



Australian
National
University

Working Papers in Trade and Development

Global production networks and the evolution of industrial capabilities: Does production sharing warp the Product Space?

Russell Thomson¹ and Prema-chandra Athukorala²

1. Centre for Transformative Innovation, Swinburne University of Technology, Melbourne, Australia. russellthomson@swinburne.edu.au
2. Arndt-Corden Department of Economics, Crawford School of Public Policy, Australian National University. prema-chandra.athukorala@anu.edu.au

May 2019

Working Paper 2019/7

Arndt-Corden Department of Economics
Crawford School of Public Policy
ANU College of Asia and the Pacific

This Working Paper series provides a vehicle for preliminary circulation of research results in the fields of economic development and international trade. The series is intended to stimulate discussion and critical comment. Staff and visitors in any part of the Australian National University are encouraged to contribute. To facilitate prompt distribution, papers are screened, but not formally refereed.

Copies are available at <https://acde.crawford.anu.edu.au/acde-research/working-papers-trade-and-development>.

Global production networks and the evolution of industrial capabilities: Does production sharing warp the Product Space?

Russell Thomson¹ and Prema-chandra Athukorala²

1. Centre for Transformative Innovation, Swinburne University of Technology,
Melbourne, Australia. russellthomson@swinburne.edu.au

2. Arndt-Corden Department of Economics, Crawford School of Public Policy,
Australian National University. prema-chandra.athukorala@anu.edu.au

Abstract: Do production capabilities of countries evolve from existing capabilities or emerge *de novo*? The Product Space approach developed by Hidalgo, Klinger, Barabási & Hausmann (2007) postulates that a country's existing industrial structure largely determines its opportunities for industrial upgrading. However, this is difficult to reconcile with the export dynamism of many developing countries such as Thailand, Malaysia, Costa Rica and Vietnam that transformed from primary commodity dependence to exporters of dynamic manufactured products. In each of these cases, global production sharing facilitated industrial transition. In this paper, we advance the Product Space approach to accommodate the role of global production sharing. Using a newly constructed multi-country dataset of manufacturing exports that distinguishes between trade within global production networks and traditional horizontal trade, we find that that existing industrial structure has smaller impact, but trade openness has greater impact, on industrial upgrading within vertically integrated global industries.

Key word: industrialization, product space, global production sharing, fragmentation

Jel codes: L60, O14, F14

Global production networks and the evolution of industrial capabilities:

Does production sharing warp the Product Space?

1. INTRODUCTION

How do countries acquire new production capabilities? Do these evolve from existing capabilities or emerge *de novo* through the interplay of countries' domestic policy context with ongoing process of global industrial transformation? The product space framework developed by Hidalgo, Klinger, Barabási & Hausmann (2007) (henceforth referred to as HKBH-2007) holds that a country's existing industrial structure largely determines their opportunities for technological upgrading and economic development. This postulate cautions of possible development 'dead ends' for countries that do not have a manufacturing base to begin with, in particular primary producing countries. This is difficult to reconcile with stylised features of export dynamism of some developing countries. Singapore, for example, successfully transformed from an economy based on *entrepôt* trade to specialise in electronics (Lee 2000). Ireland, Thailand, Malaysia, Mexico and, more recently, Costa Rica and Vietnam transformed from primary commodity dependence to exporters of dynamic manufactured products such as electronics components, hard disk drives and assembled automobiles (Ruwane and Gorg 2001, MIGA 2006, Rodriguez-Clare 2001, Athukorala and Kohpaiboon 2014, Freund and Moran 2017). In each of these cases, industrial transformation was facilitated by global production sharing, which we define here as the disintegration/splitting of the production process across

national boundaries within vertically integrated global industries.¹ To our knowledge, none of the vast literature spawned by HKBH-2007² consider the implication of global production sharing on technological upgrading, reflecting instead the traditional trade theory assumption that countries trade in products that are produced from start to finish within a given country.

Following Helleiner (1973)³, Fujita and Hamaguchi (2012) and Ando and Kimura (2010), we argue that global production sharing introduces an important nuance to the staged theory of industrial development articulated by the product space framework as well as earlier staged models of development, the Flying Geese paradigm (Akamatus 1962) and the stages approach to comparative advantage (Balassa 1979). These theories are rooted in the assumption that international trade is an exchange of goods produced entirely within given national boundaries with factors of production remaining locked in within national boundaries. Under this assumption of ‘horizontal specialisation’, a country’s ability to move from one product to another depends on reallocation of its existing resource endowment. The nature and speed of the process of industrial transformation, therefore, reflects the ease with which resources can be redeployed to new product lines. Similarities between production processes already mastered and the prospective new production activities play a pivotal role in the process of industrial upgrading.

Global production sharing poses a fundamental challenge to this view because it opens up opportunities for countries to specialise in different stages or tasks in the production process of vertically integrated global industries (Antras 2016, Jones 2000, Jones and Kierzkowski

¹ Alternative terms used in the recent international trade literature to describe this phenomenon include global production sharing, international production fragmentation, intra-process trade, vertical specialization, slicing the value chain, and offshoring.

² see e.g., Hausman *et al.* 2014; Hidalgo *et al.* 2018 for recent reviews

³ In a seminar paper on manufacturing export from developing countries, Helleiner (1973, p. 43) infers that ‘The possibility of overseas component manufacture and middle-stage processing within international industries rather knocks the bottom out of any stage theory of the development of industrialisation’.

