -\frac{\beta(M - X_2 P_{x_2})}{P_{x_1}{}^2}$ we get -

$$\eta_{X_1} = -\left[\frac{P_{x_1}}{X_1} . \frac{dX_1}{dP_{x_1}}\right] = \frac{M - X_2 P_{x_2}}{M - X_2 P_{x_2} + \frac{\beta - 1}{\beta}(Z + X_2) P_{x_1}}$$
$$= \frac{m - \overline{x}_2 P_{x_2}}{m - \overline{x}_2 P_{x_2} - \frac{1-\beta}{\beta}(z + \overline{x}_2) P_{x_1}} \tag{9}$$

Where $m =$ average household budget, we use this to denote per capita income and $\overline{x}_2 =$ average household consumption of product x_2. Equation (9) indicates that the price elasticity is declining in per capita income, indicating a steadier demand for x_1 with rising per capita income (m).

The minimum average household income (m_0), required for an average household to start consuming the skill/capital/technology intensive product x_1 is –

$$\frac{\beta(m - \overline{x}_2 P_{x_2})}{P_{x_1}} - (1-\beta)(\overline{x}_2 + z) > 0$$
$$\Rightarrow m > \overline{x}_2 P_{x_2} + \frac{(1-\beta)(\overline{x}_2 + z) P_{x_1}}{\beta} \equiv m_0 \tag{10}$$

For each product X_i, $i = 1, 2$ we minimize the expenditure on the n varieties bought of X_i where each country supplies a unique variety. Assuming functional separability of each X_i and a CES form, allows us to construct the quantity index from all the varieties of the product X_i, $X_i = \phi_i(X_{i1}, X_{i2}, ..., X_{in}) = [b_{i1} X_{i1}^{-\rho_i} + b_{i2} X_{i2}^{-\rho_i} + ... + b_{in} X_{in}^{-\rho_i}]^{-\frac{1}{\rho_i}}$. Here the price index P_{x_i} is the unit expenditure function for group of products index by i, i.e. all the varieties of product X_i. That is $P_{x_i} = e_i(P_{x_i}, 1) \equiv \min_{x_i} \left\{P_{x_i} x_i : \phi_i(X_i) = 1\right\}$ which under our CES form yields -

$$P_{x_i} = e_i(P_{x_i}) = (\sum_j \beta_{ij}^{\sigma_i} P_{x_{ij}}^{1-\sigma})^{\frac{1}{1-\sigma_i}} \tag{11}$$

here $P_{x_{ij}}$ is the price of variety j of product i.

Then via Shephard's Lemma we get the following conditional demand function -

$$X_{ij} = X_i \frac{\partial e_i}{\partial P_{x_{ij}}} = b_{ij}^{\sigma_i} X_i (\frac{P_{x_{ij}}}{P_{x_i}})^{-\sigma_i} \tag{12}$$

where $\sigma_i =$ AE (the elasticity of substitution in the i^{th} market) = $\frac{1}{1+\rho_i}$.

The market demand for a product is a function of income and prices in its own and other markets. We make a simplifying assumption that the labor intensive product y and the skill/capital/technology intensive products x_i are independent -

$$X_i = X_i(M, P_{x_1}, P_{x_2}) \tag{13}$$

Totally differentiating the market demand (13) and product variety demand (12) and using the property of P_i that -

$$\frac{dP_{x_i}}{P_{x_i}} = \sum_{k=1}^{n} S_{ik} \frac{dP_{x_{ik}}}{P_{x_{ik}}} \text{ where } S_{ik} = \frac{P_{x_{ik}} X_{ik}}{P_{x_i} X_i} \tag{14}$$

Differentiating (12) and dividing through by X_{ij} and after some manipulation -

$$\frac{dX_{ij}}{X_{ij}} = \frac{dX_i}{X_i} - \sigma_i (\frac{dP_{x_{ij}}}{P_{x_{ij}}} - \frac{dP_{x_i}}{P_{x_i}}) \tag{15}$$

Differentiate (13) and substitute into (15) and use (14) to get –

$$\frac{dX_{ij}}{X_{ij}} = \varepsilon_i \frac{dD}{D} - [(1-S_{ij})\sigma_i + S_{ij}\eta_{X_i}] \frac{dP_{x_{ij}}}{P_{x_{ij}}} + \sum_{k \neq j} [S_{ik}\sigma_i - S_{ik}\eta_{X_i}] \frac{dP_{x_{ik}}}{P_{x_{ik}}} + \sum_{f \neq i} \eta_{X_i X_f} \frac{dP_{x_f}}{P_{x_f}} \tag{16}$$

This is a general formulation of (16), in our model the third and fourth terms on the RHS do not need a summation since we have only two skill/technology/capital intensive products, and because we will assume only two varieties of each product.

