The Roles of Innovators and Labor in a Schumpeterian Factor Endowments Based Model of Intraindustry Trade

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May 2015

Abstract

This paper builds a model of Schumpeterian innovation and trade that emphasizes endowments of innovators and labor as a key factor in determining the pattern of trade. The model suggests a strong complementarity between intraindustry and interindustry trade. The pattern of interindustry vs. intraindustry trade is analyzed using the Grubel Lloyd index. The theoretical model predicts that the prominence of intraindustry trade is a nonlinear function of the ratio of the proportion of world knowledge domestically generated to the domestic share of the world labor supply. Strong empirical evidence for this key result is presented and implications are discussed.

(JEL classification: F1, O3)

Keywords: Innovation, Factor Endowments, Intraindustry Trade, Interindustry Trade

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1 Introduction

Since Grubel and Lloyd published their account of intraindustry trade in 1975, imperfect competition and scale economies have become a focus of both theoretical and empirical work within international economics. The relative factor endowments approach and models based on competitive economies, either Ricardian or Hecksher-Ohlin, now take a less prevalent role in our understanding of the pattern and gains from trade. In fact, these models are often treated as preliminaries in graduate trade courses, where the focus is on the new trade theory (Feenstra, 2004).

The internal scale economies motivation for intraindustry trade, introduced in Krugman (1979) and extended by Ethier (1982), Melitz (2003), and Melitz and Ottaviano (2008), has a mixed empirical record. These models predict an increase in intra country variety, with each surviving firm producing more output with freer trade. Head and Ries (1999) examine the impact of NAFTA on Canadian plant size and find little empirical evidence of this scale effect. On the other hand, the theoretical models predict a selection effect, whereby productivity gains are achieved as less efficient firms are driven out of the market. Here, there exists more empirical support (Trefler, 2004).

In this paper, we develop a relative factor endowments explanation of intraindustry trade based on the ratio of innovators to the general labor population. We can also alternatively view innovators as the entrepreneurs in the economy. This model suggests a complementarity between intraindustry trade and interindustry trade that is similar to the complimentarity promoted by Ethier (1982). The implication is that the pattern and gains from trade are determined by a combination of trade in vertically improved differentiated intermediate goods (giving rise to intraindustry trade) and trade based on traditional Hecksher-Ohlin determinants of trade (giving rise to interindustry trade). The model presented in this paper is consistent with selection effects, but does not imply the type of scale effect discussed above. This is covered in more detail below.

The model borrows heavily from the literature on endogenous growth. The similarities and differences of our approach compared to the existing trade literature are briefly outlined. We utilize a model of Schumpeterian vertical innovation. While this model has not been used for the present purpose, it has been used to study how nations interact through a process of international transfer of ideas (Aghion, Howitt, and Mayer-Foulkes, 2005; Howitt and Mayer-Foulkes, 2005; Acemoglu, Aghion, and Zilibotti, 2006) and the strongly supported idea of club convergence (Barro and Sala-i-Martin, 1992; Mankiw, Romer, and Weil, 1992; Sala-i-Martin, 2006). These models assume that all countries produce the full range of intermediate goods and interact only through the fully symmetric transfer of knowledge. In other words, they abstract completely from international trade in goods.

In a vast majority of published research, models of scale economies and imperfect competition rely on an endogenously determined number of horizontally differentiated goods. The scale effect at the level of the firm is a direct result of the scale economies and the profits and markups implied are a necessary feature of imperfect competition. Examples of these types of models include Krugman (1979), Ethier (1982), Helpman and Krugman (1985), Melitz (2003) and Bernard et al. (2007). In our specification, we take the number of differentiated goods to be constant. We follow Ethier (1982) and allow differentiated goods to represent intermediate goods as most intraindustry trade is between firms. Our specification, however, takes the number of intermediate goods as exogenous and relies on trade in vertically improved intermediate goods to motivate intraindustry trade, though not all trade in intermediate goods need be intraindustry.

This motivation for intraindustry trade is relatively less examined, but we are not the first to consider it. Shaked and Sutton (1984) and more recently Bernard, Redding, and Schott (2011) look at intraindustry trade and the role of vertical quality improvement along the intensive margin. The present paper, however, allows innovators to invest resources in the discovery of new patents that can be used to manufacture an improved version of an intermediate good. The patent holder can be thought to license the patent to manufacturers or set up any desired number of physical plants and earn the associated profits, these profits provide the incentive for innovation. While the research resource investment is a fixed cost, the intermediate good is produced with constant returns to scale once the patent is discovered since the fixed cost is not tied to a particular plant or physical location. Thus, the scale of the individual firm is both indeterminate and inconsequential. The model does not imply a scale effect at the firm level as a consequence of the principle that ideas are non-rival.

The relative factor motivation for intraindustry trade that naturally comes from the analysis suggests a close examination of innovator to labor ratios. Interindustry trade is motivated by Hecksher-Ohlin factor endowment considerations. Again, we are not the first to recognize the importance of providing a factor endowments basis for intraindustry trade, but existing attempts are usually theoretical and focus on endowments of capital and labor. Examples include Ethier (1982), Helpman and Krugman (1985), Davis (1995) and Bernard et al. (2007). A complementarity between intraindustry trade and interindustry trade is suggested by our model and is similar to the complementarity outlined in Ethier (1982).

The gains from trade in our model come through both intraindustry trade and interindustry trade. Intraindustry trade allows countries to use high quality intermediate goods in manufacturing final consumption goods. This boosts the productivity of labor and the wage labor earns. This is the gain from trade recognized in the traditional literature on monopolistically competitive markets and intraindustry trade, a benefit from increased product variety. In addition, intraindustry trade directly leads to dynamic gains from trade since countries can use technologies that are, perhaps, not produced at home. As these technologies improve, productivity improves in all nations utilizing them. The productivity level of a nation is a function of the degree of intraindustry trade. Trade limits the gap in per capita incomes between trading nations. This is the well-known club convergence effect from growth theory. Finally, comparative advantage provides familiar classical gains from trade based on specialization. In our model trade across intermediate goods and final consumption goods is a substitute for direct trade in the two key factors, innovators and labor.

Consistent with previous examples of endowment based explanations of interindustry and intraindustry trade, the balance of intraindustry versus interindustry trade is a function of differences in a country's factor endowments. In general, intraindustry trade between nations is maximized as a percent of total trade when the factor endowments of the nations are similar. This suggests that a high ratio of innovators to labor relative to the world ratio of innovators to labor will create interindustry trade through exports of innovative intermediate goods in exchange for final consumption goods. A low ratio of innovators to labor relative to the world ratio of innovators to labor will create interindustry trade through exports of final consumption goods in exchange for innovative intermediate goods. This suggests a nonlinear relationship between ratio of innovators to labor relative to the world ratio of innovators to labor and intraindustry trade, which serves as the main empirical test of our model.

The focus of Schumpeterian growth theory is on vertical product innovation and creative destruction. This paper contributes to the existing literature by extending the most basic Schumpeterian model to suggest a useful view of differences in factor endowments based on innovative activity per capita. We ask if differences in the ratio of innovators to labor can define differences in factor endowments significant enough to explain intraindustry trade generally. This requires extending the basic Schumpeterian framework to allow for trade in both final goods and intermediate goods. To our knowledge, the present paper is the only paper that looks directly at the issue of vertical innovation, factor endowments, and the significance of intraindustry versus interindustry trade. The next section develops the model. Section 3 provides an empirical analysis motivated by the model and Section 4 concludes.