2001, Grossman and Rossi-Hansberg 2006, Helpman 2011). For instance, a country need not set up a motor vehicle plant to benefit from the growth of the automobile industry: it is enough to be competitive in the production of a single part. In order to specialise in specific tasks/slices in the production process in line with their relative cost advantage, it is not necessary to redeploy *local* factors of production because factors of production— including capital, plant and equipment, technology, skills and managerial capability are mobile within global production networks. Thus, with preconditions relating to political stability and trade and investment liberalisation, even primary producing countries have the potential to join production networks; the existing industrial capabilities are less important in industrialisation through global production sharing than underlying business climate. Trade based on global production sharing, that is cross border exchange of parts and components and final assembly within global production networks (‘GPN’ trade for short), now constitutes over a half of global merchandise trade (Athukorala 2014).

In this paper, we confront the product space with the realities of modern international trade in this era of global production sharing. We use a new dataset covering exports of 130 countries over the period 1986-2007, compiled at the five-digit level of the Standard International Trade Classification (SITC Rev 3), which permits distinguishing between GPN trade and trade in goods which are produced from start to finish in the one country (‘horizontal trade’, or non-GPN trade).⁴ We investigate the role of existing industrial structure in determining the evolution of export capabilities, allowing for parameter heterogeneity between GPN trade and horizontal trade. Our findings are consistent with the inference of HKBH-2007, up to a point. We find that export performance in neighbouring ‘proximate’ products is

⁴ Data prior to 1986 is not available in SITC Revision 3, which reports trade at a disaggregated level required for delineating trade in parts and components..

associated with an increase in exports and also an increase in the probability of acquiring comparative advantage in a given product. However, we find that the existing industrial structure of a country has a substantially lesser impact on industrial upgrading within vertically integrated global industries than in the case of traditional horizontal industries. Complementing this finding, we also find that trade openness is more important in facilitating upgrading within global production networks than traditional horizontal industries. The upshot is that, in this era of global production sharing, the domestic policy context that facilitates specialization in a specific task/slice in the production process in line with relative cost advantage, seems to play an important role over and above the existing industrial structure, in enabling a country to acquiring new capabilities within the product space.

2. METHODOLOGY

We examine whether existing capabilities in ‘related’ products are an important prerequisite for the acquisition of new production capabilities, allowing for heterogeneous effect of trade within global production networks and conventional horizontal goods. We do this within the hugely influential analytical framework proposed by HKBH-2007. We outline the approach below before discussing potential limitations including relating to global production sharing. In applying the method, we make the minimum adaptation required to examining the sensitivity of their inferences to global production sharing, which is our primary goal. HKBH-2007 postulate that the frequency with which two products tend to be co-exported provides a good measure of the ease with which a country can acquire capability to produce one good, given that it already produces the other. They call the measure ‘proximity’. Their measure of ‘proximity’ is based on the assumption that products tend to be produced in tandem relying on similar institutions, infrastructure, factor endowment, technology or otherwise complementary

production processes. HKBH-2007 further propose that a country's propensity to acquire new production capability depends on both the number of proximate products already produced, and also exactly how proximate (related) those production processes are to the potential new capability. To capture this, they define a summary measure termed 'density', which reflects the average proximity of products already exported by the country to the potential new capability. HKBH-2007 argue that this measure indicates the overall structural conduciveness to developing capability in each possible new product.

Proximity (denoted by ϕ_{ij}) is defined as the minimum pairwise conditional probability that a country with a revealed comparative advantage in a given product has revealed comparative advantage in another:

$$\phi_{ij} = \min\{P(RCAx_i|RCAx_j), (RCAx_j|RCAx_i)\} \quad (1)$$

where $RCAx_i$ is the revealed comparative advantage index (Balassa 1965), which is measured by the share of a given industry in the country's total exports relative to the industry's share in total world exports. That is,

$$RCA_i = \frac{x(c,i)/\sum_i x(c,i)}{\sum_c x(c,i)/\sum_{c,i} x(c,i)} \quad (2)$$

where, $x(c,i)$ denotes country c 's exports of commodity i , $\sum_c x(c,i)$ is world exports of commodity i , $\sum_i x(c,i)$ is country c 's total exports, and $\sum_{c,i} x(c,i)$ is total world exports. If this index is less than unity, this is interpreted to mean that the country is at a comparative *disadvantage* in the trade of the production in question. On the other hand, if the index exceeds unity, this is taken to indicate that the country has a revealed comparative advantage in the

industry.⁵ Using the minimum conditional probability (rather than simply using $P(RCAx_i|RCAx_j)$ or $P(RCAj|RCAx_i)$) avoids measurement issue which arises for products exported by very few countries. In the extreme case of a single country accounting for the entire world export of a given product, the conditional probability of exporting any other good by that country reflects ‘the peculiarity of the country and not the similarity of the goods’ (Hausman and Klinger 2006, P10).

The *density* of product j in country k is defined as:

$$\omega_j^k = \frac{\sum_i x_i \phi_{ij}}{\sum_i \phi_{ij}} \quad (3)$$

where $x_i = 1$ if $RCA_{ki} > 1$

The numerator in Equation 3 is the sum of proximity to products which the country already has an RCA in. The denominator is the sum over proximity between the subject product and every other product and therefore reflects how central the subject product is in the product space. It reflects the proximity of a country’s existing industrial capabilities to the subject product. A high density means that the country has a comparative advantage in many products closely surrounding product j .