Differentiate (13) and (12), and use (14) to get the percentage change in demand for X_{ij} in value terms –

$$\frac{d(P_{ij}X_{ij})}{P_{ij}X_{ij}} = \varepsilon_i \frac{dM}{M} - [(1-S_{ij})(\sigma_i - 1) + S_{ij}(\eta_{X_i} - 1)]\frac{dP_{ij}}{P_{ij}}$$
$$+ \sum_{k \neq j}[S_{ik}(\sigma_i - 1) - S_{ik}(\eta_{X_i} - 1)]\frac{dP_{ik}}{P_{ik}} + \sum_{f \neq i}\eta_{X_i X_f}\frac{dP_f}{P_f} \qquad (17)$$

In (16) and (17) ε_i is the income elasticity of demand for product i, η_{X_i} is the direct price elasticity of demand for product i, $\eta_{X_i X_f}$ is the cross elasticity of demand for product i with respect to changes in the price of product f. The coefficient of $\frac{dP_{ij}}{P_{ij}}$ is the direct price elasticity of demand for X_{ij} in (16) and the price elasticity of demand for X_{ij} in value terms in (17). Similarly, coefficients of $\frac{dP_{ik}}{P_{ik}}$ in (16) and (17) are the cross price elasticity, of demand, and of demand in value terms, for X_{ij} with respect to any competing variety in the market for product X_i.

Feenstra, et al. (2012) separate the AE into two categories for a given product market: the macro AE between home and imported varieties, and the micro AE among imported varieties. In this paper we focus on the macro elasticity and therefore we collapse demand for all imported varieties from all foreign countries into a single variety j of product i. Then X_{ij} is the imported variety and the only other variety, X_{ik}, is domestically produced.

II.3 Reflecting *only* the Supply Side Forces on Variety Elasticities

In this section we allow AE to vary with technology, to isolate the impact of supply side forces of our model (Section 3.1 above). At the same time, we hold demand elasticity of product i constant. We have assumed, ceteris paribus, that the AE between varieties in the market for product i is σ_H when technical capacity is high, making it easy for consumers to substitute between imports and domestic varieties of product i. It is σ_L for low technological capacity $\sigma_L < \sigma_H$. Ordinarily, we would expect σ_L and σ_H to exceed unity, thus an improvement in competitiveness would yield an increased market share. But our model places no such restriction, which fits well with our intuitive framework where a reduction in price may not help customers adopt a particular variety if production technology differences make the varieties poor substitutes.

Using (1) in (17), the own price elasticity of variety j of product i -

$$\eta_{X_{ij}} = (1 - S_{ij})(\sigma_L e^{\frac{m}{T_{\min}} \ln(\frac{\sigma_H}{\sigma_L})} - 1) + S_{ij}(\eta_{X_i} - 1) \qquad (18)$$

Similarly the cross price elasticity of variety j with respect to change in the price of variety k of product i -

$$\eta_{X_{ij}X_{ik}} = S_{ik}(\sigma_L e^{\frac{m}{T_{\min}} \ln(\frac{\sigma_H}{\sigma_L})} - 1) - S_{ik}(\eta_{X_i} - 1) \qquad (19)$$

II.4 Reflecting *only* the Demand Side Forces on Variety Elasticities

Here we allow price elasticity of product i to vary with income (the demand side forces from Section 3.2), but hold AE constant. Substitute the price elasticity of demand for product i from equation (9) and use the definition of m_0 from equation (10) to write the own price elasticity in equation (17) of variety j of product i in the following form -

$$\eta_{X_{ij}} = (1 - S_{ij})(\sigma_i - 1) + S_{ij}(\frac{m - \bar{x}_2 p_{x_2}}{m - m_0} - 1) \qquad (20)$$

