Book Chapter

Rehabilitating the Factor-Proportions Hypothesis

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Abstract

The Heckscher-Ohlin theory of international trade remains an enigma. Despite being falsified on numerous counts (Bowen, Leamer and Sveikauskas 1987, Trefler, 1995), it persists as the core theory of international trade, found both in undergraduate and graduate textbooks, not to mention in much research and policy. Clearly, while it has failed to be confirmed by the data, the notion that factor proportions motivate trade, whether at the regional or national level, continues to hold sway. This paper is an attempt at rehabilitating the factor proportions hypothesis (FPH) as a theory of interregional and international trade. Its main premise is simple, namely that the Heckscher-Ohlin Hypothesis (HOH) is one—but not the only possible—formalization of the FPH. An alternative formalization, based on a more realistic set of assumptions (endogenous technology, mobile capital and labor) is presented and is used to rationalize the paradoxical findings of HOH empirical tests. Supporting data are also provided. It concludes by examining the policy implications.

Keywords

Heckscher-Ohlin; Value Chain; Commercial Policy

JEL Codes: D24, L60, O3, O4

Introduction

Despite being rejected empirically, the Heckscher-Ohlin (H-O) theory of international trade remains at the core of trade theory and, to a certain extent, trade policy, owing in large measure to its intuitive appeal. The idea that trade is based on relative factor proportions is universal, cutting across cultures, time and space. This paper is an attempt to rehabilitate the Factor Proportions Hypothesis (FPH) of international trade. However, unlike recent attempts (Trefler 1995, Trefler and Zhu 2000), it seeks to recast the theory from first principles. The gist of our argument is simple, namely that the failure of H-O trade theory owes in large measure to a theoretical misspecification. More to the point, the 20th century witnessed paradigm changes in economic fundamentals. Fueling these were two developments, namely modernity (Bresnahan and Trajtenberg 1995, Helpman and Trajtenberg 1996) with the accompanying vertical and horizontal production differentiation, and secondly the development of the transnational vertically-and horizontally-integrated corporation (Hymer 1976, Dunning 1981). Both we argue had far-reaching implications for the factor-proportions theory of trade. For example, the ability to innovate complete with the resulting process and product technologies would now vary across regions and countries and like other endowments would become a key determinant of trade patterns. Unfortunately, these were ignored by both Eli Heckscher and Bertil Ohlin, and later by Paul Samuelson and others.

It will be shown that when the factor-proportions theory of international trade is set in the appropriate theoretical construct (e.g. one that includes a region/country's ability/endowment to innovate and vertical specialization and the presence of multinational and multiregional value chains), then most if not all of its predictions are borne out by the data. Moreover, it is shown that by doing so, it is no longer necessary to resort to a set of unrealistic assumptions (e.g. immobility of capital and labor) to generate predictions.

Other than incorporating the idea of endogenous technological change (product and process) and the transnational firm into the corpus of H-O theory, this paper innovates in other important areas, notably in terms of the value chain *per se*. Traditionally, value chains are exogenously given. That is, for a given product, a value chain complete with its multiple vertical links is defined. We endogenize value chains by adding what we refer to as the visions-link which as its name indicates, consists of that stage at which the value chain for a given product is conceived of. As it precedes the value chain chronologically speaking, it is assumed to lie at the beginning (apex) of the vertical value chain. We shall refer to this as the visions-based value chain (VBVC).

Another important innovation is the concept of vertical comparative advantage (Beaudreau 2011). Since time immemorial, the notion of horizontal comparative advantage has dominated the debate over trade. Implicitly, it has been assumed that goods are produced entirely in a given legal jurisdiction (state, country, etc). The emergence and growth of the transnational firm has invalidated and continues to invalidate this assumption (WTO 2010).[1] As such, regions and countries do not

[1] In fact, it could be argued that trade in general since the Renaissance and even before violates this assumption. As Beaudreau (2004) argues, trade has

have a comparative advantage in the production of goods, but rather, a comparative advantage in a particular sub-process (link) or stage of production of goods. For example, resource rich regions-countries will have a vertical comparative advantage in the upstream resource links.

As our model allows for perfectly mobile capital and labor (traditional factors), the question of long-run vertical comparative advantage arises. If capital and labor are free to migrate, then factor-price equalization will remove any and all forms of comparative advantage, and ultimately end trade altogether (Mundell 1957) or so it was believed. To address this problem, two forms of comparative advantage are examined, namely structural comparative advantage and arbitrage comparative advantage. The former includes the ability to conceptualize value chains (goods and services) and natural resources, while the latter includes a capital-, labor-, or energy-based comparative advantage.

The paper is organized as follows. Section I presents a brief history of the FPH, focusing on its evolution over time, especially in the 20th century. This is followed by our model (Section II), which we refer to as the generalized factor proportions hypothesis (GFPH). Its general nature owes to the fact that technology is endogenous and, more importantly, is determined by a country's endowment of visionaries and scientists. The predictions of the model are then used to "ratonalize the paradoxical findings of HOH empirical tests. In Section III, various trade indices (regional and international) are used to support the predictions of the model. Specifically, the GFPH predicts that regions and countries that are relatively well endowed with visionaries and scientists will export what Elhanan Helpman referred to as *Headquartering Activity* (Helpman 1984); that regions and countries that are relatively well-endowed in natural resources will export upstream value added; and that states and countries that are well endowed with labor will export mid-stream value added (manufacturing activity).

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since time immemorial been vertical in nature. Early empires can be seen as country-wide value chains.

Section IV examines the policy implications of global value chains and vertical comparative advantage (WTO 2010).

FPH: Literature Review

The idea behind the FPH and HOH is relatively simple, not to mention intuitive, namely that if someone has more of something relative to another thing than someone else, then should trade occur, his/her something will be traded against the other thing. It matters little what the something actually is. It could be material as it could be immaterial. Examples include: charm for sustenance, organization for security, and/or affection for wealth. In this section, we examine the FPH and HOH from a historical perspective, focusing our attention on three periods, namely the classical period (prior to HOH), the 20th Century and the 21st Century. Within each period, we will be interested in ascertaining both the breadth of the endowment (i.e. the basis of trade) and its relationship to trade in general. For example, is it restricted to material factor inputs (capital and labor) or does it extend beyond?

Trade is inherently based on the presence of asymmetries. This is true of all forms of trade, whether they be material in nature or not. For example, it holds in human relationships, where differences across individuals are a source of attraction and a basis for trade. Which leads us to our first observation, namely that because of its intuitive nature, the FPH is probably as old as human thought in general, and intellectual endeavors (writing) in particular. Put differently, any treatise, written or other, of trade would have invariably considered factor proportions as a—if not the—basis for trade.

This being said, let us turn to the question of paternity, proper. When and where did the modern FPH arise? And under what circumstances? As in all cases involving intellectual paternity, the evidence is sparse and inconclusive. Bertil Ohlin himself attributed the HOH to “Frenchworks,” specifically to the writings of Jean-Charles Léonard Sismonde de Sismondi who in “De la Richesse Commerciale “that the comparative abundance of capital and labour in different countries determines their territorial specialisation as between industries requiring relatively much labour and those requiring relatively much capital." Simon Power however takes issue with this view, arguing that "De la richesse commerciale" is a work lacking in originality, being a popularization of the ideas of Adam Smith.

He speculates that perhaps Ohlin was referring to earlier French writers, pointing specifically to Turgot to whom the following quote is attributed:

> Effectively, all one need do is to reflect upon the immense quantity of charcoal used in the reduction of metal and the equally immense quantity used in the production of iron, to convince oneself that however abundant the mineral, it cannot be brought into production unless it happens to be located near a large quantity of wood and that the wood has little value. . . . The production and sale of iron is assigned by nature to new nations, nations which possess vast untouched forests, far from all outlets, where one finds it advantageous to burn an immense quantity of wood for the sole value of the salts that one gains from washing the remaining cinders. This commerce, weak in England, still flourishing in France, much more in Germany and in the North, should, following the natural course of events, be taken up in Russia, in Siberia, and in the American colonies, until such time as they themselves become highly populated, and all nations find themselves in equilibrium, and until the increase in the price of iron is strong enough to renew interest in its production in those countries where it had been abandoned,

> the result of not being able to compete with the poorer nations. (Power 1987, 293)

He then goes on to dispel this view, pointing out that Turgot himself was strongly influenced by the English economist Josiah Tucker. He concludes by noting that the HOH has a "far longer history that Ohlin was aware of, and it would seem most unlikely that it was first touched upon….in French works." We agree and hasten to add that the equivocal nature of its historical antecedents speaks in large measure to the intuitive nature of the FPH. We would go further and add that the FPH is as old as trade itself, extending back millennia to the early empires and beyond.

It is interesting to note that Eli Heckscher was first and foremost an economic historian and author of a highly regarded "history" of mercantilism. It could be argued that anyone studying the history of early empires could not but hold the FPH as the guiding principle underlying world trade.

This brings us to Eli Heckscher's seminal 1919 paper in which he presents the HOH for the first time. Specifically, he examined trade through the prism of factor proportions, focusing on three inputs, namely land, labor and capital. Technology was assumed to be symmetric, making for the situation in endowments and factor intensities determined trade flows.

Clearly, this assumption was critical. Unlike the Ricardian model where comparative advantage was based in large measure on technological asymmetries, Heckscher had leveled the playing field, so to speak. With the benefit of hindsight, this assumption seems both misguided and misplaced. After all, Heckscher was an economic historian, having written the history of British industrialization. But more importantly, Heckscher wrote at a time of massive technological change in the form of the second industrial revolution. Ironically, he was unable—or unwilling—to acknowledge a nation's endowment in science as a possible source of comparative advantage.

The second industrial revolution witnessed paradigm process and product innovations, not to mention the shift of economic, military and political power to the United States. U.S.-based multinational firms with their new process and product technologies conquered the planet, including Sweden. Great Britain was in decline, as was most of Europe. In short, if there was one factor endowment that marked to the point of defining Heckscher's era, it was the ability to innovate in general, and the U.S.' ability to innovate in particular.[2]

One could go as far as to argue that Heckscher was in the wrong place at the wrong time. The early 20th century was anything but a period of stable (read: unchanging) technology. In fact, it could be argued that most of the 20th century was characterized by, to the point of being defined by, changing processes and changing products.