⁵ We are mindful of well-known limitations of the RCA index as a measure of industrial capability (revealed comparative advantage). For instance, Balassa (1965) presented the index with the important caveat that that it meaningfully reflects production capabilities only in the absence of trade policy distortions, in particular quantitative restrictions. The importance of the caveat is evident from evolving patterns of trade. For example, a number of relatively high-wage developing countries, such as Fiji, the Maldives and some African countries ‘revealed’ comparative advantage in highly cost sensitive readymade garments sector under assured market accesses during the era of the Multi-Fibre Arrangement (MFA), and garment exports from these countries have dramatically declined or even disappeared after the MFA was abolished with effect from 2005. For a fuller discussion of the properties and limitations of the index, see Yeats (1985) and Donges and Riedel (1977). Regardless of the limitations, we use HABH-2007 methodology at face value: our purpose here is to examine the sensitivity of their inferences to the presence of global production sharing.

Hausmann and Klinger (2006) evaluate the applicability of the product space approach for predicting the evolution of industrial capacities by modelling the acquisition of new RCA on the density in the host country. Their estimation proceeds using both OLS and Probit. Causal inference relies on the absence of confounding factors between density and RCA. HKBH-2007 provide additional correlation-based evidence that density is typically associated with a country acquiring RCA in a new product in which it did not previously have an RCA, which they define as a ‘transition’.⁶ They calculate the Product Space using patterns of exports between 1998 and 2000 which are used to explain capabilities acquired between 1990 and 1995. Inference of causality may be considered somewhat diminished by the fact that transitions ostensibly caused by proximity are included in their calculation of the proximities.

The HKBH-2007 measure of proximity (and therefore density) has the advantage of capturing all possible mechanisms that may cause a pair of products to be commonly exported in tandem. However, bundling together all possible underlying factors comes with a cost. Patterns of exporting among the countries considered reflect both systematic and idiosyncratic factors. Systematic factors may include intrinsic technological similarities between the production processes (such as common inputs, similar machines and skill inputs) or shared policy requirements (such as low trade barriers). As in the case of assembly in consumer electronics, common inputs or technologies may matter only where other binding conditions are met (such as the size of the labour pool). These different types of factors have quite different implications for the predictive power – and therefore policy utility – of measure of proximity between products.

⁶ Following HKBH-2007 we use the term transition to mean the event of a country acquiring production capability, which the country did not previously have. We do not distinguish industrial production and primary products in this definition. Arguably, in some instances, such an event may be more accurately described as an industrial upgrading.

Density is high if the country produces ‘proximate’ products. By construction, density is correlated with all attributes of countries (or factors in countries) that produce both products simultaneously – regardless of whether or not those factors play any role in the simultaneous (or sequential) establishment and or maintenance of comparative advantage in the two products. Among these are factors that are acquired as a by-product of achieving mastery in producing the proximate product. These include easily transferable skills, relevant technology, or adaptable productive equipment. An example might be that firms producing tents for camping may have equipment that can easily be used to make sails for sailing boats. A second group of factors are shared success factors that are endowed or acquired independently of production of the proximate product. These include fixed endowments, such as size, location, natural resources, language and historic ties with neighbouring countries as well as policy setting like trade openness, education and training and infrastructure.⁷ The third group of factors are noise; idiosyncratic attributes of those countries, which have played no systematic role in the establishment of productive capacity in either subject or proximate good.

The inference reflecting spillovers between producing proximate and subject products are of most policy relevance. Inference drawn on the second group of variables – factors endowed or acquired independently of production of the proximate product – are of considerably less value to policy. In this case, there is nothing about the pre-conditions, which require capability in proximate products. Targeting ‘proximate’ capabilities would be a poor substitute for policy focused on the underlying shared driver of industrial success. Selective supply side intervention aimed at developing capacity in proximate products can run counter

⁷ Factors such as high wages are a grey area here.

to a goal of developing production capability in the second via trade and investment liberalisation.

It is important to remain mindful of the different underlying sources of correlation between exporting different products in developing an appropriate empirical approach to test the product space theory. We begin by following Hausmann and Klinger (2006) who evaluate the predictive power of existing density on the evolution of comparative advantage. We view the predictive power of existing density as an informal test of the importance of both Type 1 and Type 2 factors; the combined predictive power of both factors which are causally related and those which are not causally related but that are indicators that local conditions are conducive to establishing production expertise in the field.

Going further, we examine the explanatory power of density acquired over the previous five-year period. By mitigating time invariant common factors, using acquired density helps isolate causal factors, we ask whether establishing productive capabilities in proximate products has contributed to comparative advantage. Moreover, using density acquired over the previous five-year period speaks to the impact of changes in structure actually achieved by nations in the sample in practice.