Similarly we obtain the cross price elasticity of variety j with respect to change in the price of variety k of product i -

$$\eta_{X_{ij}X_{ik}} = S_{ik}(\sigma_i - 1) - S_{ik}(\frac{m - \bar{x}_2 p_{x_2}}{m - m_0} - 1) \qquad (21)$$

II.5 Bringing Together the Supply and Demand Side Forces

In this section we allow both demand and supply side factors to operate, so, AE varies with technology and price elasticity of product i varies with per capita income. Thus accounting for both the supply and demand side impacts together gives us the following expression for the own price elasticity of a variety -

$$\eta_{X_{ij}} = (1 - S_{ij})[\sigma_L e^{\frac{m}{T_{\min}}\ln(\frac{\sigma_H}{\sigma_L})} - 1] + S_{ij}[\frac{m - \bar{x}_2 p_{x_2}}{m - m_0} - 1] \quad (22)$$

Similarly, the cross price elasticity of demand -

$$\eta_{X_{ij}X_{ik}} = S_{ik}[\sigma_L e^{\frac{m}{T_{\min}}\ln(\frac{\sigma_H}{\sigma_L})} - 1] - S_{ik}[\frac{m - \bar{x}_2 p_{x_2}}{m - m_0} - 1] \quad (23)$$

III. NUMERICAL SIMULATION

We simulate the response of the analytical results presented, in Section 3.3, 3.4 and 3.5 above, to changes in per capita income. Our simulations study an area of practical importance. We've presented a number of real world examples throughout this paper (see Sections 1 and 3.1). Our aim is to determine how the level of a country's development impacts the demand elasticity of the variety it produces of a given product. In addition we analyse how this impact changes as the economy develops and converges towards the world technology frontier. Simulations indicate that the answer depends crucially on the domestic demand for these skill/technology/capital intensive products, the distance of the country from the world technology frontier, as well as the initial market share of the country's variety.

Table 1 presents the range of parameter values selected and explanations for each. The parameter value for market share for the imported variety ranges from 0 to 100 percent of the total market for a product. Our assumption, without any loss of generality under the Armington (1969) model, is that there are two varieties of each product: imported and domestically produced. Given the strong positive relation between per capita income and technological sophistication (Schott 2004, Balassa 1979, Romalis 2004, Hallak 2006, Barro 1991, Linder 1961), in our model simulations the percentile per capita income represents the technology index, T, as well. The per capita incomes range from the 25th to the 75th percentile. The 25th percentile is, m_0, the minimum income required for the country to start consumption of the skill/capital/technology intensive product. The 75th percentile is, T_{Min}, the level of development at which the country has attained the world technology frontier and the AE is therefore high $=\sigma_H$. These percentiles correspond closely to those used in the literature (E.g. Schott, 2004) and used by data sources that categorize countries into low, middle, and high income categories (E.g. the World Bank's Open Access Database). Furthermore, in our numerical simulations, the elasticity of substitution ranges from .5 (σ_L) to 3.1 (σ_H), this range has been estimated in the literature (Feenstra et al. (2012) and Broda and Weinstein (2008)).

We obtain the change in own price elasticity as a result of a change in per capita income by differentiating equation (22) with respect to m–

$$\frac{d\eta_{X_{ij}}}{dm} = (1-S_{ij})[\sigma_L \ln(\frac{\sigma_H}{\sigma_L})\frac{1}{m_T}(\frac{\sigma_H}{\sigma_L})^{\frac{m}{m_T}}] - \frac{S_{ij}(1-\xi)m_0}{(m-m_0)^2} \tag{24}$$

Here ξ is the proportion of income spent on x_2.

Similarly we obtain the change in cross price elasticity as a result of a change in per capita income by differentiating equation (23) with respect to m:

$$\frac{d\eta_{X_{ij}X_{ik}}}{dm} = S_{ik}[\sigma_L \ln(\frac{\sigma_H}{\sigma_L})\frac{1}{m_T}(\frac{\sigma_H}{\sigma_L})^{\frac{m}{m_T}}] + \frac{S_{ik}(1-\xi)m_0}{(m-m_0)^2} \tag{25}$$

Before interpreting the results of the numerical simulations, it is useful to review the salient mechanisms at work, in the model –

1) Role of development. Development is measured by per-capita income and the level of technology.