2 Model

In our model, we abstract from the love of product variety and scale economy motivations for intraindustry trade in order to focus entirely on the implications of the a vertical innovation factor endowments motivation for intraindustry trade. Imagine the following experiment. A fixed number of intermediate goods are produced in one large world economy without political borders. Final output is produced with a combination of intermediate goods and labor. Final output is produced in a competitive market structure and serves as the numeraire. The intermediate goods are produced in a standard monopolistically competitive market structure. The geographic distribution of world labor and intermediate goods is random and uneven. For the sake of simplicity, all final and intermediate goods in this world can be shipped anywhere without transport costs. Thus, each innovator, which can similarly be viewed as an entrepreneur, as well as some number of workers, occupy a geographic space and all final goods producers employ each intermediate good.

We depart from the existing Schumpeterian approach to international interactions and imagine rather that these locally produced intermediate goods gain a permanent global advantage. Existing research appeals to external economies of scale to explain how a permanent pattern of industrial agglomerations can arise and why the equilibrium distribution of industrial agglomeration can appear arbitrary (Audretsch and Feldman, 2004; Ottaviano and Thisse, 2004). The typical arguments for external economies of scale include Mill's (1909) recognition of labor market pooling, specialized supply chains, and localized knowledge. Evidence that spillovers of knowledge are localized has been clearly demonstrated (Jaffe, Trajtenberg, and Henderson, 1993; Keller, 2002). While we choose not to explicitly model these scale economies for reasons already discussed, the basic structure of the model is very compatible with existing models in the arena of new trade theory. Beyond these modifications, we present a canonical Schumpeterian model in as simple a framework as possible.

With production in this global economy underway arbitrarily divide the world into countries of various sizes. These countries are indexed by $j \in \{1, 2, 3, ..., J\}$ and become the focus of interest. Each nation inherits a fixed supply of labor and innovators. All nations achieve full employment of their available labor, L_j, and can trade with all other nations.

2.1 Production and GDP

Individual utility is linear in consumption and each individual lives for one period. Intermediate goods are produced on the unit interval and are indexed by i. The final good is produced by combining labor and intermediate goods:

$$Y_j(t) = L_j^{1-\alpha} \int_0^1 A(i,t)^{1-\alpha} x_j^{\alpha}(i,t) di, 0 < \alpha < 1, \tag{2.1}$$

where $x_j(i,t)$ is the input of intermediate good i in country j at time t and $A(i,t)$ is the level of productivity in industry i at time t. The production function is easily aggregated to global output. Note that each manufacturer employs each intermediate good with the same intermediate good to labor ratio, $\frac{x_j(i,t)}{L_j} = \frac{x(i,t)}{L}$ $\forall j \in \{1, 2, 3, ..., J\}$. Using this fact together with the definition of the global supply of labor, $\sum_{j=1}^{J} L_j = L$ leads to the following expression for global output:

$$Y(t) = L^{1-\alpha} \int_0^1 A(i,t)^{1-\alpha} x^{\alpha}(i,t) di. \tag{2.2}$$

The income approach is used to derive an expression for national GDP, N_j. According to Equation (2.1), the wage rate in country j at time t is $w_j(t) = (1-\alpha)\, L_j^{-\alpha} \int_0^1 A(i,t)^{1-\alpha} x_j^{\alpha}(i,t) di = (1-\alpha)\, \frac{Y_j(t)}{L_j}$. To measure national income, it is necessary to add profit income earned by innovators to the wage income generated in the final goods sector. Recall that intermediate good producers sell in a global market. An intermediate good is produced through a one to one transformation of a final good into an intermediate good. This constant returns to scale production of an already existing patent design is what eliminates the scale economies at the level of the firm, a prediction that has plagued models based on horizontal product innovation due to a lack of empirical evidence. Using Equation (2.2) to derive the demand for an intermediate good and allowing each intermediate good to be manufactured from one unit of the final good, the profit function is:

$$\pi(i,t) = A(i,t)^{1-\alpha} L^{1-\alpha} \alpha x(i,t)^{\alpha} - x(i,t). \tag{2.3}$$

The first order condition for profit maximization is:

$$L^{1-\alpha} \alpha^2 A(i,t)^{1-\alpha} x(i,t)^{\alpha-1} = 1. \tag{2.4}$$

Solving this expression for $x(i,t)$ gives:

$$x(i,t) = A(i,t) \alpha^{\frac{2}{1-\alpha}} L. \tag{2.5}$$

Combining this result with Equation (2.3) provides an alternative expression of profits:

$$\pi(i,t) = (1-\alpha) \alpha^{\frac{1+\alpha}{1-\alpha}} A(i,t) L. \tag{2.6}$$

Note the role of global population, L, rather than local population, L_j, in the profit equation.

If intermediate good i is produced in nation j, then $\kappa_j(i) = 1$, otherwise $\kappa_j(i) = 0$. We substitute out Y_j in the wage expression by combining Equation (2.5) with Equation (2.1) and use the resulting wage expression with profits to express GDP as the sum of wage income and profit income:

$$N_j = \underbrace{(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} L_j A(t)}_{Wages} + \underbrace{(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} L \int_0^1 \kappa_j(i) A(i,t) di}_{\text{Pr}ofit}, \tag{2.7}$$

where $A(t) = \int_0^1 A(i,t)di$ is the average productivity parameter. Per capita income is then Equation (2.7) divided by L_j, which can be rearranged to be:

$$\frac{N_j}{L_j} = (1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}} A(t)(1 + \alpha \frac{L}{L_j} a_j(t)). \tag{2.8}$$

The expression $a_j(t) = \frac{\int_0^1 \kappa_j(i)A(i,t)di}{A(t)}$ is defined to be a measure of country j's average proprietary knowledge in intermediate goods production relative to the global average knowledge in intermediate goods production. A few features of this expression for national income are worth pointing out. First, per capita income is increasing in the global stock of ideas, $A(i,t)$, reflecting the selection effect. The ability of final goods producers to import intermediate goods allows workers wages to reflect advances in technology anywhere around the globe. Per capita income is also rising in proprietary knowledge, $a_j(t)$. This effect works through the profit income earned by local intermediate goods suppliers. In the case where the economy conducts no innovation such that $a_j \to 0$, Equation (2.8) reduces to the expression for wages.

World income is most easily derived using a value added approach, $N = Y(t) - \int_0^1 x(i,t)di$. Using this expression with Equation (2.2) and Equation (2.5) produces an expression for per capita world income:

$$\frac{N}{L} = (1-\alpha^2)\alpha^{\frac{2\alpha}{1-\alpha}} A(t). \tag{2.9}$$

2.2 Innovation

Innovation occurs randomly with a probability $\mu(i,t)$. This probability depends on the level of productivity adjusted resources spent by the innovator, $n(i,t) = \frac{R(i,t)}{A^*(i,t)}$, where $A^*(i,t)$ represents the target level of productivity achieved if the attempt to innovate is a success. Assuming a standard Cobb Douglas innovation production function gives:

$$\mu(i,t) = \phi(n(i,t)) = \lambda n(i,t)^{\sigma},\ 0 \leq \sigma \leq 1, \tag{2.10}$$

where λ is a research productivity parameter.

A successful innovation advances the state of technology by a fixed degree known as the step size of the innovation:

$$A^{*}(i,t) = \gamma A(i,t-1),\ \gamma > 1. \tag{2.11}$$

The parameter γ signifies the step size of an innovation.

The innovator maximizes expected profits:

$$\underset{R(i,t)}{Max}\ \phi\left(\frac{R(i,t)}{A^{*}(i,t)}\right)\pi^{*}(i,t) - R(i,t). \tag{2.12}$$

The first order condition for this problem together with Equation (2.6) and Equation (2.10) leads directly to the research arbitrage equation and innovation probability:

$$n(i,t) = n = \left(\sigma\lambda(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L\right)^{\frac{1}{1-\sigma}} \tag{2.13}$$

$$\mu(i,t) = \mu = \lambda^{\frac{1}{1-\sigma}}\left(\sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}}L\right)^{\frac{\sigma}{1-\sigma}}. \tag{2.14}$$

Note that Equation (2.13) represents a standard research arbitrage equation. Equation (2.13) implies equal innovation probabilities across sectors and preserves a simple aggregation to national rates of innovation.