Following HKBH-2007, and Hausman and Klinger (2006) we first model countries' acquisition of revealed comparative advantage in a new product. HKBH-2007 term such an event a 'Transition', defined as the acquisition of RCA for a product in which the country did not previously have an RCA. Since our main interest is in the differential effect of existing structure on the acquisition export capabilities for goods produced within global production networks. We adopt the quasi difference-in-difference framework proposed by Rajan and Zingales (1998). Specifically, we model the acquisition of RCA in period t for countries which did not have RCA in period $t-5$.

$$RCA_{jkt} = \mu \text{Ln}(\omega_{jkt-5}) + \theta [\text{Ln}(\omega_{jkt-5}) \times T] + C_j \times \lambda_t + \mu_j + \varepsilon_{jkt} \quad (4)$$

where ω is density, which captures how conducive the existing industrial structure is to the establishment of export capabilities in product j . T is a dummy variable indicating whether the product produced as part of a global production network. In subsequent estimations, we consider differential impact over parts and components and trade in final assembled goods (final goods produced through global production networks).

The equation is estimated with full set of country-by-year fixed effects as well as product fixed effects. The main form of confounding factors of concern are country by year effects. Most importantly, these include how many products the country already exports with a RCA – which is correlated with density by construction. These also include broad based policy reforms and variation in macroeconomic conditions, which change the dynamism of the economy and therefore the acquisition of multiple new production capabilities in a suite. The role of acquired density is tested by estimating the following equation:

$$RCA_{jkt} = \mu \Delta \text{Ln}(\omega_{jkt-5}) + \theta [\Delta \text{Ln}(\omega_{jkt-5}) \times T] + C_j \times \lambda_t + \mu_j + \varepsilon_{jkt} \quad (5)$$

We also investigate the determinants of comparative advantage using the more commonly adopted approach, modelling exports in product j from country k year t (see e.g., Nunn and Trefler (2013) for review). Focusing on countries that did not export the good in the previous period (since we are principally interested in the acquisition of new production capabilities)⁸ the estimating equation is given by:

$$\text{Ln}(y_{jkt}) = \mu \text{Ln}(\omega_{jkt-5}) + \theta [\text{Ln}(\omega_{jkt-5}) \times T] + C_j \times \lambda_t + \mu_j + \varepsilon_{jkt} \quad (6)$$

⁸ As a robustness check we re-estimated all models allowing for small amounts of exports in the initial period, which did not alter the results.

Finally, we extend the approach augmenting the models with measure of trade policy openness. To do this, we use data from the Economic Freedom of the World Index since it reflects a broad composite index of trade and investment openness and since it is available for the entire period of analysis.

3. DATA

We compiled export data over the period 1987-2007 from the UN *Comtrade* database at the 4-digit level of the Standard International Trade Classification (SITC, Revision 3) for 130 countries. ‘Mirror data’ rather than reporter country data are used since the former presumably has better coverage and accuracy: trade flows are generally closely verified by Customs agencies of importing countries to meet tariff regulations (Feenstra et al 2005).⁹ The focus of our analysis is on differences in the relationship between existing and future production capabilities between GPN and non-GPN products. Note that HKBH-2007 use data for the period 1962-2000 from Feenstra *et al.* (2005). Updating the time coverage has the additional advantage of covering trade patterns after China’s ascension to the WTO in 2001. We decided to use 2007 as the end point to avoid disruptions in trade flows in the aftermaths of the global financial crisis (2008-09).

Our principal point of departure from HKBH-2007 is in separating GPN trade (parts and components, and final assembly) from the standard trade data. Parts and components are delineated from the reported trade data based on product description at the five-digit product

⁹ Reporter country based data is ‘free on board’ meaning it includes only the value of product not insurance and freight costs. Mirror data (reported by importing country) is measured ‘cost insurance and freight (CIF). Yeats (cite) finds that CIF varies from FoB data by an average 10 percent, though the variation will depend on country’s location and shipping routes etc. The distortion arises particularly because the CIF markup will vary by commodity, typically freight costs represent a larger share of the CIF value of low value commodities relative to high value manufactures.

list of the Standard International Trade Classification, Revision 3 (SITC Rev 3). It is important to note that parts and components are a subset of intermediate goods. Unlike the standard intermediate inputs, such as iron and steel, industrial chemicals and coal, parts and components do not have reference prices, and are not sold on exchanges and are more demanding on the contractual environment (Nunn 2007, Hummels 2002). A distinguishing feature of parts and components is that they generally do not have a ‘commercial life’ on their own unless they are embodied in a final product. To identify all parts and components we begin with the full five-digit intermediate product list of the UN Broad Economy Classification (BECs) and carefully removed all standard intermediate goods based on the products category description. This process for identifying parts and components is detailed in Athukorala (2014)¹⁰

Five-digit categories are aggregated to four digit to conform to the level of product disaggregation used by HKBH-2007. To delineate final assembly, we first identify the product categories where network trade is heavily concentrated and then deduct trade in parts and components. Seven product categories are identified: office machines and automatic data processing machines (SITC 75), telecommunication and sound recording equipment (SITC 76), electrical machinery (SITC 77), road vehicles (SITC 78), other transport equipment (SITC 79), professional and scientific equipment (SITC 87) and photographic apparatus (SITC 88). The total value of trade in final assembled goods is the difference between the value of total trade of these categories and the value of total parts and components falling under these categories. It is reasonable to assume that these product categories contain virtually no products produced from start to finish in a given country (Krugman 2008). It is important to note that the estimates do not provide a perfect coverage of final assembly in world trade since outsourcing of final assembly does take place in various miscellaneous product categories such

¹⁰ The complete dataset and the list of parts and components are available on request.

as clothing, furniture, sporting goods, and leather products. It is not possible to delineate parts and components and assembled goods in reported trade in these product categories because they contain a significant (yet unknown) share of horizontal trade.