   (a) From (9), own price elasticity for the skill/capital/technology intensive product is declining in development. Intuitively, this means more developed economies will have a steadier demand for these products.

   (b) From (1) AE will converge towards the high level, σ_H, as development tends towards the minimum needed to ensure the economy has access to world class technology. Intuitively, the economy's development leads to progress towards the world technology frontier.

2) Role of the market shares of varieties of a product. The larger the initial market share of a product variety, the smaller will be the reaction of its demand to both its own and other variety's price changes.

   (a) In (16) the coefficient of the price change of variety j indicates that, as long as $\sigma_i > \eta_{X_i}$, the own price elasticity is smaller for a variety with a larger market share.

   (b) Also in (16) the coefficient of the price change of the other variety, k, of the product indicates that as long as $\sigma_i > \eta_{X_i}$, the cross price elasticity is also smaller for variety j with larger market share.

In our simulations the range of income percentiles 25 to 75 are covered. In this range η varies between .05 and .16 while σ varies between 0.5 and 3.1. So the condition in (a) and (b) above, holds.

The figures from 1 to 4 presents the simulations as the level of a country's development, measured by its per-capita income, increases from the 25th to the 75th percentile. The initial market share of the country's domestic variety is allowed to vary from 0 to 100% in each case.

III.1 Simulation results when both the Supply and Demand Side Forces work together

Own price elasticity -

Figure 1 presents the simulations of equation (24) as the level of a country's development changes. We see that initially, at low levels of income, development leads to falling elasticity, however beyond a threshold development leads to rising elasticity of the domestic variety. Therefore the demand side forces come into play early in the development process, with steadier demand for skill/capital/technology. At this stage due to technological differences, the two varieties of the product are very different from each other. In the later stages, as the economy closes in towards the world technology frontier, elasticity rises as domestic versus foreign varieties become comparable in quality and thus easier to substitute.

Consider the example of the Indian consumer automobile market. Throughout the decades of the 60s, 70s and 80s the Padmini and Ambassador did well as incomes grew (Sumantran, 1993). These were demand side forces. However due to lack of innovation in the protectionist economy, the supply side forces were never unleashed. Thus when trade was finally opened up, domestic car varieties were entirely obsolete and could not compete with the foreigners.

Another observation we can make from Figure 1 is that the larger the initial market share of a variety, the higher the threshold at which its elasticity will rise with income. Therefore the demand side forces seem to hold sway for longer for the product variety with larger market share. Its elasticity continues to decline for a longer range of the development cycle as well. It is only when the economy reaches very close to the world technology frontier that the variety finally experiences a rise in elasticity. Even then, the rise is much less than in a variety with a smaller market share.

The case of Asian dominance of the electric car battery market is instructive here. The large initial market share helps keep demand for Asian-made batteries strong. While in this case all countries involved, European as well as Asian are at the world technology frontier. Here the prediction of the model where closeness to the world technology frontier leads to rising elasticity might only come about with the next generation of “solid state” batteries puts everyone on a more level playing field in terms of market shares. The absolute market dominance graph when the market share of the variety is 100% seems to be the closest to reality for this market.

Cross price elasticity

Figure 2 presents the simulations of equation (25). Cross price elasticity rises with income, at all levels of income. The rise is higher at lower levels of income. Higher market share of the other variety (whose price is changing) creates a higher rise in cross price elasticity of variety j.

An instructive example is the relocation of Asian battery manufacturers to Europe, which is projected to bring down their prices due to saving transport cost (Onstad, et al., 2018). This price change is not expected to change their market share by much, it is already very high. But this price change is expected to sweep out all European competition from the market reducing their market share dramatically.

III.2 Simulation results when only Supply or Demand Side Forces work

Own elasticity: only demand side forces operating

Figure 3 represents this case. The variety elasticity declines with income at all levels of income. Decline is more with higher market shares, as demand becomes increasingly steadier. But the greatest decline is at the point where the economy reaches the level of income where it starts consuming skill/capital/technology intensive products.

Own elasticity: only supply side forces operating

Figure 4 represents this case. The variety elasticity increases with income at all levels of income. The increase is higher at higher income, as rising income makes technology improve and varieties become easier to substitute for one another, so a small change in the price of one variety would result in large change in quantity demanded. This change is dampened only by higher market share of the variety.