Not surprisingly, the HOH performed poorly, empirically speaking (Leontief 1953, Bowen, Leamer and Sveikauskas 1987). After all, proprietary technological change against a backdrop of global vertical integration violated two of the model's most important assumptions, namely symmetric technology and immobile factors. In the late 1990s, an attempt was made to "salvage" the HOH by invoking country-wide technology and preference asymmetries (Trefler 1995, Trefler and Zhu 2000, Davis and Weinstein 2001). Using a 1983 data set consisting of nine factors and 33 countries, he like Bowen, Leamer and Sveikauskas was unable to corroborate the HOH. In fact, he went further, pointing out the presence of "missing trade," which by definition is the absence of trade despite a non-negligible factor endowment. Also, he found that rich countries (i.e. the North) were scarce in most factors, while poor countries were abundant. Pushing the analysis further, he invoked two possible explanations, namely higher productivity in the *North* and asymmetric preferences. Both hypotheses were tested and confirmed by the data. Davis and Weinstein showed that when the HOH is modified to permit technical differences, a

[2] However, unlike land, labor and capital, the ability to innovate is a more difficult concept to measure. Put differently, it does not offer itself as a readily measurable metric.

breakdown of factor price equalization, the existence of non-traded goods and costs of trade, it is consistent with the data for 10 OECD countries.

The problem with this literature, however, is its apologetic nature. In fact, the HOH as originally formulated by Heckscher and Ohlin is barely recognizable. The HOH was about trade being determined by relative factor endowments (capital and labor) in a world of symmetric technology. In their model, trade is determined by a host of other factors, the origins of which are exogenous to the model. This is where our works enters. Namely, if (*i*) technology is indeed asymmetric as Trefler, Davis and Weinstein contend and (*ii*) technology is not exogenous, but rather is determined by a country's endowment of visionaries and scientists, then it stands to reason that a more complete reformulation of the FPH would include the determinants of technology as legitimate factor inputs and hence causes of comparative advantage and trade.

While these authors have addressed the question of technology and other possible *ex-post* rationalizations, they have failed to address two important shortcomings of the HOH literature in general, namely, the presence of global value chains (throughout the period under study, namely the 20th century), the use of value-of-shipments as opposed to value added data and its aggregative nature. For example, Trefler assumes that all firms and all sectors of the U.S. economy have the same productivity advantage over their foreign rivals. U.S. copper mines are twice as productive as foreign ones despite the fact that in many cases, the latter are owned and operated by U.S. firms. Lastly, because HOH (or alternatively HOV) empirical tests use value-of-shipments data (WTO 2010), they invariably yield biased and unreliable results. In fact, one could go as far as to argue that value-of-shipments data explains the "mystery" of the North's sizeable trade volumes in the face of what are few abundant factors. More specifically, they bias the value of the North's exports upwards. Ideally, large-scale HOH tests should use value added-based export and import data.

This paper attempts to deal with these problems, both theoretically and empirically, First, it begins with a complete or general formalization in which both material (land, labor, capital, energy) and immaterial (the propensity to innovate) factor endowments are considered at the industry level. The result (the generalized factor proportions hypothesis — GFPH) is a more complete and far-reaching theory of international trade, one that is both intuitive and practical and one which includes Eli Heckscher and Bertil Ohlin's version as a special case.

II-Analytical Framework

For our purposes, the "problem" of international trade will be viewed as an optimal assignment problem where the social planner maximizes social welfare by assigning the production of goods (and services) to regions or countries on the basis of "comparative advantage." In so doing, he maximizes the overall, system-wide gains from trade, thus maximizing welfare. In this paper, the social planner is replaced by individual firms that solve a similar optimal assignment problem. Specifically, the firm will localize in geographical space, the various vertical stages (or links) of the production value added chain on the basis of comparative advantage.

Our starting point is the vision-augmented value chain (VBVC) which consists of the vision (of the product and/or process, and the *n* vertical stages which together comprise the relevant value chain (Beaudreau 1989, 2011). The former is defined in Lancasterian characteristic space consisting of the set of characteristics that define a product/service, while the latter consists of a multi-link, value chain (value tree), each defined by a specific material process. To capture the evolutionary character of VBVCs over time and consequently of trade (Nelson and Winter 1982), we consider a three-stage model. In the first stage, VBVCs are conceived of by visionaries/entrepreneurs/managers. Typically, this will involve either a new product and/or a new process and will be the result of a "vision-creating processes." Conceptually, they can result from (*i*) an individual's imagination (e.g. Henry Ford, George Westinghouse, Nikolai Tesla), (*ii*) from informal R&D, and/or (*iii*) from formal R&D

(i.e. R&D laboratory). The result is a set of VBVCs that run across industries and sectors. In the second stage, VBVCs take form with the creation of vertically-integrated value chains localized across regions/countries, the latter being defined primarily in terms of relative factor endowments and relative factor prices. Put differently, the value chain takes shape in time and space. In the third stage, VBVCs produce, sell and report earnings and a filter is then applied. Those that are profitable/successful go on to the next round/period and enter the set of VBVCs, while the others are meted out. In the next round/period, a similar three-stage process occurs with the surviving VBVCs and new ones that will have conceived of. Accordingly, there is no equilibrium in the conventional sense as new VBVCs are forever being conceived of while some VBVCs are being meted out.[3]

We now turn to the Stage 2 optimization problem. Let v_{ij} represent value link i of chain j, where i=1,2,3,.....m_j, m_j being the number of links in the j^{th} value chain. Equation 1 describes Stage 2 link *ij's* process technology, defined over three inputs, ρ_{ij}, natural resources, k_{ij} capital and n_{ij} labor.[4] Factor intensities are assumed to vary across links and across value chains. In general, upstream links (primary sector) are resource and capital intensive, while manufacturing links (secondary sector) are more labor intensive (however, increasingly less so, with the advent of

[3] This framework is consistent with the "evolutionary regime" in evolutionary economics, defined by the following three-phase sequence: In the first phase, generic ideas originate; in the second phase, macroscopic (population-level) adoptions governed by various mechanisms (selection, path dependence, learning effects etc.) occur; in the third phase, stabilization based on high-frequency adoption, happens.

[4] Energy enters the analysis via resources. However, in addition to being a factor input, it is also a link (sub-link) for each of the m_j links. The idea here is simple. Energy rich regions/country will hold a vertical comparative advantage in the extraction/refinement of the energy in question. However, once extracted and transformed (refined/transported), it will enter each of the remaining m_j links as a factor input (not an intermediate product or semi-finished good). Hence, energy sources will be a factor in structural vertical comparative advantage (e.g. Saudi Arabia); however energy products *per se* will constitute links/sub-links for all other activities. However, in cases where the energy in question is immobile (e.g. hydroelectricity), it stands to reason that energy can, conceptually speaking, constitute a source of a structural vertical comparative advantage.

control technologies). Lastly, downstream links (e.g. advertising, distribution and marketing) are highly labor intensive (Beaudreau 1989).

Equation 2 describes the corresponding Leontief, fixed-proportions process technology where $\alpha_{\rho ij}$ corresponds to the ratio of resources per unit of link *ij* value added, α_{kij} corresponds to the ratio of capital per unit of link *ij* value added, and α_{nij} corresponds to the ratio of labor per unit of link *ij* value added.

$$v_{ij} = v_{ij}\left[\rho_{ij}; k_{ij}, n_{ij}\right] \; \forall i = 1,2,3,4,\ldots\ldots m_j. \quad (1)$$

$$v_{ij} = \min\left[\frac{\rho_{ij}}{\alpha_{\rho_{ij}}}, \frac{k_{ij}}{\alpha_{k_{ij}}}, \frac{n_{ij}}{\alpha_{n_{ij}}}\right] \; \forall i = 1,2,3,4,\ldots,m_j. \quad (2)$$

The corresponding unit cost of Stage 2 link *ij* in region/country *l* can be formalized as Equation 3 where p_ρ, p_k, and p_n are the corresponding link location-specific factor prices.

$$c_{ijl} = \alpha_{\rho_{ij}} p_{\rho_l} + \alpha_{k_{ij}} p_{k_l} + \alpha_{n_{ij}} p_{n_l} \; \forall i = 1,2,3,4,..m_j. \quad (3)$$

Equation 4 describes the relevant final good/service production technology (Stage 2)—in this case, Leontief, while Equation 5 describes the corresponding cost equation (Stages 1 and 2) for a given region/country (i.e. *l*).[5] K corresponds to the fixed cost of the VBVC (cost of the vision).[6] As such, the unit VBVC cost is a decreasing function of q_j, the quantity of the final good/service produced. Here, the β_{ij}'s correspond to the relevant Leontief

[5] Here, it is assumed that all links are localized in the *l*th region/country. Later, we relax this assumption and allows for multi-localization value chains (i.e. more than one *l*).

[6] Here, it is assumed that K is an up-front cost and not a residual in the Knightian sense. This assumption could be relaxed without affecting the results. In other words, factor payments to the "visionaries" could be part up-front, and part residual. Think of Steven Jobs drawing a salary from Apple as well as cashing in on higher-than-anticipated earnings via stocks or stock options.

value-chain input-output parameters. That is, to the units of link *i* output in the *j*th value chain.

$$q_j = \min\left[\frac{v_{1j}}{\beta_{1j}}, \frac{v_{2j}}{\beta_{2j}}, \frac{v_{3j}}{\beta_{3j}} \ldots\ldots, \frac{v_{mj}}{\beta_{mj}}\right] \quad (4)$$

$$c_{jl} = \mathrm{K} / q_j + \beta_1 c_{1jl} + \beta_2 c_{2jl} + \beta_3 c_{3jl} + \ldots\ldots\ldots + \beta_{mj} c_{mjl}$$

We now proceed to formalize the process of link localization—that is, the localization in geographical space of the m_j Stage 2 links of the representative value chain. Specifically, link localization is modeled in terms of classical optimization behavior where the firm (owner(s) of the relevant VBVC) maximizes profits/minimize costs by choosing localizations for each of the *i* Stage 2 links across the set of regions and countries. The relevant optimization problem (Equation 6) is relatively straightforward and consists of choosing link localizations l_{ij} for all $i=1, 2, 3, 4, \ldots..m_j$ in such a way so as to maximize overall value-chain profits. This differs somewhat from the conventional profit maximization problem in that here the firm (VBVC) chooses localizations for its links given the set of region/country factor prices, and not optimal quantities of factor inputs for each link of a given value chain. We believe that this approach describes well the potential firm's problem in a multi-region/country setting. Technology is Leontief in nature, leading firms to choose localizations (i.e. l_{ij}'s), not relative factor input quantities (Markusen and Maskus, 1999).[7]

$$\max_{\{ijl\}} \pi = (p_j - \beta_{1j}c_{1jl} - \beta_{2j}c_{2jl} - \beta_{3j}c_{3jl} - \ldots.. - \beta_{mj}c_{mjl}) \min\left[\frac{v_{1j}}{\beta_{1j}}, \frac{v_{2j}}{\beta_{2j}}, \frac{v_{3j}}{\beta_{3j}}, \ldots\ldots, \frac{v_{mj}}{\beta_{mj}}\right] \quad (6)$$