With the same probability of innovation in each intermediate good sector, every sector innovates with probability μ and fails to innovate, maintaining the previous period's level of technology, with a probability $(1-\mu)$. Given that those who innovate and those who do not innovate are drawn at random, the law of large numbers suggests that the expected value of average productivity parameter is:

$$A(t) = \mu\gamma A(t-1) + (1-\mu)A(t-1), \tag{2.15}$$

From this equation it immediately follows that the growth rate of the global economy, g, is

$$g = \mu(\gamma - 1). \tag{2.16}$$

This formula is the standard Schumpeterian growth rate expressed as a function of the frequency of innovation and the step size of innovation.

Nations experience club convergence. In the steady state, all nations experience the same aggregate growth rate equal to the global growth rate. Differences in per capita income persist in the steady state. GDP per capita is increasing in the number of innovators residing in the domestic economy.

Equation (2.8) implies that the growth rate of any national economy equals the growth rate of $A(t)$ if $a_j(t) = \frac{\int_0^1 \kappa_j(i)A(i,t)di}{A(t)}$ is constant and the national share of world population, $\frac{L}{L_j}$, is constant. Assume $\frac{L}{L_j}$ is fixed. $a_j(t)$ is constant and the growth rate is governed by Equation (2.16). Equation (2.7) shows that the convergence in growth rates does not imply convergence of per capita income. Per capita income is an increasing function of the number of per capita innovators, $\frac{\int_0^1 \kappa_j(i)A(i,t)di}{L_j}$.

Note also that national growth rates are not a function of local population or scale, L_j, but are a function of global population or scale, L.

Substituting (2.14) into (2.16) gives:

$$g = \lambda^{\frac{1}{1-\sigma}} \left(\sigma(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} L\right)^{\frac{\sigma}{1-\sigma}} (\gamma - 1). \tag{2.17}$$

Equation (2.17) is consistent with the type of global scale identified by Kremer (1993).[1] Since Equation (2.17) is not a function of L_j, it does not predict the type of local scale effect criticized by Jones (1995a and 1995b). Because all intermediate goods enter each nation's production function for final goods symmetrically and all nations have access to each intermediate good, this growth equation applies to each nation. This club convergence result suggest a dynamic gain from trade, whereby trading economies benefit from the technological advances at home and abroad. While differences in per capita income can persist, the rate of growth in per capita income is constant. Trade limits how the degree to which countries can diverge over time. This gain is distinct from the benefit of knowledge spillovers.

2.3 Trade

In interpreting the model's implications for trade, it is important to note that the distinction between final goods and intermediate goods is of little consequence. In reality, many goods are traded as both final goods and intermediate goods and our data does not allow us to differentiate industry exports or imports destined for intermediate goods production ver-

[1] Global scale effects could also be eliminated from the model by allowing innovation along the extensive margin to deplete resources used in productivity enhancing innovation along the intensive margin as in Segerstrom (1998).

sus final goods consumption. Furthermore, many final goods are traded in highly innovative monopolistically competitive industries. Examples include goods ranging from automobiles to cell phones. Some intermediate goods are produced in industries with relatively low levels of product innovation. Some natural resource and extractive industries are likely to fall into this category. As such, we see the key distinction between final goods and intermediate goods as a distinction between market structure and the incentive to undertake innovation. To emphasize this point, we discuss the trade implications using the terms basic commodity good for the final good and innovation goods for intermediate goods.

In this simple setup, net exports, NX_j, are equal to zero and the value of exports equals the value of imports. Denoting the net exports of the basic commodity good as $NX_{j,Y}$ and the net exports of innovative goods as $NX_{j,X}$, it follows that $NX_j = NX_{j,Y} + NX_{j,X} = 0$. Net exports of the innovative goods for an arbitrary economy j^* is:

$$\begin{aligned} NX_{j^*,X} &= \underbrace{\sum_{j=1}^{J}\int_0^1 \kappa_{j^*}(i)x_j(i,t)di - \int_0^1 \kappa_{j^*}(i)x_{j^*}(i,t)di}_{Exports} \\ &- \underbrace{\int_0^1 \left(1-\kappa_{j^*}(i)\right) x_{j^*}(i,t)di}_{Imports} \\ &= \int_0^1 \left(\sum_{j=1}^{J}\kappa_{j^*}(i)x_j(i,t) - x_{j^*}(i,t)\right) di. \end{aligned} \tag{2.18}$$

Result 1: The absolute value of the sum of net exports between economy j^* and the rest of the world, $T_{j^*,W} = |NX_{j^*,X}| + |NX_{j^*,Y}|$, is a function of the the imbalance between the local population level, L_{j^*}, and the total amount of labor needed to produce enough of the economy's basic commodity good to satisfy local consumption and the global demand for goods from the economy's innovative sectors, $a_{j^*}L$. If the economy is large relative to the number of domestically located innovative sectors, then $L_{j^*} > a_{j^*}L$, $NX_{j^*,X} < 0$, and $NX_{j^*,Y} > 0$. If the economy is small relative to the number of domestically located innovative sectors, then $L_{j^*} < a_{j^*}L$, $NX_{j^*,X} > 0$, and $NX_{j^*,Y} < 0$. If $L_{j^*} = a_{j^*}L$, then $NX_{j^*,X} = 0$ and $NX_{j^*,Y} = 0$.

Equation (2.18) is simplified using $\frac{x_j(i,t)}{L_j} = \frac{x(i,t)}{L}$ $\forall j \in \{1, 2, 3, ..., J\}$ and (2.5). After some algebra, the expression for $T_{j^*,W}$ is expressed as:

$$T_{j^*,W} = 2A(t)\alpha^{\frac{2}{1-\alpha}} \left|(a_{j^*}L - L_{j^*})\right|.^2 \tag{2.19}$$

Result 1 follows directly from (2.19). Recall that the production function for any innovative good requires one unit of the basic commodity good. Basic commodity goods are produced with innovative goods and labor. When an economy is host to a large number of innovative sectors relative to the size of the economy's population, it experiences a large demand for its innovative goods relative to its size. The local production of the basic commodity good is limited by the relatively small population and the economy must import the basic commodity good. Some of these imports support consumption, while some are transformed into innovative goods to satisfy the local and global demand for innovative goods. When an economy is host to a small number of innovative sectors relative to the size of the economy's population, it experiences a relatively small demand for its innovative goods. The local production of the basic commodity good is relatively large and can be exported in exchange for the innovative goods needed in the basic commodity goods sector. The model generates intraindustry and interindustry trade without productivity-based comparative advantage or internal scale economies.

Result 2: Given the distribution of innovative industries across nations, the proportion of trade that is intraindustry is a function of the imbalance between the local population level, L_{j^*}*, and the total amount of labor needed to produce enough of the economy's basic commodity good to satisfy local consumption and the global demand for goods from the economy's innovative sectors,* $a_{j^*}L$*. Intraindustry trade is maximized when* $L_{j^*} = a_{j^*}L$*. The larger the discrepancy between* L_{j^*} *and* $a_{j^*}L$*, the lower the proportion of trade that is intraindustry.*

The extent of intraindustry trade is measured with a Grubel Lloyd index (GL).[3] The value of any index of intraindustry trade depends critically on the definition of an industry, which is somewhat arbitrary. Clearly all innovative goods, as well as the basic commodity good, can be defined as individual industries. By definition, all trade is now interindustry. It is well known that the more broadly an industry is defined (lower digit industrial codes), the greater the value of the Grubel Lloyd index. We treat industry definitions in a completely general way. Imagine industries, indexed by I from 1 to N, as a set of intervals on the unit interval containing the firms, which are indexed by i. Each industry is defined by a lower limit, $i_{n-1,}$and an upper limit, i_n, where $i_0 = 0$ and $i_N = 1$. Industry definitions are

[2]With balanced trade $T_{j^*,W} = |NX_{j^*,X}| + |NX_{j^*,Y}| = 2\,|NX_{j^*,X}|$. Substituting $\frac{x_j(i,t)}{L_j} = \frac{x(i,t)}{L}$ and $x(i,t) = A(i,t)\alpha^{\frac{2}{1-\alpha}}L$ into 2.18 results in $NX_{j^*,X} == \int_0^1 \left(\sum_{j=1}^{J} \kappa_{j^*}(i)A(i,t)\alpha^{\frac{2}{1-\alpha}}L_j - A(i,t)\alpha^{\frac{2}{1-\alpha}}L_{j*}\right) di = A(t)\alpha^{\frac{2}{1-\alpha}}(a_{j*}L - L_{j*})$. Substituting this expression into the deifinition of $T_{j^*,W}$ yields Equation (2.19).