Cross elasticity: only demand side forces operating

Refer to figure 5 for this case. The change in cross price elasticity of the variety as the income level varies, is positive throughout. It is higher at lower income levels, the greatest impact is at m_0. As usual, the higher the market share of the variety whose price changes (variety k), the greater is the impact on variety j.

Cross elasticity: only supply side forces operating

Refer to figure 6 for this case. The change in cross price elasticity for the variety is again positive throughout the spectrum of per capita income. The supply side impact increases as technology converges to T_{Min}. As in the previous case, the market share of the other variety (k) is linked positively with the cross elasticity of variety j.

III.2 General Conclusions

Across both own and cross price elasticity of a variety of the product we see that: 1) market share is negatively related to the elasticity for the variety, 2) the demand side impact is strongest at m_0, and 3) the supply side impact is strongest at T_{Min}. The knowledge of the threshold points that 2) and 3) represent, provides insights into the theory behind the Armington approach widely used in international trade modelling. In addition, it can be useful to both policy makers and competing firms in these markets.

IV. CONCLUSION

The theoretical contribution of the model in this paper is to enrich, the widely used, Armington approach (in for example CGE models) by accounting for the supply and demand side implications of technological and economic development. The model yields a theoretical framework where technology, market shares, and consumers' demand for technologically advanced products are closely linked. Our simulations present the implications for the competitiveness of the domestic variety over the course of economic development.

This framework also has widespread practical and policy applications in international trade. For instance, the simulations give us an interesting insight into the hoped-for versus the realized impact, of policy intervention. We have seen that government policy initiatives might aim to increase market share and/or accelerate technological progress. We see from our model that both the demand and supply side can help spur demand for domestically produced skill/capital/technology intensive product's variety produced at home. However if the government's policy is only nurturing the demand side forces, say through trade protection, the domestically produced variety might only benefit while the protection lasts. When the economy is opened up to foreign competition, e.g. India in the 1990s, the domestic producers will lose out in the absence of supply side technology advances.

Strategic government intervention that targets technological progress, and results in market share gain based on that solid foundation, might lay groundwork for long term strength of domestic producers. This might be the difference between the success of government policy in promoting domestic companies in the rest of Asia, versus the failure in pre- 1990s India. And this holds a cautionary note for all governments that promote inward looking policies coupled with trade protection.

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Table 1 – Parameter Values for Numerical Simulation of Equations (24) and (25)

Parameter	Definition	Values	Justification of Values
S_{iq}	Market-share of variety q in the market for product i	0-100 percent of the market	Entire range of possible values is included.
σ_L	Assumed low value of the Armington elasticity, when the technological capacity and per capita income are low.	0.5	The lowest value of the spectrum of values derived for Armington elasticity in Feenstra et al. (2012)
σ_H	Assumed high value of the Armington elasticity, when the technological capacity and per capita income are high.	3.1	The value of elasticity of substitution obtained in Broda and Weinstein (2008) and this is comparable to the highest value of Armington elasticity obtained in Feenstra et al. (2012)
$m_T = T_{Min}$	The per capita income percentile and the technology index, at which the economy's technology level is high enough to produce good quality import substitutes such that σ_H prevails.	75th percentile of per capita income	These match with the World Bank's classification of high and low income countries
m_0	The income at which economy's technology level is so low as to produce import substitutes such that σ_L prevails	25th percentile of income	
ξ	The share of income spent on product x_2	.25	We assume that on average half of income is used to purchase the x products and half to purchase the y. And a quarter each goes to x_1 and x_2