Consequently, the localization of the various Stage 2 links that comprise a given value chain will be based on the concept of relative factor abundance as measured by relative factor input

[7] In fact, it could be reasonably argued that this mimics the firms traditional problem, consisting of localizing links within a given geopolitical jurisdiction in such a way so as to minimize overall costs

prices.[8] For example, regions/countries that are labor abundant (e.g. Asia, India, Mexico) will/should have lower-than-average wages and, as such, will/should attract investment on the part of firms wanting to localize their labor-intensive links there. The presence of trade barriers will, as such, affect the outcome, forcing firms to localize production links in a sub-optimal fashion. Tariffs on imports of natural resources, semi-finished or finished products will, in general, favor home region/country investment for obvious reasons, as will various investment incentives (subsidies, tax incentives, local-content clauses). Likewise, restrictions on natural resource exports (unprocessed) will favor home region/country investment also. That is, the representative VBVC will localize more Stage 2 links in the natural resource-abundant region.[9]

In the third and final stage, the market (consumers) selects from among the available VBVCs. Successful VBVCs will cover their costs and earn non-negative profits, while unsuccessful ones will be forced out. This corresponds to the selection stage (Nelson and Winter, 1982). Successful VBVCs will continue into the next stage, while unsuccessful ones will be forced out of the market, at least in their current incarnation. In some cases, the failure of a specific VBVC may be met with revisions/modifications, or the VBVC may be simply dismantled and sold-off. As it turns out, this is a common occurrence. Large, multi-VBVC corporations oftentimes sell off some of their divisions (e.g. *IBM* selling its PC division to *Le Novo, Bombardier* selling its recreational products division to *Bain Capital*), focusing on either the most profitable ones, or ones that are related to their "core activities."

[8] Implicit in our analysis are the various trade theorems found in traditional models, specifically the gains from trade theorem. In our analysis, countries gain from trading value added (links) as opposed to goods/services.

[9] It is important to note that the standard trade results (specialization, gains from trade) all hold in this model, but at the VBVC-link level (i.e. value added, not final goods are traded). One way to see this is to deconstruct goods into their component parts/Lancasterian characteristics. The latter are then the object of trade.

The GFPH and Vertical Comparative Advantage

This simple approach allows us to generate a number of predictions regarding regional/national vertical comparative advantage. More specifically, region/country-based vertical comparative advantage (Stages 1 and 2 combined) will be based on the relative endowments of four factor inputs, namely (*i*) the ability to generate VBVCs (knowledge), (*ii*) natural resources, (*iii*) capital and (*iv*) labor. The ability to generate VBVCs refers to a region/country's ability to literally come up with new products and processes—in short, innovate (Stage 1). This will depend on a number of factors— social, cultural, historical and economic (Lundstedt and Colagzier, 1982; Beaudreau, 1989; Griffiths and Kickul, 2008). Implicit here is the notion that regions/countries differ in their ability to innovate.

Here, we combine Stages 1 and 2. Specifically, an additional link (i.e. the conception of the VBVC) is added to the m_j Stage 2 links. By combining both the attributes of a region/country (as defined by its endowments of the five factor inputs), with the exigencies of the value chain (for all m_j+1 links), we can formalize link localization in terms of a simple assignment problem. That is, assign a particular link to its most likely localization. In other words, links that are labor intensive will be localized in labor-abundant regions/countries, those that are capital intensive will be localized in capital-abundant countries, etcetera.[10] Equation 7 formalizes this process in probabilistic terms. Specifically, p_{ijl}, the *ex-ante* probability that link *ij* will be localized in region/country *l*, is modeled as an increasing function of the "technological exigencies" of link *ij* as they relate to the factor endowment of region/country *l*, defined as the inner product of the various factor intensities (i.e. the αs) and the ratio of region/country *l*'s endowment to the overall world endowment.[11] Accordingly, if α_κ is high, and κ_l/κ_w is low, then

[10] This is oftentimes referred to as the "international division of labor."

[11] Alternatively, factor prices could be used for Stage 2 links. For example, the cost of capital in location *l* relative to the average, worldwide cost of capital could be used.

the probability that region/country *l* will attract the "conception of" VBVCs link will be low. That is, the region/country in question doesn't have the wherewithal to attract "conception of" VBVC links. Alternatively, if α_k is high, and k_l/k_w is also high, then the probability that region/country *l* will attract the "conception of" VBVCs link will be high. As a rule, the more a region/country is well-endowed in a factor input, the greater is the probability that it will attract a link that makes intensive use of it.[12] If region/country *l* is capital abundant (i.e. its relative share of the overall world capital stock is non-negligible), then it will attract capital-intensive links.

This approach to link localization and vertical comparative advantage is probabilistic in nature. That is, relative factor abundance increases the *ex-ante* probability that a region will attract a compatible link. As such, a capital-abundant region may or may not attract capital-intensive links; however the presence of a low cost of capital will increase the *ex-ante* probability.[13]

$$p_{ijl} = f\left[\alpha_{\kappa_{ij}} \frac{\kappa_l}{\kappa_w}, \alpha_{\rho_{ij}} \frac{\rho_l}{\rho_w}, \alpha_{k_{ij}} \frac{k_l}{k_w}, \alpha_{n_{ij}} \frac{n_l}{n_w}\right] \forall i = 1,2,3,4,\ldots,m_j + 1 \qquad (7)$$

Equation 7 captures the essence of the generalized factor proportions hypothesis.[14] Whereas the HOH assumes that technology exists and is free, the GFPH model endogenizes it (i.e. Stage 1) and renders it proprietary (i.e. analogous to the notion of ownership advantage in the multinational firm literature-(Hymer 1976, Dunning 1981)). Certain regions/countries will hold a vertical comparative advantage in the "conception of" VBVCs. Consequently, they will be home to the resulting corporations

[12] Econometrically speaking, it consists of a Probit (0-1) model with the various factor intensities and factor endowments as the independent variables.
[13] Equation 4 could be used to study both industrial and commercial policy. Specifically, it could be used to analyze and/or guide decisions to either finance or subsidize the presence of certain links on their territory. Another way of looking at this is that governments must combine the "winning combinations" for investment to occur—that is to maximize p_{ijl}.
[14] Another way of looking at Equation 7 is as an expression of factor proportions-based (link) localization theory. That is, one in which factor abundance constitutes the basis of localization decisions made within large, vertically-integrated multinational firms.

(headquarters).[15] A good example is Silicon Valley in California, or Bangdalore in India. It is important to note that theoretically speaking, the localization of the first link will have no bearing on the localizations of the ensuing m_j Stage 2 links.

Sectoral/Strands of Links Comparative Advantage

Sectoral comparative advantage can be defined as "entire"-value chain comparative advantage and corresponds to the notion of horizontal comparative advantage found in classical and neoclassical trade theory. As our value chains are the sum of the m_j+1 Stage 1 and 2 links, and strands of links, it stands to reason that sectoral horizontal comparative advantage can be defined and estimated for each localization (region and/or country).[16] For example, for region/country *A* to have a horizontal comparative advantage in value chain *j*, its relative final-good price (*vis-à-vis* value chain *s*) would have to be lower than in region/country *B*.[17] That is, the cost of localizing all m_j+1 links in region/country *A*, relative to the same cost of a *numéraire* good (i.e. *s*), would have to be less than in region/country *B*.

In the context (and historical context) of globally-dispersed value chains, the very meaning of horizontal comparative advantage is very much in question (Hummels, Rapoport and Yi, 1998; Hummels, Ishii and Yi, 2001; Reimer, 2006; Johnson, 2008; Johnson and Noguera, 2008). It is our view that value chains *have been* rarely region/country specific, *are* rarely region/country specific and *will no doubt continue to be* rarely region/country specific. Since time immemorial (i.e. early trade empires), value chains have been geographically dispersed, making conventional horizontal comparative advantage a largely irrelevant (theoretically and empirically) and meaningless

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[15] Clearly, with time some VBVCs will enter the public domain and become "free goods," however for our purposes, we will assume that all VBVCs are proprietary in nature.

[16] Note that in both the Ricardian and Heckscher-Ohlin models, the Stage 1 link (conception of VBVC) is absent, making for only Stage 2 links.

[17] This assumes that both regions can come up with comparable VBVCs. If not, then comparisons are meaningless.

concept. For example, nineteenth-century Great Britain did not have a horizontal comparative advantage in textiles, but rather, had two vertical comparative advantages, namely a Stage 1 knowledge-based vertical comparative advantage in the conception of high-throughput, value chains and secondly, a Stage 2 vertical comparative advantage in the processing of the various fibers imported from its colonies (Beaudreau, 2004).

The emphasis on either defining or deriving sectoral horizontal comparative advantage at the country level, we believe, is, in large measure, to blame for the failure of comparative advantage to make important inroads in the empirical trade and policy literature (Beaudreau 2011). The value chains and the material processes that characterize most material processes are infinitely more complex than the trivial production functions/relationships found in international trade text books. Moreover, as pointed out, from time immemorial, value chains have been dispersed across regions/countries, making horizontal comparative advantage little more than an abstraction (Beaudreau 2011).

The GFPH-Based Vertical Comparative Advantage Taxonomy

Our approach easily lends itself to various taxonomies of regional/national vertical comparative advantage, starting at the very top/beginning of value chains (Stage 1), namely the ability of a region/country to generate/conceive of VBVCs (i.e. visions). Specifically, it can be argued that certain regions/countries will have a vertical comparative advantage in generating/conceiving of firm visions defined as products and their associated production processes (i.e. the business process). This is analogous to what Elhanan Helpman referred to as *Headquartering Activity* (Helpman 1984) and consists of the ability to generate new visions (i.e. new products, new processes). Its presence will depend on a number of factors, including R&D expenditure, education, and the overall level of innovation in the region/country (Lundstedt and Colgazier, 1982; Beaudreau, 1989; Griffiths and Kickul, 2008). Other regions/countries will have a Stage 2 vertical comparative advantage in natural resources based on their endowments.