[3]The Grubel Lloyd index is defined as $GL = \frac{\sum\{(X_i+M_i)-|X_i-M_i|\}}{\sum(X_i+M_i)}$. This index takes a value between 0 and 1. A value of 0 indicates no intraindustry trade and a value of 1 indicates that all trade is intraindustry.

exhaustive and mutually exclusive over the unit interval as illustrated in Figure 1.

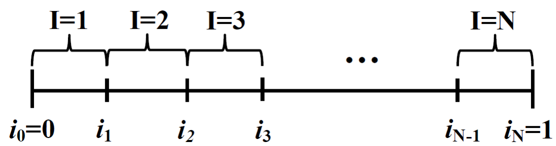

Figure 1: Industry Definitions

Define the following terms for each firm on the unit interval: $NX_{j*,i} = \sum_{j=1}^{J} \kappa_{j^*}(i)x_j(i,t) - x_{j^*}(i,t)$ and $(X_{j*,i} + M_{j*,i}) = \left(\sum_{j=1}^{J} \kappa_{j^*}(i)x_j(i,t) - \kappa_{j^*}(i)x_{j*}(i,t)\right) + (1 - \kappa_{j^*}(i))\, x_{j*}(i,t)$. The application of the Grubel Lloyd index to our model produces:

$$\begin{aligned} GL &= \frac{\sum_{I=1}^{N} \left(\int_{i_{I-1}}^{i_I} (X_{j*,i} + M_{j*,i}) di - \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right| \right)}{\sum_{I=1}^{N} \int_{i_{I-1}}^{i_I} (X_{j*,i} + M_{j*,i}) di + |NX_{j*,Y}|} \\ &= \frac{\sum_{I=1}^{N} \int_{i_{I-1}}^{i_I} (X_{j*,i} + M_{j*,i}) di - \sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right|}{\sum_{I=1}^{N} \int_{i_{I-1}}^{i_I} (X_{j*,i} + M_{j*,i}) di + |NX_{j*,Y}|}. \end{aligned} \tag{2.20}$$

For the basic commodity good sector, $(X_{j*,Y} + M_{j*,Y}) - |X_{j*,Y} - M_{j*,Y}| = 0$ because in our simple model with just a single basic commodity good, each nation is either an exporter or importer of the basic commodity good, but never both. Many aspects of GL are standard and well-known. For example, a diverse industrial base maximizes GL. In this example, GL is maximized when 50% of the varieties in each industry are produced in the home country and 50% are produced in the rest of the world.

Result 2 states that intraindustry trade is maximized when $L_{j^*} = a_{j^*}L$. GL is maximized when $\sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right|$, which is the second term in the numerator of Equation (2.20), is minimized and when $|NX_{j*,Y}|$, the second term in the denominator of Equation (2.20), is equal to zero. There is a similarity between $\sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right|$ and the expression for net exports from Equation (2.18). Take the absolute value of Equation (2.18) to produce $|NX_{j^*,X}| = \left| \int_0^1 \left(\sum_{j=1}^{J} \kappa_{j^*}(i)x_j(i,t) - x_{j^*}(i,t) \right) di \right| = \left| \sum_{I=1}^{N} \int_{i_{I-1}}^{i_I} \left(\sum_{j=1}^{J} \kappa_{j^*}(i)x_j(i,t) - x_{j^*}(i,t) \right) di \right|$,[4]

[4]The second term is possible given the continuity of the interval of integration.

while $\sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right| = \sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} \left(\sum_{j=1}^{J} \kappa_{j^*}(i) x_j(i,t) - x_{j^*}(i,t) di \right) \right|$. According to the triangular law of absolute values,[5] $|NX_{j^*,X}|$ provides a *ceteris paribus* lower bound for $\sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right|$ and therefore a *ceteris paribus* upper bound for the GL index. Result 1 established that the lower bound of $\sum_{I=1}^{N} \left| \int_{i_{I-1}}^{i_I} NX_{j*,i} di \right|$ is established when $|NX_{j^*,X}| = 0$, occurring when $L_{j^*} = a_{j^*} L$. When $L_{j^*} = a_{j^*} L$, Result 1 also establishes that $|NX_{j*,Y}| = 0$. Thus, the GL index achieves its largest upper bound when $L_{j^*} = a_{j^*} L$. Note that GL need not equal 1 at its maximum. All interindustry trade, however, is across innovative products when GL is at its maximum value.

GL will equal 1 at its maximum in the special case where all innovative goods are assigned to the same industry. Define X_X as exports from the innovative industry and M_X as imports from the innovative industry. Note that $|NX_X| = |NX_Y|$. GL simplifies to:

$$GL = \frac{(X_X + M_X) - |X_X - M_X|}{(X_X + M_X) + |NX_Y|} = \frac{(X_X + M_X) - |NX_X|}{(X_X + M_X) + |NX_X|}. \tag{2.21}$$

This index equals 1 in value if $NX_X = 0$. Again, Result 1 establishes that $NX_X = 0$ when $L_{j^*} = a_{j^*} L$.

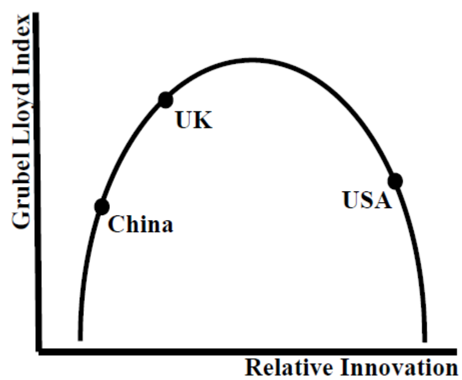

Figure 2: Non-linear Relationship Between Grubel Lloyd Index and Relative Innovation

Figure 2 demonstrates the basic relationship between intraindustry trade and the relative amount of innovation suggested by Result 2. The figure represents a result common to models that include a factor endowments foundation for intraindustry and interindustry trade; the degree of intraindustry trade is maximized when economies are similar (Ethier, 1982; Krugman and Helpman, 1985; Davis, 1995; Bernard et al., 2007). Here, however, the relevant factors are innovators and labor. To illustrate this point, three representative

[5] The triangular law of absolute values states that $|a + b| \leq |a| + |b|$.

economies are presented here using actual data. The model suggests that China, despite being the world's largest economy and having the second largest volume of trade globally, should have a relatively low value of intraindustry trade measured by the GL index. In fact, China had a low value of relative innovation and a GL index of 0.252 in 1990. Their position on the nonlinear relationship suggests that they are trading a high volume of basic commodity goods in exchange for innovative goods, generating a large volume of interindustry trade. The United Kingdom looks much more like a typical nation in terms of its relative innovative activity. With a GL of 0.646 in 1990, they are trading a relatively high volume of innovative goods for innovative goods leading to a large share of intraindustry trade in total trade. The United States has a GL index of 0.514 in 1990, which is lower than the United Kingdom. The model predicts this would occur if the US has a very large amount of innovation relative to global innovation, which is in fact the case. The mechanism at work in the model is consistent with the positive correlation between per capita income and intraindustry trade since more developed economies innovate more. However, a unique prediction of the model is that the relationship between innovation intensity and intraindustry trade is nonlinear in nature, thus the model provides a potential explanation for the rather diverse values of GL. We now turn the focus to a formal empirical investigation.