Figure 1: Change in Own Price Elasticity of Variety j as Income Changes

Both demand and supply side forces operating

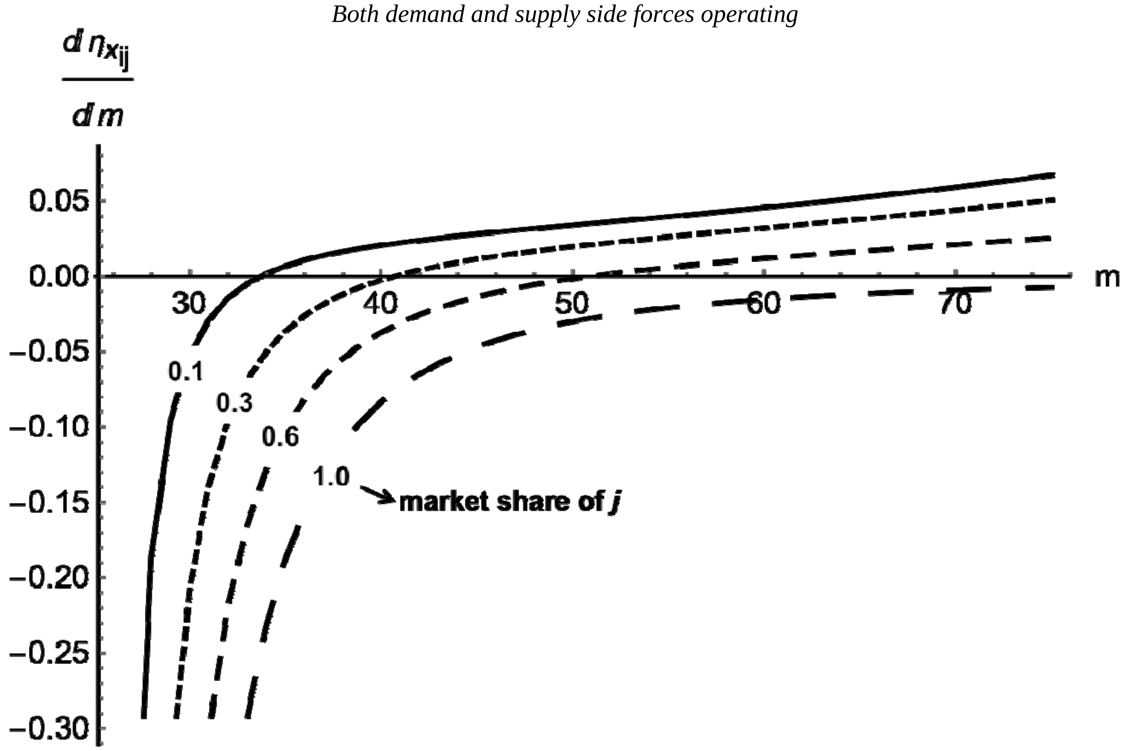

Figure 2: Change in Cross Price Elasticity of Variety j as Income Changes

Both demand and supply side forces operating