These include metallic and non-metallic ores, various chemical elements, energy and other carbon-based products (biomass). We assume that both of these vertical comparative advantages are, in the spirit of the Heckscher-Ohlin approach, exogenous (at least in the short run) and immobile. That is, the Stage 1 capacity to generate VBVCs not the VBVC itself, and natural resources will be considered immobile across localizations.[18] The former owes to the social, political, historical and economic nature of innovation (Lundstedt and Colgazier, 1982; Beaudreau, 1989; Griffiths and Kickul, 2008). Certain regions/countries are, owing to structural factors, more likely to generate Stage 1 VBVCs. What's more, because this advantage is rooted in the social and intellectual fabric of the region/country, it is not transferable (i.e. mobile).

To refine the analysis, we shall distinguish between two types of vertical comparative advantage, namely structural and arbitrage (see Table 1). Structural vertical comparative advantage refers to either the Stage 1 ability to generate VBVCs or to the presence of natural resources (Stage 2).[19] Arbitrage vertical comparative advantage refers to short-run comparative advantage—that is comparative advantage that owes to capital and labor factor-cost price differentials that owe, in turn, to the relative abundance of these factors in the region/country. VBVCs (firms) will as such have a financial interest in localizing the links that use the factor input in question intensively in the region/country.

[18] For example, iron ore is assumed to be immobile; however, pig iron or steel is not. Likewise, oil wells are immobile; however, the oil itself is not. There are, of course, exceptions such as hydroelectricity which cannot be transported over long distances. In this case, both the resource and the output are immobile and hence a source of structural comparative advantage.

[19] VBVC-based Stage 1 structural vertical comparative advantage is similar but not analogous to classical Ricardian comparative advantage. The latter is technology-based (i.e. knowledge) while the former is process-based (i.e. the process of generating knowledge). One could, however, argue that Great Britain held a structural vertical comparative advantage in steam-based process technologies at the start of the 19th century as evidenced by the stream of innovations that followed James Watt's original steam engine. Examples include high-pressure steam and Charles Parson's Steam Turbine.

As these factor inputs are mobile, it stands to reason that any resulting vertical comparative advantage will, owing to arbitrage activity, be eliminated over time either by an increase in the demand for the factor in question, by an outflow of the factor input to other regions/countries (as owners of the factor look for a higher return), or by a combination of these two. For example, low wages in a given region/country will prompt labor intensive firms to localize in the region/country but will prompt workers to emigrate to high-wage regions/countries (Mundell 1957). [20]

Table 1: Taxonomy of Vertical Comparative Advantage.

VCA	Type	Description
Knowledge-Creation Advantage	Structural (Stage 1)	Ability to abstract, innovate, conceiveand realize VBVCs
Resource Advantage	Structural (Stage 2)	Possess natural resources, renewable and non-renewable
Labor Advantage	Arbitrage (Stage 2)	Abundant, cheap labor (skilled and unskilled)
Capital Advantage	Arbitrage (Stage 2)	Abundant, cheap capital (long-term and short-term)

Vertical Comparative Advantage in the Presence of Perfect Labor and Capital Mobility

Thus far, we have assumed that factors are immobile across regions/countries. Firms localize the various links of their value chains according to relative factor abundance/relative factor prices, giving rise to geographically-dispersed “global value chains.” In this section, we ask the counterfactual question, what if arbitrage vertical comparative advantage-based factors (e.g. labor and capital) were perfectly mobile? That is, they could cross borders (region/country borders) costlessly and instantaneously, much like financial capital does today? What then would determine vertical comparative advantage?

[20] A good example of the transitory nature of arbitrage vertical comparative advantage is the current decline in popularity of various foreign direct investment localizations in Asia at the hands of lower-wage localizations such as Vietnam, Burma and Laos.

The answer is straightforward: structural comparative advantage. Well-endowed vision-producing and resource regions/countries would have a structural vertical comparative advantage. For example, in a world of perfect labor and capital mobility, Silicon Valley would continue to have a structural vertical comparative advantage in the conception of new IT products. As capital and labor would be identical across regions/countries, it stands to reason that it may or may not actually manufacture these products (e.g. the *iPhone* which was conceived of in Silicon Valley, but produced globally). Similarly, Milan would continue to have a structural vertical comparative advantage in designing new lines of clothing (fashion). Again, it may or may not manufacture these products. Resource-rich countries like Canada would, in such a world, continue to have a resource-based structural vertical comparative advantage, as would Africa and Australia. Arbitrage vertical comparative advantage would, on the other hand, not exist for obvious reasons. As factors could move across borders instantaneously, responding to factor-price differentials, a single price would emerge. In short, arbitrage-based vertical comparative advantages would, in the long run all but disappear, leaving structural vertical comparative advantage as the ultimate arbitrager in so far as interregional and international trade goes. Regions/countries would either have a visions-based vertical comparative advantage, a resource-based vertical comparative advantage, some combination of the two, or no vertical comparative advantage whatsoever.[21] It is important to point out that it is not inconceivable for a region/country to have both a visions-based and resource-based vertical comparative advantage. For example, a region/country could be adept at "conceiving of" Stage 1 VBVCs as well as be well-endowed resource-wise. The corresponding Stage 2 manufacturing activity could, however, be localized elsewhere.

Hence, one could argue that vertical comparative advantage in the long-run is affected primarily by structural factors, not arbitrage ones, a fact borne out amply by history. Great Britain did not develop a vertical comparative advantage in feedstock processing on account of its capital, labor or energy endowment;

[21] In which case, labor would flow out of the region in question.

rather, its vertical comparative advantage owed to its ability to generate new products and processes (i.e. knowledge-based vertical comparative advantage). Once developed, traditional factors (labor especially) found their way to England (from Ireland and Scotland) to oversee the workings of the new power drive technology known as the steam engine. It is also borne out by current industrial policy throughout Western industrialized countries that is based on R&D and product niches (i.e. Michael Porter's "clusters" and "diamonds.") Also, it validates and refines the Heckscher-Ohlin approach to trade, namely as being based on relative endowments. Specifically, long-run vertical comparative advantage is ultimately based on a region/country's relative endowments of knowledge and resources. Traditional factor inputs, being increasingly mobile, have less bearing on vertical comparative advantage. Good examples of this are the many outsourcing and plant relocalizations of the past two decades. As wages and interest rates adjust, it is quite conceivable that no one region/country hold a vertical comparative advantage in capital-, labor- or energy-intensive industries. Which would leave the two structural vertical comparative advantages.

The GFPH: The Evidence

As pointed out, one of the innovative features of the generalized factor proportions hypothesis is the unit of analysis, namely value added as opposed to goods. Not surprisingly, this will have far-reaching implications in so far as empirical work is concerned. Given the presence of global value chains (both historically and presently), it stands to reason that any and all tests using value of shipments data will be flawed and consequently of little scientific value (regardless of the findings). Ideally, value added data would be required (WTO 2010) for obvious reasons, not the least of which would be to avoid double, triple or quadruple counting. Since the dawning of modernity a century ago, there are few products that are produced entirely in a single region of country. The tendency towards the increasingly geographical fragmentation of value chains was accentuated in the 1980s by the energy crisis and the productivity slowdown. Increasingly, large multinational corporations outsourced their manufacturing operations (links in the value chain) to low-wage countries.

As value-added trade data are not available (and unlikely to be available in the near future), we propose an alternative approach to "testing" the generalized factor proportions hypothesis presented in this paper. In a nutshell, it consists of (*i*) reinterpreting the results of existing tests in light of the predictions of the GFPH, and (*ii*) offering a series of indirect tests à la Bela Belassa of the GFPH as the basis for vertical comparative advantage and hence international trade.

Existing Empirical Results Seen Through the Prism of the GFPH

We begin by reexamining the existing evidence through the prism of the generalized factor-proportions hypothesis. Operationally, this involves reinterpreting evidence in light of anecdotal and other information regarding the localization of the various links in a given value chain.

We begin with Wassily Leontief's early tests of the HOH using U.S. post-war data (Leontief 1953). In the 1950s, Leontief, the father of input-output analysis in the U.S., set out to test the commonly held, Heckscher-Ohlin based prediction that because the U.S. was a capital rich country, its exports would be capital intensive, while its imports would be labor intensive. Not surprisingly, this view subsumed a number of things, notably that U.S. exports and imports were entirely produced in the U.S. and its trading partners, respectively. History, however, shows this to be an erroneous assumption. By the mid 1950s, the U.S. had exhausted many of its resources (iron ore, forests, oil) and had become a net importer. Its strength lay in its ability to transform resources into U.S. VBVC-based commercially-viable goods and services. Cast in terms of value chains, U.S. activity was increasingly concentrated in downstream Stage 2 links (manufacturing).

While a surprise—and indeed a paradox—to most, the fact that U.S. imports were found to be more capital-intensive than its exports is consistent with our model. Raw materials are highly capital intensive, while manufacturing is, on average, more labor intensive. The U.S.'s vertical comparative advantage at the time was in (*i*) the Stage 1-based conception of visions-based value chains, and (*ii*) mid-stream manufacturing. While absent from Leontief's analysis, we speculate that the R&D intensity of U.S. exports at the time, would have been significantly greater than the R&D intensity of its imports.

It is worth noting that this result is not inconsistent with the commonly-held view (at the time) that the U.S. was wealthier than its trading partners if allowance is made for direct and indirect foreign investment. As it turns out, many of the overseas companies exploiting—and exporting resources to the U.S.—were vertically-integrated U.S. multinational branch plants. So in actual fact, the U.S. was *de facto* importing its own capital, not that of foreigners. A good example of this is U.S. iron-ore imports from Canada in the 1950s, more specifically from the U.S.-based *Iron Ore of Canada* corporation in Northern Quebec.

Our second set of result consists of Harry Bowen, Edward Leamer and Leo Sveikauskas' seminal 1987 *American Economic Review* paper entitled "Multicountry, Multifactor Tests of the Factor Abundance Theory," and consists of their estimates of the *ratio of adjusted net trade in factors to national endowment* for twenty-seven countries and twelve factors presented in Table 2. We see that countries (e.g. Argentina, Australia, Canada) that export primary-sector commodities (SITC 1-4) are also net exporters, factor-input wise, of *Capital*, *Agriculture*, *Arable*, *Forest and Pasture*, while those (e.g. France, Germany, Switzerland, UK) that export manufactures (SITC 5-9) are net exporters of *Labor*, *Prof/Tech*, *Manager*, *Clerical*, *Sales* and *Service*. The *Prof/Tech* and *Manager* inputs can be viewed as proxies for the "ability to generate VBVCs" Stage 1 structural vertical comparative advantage. Further, Bene-Lux, Germany, Hong Kong, Japan, Switzerland and the U.K. are all net importers of Stage 2 resources. Argentina, Australia and Denmark are resource net exporters and hence can be regarded as having a Stage 2 resource-based vertical comparative advantage.