The model suggests a complementarity between intraindustry and interindustry trade. The fact that countries engage in intraindustry trade allows them to exploit the full interval of intermediate goods, which directly enhances productivity. Interindustry trade, however, is what makes it possible for the full benefits of international exchange to be realized. It enables countries with relatively few innovators to secure the intermediate goods needed to boost productivity and it allows countries with a relatively large number of innovators to get the basic commodities needed to satisfy world demand for their intermediate goods and satisfy local consumption needs. This gain from specialization is Hecksher-Ohlin in nature, thus providing a strong comparative advantage explanation for both interindustry and intraindustry trade.

3 Empirical Analysis

The model of vertical innovation suggests a factor endowments based explanation of intraindustry trade. A unique implication of this approach is that it predicts that the country's pattern of trade exhibits a nonlinear relationship with innovation (Result 2). This is a testable hypothesis that can be used to evaluate this approach to modeling intraindustry trade on empirical grounds. This section provides the empirical analysis used to test this theoretical result. We proxy for innovation based on the number of utility patents filed in the United States by applicants both domestically and abroad. Using a two-way fixed effects regression model, we show that our proxy variable for innovation exhibits the nonlinear relationship with the country's Grubel Lloyd index as illustrated in Figure 2. The robustness of the results is also explored.

3.1 Data

The data used for this paper is combined from various sources. Robert Feenstra and Robert Lipsey construct their NBER-United Nations Trade Data (1962-2000), which provides data on annual bilateral trade flows. This data is aggregated by SITC4 code to provide information on a country's imports and exports with the rest of the world. We obtain several macroeconomic variables, including real GDP, population, and distance between and within trading countries, from both CEPII's GeoDist dataset and the Penn World Tables. Data is gathered for years between 1962-2000 to keep in line with data from the NBER-United Nations Trade Data. Patent data is obtained from the U.S. Patent and Trademark Office, which provides the number of utility patent applications filed in the United States by year (1965-2000) and the applicant's country of residence. We obtain a list of regional trade agreements (RTA) by year (1962-2000), as well as the membership list and initiation dates for the General Agreement on Tariffs and Trade (GATT) and World Trade Organization (WTO), from the WTO's website. Finally, we gather information on membership in the Organization of the Petroleum Exporting Countries (OPEC) and the Organization for Economic Co-Operation and Development (OECD) from their respective websites.

The Grubel Lloyd index is constructed using bilateral trade flows data from the NBER-United Nations Trade Data. Following Equation (2.21) and defining an industry i by SITC4 code, we calculate country j's Grubel Lloyd index (GL) in year t as:

$$GL_{jt} = \frac{\sum_i (X_{ijt} + M_{ijt}) - \sum_i |X_{ijt} - M_{ijt}|}{\sum_i (X_{ijt} + M_{ijt})}, \tag{3.1}$$

where X_{ijt} and M_{ijt} is the amount of exports and imports between country j and the rest of the world, respectively. Note that the numerator is the amount of intraindustry trade since $\sum_i (X_{ijt} + M_{ijt})$ is the total value of trade and $\sum_i |X_{ijt} - M_{ijt}|$ is the amount of interindustry trade. Therefore, the GL variable can take on any value between 0 and 1, where $GL = 0$ implies that all trade is interindustry trade and $GL = 1$ implies that all trade in intraindustry trade.

Brulhart (2008) provides evidence that gravity influences the value of the Grubel Lloyd index. The existing literature on gravity in trade suggests that a country's volume of trade is not only directly proportional to the size of that economy and the size of its trading partners, but also inversely proportional to the distance between a country and its trading partners. We proxy for the size of country j's economy in year t by using real GDP in 2005US$ ($rgdpna_{jt}$), which is obtained from the Penn World Tables. CEPII's GeoDist data sets obtain the distance in kilometers ($distcap_k$) between the capitals of country j and country k, its trading partner, as well as a measure for the internal distance within country j ($distint_j$). We use this information to generate our gravity variable, which is defined as:

$$gravity_{jt} = \frac{rgdpna_{jt}}{disint_j} + \sum_k \frac{rgdpna_{kt}}{distcap_k}. \tag{3.2}$$

Result 2 from our theoretical model suggests that intraindustry trade is a function of the relative amount of per capita innovation within a country versus the amount of global per capita innovation. This variable is proxied using the patent data obtained from the U.S. Patent and Trademark Office (USPTO), which provides the number of utility patents filed in the United States by residents of country j in year t ($PATENTAPP_{jt}$). The World Intellectual Property Organization (WIPO)[6] reports that the US receives more nonresident patent applications than any other patent and trademark office. This makes a complete series of data from the USPTO the best candidate data for measuring relative innovation. This measure is not without problems. The biggest potential problem is that United States residents have a much higher likelihood of patenting with the USPTO than residents of other countries. However, dropping the United States from the dataset provides qualitatively similar results as discussed in this paper. We construct per capita innovation within country j in year t to be $pcPATENTAPP_{jt} = \frac{PATENTAPP_{jt}}{pop_{jt}}$, where pop_{jt} is the population (in millions of people) in country j in year t. Global per capita innovation in year t is similarly constructed to be $globalpcPATENTAPP_t = \sum_j \frac{PATENTAPP_{jt}}{pop_{jt}}$. Thus, we define our innovation variable as:

$$relativepatents_{jt} = \frac{pcPATENTAPP_{jt}}{globalpcPATENTAPP_t}. \tag{3.3}$$

As such, country j is interpreted to have a larger amount of per capita innovation relative to the world whenever $relativepatents > 1$. The larger the value of $relativepatents_{jt}$, the more intensive the amount of innovation within a country. For example, the United States had the largest observed value for $relativepatents$ ($relativepatents$=10.736) of any country in 1990, implying that the United States produces 10.736 times more patents per capita than the global average in that year. On the other hand, there were several countries,

[6]http://www.wipo.int/portal/en/index.html

including Vietnam, that had no citizen file a patent in 1990. As such, the observed value for *relativepatents* for Vietnam in 1990 was equal to 0, which is the smallest possible value, since the numerator in Equation (3.3) is equal to 0.

Table 1: Summary Statistics

Variable	Definition	Mean (Std. Dev.)
GL_{jt}	Grubel Lloyd index for country j in year t	0.142
		(0.161)
pop_{jt}	Population (in millions) for country j in year t	32.186
		(111.657)
$gravity_{jt}$	Gravity measure for country j in year t	0.932
		(2.673)
RTA_{jt}	Indicator equal to 1 if country j signed a RTA	0.397
	in year t, and 0 otherwise	(0.489)
WTO_{jt}	Indicator equal to 1 if country j signed the GATT	0.854
	or is a member of the WTO in year t, and 0 otherwise	(0.493)
$OPEC_{jt}$	Indicator equal to 1 if country j is a member	0.051
	of OPEC in year t, and 0 otherwise	(0.220)
$pcGDP_{jt}$	Real per capita GDP (in tens of thousands of 2005US$)	0.830
	for country j in year t	(1.249)
$PATENTAPP_{jt}$	Number of utility patent applications filed in the	1041.909
	United States by residents of country j in year t	(7781.323)
$relativepatents_{jt}$	Ratio of per capita patents from country j	0.569
	to global per capita patents in year t	(1.696)
Countries	Number of countries in the sample	126
N	Number of observations	885

Our data set consists of 35 years of unbalanced data across 126 countries. Given the long series of consecutive annual data, unit roots become a concern. In order to resolve possible issues related to spurious regressions, we average our dependent variable within a particular half-decade (1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, and 1995-1999) and regress these averages on the values of the regressors in the initial year of the half-decade (1965, 1970, 1975, 1980, 1985, 1990, and 1995) for each country j. This procedure is often employed in the empirical growth literature as it has the added benefit of making it more likely that the regressors can be considered exogenous. Our final data set contains 885 observations across 126 countries. Summary statistics is provided in Table 1. Details on variable construction are provided in the Data Appendix at the end of the paper.