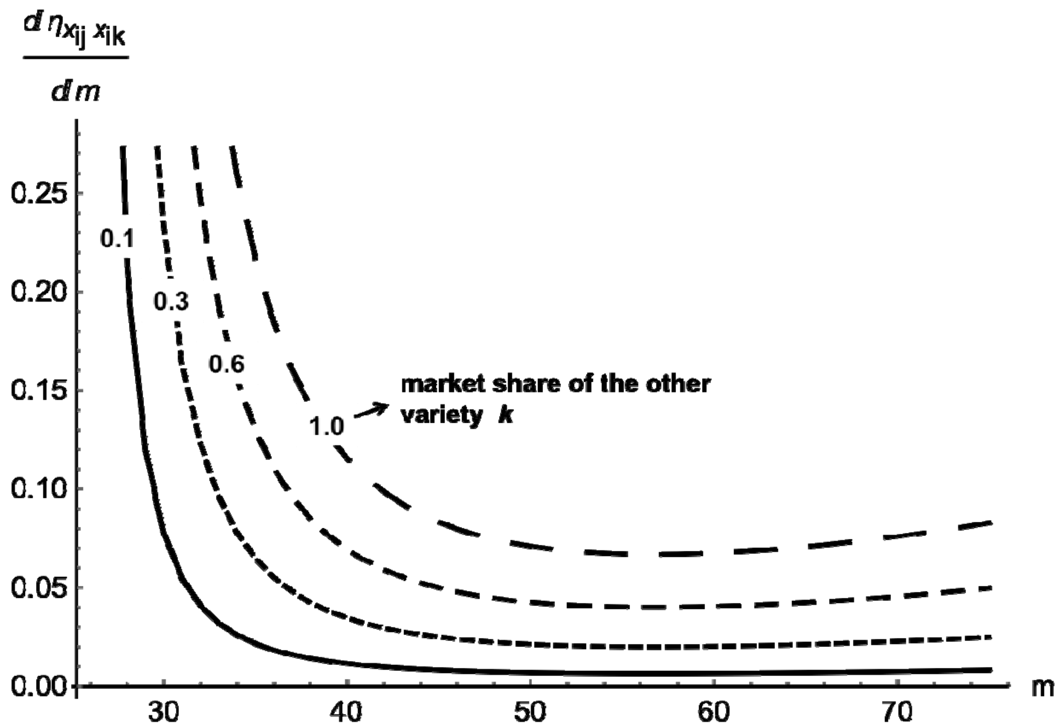

Figure 3: Change in Own Price Elasticity of Variety j as Income Changes

Only demand side forces operating

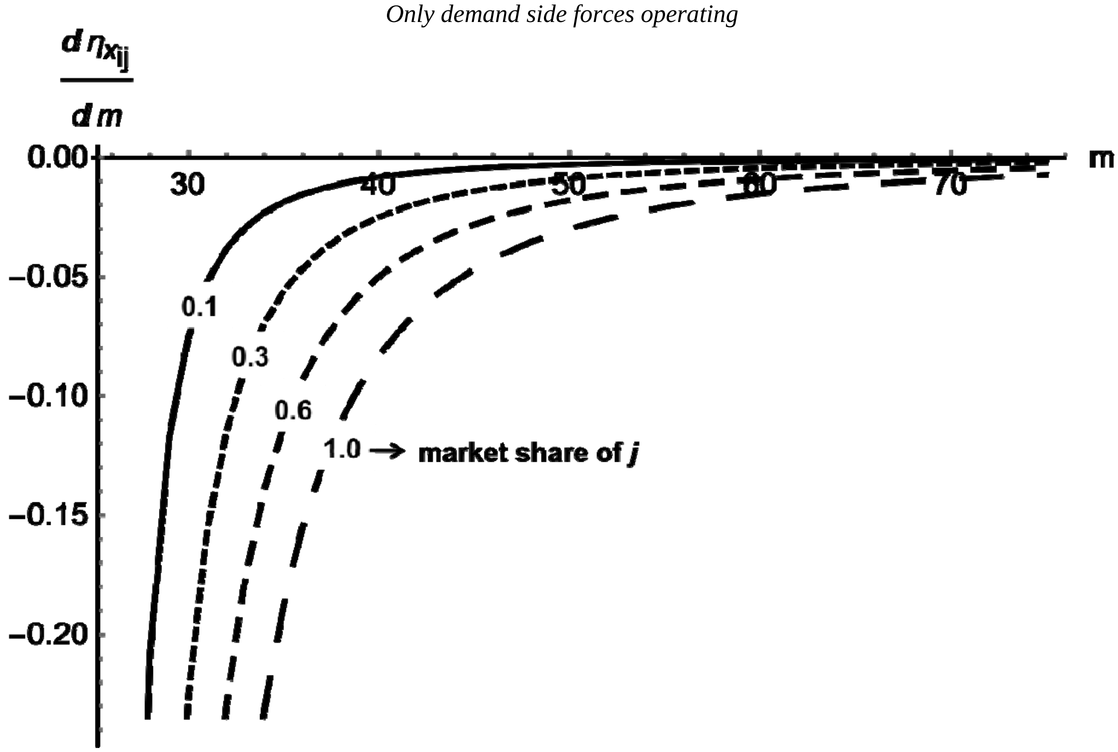

Figure 4: Change in Own Price Elasticity of Variety j as Income Changes

Only supply side forces operating