The U.S. case is *prima facie* an enigma as it exports capital and imports resources (capital intensive). Also, it imports labor as well as human capital (*Labor, Prof/Tech, Manager, Clerical, Sales and Service*), unlike other G-6 countries. Specifically, Japan, Germany, France, Italy and Great Britain are all net exporters of *Labor* and net importers of *Capital*. This, we argue reflects the nature of Stage 2 value chains in both countries, namely as being primarily downstream (i.e. in labor-intensive Stage 2 links). All are net importers of raw materials (capital-intensive Stage 2 links). However, given both the size and breadth of the U.S. economy (having multiple vertical comparative advantages), more of its exports are capital intensive.[22]

When broken down by value chain and link, Bowen, Leamer and Sveikauskas' results are less troublesome. Countries hold multiple vertical comparative advantages. Seen in this light, seemingly paradoxical results disappear. For example, the Leontief Paradox, the bane of Heckscher-Ohlin trade theory, can be seen as having resulted from (*i*) confusion over the very nature of value chains in the U.S. and (*ii*) the corresponding definition of comparative advantage. From the early 20th century, U.S.-based VBVCs relied increasingly on imported raw materials (mineral ores and energy). As U.S. multinationals (Stage 1 VBVCs) localized Stage 2 natural resource links abroad, intra-firm imports became increasingly more capital intensive, while exports became increasingly more labor intensive (owing to Stage 2 U.S. VBVCs' vertical comparative advantage). When combined with an empirically-flawed definition of comparative advantage, namely horizontal comparative advantage, one gets the Leontief Paradox. As we have shown, large federal countries have multiple vertical comparative advantages (Stage 1 and Stage 2). To want to somehow reduce this to a simple 2x2 or *n*x*m* assignment problem is, in our view, a questionable practice. The problem,

[22] In other words, it has less of a dominant vertical comparative advantage in downstream processing than the other G-6 countries.

we argue, can be traced back to early attempts by writers such as David Ricardo and others to compare countries using aggregate measures of horizontal comparative advantage. Clearly, the U.S. does not have a horizontal comparative advantage in capital-intensive goods, no more so than it has a horizontal comparative advantage in R&D-intensive goods.

Table 2: Bowen, Leamer and Sveikauskas's Empirical Results.

Country	Capital	Labor	Prof/Tech	Manager	Clerical	Sales	Service	Agriculture	Production	Arable	Forest	Pasture
Argentina	1.32	−0.30	−1.64	−2.60	−1.07	−0.62	−0.83	4.30	−1.46	21.24	−6.94	2.40
Australia	−3.77	−0.41	−2.95	−1.79	−1.68	0.21	−0.11	18.10	−3.65	17.15	−13.68	0.80
Austria	−2.03	3.01	2.74	5.64	2.91	3.81	3.20	3.12	2.59	−80.74	13.52	24.35
Bene-Lux	−2.36	1.81	0.88	1.82	1.90	1.36	2.39	−4.26	2.76	−364.25	−922.53	53.27
Brazil	−5.54	−0.27	−0.85	−0.49	−0.82	−0.32	−0.23	−0.04	−0.61	2.10	−0.04	−0.02
Canada	1.82	−3.49	−3.40	−2.23	−4.00	−2.73	−1.88	4.00	−6.84	12.13	6.16	2.84
Denmark	−4.89	5.82	2.37	8.70	4.25	5.08	4.51	24.56	1.21	33.57	803.73	1763.42
Finland	4.69	2.14	0.49	4.22	1.78	1.94	1.89	1.26	3.21	−24.44	30.48	434.70
France	−4.07	0.82	0.70	1.17	1.02	0.90	1.06	0.16	1.04	−21.33	−198.68	1.79
Germany	−1.05	−0.43	1.01	1.34	0.51	−1.08	−1.05	−11.86	2.07	−323.61	−377.64	−124.77
Greece	−5.50	2.93	4.48	14.95	5.37	4.49	4.68	2.20	2.02	46.92	−61.16	1.08
Hong Kong	−46.06	4.52	5.24	3.68	8.10	3.48	3.03	−14.19	6.46	−21,568	−30,532	−91,627,216
Ireland	−1.93	6.73	4.49	13.84	7.19	6.10	8.07	10.59	2.67	17.31	−129.98	72.68
Italy	−7.03	0.74	1.25	4.67	1.42	0.39	1.27	−1.73	1.87	−39.91	−431.67	−131.90
Japan	−5.47	0.10	0.44	0.48	0.33	−0.05	−0.03	−1.54	1.18	−341.42	−268.58	−1998.58
Korea	−30.51	0.61	1.53	2.85	1.81	0.76	1.73	0.27	0.85	−42.34	−29.42	1206.60
Mexico	−0.78	0.57	0.19	0.47	0.51	0.80	0.70	0.87	−0.21	12.40	5.69	0.97
Netherlands	−4.56	4.61	3.49	6.36	3.65	4.72	5.53	22.78	1.41	82.74	−719.88	330.86
Norway	−5.54	5.57	3.75	6.15	7.98	0.22	10.58	14.59	−0.06	−125.48	105.96	660.35
Philippines	−13.94	−0.10	−0.59	−0.36	−0.81	0.03	0.06	0.14	−0.81	10.47	−8.43	−17.03
Portugal	−10.31	1.92	3.92	10.85	3.75	2.83	2.72	0.63	2.49	−28.46	24.79	12.03
Spain	−6.19	3.04	4.56	13.88	4.36	4.13	3.89	2.45	2.23	−2.74	−12.00	4.92
Sweden	0.79	1.36	0.59	2.26	1.05	1.09	1.44	−0.66	2.18	−67.23	30.93	48.00
Switzerland	−5.72	3.42	4.46	11.57	3.52	5.42	4.13	−0.79	3.04	−862.95	−352.36	−12.18
UK	−12.86	0.63	1.77	2.04	1.37	1.30	1.32	−18.57	1.11	−313.42	−2573.99	−91.89
United States	0.08	−0.25	0.23	−0.11	−0.19	−1.10	−0.68	1.54	−0.34	19.45	−23.82	−1.63
Yugoslavia	−3.15	0.68	0.39	1.59	1.12	2.05	1.15	0.46	0.76	−0.08	2.81	14.24

Our third set of results consists of the findings of Neil Foster, Robert Stehrer and Gaaitzen de Vriees on trade in value added and factors (Foster, Stehrer and de Vriees 2011). Specifically, the authors decompose exports and imports of 35 industries into intermediate goods and final goods, providing export value added as well as capital and labor data, the latter disaggregated by types. Table 3 presents net trade in capital and labor by use categories—intermediates and final goods. G-6 countries are, in general, net importers of capital, both for intermediates and final goods, as well as net exporters of labor. According to the GFPH, this owes to high capital intensity of imported raw materials, and the high labor intensity of manufacturing activity. For example, France is a net importer of capital and a net exporter of labor, both for intermediates and final goods. That it be a net importer of capital for final goods owes to the capital intensity of fossil fuel imports (petroleum and natural gas). The latter holds true for virtually all G-6 countries. Natural resource-rich countries (Canada, Australia, and Russia) are net exporters of capital and net importers of labor in so far as intermediates are concerned. It is important to point out that most of this capital is foreign-owned, typically by large vertically and horizontally-integrated G-6-based multinational firms. Their vertical comparative advantage, it therefore follows, lies in the presence of resources (Structural Vertical Comparative Advantage).

Table 3: Net Trade in Capital and Labor by Use Categories, US$ Billion.

Country	NEK-Int.	NEK-Fin.	NEL-Int.	NEL-Fin.
Austria	2.6	−5.1	10.2	−5.8
Belgium	0.6	−3.3	20.2	−3
Denmark	−0.9	0.3	3.8	4.9
Finland	1.6	−1.6	8	−1.1
France	−43	−26.8	24.9	8.6
Germany	59.8	−80.8	214.6	17.5
Greece	−4.2	−11.2	−4.6	−22.5
Ireland	23	2.1	−0.6	−1.1
Italy	−34.5	−12.9	10.6	13.1
Luxembourg	0.4	2.4	3	0.1
Netherlands	5.6	−4	34.7	9
Portugal	−6.2	−6	−3.3	−7
Spain	−35.9	−10.7	−34.2	−14.5
Sweden	0.6	0.9	16.1	6
United Kingdom	−43	−48.7	26	−4.5
Bulgaria	−1.5	−0.8	−0.3	−1.1
Cyprus	1.1	−1.7	1.8	−2.3
Czech Republic	−2.5	2.1	−1.3	3
Estonia	0.1	−0.9	1	−0.6
Hungary	−4.1	1.6	−2.3	1.1
Latvia	−0.2	−1.3	0.8	−1.7
Lithuania	−1.1	−1.1	1	−0.9
Malta	0.3	−0.4	0.7	−0.7
Poland	−2.6	4.8	−6.9	0.9
Romania	−4.7	−2.4	−1	−2.4
Slovak Republic	−0.8	−0.1	−2.2	−0.6
Slovenia	−1.1	0.3	0.5	1.2
Turkey	−23.1	−4.9	−8.4	3.2
Canada	73.9	−41.3	69.6	−62.9
United States	−251.6	−202.5	−126.2	−141.1
Mexico	29.1	11.4	−35	−12.2

Japan	−33.1	30.7	42	46.5
South Korea	−12.3	10.3	13.9	25.6
Taiwan	2.6	−3.1	24.1	−1
Australia	59	−57.9	30.4	−35.2
Brazil 1	5.7	6	9.5	4.6
China	−32.7	132.6	−21.8	139
Indonesia	30.2	−5.4	−0.5	−6.2
India	5.3	25.4	−17.4	−1
Russia 1	22.6	−11.1	44.7	−40.5
Rest of World	105.2	315.2	−346	120.8

Source: Foster, Stehner and de Vries (2011), 24.