3.2 Estimation Strategy

We implement a two-way fixed effects regression model in order to determine whether our proxy variable for innovation exhibits a nonlinear relationship with the Grubel Lloyd index as predicted by the theoretical model. Since the Grubel Lloyd index is bounded between zero and one, we also measure the pattern of trade using the log-odds ratio of the Grubel Lloyd index, which creates an unbounded statistic.[7] We control for several factors that can impact a country's Grubel-Lloyd index, including our gravity variable ($gravity$), participation in a regional trade agreement (RTA), membership in the GATT/WTO (WTO), membership in OPEC ($OPEC$), as well as per capita GDP ($pcGDP$). We also our proxy variables for innovation ($relativepatents$ and $relativepatents^2$), which are our two key variables of interest.

Our basic specification is as follows:

$$y_{jt} = \gamma_j + \mu_t + \alpha X_{jt} + \beta_1 relativepatents_{jt} + \beta_2 relativepatents_{jt}^2 + \epsilon_{jt}, \qquad (3.4)$$

where y_{jt} is either the Grublel Lloyd index (GL_{jt}) or the log-odds ratio of the Grubel Lloyd index ($loddGL_{jt}$) for country j in year t, γ_j is the country fixed effects, μ_t is the year fixed effects, and $X_{ij,t}$ are the remaining control variables listed above. We are particularly interested in the sign and significance associated with the $relativepatents$ and $relativepatents^2$ variables.

3.3 Results

Our theoretical model would be empirically supported if the regression results suggest that there is a nonlinear relationship between the pattern of trade and innovation as illustrated in Figure 2. Countries that have innovation-intensive labor forces (high value of $relativepatents$) are more likely to produce and export final goods and import intermediate goods. Therefore, the pattern of trade is these countries can be classified as interindustry trade, resulting in a low value of the Grubel Lloyd index. Countries with labor forces that do not produce any patents are more likely to produce and export intermediate goods in exchange for final goods. As such, the pattern of trade for these countries can also be classified as interindustry trade. Thus, countries exhibiting extremely large or small values for $relativepatents$ should be associated with low values for Grubel Lloyd index. On the other hand, countries with a balance of innovative and non-innovative workers will trade intermediate goods for other intermediate goods and final goods for other final goods. As

[7] The log-odds ratio of the Grubel Lloyd index (GL) is defined as $loddGL = ln\left[\frac{GL}{(1-GL)}\right]$.

a result, these countries with intermediate values of *relativepatents* engage in intraindustry trade, which leads to a large value for the Grubel Lloyd index.

Table 2: Fixed Effects Regression (Main Results)

Dependent variable	*GL*		*loddGL*	
Variable	Coefficient	Standard error	Coefficient	Standard error
gravity	0.015***	(0.003)	0.075***	(0.021)
RTA	0.016***	(0.006)	0.263***	(0.068)
WTO	0.018**	(0.009)	0.258***	(0.096)
OPEC	−0.038***	(0.009)	−0.603***	(0.249)
pcGDP	0.012***	(0.005)	0.025	(0.029)
relativepatents	0.025***	(0.008)	0.118**	(0.054)
$relativepatents^2$	−0.002***	(0.001)	−0.008**	(0.004)
N	779		777	
R^2	0.422		0.241	

Note: This table presents the results for the fixed effects regression model on the Grubel Lloyd index and the log-odds ratio of the Grubel Lloyd index. Observations are at the country-year level. HAC standard errors are presented in parentheses. Country and year fixed effects suppressed. One-tailed test conducted for each variable except for *WTO* since the expected sign for *WTO* is not predetermined.

* indicates significance at 10% level.

** indicates significance at 5% level.

*** indicates significance at 1% level.

Table 2 reports the results for our two-way fixed effects regression model using both the Grubel Lloyd index (*GL*) and the log-odds ratio of the Grubel Lloyd index (*loddGL*) as the dependent variable. The estimated coefficient for *relativepatents* is positive and statistically significant at the 1% level using *GL* and the 5% level when using *loddGL* dependent variable. Moreover, the estimated coefficient for $relativepatents^2$ is negative and statistically significant at the 1% level and 5% level when the dependent variable is the Grubel Lloyd index and the log-odds ratio of the Grubel Lloyd index, respectively. These empirical results confirm our theoretical prediction that innovation exhibits a nonlinear relationship. Thus, the key result of the paper is that countries with large amounts of per capita innovation or small amounts of per capita innovation engage in more interindustry trade, whereas countries with an intermediate amount of per capita innovation engage in more intraindustry trade.

Brulhart (2008) shows that gravity, which is the economic size and distance between trading partners, has a significant effect on the amount of intraindustry trade vs. interindustry trade. Our results similarly show that countries with more gravity engage in more intraindustry trade. We also control for per capita GDP (*pcGDP*) since many trade economists have noted that more developed economies produce and trade in a wider variety of industries and have higher values of GL. We want to avoid the criticism that highly developed countries innovate more and engage in intraindustry trade for reasons not captured in our model. If this is the case, then omitting $pcGDP$ would create an upward bias on the coefficient estimate on $relativepatents$. We should point out that our model provides an explanation for the positive correlation between income per capita and intraindustry trade, at least up to the peak of the curve represented in Figure 2. Therefore, any specification that includes $pcGDP$ should be viewed as a very strong test of our theory. The coefficient on $pcGDP$ is positive, as expected, when using either GL or $loddGL$ as the dependent variable. It is, however, insignificant in the $loddGL$ specification.

Our regression results also suggest that participation in a regional trade agreement and membership in the GATT/WTO is also associated with more intraindustry trade. This is expected if membership in an RTA promotes trade between similar nations since this trade is more likely to be within industry. Membership in the WTO appears to have a similar inclination towards more intraindustry trade. However, the results suggest that membership in OPEC has a negative and significant effect on the country's pattern of trade when using either the Grubel Lloyd index or the log-odds ratio of the Grubel Lloyd index. These results support the findings in the existing literature.

Is the role of the nonlinear relationship economically important? For the mean country, the impact of a one standard deviation change in $relativepatents$ leads to a 0.039 increase (27.1%) in GL.[8] Furthermore, a one standard deviation increase in $relativepatents$ for the United States in 1990 is predicted to cause a decline in GL of -0.030 (5.9%).[9] As such, it is difficult to argue that these changes, especially for the average economy, are economically insignificant. We contribute to the existing literature by showing that the amount of innovation in a country also impacts the pattern of trade and the degree of within industry trade.

We investigate the potential role of an endogeniety bias using a series of hypothesis tests and a presentation of two stage least squares results. Given the panel nature of the data, we require time variant instrumental variables. As such, measures often used in the literature, such as latitude or year of independence, cannot be used in this paper. Instead, we utilize variable lags. In particular, we run a fixed effects regression using the five-year lagged value

[8] A one standard deviation increase in $relativepatents$ increases GL for mean country by 0.025(1.696)-0.002[2(0.569)(1.696)] = 0.039. Since the average value for GL is 0.142 as mentioned in Table 1, GL increases, on average, by $\frac{0.039}{0.142}$=27.1%.