Summary statistics of the data set are given in Table 1. As noted previously, since the original HKBH-2007 analysis uses SITC Rev 2 and focuses on a different timeframe the data cannot be perfectly compared. However, we note that the summary statistics are very similar. For example, we calculate average density using HKBH-2007 data as 0.11 (as compared to 0.10 which we arrive at using the more recent data in Rev 3) and the mean RCA to be 0.09 (as compared with our 0.10)¹¹

4. RESULTS

We first calculate the proximity between each pair of commodities using equation (1). Our estimates of pairwise proximities are not strictly comparable with these of HKBH-2007 as the used data based on the ITC Rev. 2. However, the patterns suggest that the overall structure is very similar. As reported by HKBH-2007, the ‘product space’ is sparse, with many weak or negligible ties. The product space exhibits a tightly interconnected core of manufactured goods and a more sparsely connected periphery of primary products.

¹¹ These comparison summary statistics are calculated by us using HKBH’s dataset downloaded from <http://chidalgo.org/productspace/data.htm>

Table 1. Summary Statistics

Continuous Variables	Mean	Std. Dev.
Exports (\$USD '000s)	23,833	365,078
Density	0.10	0.08
Trade openness	5.91	1.90

Categorical variables	Proportion
Revealed Comparative Advantage	0.11
Transition (Acquired RCA)	0.04
Global Production Network Goods	0.30
Parts and Components	0.18
Final (assembled) Goods	0.12

N =183,494

Reported in Table 2 are the estimates of equation 4. Consistent with the original formulation of Hausman and Klinger (2006) the dependent variable is a binary indicator as to whether a revealed comparative advantage was acquired by that country in that product group conditional on them having initially had an RCA of 0. The focus here is on modelling the binary event of a shift to $RCA = 1$ from $RCA = 0$ over the five-year period. In each equation country by year fixed effects and industry fixed effects are included in order to account for general changes in industrial or trade policy on overall export performance. We apply a linear probability model here owing to the very intensive inclusion of fixed effects and the resulting concern of incidental parameter problem if we were to use a Probit. The LPM produces consistent estimates of the local average ‘treatment’ effect of density (Angrist and Krueger, 2001). The estimates reported here exclude developed countries (matured industrial economies)¹² since our focus is on industrial upgrading of ‘newcomers’.

The model in Column (1) of Table 2 shows that capability in ‘proximate’ products, as summarized by density, is associated with an increased probability that a country acquires an

¹² Classified based on the United nation’s *Standard Country Classification*.

RCA in the subject product. Note that due to the number of observations we highlight relationships significant at the 0.05-0.1 percent level. The equation augmented with the interacted term (column 2) shows that the predictive power of density is significantly weaker in the case of GPN goods. We note also that the coefficient on density for non-GPN goods is marginally higher than in column 1 where GPN and non-GPN goods are mixed together, suggesting the Product Space may be more impactful for these goods.

**Table 2. Product density and acquisition of revealed comparative advantage
(Dependent variable: RCA)**

	(1)	(2)	(3)	(4)
$Density_{t-5}$	0.0848*** (0.00276)	0.0875*** (0.00280)		
$Density_{t-5} \times GPN$		-0.00525*** (0.00104)		
$\Delta Density_{t-5}$			0.0180*** (0.00478)	0.0242*** (0.00490)
$\Delta Density_{t-5} \times GPN$				-0.0148*** (0.00254)
$Country \times Year FE$	Y	Y	Y	Y
$Industry FE$	Y	Y	Y	Y
Observations	183,494	183,494	117,371	117,371
R-squared	0.057	0.057	0.048	0.048

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05

We have argued previously that the margin of policy relevance is whether acquired industrial capabilities (as opposed to endowed capabilities) predict the promotion of comparative advantage in related products. The equation reported in Column (3) focuses on the relationship between product density acquired by a country over the previous half decade with its acquisition of RCA over the subsequent half decade. This specification has the added advantage of washing out the role of non-causal factors which co-exporters have in common, and those which cannot be acquired by a country hoping to promote industrial development. In column (4) the interaction term is included in the differenced setup. Note that the overall effect of density on GPN goods (the sum of the two coefficients) is not clearly distinguishable from

zero (joint F test suggests significance above 6 percent, which we consider low given the large number of observations). This result indicates that acquired density plays a small or negligible role in determining the acquisition of RCA for GPN goods.

Estimates of Equation 6 are presented in Table 3. The dependent variable is exports in logs. As in the previous results, country-year and industry fixed effects are included in the models. Column 1 shows that density is positively associated with growth in exports, with an elasticity coefficient of 56.8 percent. The equation reported in Column 2 includes the key interactive term, which isolates the differential explanatory power of density over GPN goods over non-GPN goods. The coefficient attached to it suggests that elasticity of export growth with respect to density is around 10 percentage points lower for GPN goods than horizontal goods.