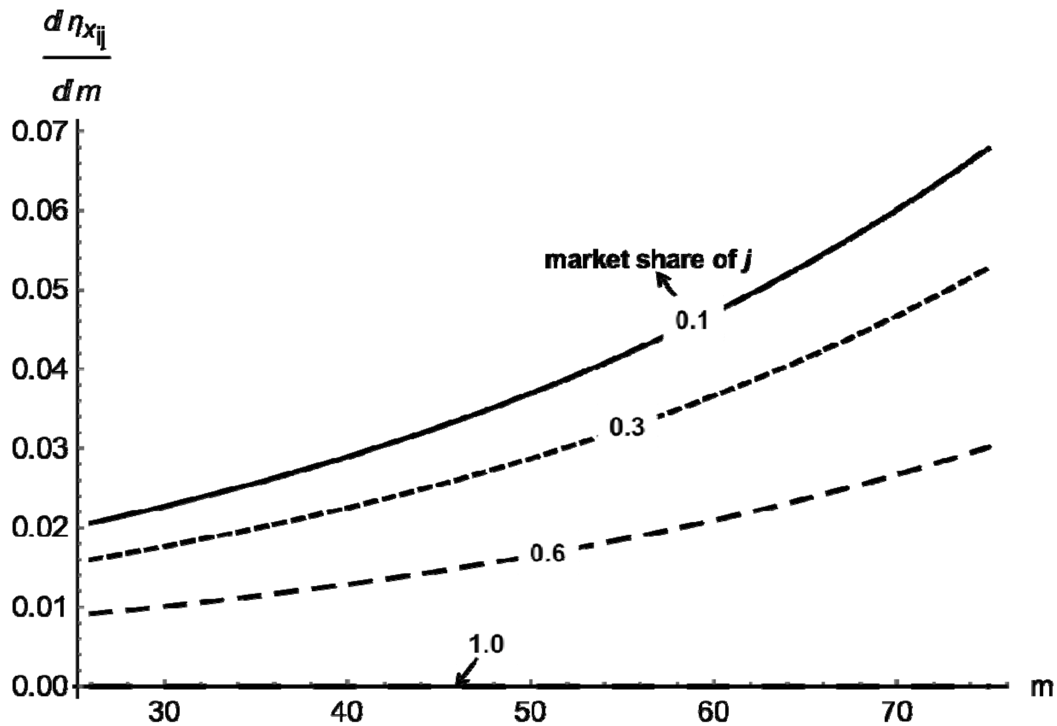

Figure 5: Change in Cross Price Elasticity of Variety j as Income Changes

Only demand side forces operating

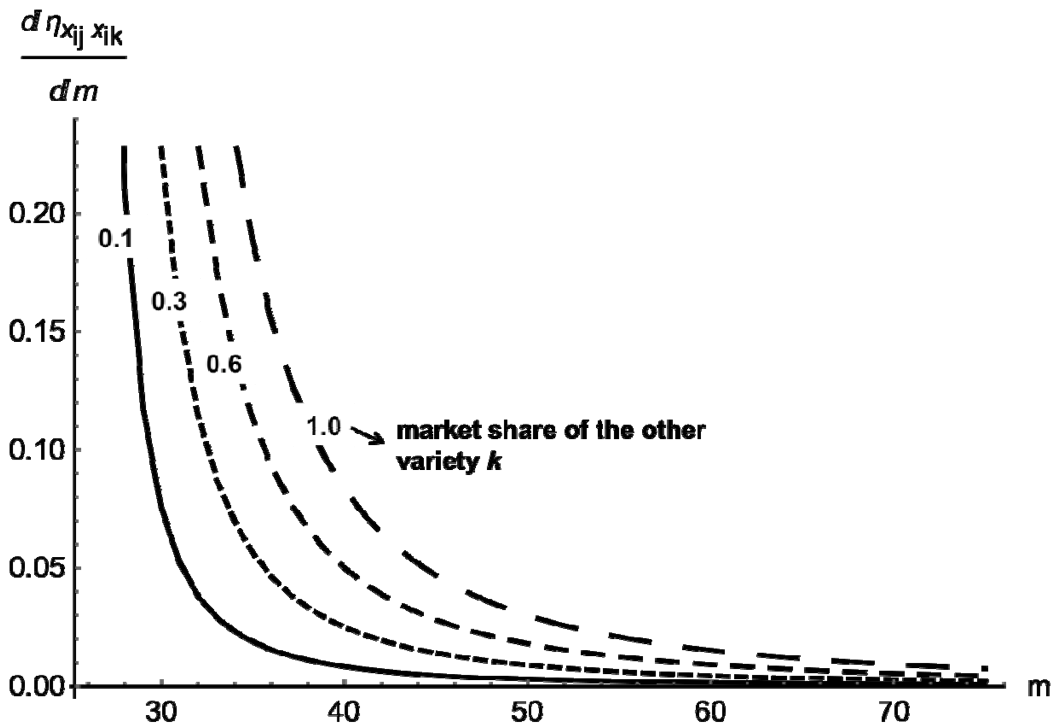

Figure 6: Change in Cross Price Elasticity of Variety j as Income Changes

Only supply side forces operating