The GFPH and Heterogeneity

Like most scholars, trade theorists long for regularity in so far as their results are concerned. In the 1960s and 1970s, most longed to find rich countries exporting capital and importing labor from poorer countries. Instead, they found a hodge-podge of results, some consistent with the theory, while others were abject violations—in short, heterogeneity.

While heterogeneity is anathema to HOH, it is consistent to the point of being predicted by the GFPH. Mobile labor and capital combined against a backdrop of multinational firms (global value chains) are sufficient to generate such results. For example, some multinationals might choose to exploit natural resources at the source (region/country), while others send them for processing elsewhere.

Where the GFPH generates more regularity is with regard to "structural vertical comparative advantage." Specifically, it maintains that the ability to generate VBVCs and natural resources are the two "anchors" in so far as net factor exports and imports are concerned. This owes to their immobility. While products and processes can be exported or imported, the ability to conceive them cannot. It predicts that while the traditional factor inputs will yield heterogeneous results, these will not. Regions and countries that are well endowed with visionaries will continue to be net exporters of "headquartering activity," while countries that are well endowed with resources will continue to be net exporters of resources.

Proto-Evidence of GFPH-Based International Trade

In this section, evidence of the GFPH at the regional level (within the U.S.) and at the country level is provided. To begin with, data on R&D spending and headquartering activity by U.S. state will be used to draw inferences about the ability to generate Stage 1 VBVCs. The basic idea here is that R&D and "visions" are, geographically speaking, collinear.[23] Regions within the U.S. that are R&D rich are also more likely to generate VBVCs. This will be followed by an attempt to draw inferences about country-level vertical comparative advantage from a series of Balassa-like factor intensity indices. It should be kept in mind that these findings are, at best, suggestive given the limitations of the data (value of shipments).

We begin with U.S. interstate (inter-regional) trade, the underlying idea being that value chains in the U.S. are geographically dispersed across the fifty states according to vertical comparative advantage. That is, resource-rich states will process and export resources (Stage 2), while knowledge-rich states will, on average, produce and export Stage 1 knowledge/visions (VBVCs). Given the presence of perfect (or near perfect) labor and capital mobility within the U.S. it stands to reason that no one state will have an arbitrage vertical comparative advantage, putting the focus on structural vertical comparative advantages.[24] Two proxies are used for the presence of a knowledge-based, visions-generating structural vertical comparative advantage, namely research and development expenditure by state and, secondly, the number of Fortune 500 companies by state. Both, we argue, are proxies for the presence of a VBVC-generating culture, one that ultimately gives rise to new firms, products/services and material processes. Research and development expenditure by state is used as a proxy for the state's ability to generate VBVCs and hence have the corresponding structural vertical comparative advantage. It is important to note that this does not imply that the state in question will ultimately produce the good/service in question, but rather that the state is the "cradle" of the VBVC.

Table 4 presents total R&D spending by state for 1997, gross state product (GSP), the ratio of the former to the latter, the state's share of overall R&D (Column 7), the corresponding rank (Column 6), and lastly the number of Fortune 500 firms (Column

[23] Although, with the emergence of China and India, G6 multinationals are increasingly localizing R&D links abroad, making this link more dubious.

[24] Seen in this light, the internal U.S. market is a metaphor for a world economy characterized by complete capital and labor mobility, one in which structural factors would determine vertical comparative advantage. Perfect labor and capital mobility within the U.S. makes for a situation in which knowledge and resources become the relevant comparative advantage criteria.

8). Heading the list is California with R&D spending of $41 billion, a GSP of $1 trillion and 52 Fortune 500 firms. Next comes Michigan and New York with $13 and $12 billion in R&D, and 22 and 57 Fortune 500 firms, respectively. Whether measured in terms of Fortune 500 headquarters or R&D spending, there can be little doubt: the "golden state" and the "Empire State" have an important vertical comparative advantage in the generation of knowledge. One could argue that the first fifteen states on the list (from California to Minnesota) have a similar advantage, albeit of a lesser degree. New Jersey and Massachusetts both have a knowledge-based structural vertical comparative advantage. States in the bottom fifteen, it stands to reason, do not have such an advantage. States such as South Dakota, Wyoming, Alaska and Maine have a comparative vertical disadvantage when it comes to knowledge generation. It also stands to reason that their structural vertical comparative advantage, if it exists at all, will lie with their natural resources. It is well known that most of these states produce and export raw materials.

It is important to keep in mind that these results are suggestive of a pattern, of a trend, and not definitive. That California has a vertical comparative advantage in the "conception of products and processes" does not preclude mining activity in the state, nor does it preclude manufacturing. However, given that capital and labor are perfectly mobile within the U.S., one cannot infer the presence of a labor or capital-based arbitrage vertical comparative advantage. Similarly, they do not preclude the emergence of VBVCs in Colorado, Montana or Wyoming. A good example is Minnesota, a longtime resource-rich state that is also the home of 3M, a Fortune 500 company.

Table 4: Total R&D and GSP, by State, 1997.

Rank	State	R&D	GSP	R&D/GSP	Rank	R&D/Total	Fortune 500
1	California	41,670	1,033,016	4.03	9	19.72	52
2	Michigan	13,991	272,607	5.13	3	0.62	22
3	New York	12,307	651,652	1.89	25	5.83	57
4	New Jersey	12,067	294,055	4.1	8	5.71	24
5	Massachusetts	11,097	221,009	5.02	4	5.25	10
6	Texas	9487	601,643	1.58	28	4.49	56
7	Pennsylvania	8209	339,940	2.41	15	3.89	25
8	Illinois	8034	393,532	2.04	21	3.8	33
9	Washington	7543	172,253	4.38	6	3.57	10
10	Maryland	7395	153,797	4.81	5	3.5	6
11	Ohio	7145	320,506	2.23	17	3.38	28
12	Florida	4784	380,607	1.26	31	2.26	12
13	North Carolina	4667	218,888	2.13	18	2.21	14
14	Virginia	4136	211,331	1.96	23	1.96	17
15	Minnesota	3605	149,394	2.41	16	1.71	20
16	Connecticut	3454	134,565	2.57	12	1.63	11
17	Colorado	3205	126,084	2.54	13	1.52	12
18	Indiana	3149	161,701	1.95	24	1.49	5
19	New Mexico	3028	45,242	6.69	1	1.43	0
20	DC	2768	52,372	5.29	2	1.31	2
21	Arizona	2410	121,239	1.99	22	1.14	4
22	Georgia	2272	229,473	0.99	38	1.08	15
23	Wisconsin	2256	147,325	1.53	30	1.07	9
24	Missouri	1826	152,100	1.2	33	0.86	10
25	Alabama	1637	103,109	1.59	27	0.77	1
26	Tennessee	1566	146,999	1.07	36	0.74	9

27	Oregon	1520	98,367	1.54	29	0.72	1
28	Utah	1381	55,417	2.49	14	0.65	1
29	Kansas	1351	71,737	1.88	26	0.64	1
30	Idaho	1270	29,149	4.36	7	0.6	2
31	Delaware	1089	31,585	3.45	11	0.52	1
32	Rhode Island	1040	27,806	3.74	10	0.49	2
33	South Carolina	1040	93,259	1.11	35	0.49	1
34	Iowa	980	80,479	1.22	32	0.46	1
35	New Hampshire	799	38,106	2.1	19	0.38	0
36	Oklahoma	644	76,642	0.84	40	0.3	4
37	Louisiana	554	124,350	0.45	50	0.26	3
38	Kentucky	526	100,076	0.53	46	0.25	6
39	Nevada	517	57,407	0.9	39	0.24	2
40	West Virginia	427	38,228	1.12	34	0.2	0
41	Mississippi	370	58,314	0.63	43	0.17	0
42	Vermont	314	15,214	2.06	20	0.15	0
43	Nebraska	275	48,812	0.56	44	0.13	5
44	Hawaii	275	38,024	0.72	42	0.13	0
45	Arkansas	272	58,479	0.46	49	0.13	5
46	Montana	199	19,160	1.04	37	0.09	0
47	Maine	149	30,156	0.49	48	0.07	1
48	Alaska	136	24,494	0.55	45	0.06	0
49	North Dakota	116	15,786	0.73	41	0.05	0
50	Wyoming	87	17,561	0.5	47	0.04	0
51	South Dakota	71	20,186	0.35	51	0.03	0

Source: Beaudreau (2004), 94.

International Evidence

As previously mentioned, in an ideal world, trade statistics would be reported on a value-added basis, making the task at hand (providing evidence) all the more easier. As the above data on the U.S. economy make abundantly clear, regions and countries are highly heterogeneous in their makeup, making it difficult, if not impossible, to categorize them (e.g. capital abundant, labor abundant, etc.).[25] Large federal political entities like the U.S., Canada, Australia, France, Great Britain and Germany consist of multiple heterogeneous regions, each with any number of vertical comparative advantages. What follows is an attempt at categorizing countries according to their "dominant" vertical comparative advantage, despite the limitations to this approach raised in this paper (see *Introduction*). We begin by examining the relationship between traditional factor intensities (Heckscher-Ohlin) and knowledge-based structural vertical comparative advantage.

Table 5 presents three factor intensities for each of the 14 2-digit SIC industries listed, specifically the ratio of research and development expenditure to overall sales, electric power consumption to labor and the ratio of capital to labor. The results show that primary and intermediate products (upstream-value-chain links) are, on the whole, more electric power and capital intensive and less research and development intensive than finished products. For example, the capital-labor and electric power-labor ratios in SIC 29, Petroleum and Coal Products, SIC 26, Paper and Allied Products, and SIC 33, Primary Metal Industries are $169,808.60 and 377,521*kwh* per worker, $58,443.99 and 154,278*kwh* per worker, and $58,407.28 and 205,442*kwh* per worker, respectively. Conversely, in SIC 36, Electric and Electronic Equipment, SIC 37 Transportation Equipment, and SIC 35, Machinery, except Electrical, these ratios are $14,473.98 and 20,870*kwh* per worker, $20,775.98 and

[25] See Garreau (1981) for a look at the North American economy from the vertical comparative advantage perspective.

24,717*kwh* per worker, and $18,500.16 and 19,248*kwh* per worker, respectively.

Table 5: Two-digit SIC Industry Factor Intensities.