Table 3 Product density and export performance (Dependent variable is exports in logs)

	(1)	(2)	(3)	(4)	(5)
$\ln(Density_{t-5})$	0.568*** (0.0353)	0.605*** (0.0357)			
$\ln(Density_{t-5}) \times GPN$		-0.106*** (0.0165)			
$\Delta \ln(Density_{t-5})$			0.232*** (0.0550)	0.288*** (0.0567)	0.403*** (0.0493)
$\Delta \ln(Density_{t-5}) \times GPN$				-0.146*** (0.0331)	-0.154*** (0.0274)
Country \times Year FE	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y
Observations	72,397	72,397	38,327	38,327	79,771
R-squared	0.285	0.285	0.239	0.239	0.431

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05

Column (3) shows the results to an analogous model of growth in exports but focusing on the relationship between product density acquired over the previous half decade with growth in exports over the subsequent half decade. The results suggest an elasticity of 28.9 percent. In

the equation in Column (4) we have augmented the model to identify any possible differential effect of density for GPN and non-GPN goods. The results suggest that export-density elasticity is 14.5 percentage point lower for GPN goods compared to non-GPN goods. Reported in Column 5 is the equation estimated after expanding the country coverage to countries which export a small or negligible amount initially (< \$100,000 USD). The idea here is that countries without industrial capability in a specific product can record non-zero exports for a range of reasons including re-export. The results are robust to this sample selection.

Table 4. Product density and evolution of revealed comparative advantage: Augmented models

	(1)	(2)	(3)	(4)
	Dependent variable: RCA = 1		Dependent variable: Ln(exports)	
$\ln(Density_{t-5})$	0.0875*** (0.00280)		0.604*** (0.0357)	
$\ln(Density_{t-5}) \times P\&C$	-0.00339** (0.00126)		-0.0211 (0.0201)	
$\ln(Density_{t-5}) \times FAG$	-0.00802*** (0.00144)		-0.194*** (0.0229)	
$\Delta \ln(Density_{t-5})$		0.0242*** (0.00490)		0.286*** (0.0567)
$\Delta \ln(Density_{t-5}) \times P\&C$		-0.0176*** (0.00293)		-0.0595 (0.0385)
$\Delta \ln(Density_{t-5}) \times FAG$		-0.0106** (0.00362)		-0.257*** (0.0487)
<i>Country</i> × Year FE	Y	Y	Y	Y
<i>Industry</i> FE	Y	Y	Y	Y
Observations	183,494	117,371	72,397	38,327
R-squared	0.057	0.048	0.286	0.239

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05

The model presented in Table 4 is augmented to allow for differential predictive power of density for different types of global production network goods: parts and components and final assembled goods. Column (1) shows a model of the acquisition of RCA for those country-industries which did not have an RCA five years previously, including density interacted with a dummy variable for the product being either “parts and components” (denoted as P&C) or

“final assembled goods” (denoted as FAG). Column 2 presents the same model but focusing on the explanatory power of acquired density (5-year differenced). In columns 3 and 4 we present analogous models for growth in exports. Overall, the results presented in table (4) suggest that density is even weaker predictor of future export performance for final assembled goods than of parts and components.

One of the reasons why we expect density to perform poorly in predicting export performance in GPN goods compared to non-GPN products is the many confounding factors which may be common to countries co-exporting GPN goods. One of these factors is trade and investment liberalization. As a preliminary step to investigating the role of trade and investment policy in promoting density, we included Fraser Institute’s Economic Freedom of the World indicator for ‘freedom to trade internationally’ as an interaction term in the various equations of export performance. This index provides a broad indicator of trade and investment liberalisation incorporating tariffs, regulatory and non-tariff barriers, black market exchange rate and controls over the movement of capital and people. For details of the measure see Frazer Institute (2017). Note that the model includes full country by year fixed effects which accounts for the average effect of national trade policy settings, which may vary by year. The approach allows us to examine whether trade openness has any differential impact on GPN goods. Additionally, since we expect trade openness to be more confounded with co-exporting GPN goods (and therefore density for GPN goods) we anticipate that when trade and investment policy are included in the model the explanatory power of density for these goods will be diminished.

Results are presented in Table 5. In Column (1) the base case analogous to that presented in column (2) in Table 2. In Column (2) this equation is augmented with the indicator of trade and investment liberalization. The coefficient on *Trade openness* × *GPN* is small but statistically significant at the 1 percent level, suggesting that trade policy matters more for GPN

goods compared to horizontal goods. The effect of density on export growth in related sectors is also smaller for GPN goods when trade openness is incorporated in the model. In Columns 3 and 4 we repeat the exercise using the export growth approach, again the coefficient of the trade policy interacted with GPN goods is negative and significant at the one percent level. Overall the result supports the specific role of trade policy in the promotion of exports in GPN goods.

Table 5 Product density and export performance: Augmented with policy variable

	Dependent variable: RCA = 1		Dependent variable: Ln(exports)	
	(1)	(2)	(3)	(4)
<i>Density</i> _{<i>t</i>-5}	0.0892*** (0.00316)	0.0892*** (0.00316)	0.589*** (0.0417)	0.592*** (0.0417)
<i>Density</i> _{<i>t</i>-5} × <i>GPN</i>	-0.00375** (0.00117)	-0.00536*** (0.00136)	-0.121*** (0.0205)	-0.138*** (0.0218)
<i>Trade openness</i> × <i>GPN</i>		0.00169** (0.000600)		0.0198* (0.00875)
<i>Country</i> × <i>Year FE</i>	Y	Y	Y	Y
<i>Industry FE</i>	Y	Y	Y	Y
Observations	143,198	143,198	52,881	52,881
R-squared	0.057	0.057	0.293	0.293

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05

Our hypothesis is that establishing export capabilities in GPN goods is less reliant on existing industrial structure owing to the mobility of factors of production of GPN goods in particular. To test this hypothesis, we examined whether GPN goods are disproportionately represented among transition events that were not well supported by existing industrial structure. To do this, we first estimate a parsimonious model of RCA on density, the results of which are given in column (1) of Table 2. We then forecast the likelihood that each industry which is RCA = 0 transitions to RCA = 1 according to the parsimonious model. Considering only those where a transition event actually took place, we divide these into groups according to the predicted likelihood of transition. In this way we are considering, respectively,

the type of products in the group of transitions which are among the 5, 10 and 25 percent most unlikely to have occurred according to the forecast.