[9] The value for GL and $relativepatents$ for the United States in 1990 is 0.514 and 10.737, respective. As such, a one standard deviation increase in $relativepatents$ increases GL for the United States by 0.025(1.696)-0.002[2(10.737)(1.696)] = -0.030.

for *relativepatents*, *relativepatents*^{2}, *pcGDP*, and *gravity* as instrumental variables in order to resolve a possible endogeneity issue associated with the *relativepatents*, *relativepatents*^{2}, and *pcGDP* variables. The first stage results have an R^2 of 0.956 so the vast majority of variation in the *relativepatents* variable can be explained by our four instruments.[10] Table 3 presents the second-stage regression results and three important endogeneity tests. The results for both dependent variables (*GL* and *loddGL*) are qualitatively similar with our main results (Table 2) with our key variables of interest (*relativepatents* and *relativepatents*^{2}) maintaining their sign and statistical significance, providing additional empirical support for the nonlinear relationship between innovation and intraindustry trade.

Table 3: Fixed Effects / Instrumental Variables Regression

Dependent variable	*GL*		*loddGL*	
Variable	Coefficient	Standard error	Coefficient	Standard error
gravity	0.017***	(0.003)	0.079***	(0.022)
RTA	0.009	(0.007)	0.184***	(0.074)
WTO	0.023**	(0.010)	0.302***	(0.107)
OPEC	−0.030***	(0.010)	−0.418**	(0.200)
pcGDP	0.019***	(0.006)	0.115*	(0.072)
relativepatents	0.039***	(0.015)	0.170**	(0.100)
relativepatents^2	−0.003**	(0.001)	−0.009*	(0.006)
Kleibergen-Paap rank LM statistic	6.281**		6.281**	
Hansen J statistic	0.015		0.112	
Endogeneity test statistic	2.672		3.906	
N	661		661	
R^2	0.413		0.222	

Note: This table presents the results for the fixed effects instrumental variables regression model on the Grubel Lloyd index and the log-odds ratio of the Grubel Lloyd index. The endogenous variables are presumed to be *relativepatents*, *relativepatents*^{2}, and *pcGDP*, while the five-year lagged value for *relativepatents*, *relativepatents*^{2}, *pcGDP*, *gravity* are used as instrumental variables. Observations are at the country-year level. HAC standard errors are presented in parentheses. Country and year fixed effects suppressed. One-tailed test conducted for each variable except for *WTO* since the expected sign for *WTO* is not predetermined.

* indicates significance at 10% level.

** indicates significance at 5% level.

*** indicates significance at 1% level.

We conduct three endogeneity tests associated with the regression results in Table 3. First, the Kleibergen-Paap rank LM statistic provides an underidentification test, in which

[10] The first stage regression results are available upon request.

the null hypothesis is an underidentified regression model. Regardless of whether the dependent variable is *GL* or *loddGL*, we reject the null hypothesis with a test statistic of 6.281 (p-value: 0.0433), implying that our instruments are correlated with our potentially endogenous variables.[11] Second, we conduct an overidentification test of all instruments using the Hansen J statistic, in which the joint null hypothesis is that our instruments are uncorrelated with the error term.[12] The Hansen J statistic when the dependent variable is *GL* is 0.015 (p-value: 0.9029), implying that our instruments are valid. Similarly, we fail to reject the null hypothesis when the dependent variable is *loddGL* since the corresponding Hansen J statistic is 0.112 (p-value: 0.7376). Finally, we run an endogeneity test, in which the null hypothesis is that the specified endogenous variables can actually be treated as exogenous. We fail to reject the null hypothesis when the dependent variable is *GL* (test statistic: 2.672; p-value: 0.445) and when the dependent variable is *loddGL* (test statistic: 3.906; p-value: 0.272), suggesting that the use of instrumental variables is not necessary. Indeed, our results in Table 2 are generally more efficient.

Table 4: Pooled OLS Regression Results

Dependent variable	*GL*		*loddGL*	
Variable	Coefficient	Standard error	Coefficient	Standard error
gravity	0.012***	(0.003)	0.090***	(0.021)
RTA	0.057***	(0.010)	0.628***	(0.089)
WTO	0.024***	(0.008)	0.152**	(0.089)
OPEC	−0.108***	(0.011)	−1.526***	(0.162)
pcGDP	0.016***	(0.006)	0.140**	(0.076)
relativepatents	0.121***	(0.010)	0.802***	(0.076)
$relativepatents^2$	−0.010***	(0.001)	−0.068***	(0.009)
N	797		796	
R^2	0.589		0.460	

Note: This table presents the results for the pooled OLS regression model on the Grubel Lloyd index and the log-odds ratio of the Grubel Lloyd index. Observations are at the country-year level. Robust standard errors reported. One-tailed test conducted for each variable except for *WTO* since the expected sign for *WTO* is not predetermined.

* indicates significance at 5% level.

** indicates significance at 1% level.

[11] We fail to reject the null hypothesis when using ten-year lagged values as our instruments, which is not surprising given the long time duration.

[12] This test requires the number of instruments to be greater than the number of endogenous variables, which is satisfied by the use of four instrumental variables for three potentially endogenous variables in our regression model.

Our main specification for our regression model includes both country fixed effects in order to account for time-invariant factors and year fixed effects in order to account for a time trend. We run a pooled OLS regression using the same dependent and independent variables specified in Equation 3.4 except we omit the fixed effects. Table 4 reports the regression results for a pooled OLS regression with robust standard errors. The signs for all of our independent variables are consistent with the results reported in Table 2. Moreover, the pooled OLS regression results continue to suggest the nonlinear relationship between innovation and pattern of trade. Thus, these results show that our main results are not reliant on the presence of fixed effects.

We break down the dynamic aspect of our data set by running an OLS regression for each decade and for each of the two dependent variables. Tables 5 and 6 report the regression results for our cross-sectional analysis when using the Grubel Lloyd index and the log-odds ratio of the Grubel Lloyd index, respectively. The estimated signs for *relativepatents* and $relativepatents^2$ is qualitatively similar to our main results and is consistent over each time period. This robustness check shows that the estimated nonlinear relationship between innovation and the pattern of trade is robust to individual decades.

Table 5: Cross-Sectional Regression Results (Dependent Variable: *GL*)

Decade	1970s		1980s		1990s	
Variable	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
gravity	0.021**	(0.007)	0.007	(0.007)	0.015**	(0.005)
RTA	0.055*	(0.030)	0.068**	(0.020)	0.072**	(0.022)
WTO	0.003	(0.018)	0.028	(0.019)	0.036	(0.022)
OPEC	−0.100**	(0.024)	−0.089**	(0.023)	−0.127**	(0.024)
pcGDP	0.003	(0.005)	0.013	(0.012)	0.039*	(0.023)
relativepatents	0.168**	(0.026)	0.119**	(0.023)	0.128**	(0.024)
$relativepatents^2$	−0.015**	(0.003)	−0.009**	(0.002)	−0.014**	(0.002)
N	113		114		116	
R^2	0.643		0.599		0.678	

Note: This table presents the cross-sectional results for the OLS regression model for each decade in the data set on the Grubel Lloyd index. Observations are at the country-year level. Robust standard errors reported. One-tailed test conducted for each variable except for *WTO* since the expected sign for *WTO* is not predetermined.

* indicates significance at 5% level.

** indicates significance at 1% level.

Table 6: Cross-Sectional Regression Results (Dependent Variable: *loddGL*)

Decade	1970s		1980s		1990s	
Variable	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
gravity	0.170**	(0.051)	0.074	(0.046)	0.089**	(0.033)
RTA	0.318	(0.252)	0.895**	(0.193)	0.805**	(0.233)
WTO	0.107	(0.205)	0.185	(0.238)	0.198	(0.260)
OPEC	−1.673**	(0.378)	−1.355**	(0.340)	−1.439**	(0.407)
pcGDP	0.025	(0.096)	0.137	(0.181)	0.366	(0.229)
relativepatents	1.118**	(0.195)	0.834**	(0.183)	0.721**	(0.217)
$relativepatents^2$	−0.104**	(0.019)	−0.062**	(0.014)	−0.079**	(0.020)
N	113		114		116	
R^2	0.486		0.492		0.535	

Note: This table presents the cross-sectional results for the OLS regression model for each decade in the data set on the log-odds ratio of the Grubel Lloyd index. Observations are at the country-year level. Robust standard errors reported. One-tailed test conducted for each variable except for *WTO* since the expected sign for *WTO* is not predetermined.
* indicates significance at 5% level.
** indicates significance at 1% level.