SIC	Industry	R&D/GDP	k/n($)	e/l(kWh)
20	Food and Kindred Products	0.4	40,801	39,756
22,23	Textiles and Apparel	0.4	9453	21,149
24	Lumber, Wood Products	0.8	12,657	28,339
26	Paper and Allied Products	0.9	58,443	154,278
28	Chemicals and Allied Products	3.6	107,263	266,175
29	Petroleum and Coal Products	0.7	169,808	377,521
30	Rubber and Plastic Products	2.4	24,403	39,788
32	Stone, Clay and Glass Products	1.2	35,431	64,297
33	Primary Metal Industries	0.8	58,407	205,442
34	Fabricated Metal Products	1.2	16,969	20,686
35	Machinery	5	18,500	19,248
36,48	Electronic Equipment	6.3	14,473	20,870
37	Transportation Equipment	3.1	20,775	24,717
38	Instruments and Related Products	5.6	16,704	16,149

Source: U.S. Department of Commerce (1981).

These three factor intensities were used to construct Balassa-like indices of the relative factor content of trade.[26] Specifically, weighted (by trade flows) averages of the R&D content, the electric power-labor ratio, and the capital-labor ratio of exports and imports were calculated for 110 countries. The weights in this case were derived using United Nations export/import data by industry. The complete results are presented in Appendix 1. Table 6 presents the results for five countries, namely the U.S., Japan, Canada, Australia and Norway. Referring to Column 2, we see that average R&D intensity for U.S. exports and imports

[26] $R\&D_{imports} = \sum_{j=1}^{v} R\&D_j \left[\frac{Exports_j}{Total\ Exports} \right]$ where $R\&D_j$=research and development expenditure per dollar of output, $Exports_j$=Sector *j* exports and *Total Exports*=total country exports. The other two are derived using *capital-labor* and *energy-labor* ratios in lieu of *R&D*.

are 2.79 percent and 2.04 respectively, making the U.S. a net exporter of R&D. The corresponding capital-labor and energy-labor indices show the U.S. to be a net importer of capital and energy. That is, U.S. imports are more capital and energy intensive than its exports, confirming Leontief's paradoxical findings. It is important to remember that upstream industries (raw materials and intermediate goods) are more capital and energy intensive than downstream industries. This allows us to infer that the U.S.'s dominant vertical comparative advantage lies in the Stage 1 "conception of VBVCs" link as well as in downstream labor-intensive industries (manufacturing). Again, it is important to keep in mind the summary nature of these results. While the U.S. imports raw materials, it also produces raw materials; likewise, while it exports finished goods, it also imports finished goods.[27]

Consider next the four other countries, Japan, Canada, Australia and Norway.[28] The Japanese results are similar to those of the U.S.: a net exporter of R&D and labor and a net importer of capital and energy (resource). Interestingly, it exports more R&D and imports more capital and energy than the U.S., a fact that can be attributed to the more homogeneous structure of its economy—that is, not having raw materials, its activities are concentrated in manufacturing. The U.S. and Japanese cases contrast with the latter three cases where each country is a net importer of R&D and a net exporter of capital and energy (resource). In the case of Norway, a dollar's worth of exports has less than one cent of R&D content, while a dollar's worth of imports has three cents of R&D content. Clearly, Norway's dominant vertical comparative advantage is resource based, a finding corroborated by the generally-accepted view of Norway as a resource-abundant country, especially with its share of North Sea oil. All three are resource-abundant countries which explains the relatively low R&D and high capital and energy

[27] That the U.S. both export and import finished goods can be rationalized in terms of the heterogeneous nature of the VBVCs across countries (i.e. differentiated products).

[28] Condensed results for 110 countries are presented in the *Appendix* where the ratio of *R&D exports to imports*, the ratio of *k/n exports to imports* and the ratio of *e/n exports to imports* are presented. We see, for example, that the U.S. *R&D exports to imports* ratio is 1.3676 (2.79/2.04 from Table 4).

content of their net exports. Cast in terms of Equation 7, all three attract direct foreign investment in the upstream strand(s) of Stage 2 global value chains. For example, Canada's abundant forests, minerals, and fossil fuels provide it with a resource-based structural vertical comparative advantage. Historically, these resources have been exploited by foreign multinational firms that localized and continue to localize their up-stream operations/links in the provinces of Quebec, Ontario, British Columbia and Alberta. It is important to note that this does not rule out the presence of knowledge-based vertical comparative advantages in these countries as evidenced by non-zero levels of R&D expenditure. In other words, Canadian, Australian and Norwegian VBVCs do nonetheless exist as evidenced by the existence of Canadian, Australian and Norwegian multinational firms.

Table 6: Factor Content of Trade: U.S., Japan, Canada, Australia and Norway.

Index	US	Japan	Canada	Australia	Norway
$R\&D_{exports}$	2.79	3.51	1.95	0.93	1.44
$R\&D_{imports}$	2.04	1.14	2.93	2.94	2.54
$k/n_{exports}$	40,278	25,086	60,047	60,378	105,228
$k/n_{imports}$	81,065	116,396	41,210	53,436	56,016
$e/n_{exports}$(kWh)	75,335	43,083	126,795	113,909	236,849
$e/n_{imports}$(kWh)	173,257	254,383	80,355	108,287	114,719

Source: Beaudreau (2004), 95.

These results are corroborated by data on R&D spending at the country level. The U.S. and Japan spent considerably more on R&D than do the others. For example, the U.S. and Japan spend roughly 2.70 and 2.98 percent of their GDP on R&D, respectively while Canada, Australia and Norway spend 1.93, 1.53 and 1.70 percent, respectively. While Canada, Australia and Norway have made greater R&D a policy objective (as have most OECD countries), their overall foreign trade is, in general, still very much dominated by their resource-based Stage 2 structural vertical comparative advantage.[29] Again, this is not to say that all regions within these countries have a resource-based structural vertical comparative advantage, but rather that the countries taken as a whole do. Also, as pointed out earlier, it does not preclude the existence of knowledge-based structural comparative advantages. For example, despite its important resource-based vertical comparative advantage, Canada has knowledge-based vertical comparative advantages in a number of sectors, including transportation, food processing and entertainment. The same holds in the case of Norway which despite its resource-based vertical comparative advantage has a knowledge-based Stage 1 vertical comparative advantage in the machine tool sector.

The GFPH and Trade Policy

The Ohlin-Samuelson formalization of the HOH suffers from a number of shortcomings not the least of which is the dearth of policy recommendations. While it offers a convenient framework to study price distortions (tariffs, subsidies) and other market-based distortions (quotas), it offers little in the way of pro-active policy measures—that is, measures designed to alter fundamentals. In its *2x2x2* version, a country wanting to export more capital-intensive goods (typically referred to as manufactures) has to increase savings with the hope of increasing the rate of capital formation. As technology is free, investment in R&D is irrelevant.

In short, it leaves much to desire, especially in this, the age of R&D, innovation, Michael Porter's diamond, etc. Enter our formalization of the FPH. It is our view that the Generalized FPH model of trade presented here goes a long way to address the shortcomings of the traditional approach, especially with regard to technology, resources, value chains, and knowledge creation in general. Specifically, it is able to rationalize Michael Porter's diamond approach to the competitive advantage of nations in factor-proportions terms. Specifically, by fostering knowledge creation, a country can increase its advantage in the

[29] This is especially true of Canada whose principal export in 2009 is energy.

conception of products and processes (and the corresponding value chains).

In this section, we examine the policy implications of the GFPH as presented above. Unlike the HOH, the GFPH has important policy implications. Moreover, as it turns out, most of these are concordant with the policy measures that have been adopted in Western industrialized nations over the course of the past three decades, a finding that further corroborates the GFPH empirically. As argued, GFPH-based vertical comparative advantage can be either structural or arbitrage in nature. In the case of the former, vertical comparative advantage is based on knowledge and/or resources, while in the latter, it is based on labor or capital. As each can be affected by government policy, it stands to reason that vertical comparative advantage as defined here can be viewed as an endogenous variable.[30] We begin by examining the first of two types of vertical comparative advantage, namely structural vertical comparative advantage.

Structural vertical comparative advantage consists of either broadly-defined knowledge-based vertical comparative advantage or broadly-defined natural resource-based vertical comparative advantage. A knowledge-based vertical comparative advantage refers to the ability of a given region/country to generate knowledge in the form of VBVCs . While research and development expenditure is typically invoked as the relevant policy instrument, it is, by no means, the only instrument. As we have argued, knowledge is a cultural phenomenon, one that is intimately tied to cultural values (Lundstedt and Colgazier, 1982; Griffiths and Kickul, 2008). For example, how a society responds to novelty, to change, to new ideas, to new ways of seeing things, are good predictors of its propensity to create knowledge. “Closed” societies are less likely to innovate and, as such, are less likely to generate knowledge-based vertical comparative advantages (Beaudreau, 1989).
As cultural values are difficult to define and measure systematically, proxies are oftentimes used. For example, per-capita expenditure on education can be used as a proxy. Societies

[30] Perhaps the best examples are the U.S., Japan and Germany, all of which went from industrial laggards to leaders as a result of government policy.

that invest heavily in education value knowledge more than those that do not. Another possible proxy would be a measure of religious and/or political freedom, the argument being that societies (regions/countries) that accommodate/tolerate different beliefs, are tolerant of differences are more likely to be open to new ways of looking at things—in short, more open to novelty.[31]

A related proxy is the nature of the relevant R&D institutions. For example, is R&D organized hierarchically where decisions regarding research programs are taken by majority rule (or by a director) or is it organized along collegial/competitive lines where individual scientists/scholars enjoy considerably more “intellectual freedom?" In many regards, this is analogous to religious freedom. Highly rigid (hierarchical) research environments are analogous to monotheistic cultures, while more collegial/competitive environments are analogous to more tolerant, polytheistic cultures (Beaudreau 1989).

Table 7 presents a non-exhaustive list of vertical comparative advantage policy tools, ranging from education, R&D, to tax policy. Given the existence of two types of advantages, there are two types of tools, namely those aimed at structural vertical comparative advantage and those aimed at affecting arbitrage vertical comparative advantage. Structural vertical comparative advantages have the advantage of being more permanent. An arbitrage vertical comparative advantage can, given the mobility of capital and labor, be ephemeral—here today, gone tomorrow. Tax holidays will attract capital; however, it is not clear that the resulting advantage will be permanent, unless of course it can generate some form of localization-specific knowledge which, over the long run, would give rise to a structural vertical comparative advantage. Likewise, immigration and/or high birth rates may result in an arbitrage vertical comparative advantage; however, labor market conditions abroad may evolve in such a way so as to eliminate it.

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[31] Beaudreau (1989) empirically demonstrated that R&D content in international trade is an increasing function of a number of cultural values, including expenditure on education, number of book titles published, and political and religious freedom.