The results are summarized in Table 6. This shows that GPN trade accounts for only 22 percent of all transitions in our dataset. However, for those transitions which are among the 5 percent least likely to have occurred (according to the forecast based on industrial structure alone) the share of GPN goods rises to 32 percent.

Table 6. GPN goods are disproportionately represented among ‘unlikely’ transitions

	Percentage GPN
All transitions:	22%
Prediction of transition in the least likely 50 percent	28%
Prediction of transition in the least likely 25 percent	29%
Prediction of transition in the least likely 10 percent	30%
Prediction of transition in the least likely 5 percent	32%

Summarizing across the results presented here, our data support the conclusion of HKBH-2007 and Hausmann and Klinger (2006) that export performance in neighbouring ‘proximate’ products is associated with an increase in exports and also an increase in the probability of acquiring RCA in a given product. However, we find that the explanatory power of the country’s existing industry structure is significantly diminished in the case of goods produced within global production networks. Proximate export capabilities acquired in the previous 5-year window provide very little if any explanatory power over the promotion of new export capabilities. This finding casts some doubt on the usefulness of the Product Space framework for policy guidance in promoting industrial production within global production networks. Finally, our data confirm that trade policy plays a role in the acquisition of comparative advantage in GPN goods over and above existing export structure.

5. CONCLUSION

The Product Space approach of HKBH-2007 postulates that a country's existing industrial structure largely determines their opportunities for technological upgrading and economic development and in particular, that primary producing countries can face highly limited opportunities for industrial upgrading. In this paper we have advanced the product space approach to accommodate the role of global production sharing – disintegration of the production process across national boundaries within vertically integrated global industries – in developing new industrial capabilities. Using a newly constructed multi-country panel dataset of manufacturing exports, we examined the extent to which exiting capabilities predict the evolution of national industrial capacities vis-à-vis policy features of developing economies in the context of unfolding opportunities for specialisation in specific task within vertically integrated global industries.

The findings suggest that production sharing opens up opportunities for countries to specialise in different stages or tasks in the production process of vertically integrated global industries in line with their relative cost advantage depending on the policy context and the overall investment climate. Thus, contrary to HKBH-2007) findings, 'large jumps' that generate subsequent structural transformation are possible on the path to industrialization independently of the existing industrial capabilities. The findings caution that selective supply side intervention aimed at developing capacity in proximate products may run counter to the goal of developing production capability via trade and investment liberalisation.

It is pertinent to close the paper with an important caveat. Given the nature of data availability, we had to use 1988 as the starting point of the time coverage of our statistical analysis. However, the spread of global production networks to developing countries, which

acted as the harbinger of industrial transformation is number of developing countries such as Singapore, Ireland, Malaysia, Thailand and Mexico (noted at the outset of the paper) started well before this year. We believe that the ideal data set that extended back to the late 1960s would have made much stronger the findings in support of the power of global production sharing in generating industrial transformation independently of the existing industrial bases.

References

- Akamatsu Kaname (1962), 'A historical pattern of economic growth in developing countries', *Journal of Developing Economies*, 1(1):3–25
- Ando, Mitsuyo & Fukunari Kimura (2010), 'The Spatial Patterns of Production and Distribution Networks in East Asia', in P. Athukorala (ed.), *The Rise of Asia: Trade and Investment in Global Perspective*, London: Routledge, 61-88.
- Antras, Pol (2016), *Global Production: Firms, Contracts, and Trade Structure*. Princeton University Press, Princeton NJ.
- Athukorala, Prema-chandra (2011), 'Production networks and trade patterns in East Asia: Regionalization or globalization?', *Asian Economic Papers*, 10(1), 65-95.
- Athukorala, Prema-chandra (2014), 'Global Production Sharing and Trade Patterns in East Asia', Chapter 13 in Inderjit Kaur and Nirvika Singh (eds), *Oxford Handbook of the Economics of the Pacific*, New York: Oxford University Press, 333-361.
- Athukorala, Prema-chandra (2014), 'Growing with global production sharing: The tale of Penang Export Hub, Malaysia', *Competition & Change*, 18(3), 221-245.