The results based on our main regression specification, Equation (3.4), and these robustness check all empirically corroborate the testable hypothesis of our theoretical model. Namely, a country's pattern of trade is influenced by the amount of innovation (or lack thereof) generated by its citizens. Not only have we shown that our proxy for innovation, *relativepatents* has a significant effect on the amount of intraindustry vs. interindustry trade, but we have consistently shown that this relationship is nonlinear.

4 Conclusion

Intraindustry trade remains an important area of research in the area of new trade theory. This is to be expected given the prevalence and growing importance of intraindustry trade. If industries are defined broadly at the 3-digit level, then Brulhart (2008) finds that 44% of world trade was intraindustry in 2006 and the share of intraindustry trade has steadily grown over his sample period, which begins in 1962. The present paper develops a relative factor endowment based explanation of the pattern of intraindustry and interindustry trade. Trade in intermediate goods gives rise to intraindustry trade while differences in factor endowments give rise to interindustry trade. Unique to this paper, the factor endowments in question are endowments of innovators and labor.

The model does not rely on scale economies in manufacturing intermediate goods. Therefore, the model does not predict the internal economies of scale effect that plagues more static models of intraindustry trade. Furthermore, the relative factor motivation for intraindustry trade that naturally comes from the analysis suggests a close examination of innovator to labor ratios. Interindustry trade is motivated by Hecksher-Ohlin factor endowment considerations. The model, consistent with other models that provide factor endowments foundation for intraindustry trade, predicts intraindustry trade between economies is maximized as a percent of total trade when the factor endowments of the economies are similar. The difference here is that the factor endowments in question lead to the prediction that the relationship is nonlinear in the amount of innovation occurring in a country relative to the world, which serves as the main empirical test of the model.

In summary, the model shows how the significance of intraindustry trade in a Schumpeterian model is a function of the imbalance between the domestic population level and the total amount of labor that would be needed to produce enough basic commodity goods to satisfy local consumption and the global demand for goods from the economy's innovative sectors. Intraindustry trade is low when there is a mismatch between the local population size available to produce the basic commodity goods and the economy's required labor supply needed for self-sufficiency in both production of the basic commodity goods and innovative goods. In the case where the local population is small relative to the number of domestically located innovative sectors, the limited supply of basic commodity goods needed for consumption and the production of innovative goods leads to a large export of innovative goods in exchange for basic commodity goods. This suggests a low value for our intraindustry trade index and a larger role for interindustry trade. In the case where the local population is large relative to the number of domestically located innovative sectors, the relatively large supply of basic commodity goods is exported in exchange for needed innovative sector goods. This also suggests a low value for our intraindustry trade index and a larger role for interindustry trade. Thus, a unique empirical implication of the Schumpeterian model applied to trade is a nonlinear relationship between intraindustry trade and a measure of innovation, such as relative patents. The model performs well empirically.

The gains from trade include the standard impact of greater variety from intraindustry trade, as well as the gains from comparative advantage suggested by differences in factor endowments. In addition, countries gain dynamically as they benefit from productivity enhancing innovations that originate both at home and abroad. This is the well-known club convergence effect from growth theory. The gap between any two nations GDP per capita is determined by relative innovation. Thus, the institutional economics studied in the areas of development and growth, such as protection of property rights and the role of the government, might be important considerations in determining international trade patterns and the gains from trade. This is an important question we leave for future research.

A Data Appendix

We collect data primarily from four publicly available sources. Data on bilateral trade flows is provided by the NBER-United Nations Trade Data (1962-2000), which Robert Feenstra and Robert Lipsey have constructed using United Nations trade data. We add data on distances between countries and within a country from CEPII's GeoDist dataset and macroeconomic variables (1962-2000) from the Penn World Tables. Finally, we obtain utility patent application data by country and year (1965-2000) from the U.S. Patent and Trademark Office. We maintain original variable names when possible to ease the process of data replication.

The following steps enumerate the process taken of cleaning the data and constructing the variables (in italics) used in this paper:

1. We merge all of the NBER-United Nations Trade Data from 1962 to 2000.

2. We add up the value of trade by SITC4 code in order to calculate the annual value of imports (M_{ijt}) and exports (X_{ijt}) for industry i between country j and the rest of the world in year t. Note that we define an industry i by SITC4 code.

3. We create the Grubel Lloyd index (GL_{jt}) by calculating

$$GL_{jt} = \frac{\sum_i (X_{ijt} + M_{ijt}) - \sum_i |X_{ijt} - M_{ijt}|}{\sum_i (X_{ijt} + M_{ijt})} \tag{A.1}$$

   for country j in year t

4. We merged the GeoDist dataset with the data from the Penn World Tables.

   - Using the *distcap* and *disint* variable from the GeoDist dataset and the *rgdpna* variable from the Penn World Tables, we created our *gravity* variable for country j that is defined as $gravity_{jt} = \frac{rgdpna_{jt}}{disint_j} + \sum_k \frac{rgdpna_{kt}}{distcap_k}$, where k is the trading partner for country j, $rgdpna_j$ is country j's real GDP (in 2005US$) in year t, $disint_j$[13] is an internal distance measure within country j, $rgdpna_k$ is country k's real GDP

[13]CEPII defines $disint_j = 0.67\sqrt{\frac{area_j}{\pi}}$, where $area_j$ is the square area of country j (in kilometers).

(in 2005US$) in year t, and $distcap_k$ is the simple distance (in kilometers) between the capitals in country j and country k.

5. We merged the constructed $gravity_{jt}$ variable along with other macroeconomic variables (including pop_{jt}, the population of country j in year t) in the Penn World Tables and GeoDist datasets with the NBER-United Nations Trade Data containing the constructed GL variable.

6. We augment this data set with the $PATENTAPP_{jt}$ variable in the patents data collected from the U.S. Patent and Trademark Office. $PATENTAPP_{jt}$ is the number of utility patent applications filed in the United States by residents of country j in year t.

7. We define the key variable of interest as:

$$relativepatents_{jt} = \frac{pcPATENTAPP_{jt}}{globalpcPATENTAPP_t}, \tag{A.2}$$

where $pcPATENTAPP_{jt}$ is country j's per capita patent applications ($pcPATENTAPP_{jt} = \frac{PATENTAPP_{jt}}{pop_{jt}}$) and $globalpcPATENTAPP_t$ is global per capita patent applications ($globalpcPATENTAPP_t = \sum_j \frac{PATENTAPP_{jt}}{pop_{jt}}$).

8. Per capita GDP ($pcGDP$) is created as $pcGDP_{jt} = \frac{rgdpna_{jt}}{10000 * pop_{jt}}$. Note that $pcGDP$ is constructed to be in tens of thousands of 2005US$.

9. An indicator variable associated with participation in at least one regional trade agreement (RTA_{jt}) is constructed to equal 1 if country j participates in one or more regional trade agreements (RTA) in year t, and 0 otherwise.

10. An indicator variable associated with GATT/WTO membership (WTO_{jt}) is constructed to equal 1 if country j either participates in the General Agreement on Tariffs and Trade (GATT) or is a member of the World Trade Organization (WTO) in year t, and 0 otherwise.

11. An indicator variable associated with OPEC membership ($OPEC_{jt}$) is constructed to equal 1 if country j is a member of the Organization of the Petroleum Exporting Countries (OPEC) in year t, and 0 otherwise.

This data set is available from the authors upon request.

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