Table 7: Vertical Comparative Advantage Policy Tools.

VCA	Type	Tools
Knowledge Advantage	Structural	Education, R&D, Arts, Culture
Resource Advantage	Structural	Exploration, Sustainable Development
Labor Advantage	Arbitrage	Immigration, Fertility, Human Capital
Capital Advantage	Arbitrage	Tax Policy

Of the policy tools enumerated in Table 7, education and R&D are by far the most utilized. Whereas prior to the 1980's government policy focused on stabilization (Keynesian), since, governments have sought to foster the creation of knowledge with two goals in mind, namely increasing overall growth and generating comparative advantage (OECD 2007). As growth is assumed to be increasing in exports, it stands to reason that countries will want to invest massively in knowledge. Which is precisely what we observe. Governments, ranging from federal to state to municipal have, over the course of the past two decades, adopted policies aimed at generating structural vertical comparative advantages for their city/state/country.

Another important policy implication of our analysis pertains to welfare analysis. In the majority of cases, government-sponsored investment in education and R&D is motivated by a number of considerations, the most important of which is job and wealth creation. For example, the government of Brazil has invested heavily in its aeronautics industry by way of subsidies, loans and tax breaks for *Embraer*, its premier multinational. However, given the spatially diffuse nature of value chains (i.e. global value chains), it is by no means clear that the creation of a structural vertical comparative advantage will confer wealth upon the region/country. As we have shown, Stage 1 and Stage 2 in our model are completely independent. Regions/countries that develop VBVCs are not necessarily those that will produce the corresponding goods and services. According to John D. Pepper, former chairman of the board of Proctor and Gamble:

> I will start by discussing the importance of global innovation

> leadership. In our businesses, innovation leadership, not just in the U.S. but globally, is vital to building market leadership and a strong economic position here in the United States. Why? There are two reasons. First, there are major scale advantages that come from being global. We're able to purchase raw and packaging materials from the best and most capable global suppliers. This not only lowers costs but permits suppliers to invest in their own discovery research that can lead to stronger product innovation. Probably even more importantly, global R&D capability gives us access to leading-edge scientific developments, technologies, and new ideas, wherever they exist. Our competitors scour the world for the best ideas. We must do the same; indeed we must be ahead of them. Otherwise, we will lose our leadership position, not only abroad, but also here in America. This I think we'd all agree is not debatable. (Pepper, 1999, 1)

Summary and Conclusions

Finding the HOH version of the FPH to be theoretically and empirically incomplete, especially with regard to technology (endogenous technological change) and institutions (the presence of geographically-dispersed value chains, immobile factor inputs), this paper set out to rehabilitate the factor proportions hypothesis of trade, be it regional or international. The gist is simple and straightforward, and turns around a fundamental oversight in Eli Heckscher and Bertil Ohlin's pioneering work, namely the absence of endogenous technology and multinational firms. What is surprising is the fact that the 1910s, 1920s and 1930s were decades of massive technological change, which altered trade patters significantly, if not paradigmingly. Once sufficient allowance is made for endogenous technology (specifically via a country's endowment of VBVCs) and for spatially-dispersed value chains, the predictions of the FPH are consistent with the data. Also, the Leontief Paradox is "resolved" as are the conflicting and conflicted findings of Harry Bowen, Edward Leamer and Leo Sveikauskas, and Neil Foster, Robert Stehrer and Gaaitzen de Vries.

The resulting General Factor Proportions Hypothesis upholds the view that factor endowments are the basis of trade. It is sufficiently general to allow for both mobile and immobile factors. In its most realistic form, knowledge (read: knowledge generation) and natural resources are viewed as being immobile while capital and labor are mobile, thus giving rise to two types of vertical comparative advantage (VCA), namely structural and arbitrage. As such, regions/countries can be ranked according to their factor proportions-based vertical comparative advantages. Moreover, governments can through the judicious use of policy affect their VCAs. As was shown, the large majority of trade policy measures (i.e. policy instruments) used today are consistent with the predictions and recommendations of the model.

Further, the General Factor Proportions Hypothesis as developed here (*i*) endogenizes Ricardian trade theory (*ii*) incorporates the concept of value chain (value bush), and (*iii*) allows for the presence of multinational firms and value chains. More specifically, Ricardian technology-based comparative advantage is modeled in factor-proportions terms. Regions and countries that are well-endowed with innovative entrepreneurs/managers will generate more product and process-based VBACs resulting in a Ricardian vertical comparative advantage. Unlike traditional approaches that are based on simple neoclassical production functions, this paper innovates by incorporating the concept of value chain, a key concept in this the era of globalized production, as well as the multinational firm. Altogether, this makes for a more realistic, not to mention compelling, view of interregional and international trade, one that is consilient with the related fields of business strategy, the multinational firm, and process engineering.

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Appendix

Factor Content of Trade

Country	E/L1978	R&D1978	K/L1978
Afghanistan	1.553326	0.139296	1.734469
Algeria	1.197633	0.701748	0.694112
Argentina	0.254041	0.925864	0.685999
Australia	0.316109	1.204025	1.309904
Austria	1.059126	0.597491	0.644605
Bangladesh	0.225636	0.290352	0.228108
Belgium-Luxembourg	1.087999	0.806263	0.836120
Belize	0.237553	0.545203	0.294494
Benin	0.227708	0.962845	0.542161
Bolivia	0.204072	1.723181	2.327743
Brazil	0.859222	0.414197	0.357569
British Virgin Islands	0.705558	0.488519	0.416753
Bulgaria	0.705711	0.706609	0.521595
Burma	0.195572	0.886165	0.554160
Burundi	0.213169	0.568461	0.278484
Canada	0.76983	1.084426	1.149509
Central African Rep.	0.311729	0.739121	0.594202
Chad	0.286149	0.482828	0.43355
Chile	0.36758	0.845901	1.25567
Colombia	0.276779	0.734514	0.441065
Cook Islands	0.421048	0.229505	0.799291
Costa Rica	0.476247	0.753534	0.492964
Cuba	0.222552	0.470132	0.246174
Cyprus	0.599331	0.641494	0.531398
Czechoslovakia	1.353644	0.530379	0.49622
Denmark	1.059866	0.470512	0.368508
Dominica	0.467396	0.971854	0.736985
Dominical Republic	0.319279	0.521154	0.379522
Ecuador	0.18188	2.784701	2.746503
Egypt	0.284416	2.774566	3.4184
El Salvador	0.439627	0.544251	0.435541
Ethiopia	0.186352	0.761277	0.494657
Fiji	0.323281	0.888106	0.704338
Finland	0.808155	0.533692	0.573808
France	1.247571	0.580828	0.541558
Germany	1.620924	0.593447	0.585385
Ghana	0.181388	0.594074	0.386978
Greece	0.487114	0.743621	0.73526

Guatemala	0.511509	0.469705	0.352328
Honduras	0.236993	0.619849	0.394077
Haiti	0.620852	0.723698	0.68333
Hong Kong	1.148382	0.540261	0.50828
Hungary	1.080037	0.878956	0.779493
Iceland	0.209668	0.728023	0.485188
India	0.694228	0.30401	0.250187
Indonesia	0.312776	1.989717	2.00542
Iraq	0.227811	4.819997	5.314853
Ireland	1.006058	0.706071	0.597347
Israel	1.089991	0.561809	0.5155
Italy	1.368548	0.480249	0.461098
Ivory Coast	0.333827	0.634888	0.451045
Jamaica	0.4918	0.660255	0.964197
Japan	3.19064	0.251333	0.237154
Congo	0.292854	1.28692	1.150984
Korea	1.051003	0.36138	0.358363
Kuwait	0.381894	5.065906	6.245257
Liberia	0.450793	0.659097	1.006164
Libya	0.257064	5.623624	7.333882
Malawi	0.210086	0.633294	0.299503
Malaysia	0.528576	1.152944	1.163494
Malta	0.846098	0.525571	0.495602
Mauritania	0.20079	1.650788	2.119897
Mauritius	1.000297	1.000354	1.000349
Mexico	0.298141	3.71502	4.06012
Morocco	0.707574	0.788365	0.787996
Nepal	0.193914	0.375939	0.25636
Netherlands	1.042038	1.059349	1.052346
Nicaragua	0.153623	1.048262	0.870926
Nigeria	0.238894	3.960244	4.471093
Norway	0.551915	2.04623	2.198988
Pakistan	0.370322	0.288618	0.27458
Panama	0.807335	0.619838	0.243969
Papua New Guinea	0.284298	0.672894	0.369644
Paraguay	0.447954	0.729629	0.487748
Peru	0.415777	1.501802	1.632591
Philippines	0.382155	0.458245	0.42437
Poland	1.311398	0.72212	0.725683
Portugal	0.696748	0.522928	0.508487
Rumania	0.82163	0.932579	0.79325
Rwanda	0.21298	0.84063	0.558451
Saudi Arabia	0.257615	5.649036	6.828708
Senegal	0.587175	1.234513	1.248459
Seychelles	0.274075	0.588776	0.289645
Sierra Leone	0.59882	1.212409	2.094001
Singapore	0.980487	1.000922	0.992834

South Africa	0.235586	1.478172	1.779684
Spain	0.987262	0.480634	0.465698
Sri Lanka	0.367437	0.736497	0.605077
Saint Vincent	0.219321	0.711801	0.393523
Sudan	0.560842	0.671742	0.265724
Sweden	1.165211	0.543956	0.561291
Switzerland	1.523309	0.753772	0.753573
Syrian Arab Republic	0.350560	1.882503	1.884686
Thailand	0.392818	0.452186	0.304141
Togo	0.291439	0.903547	0.549882
Tonga	0.254268	0.676087	0.349865
Trinidad and Tobago	0.476716	1.866536	1.941574
Turkey	0.369368	0.330624	0.222932
Uganda	0.182421	0.514712	0.266515
USSR	0.941911	1.838774	2.376494
Cameroon	0.234172	1.403889	1.254252
Tanzania	0.191221	0.583639	0.387587
U.S.	1.367647	0.551994	0.480474
Uruguay	0.480176	0.284985	0.182436
U.K.	1.175899	1.145269	1.160734
Venezuela	0.245011	4.312668	5.016976
Yugoslavia	1.043607	0.517408	0.486514
Zaire	0.304321	1.095989	1.522621
Zambia	0.340112	0.835421	1.321061
Zimbabwe	0.245448	0.632634	0.589603

Source : Beaudreau (2004), 97.