- Athukorala, Prema-chandra, and Archanun Kohpaiboon (2014), 'Global Production Sharing, Trade Patterns and Industrialization in Southeast Asia', in Ian Coxhead (Ed.), *Routledge Handbook of Southeast Asian Economies*, London: Routledge, 139-161.
- Balassa, Bela (1965), 'Trade Liberalisation and Revealed Comparative Advantage', *The Manchester School*, 33 (1), 99-123.
- Balassa, Bella (1979), 'The changing pattern of comparative advantage in manufactured goods', *Review of Economics and statistics* (1979), 259-266.
- Baldwin, Richard (2014), 'Trade and Industrialization after Globalization's Second Unbundling: How Building and Joining a Supply Chain are Different and why it Matters', in Robert C. Feenstra and Alan M. Taylor (eds) *Globalisation in an Age of Crisis: Multilateral Economic Cooperation in the Twenty-First Century*, Chicago: University of Chicago Press, 165-214
- Blundell, Richard & Stephen Bond (1998), 'Initial conditions and moment restrictions in dynamic panel data models', *Journal of Econometrics*, 87(1), 115–143.
- Donges, Juergen B., and James Riedel (1977), 'The expansion of manufactured exports in developing countries: An empirical assessment of supply and demand issues', *Review of World Economics* 113 (1), 58-87.
- Feenstra, Robert C. Richard E. Lipsey, H. Deng, A.C. Ma, and H. Mo (2005), 'World Trade Flows, 1962–2000', *National Bureau of Economic Research (NBER) Working Paper 11040*. Cambridge, MA: NBER.
- Freund, Caroline, and Theodore Moran (2017), 'Multinational Investors as Export Superstars: How Emerging-Market Governments Can Reshape Comparative Advantage.', *PIIE*

Working paper 17-1, Washington DC: Pearson Institute for International Economics
<https://piie.com/system/files/documents/wp17-1.pdf>

Fujita, Masahisa, and Nobuaki Hamaguchi (2012), 'Japan and economic integration in East Asia: post-disaster scenario', *The Annals of Regional Science*, 48(2), 485-500.

Grossman, Gene M., and Esteban Rossi-Hansberg (2006), 'The rise of offshoring: it's not wine for cloth anymore', in *The new economic geography: effects and policy implications*, Jackson Hole: Federal Reserve Bank of Kansas City, 59-102.

Hausmann, R., Hidalgo, C.A., Bustos, S., Coscia, M., Simoes, A. and Yildirim, M.A., 2014. *The atlas of economic complexity: Mapping paths to prosperity*. Mit Press.

Hausmann, Ricardo and B. Klinger (2006), 'Structural Transformation and Patterns of Comparative', *Centre for International Development Working Paper 128*, Cambridge, Mass: Harvard University. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=939646

Helleiner, Gerald K. (1973), 'Manufactured Exports from Less-Developed Countries and Multinational Firms', *Economic Journal*, 83(329), 21-47

Helpman, Elhanan (2011), *Understanding Global Trade*, Cambridge, Mass: Harvard University Press.

Hidalgo, C.A., Balland, P.A., Boschma, R., Delgado, M., Feldman, M., Frenken, K., Glaeser, E., He, C., Kogler, D.F., Morrison, A. and Neffke, F. (2018), The principle of relatedness. In *International Conference on Complex Systems* (pp. 451-457). Springer, Cham.

Hidalgo, Cesar A., Baily Klinger, Lazlo Barabási & Ricardo Hausmann, R. (2007), 'The product space conditions the development of nations', *Science*, 317(5837), 482-487.

Hummels, David (2002), 'Review of Fragmentation: *New production pattern in the world economy* by S.W. Arndt and H. Kierzkowski', *Journal of Economic Geography* 2, 368–369.

Jones, Ronald W. (2000), *Globalization and the theory of input trade*, Cambridge, Mas: MIT Press

Jones, Ronald W. and Henryk Kierzkowski (2001), 'A Framework for Fragmentation', in Steven Arndt and Henryk Kierzkowski (eds.), *Fragmentation: New Production Patterns in the World Economy*, Oxford: Oxford University Press, 17-34.

Kaminski, Bartlomiej, and Francis Ng (2005), 'Production disintegration and integration of Central Europe into global markets', *International Review of Economics & Finance* 14(3), 377-390.

Lee, Jaeho, and Jim Slater (2007), 'Dynamic capabilities, entrepreneurial rent-seeking and the investment development path: The case of Samsung', *Journal of International Management* 13 (3), 241-257.

Lee, Kuan Yew (2000), *From Third World to First: The Singapore Story: 1965-2000*(Memoirs of Lee Kuan Yew, Vol. 2. Singapore: Singapore Press Holding

MIGA (Multilateral Investment Guarantee Agency) (2006), *The impact of Intel in Costa Rica. Nine years after the decision to invest*, Washington, DC: MIGA/World Bank.

Nunn, Nathan (2007), 'Relationship-Specificity, Incomplete Contracts, and the Patterns of Trade', *Quarterly Journal of Economics*, 122(2), 569-600.

- Rajan, R.G. and Zingales, L., (1998). *Financial Dependence and Growth*. The American Economic Review, 88(3), pp.559-586.
- Rodriguez-Clare, Andres (2001), 'Cost Rica's Development Strategy Based on Human Capital and Technology: How it got there, the Impact of Intel, and Lessons for Other Countries', *Journal of Human Development*, 2(2), 311-324.
- Ruwane, Frances and Holger Gorg (2001), 'Globalization and Fragmentation: Evidence for the Electronics Industry in Ireland', in Seven Arndt and Henryk Kierzkowski (eds.), *Fragmentation: New Production Patterns in the World Economy*, Oxford: Oxford University Press, 17-34.
- Yeats, Alexander J. (1985), 'On the appropriate interpretation of the revealed comparative advantage index: implications of a methodology based on industry sector analysis'. *Review of World Economics* 121(1), 61-73.