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What Do We Really Know about Offshoring? Industries and Countries in Global Production Sharing

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Abstract

Theories of offshoring model how firms divide production stages across borders. Empirical work on the phenomenon has long been hampered by a paucity of cross-country data on specialization within industries. In standard trade sources, we observe flows of goods between countries at the product level, but not the specific tasks that countries perform in manufacturing these products. The literature has consequently developed an inventive arsenal of indirect measures of industry fragmentation. In this paper, I turn to data on trade in assembly services — a labor-intensive task that typically occurs at the end of the production chain — to document which industries and countries are engaged in this common form of global production sharing. Trade in assembly services is prominent in just a handful of sectors, including apparel, electronics, footwear, furniture, toys, and transportation equipment. Data for the United States — prior to the post-1980 growth in trade with developing countries — reveal that most offshoring industries are relatively intensive in the employment of very low-wage labor, exhibit relatively wide variation in the wages paid to their employees, and use capital relatively unintensively. These industries tend to be less likely to hire workers in occupations that are intensive in routine tasks. Offshoring thus appears to be most prominent in sectors for which firms have a strong incentive to divide production between high-wage and low-wage countries and in which the automation of routinized jobs offer few opportunities to reduce labor intensity. Countries that specialize in manufacturing tend to cycle through offshoring industries as they accumulate capital, starting out in apparel, footwear, and toys and later moving into electronics and electrical machinery. These industry dynamics are most pronounced in labor-abundant East Asia. They are not present in the resource-abundant countries that specialize in primary commodities.

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1 Introduction

Global production sharing is a well-documented feature of international trade (Feenstra and Hanson, 2003). As national economies become more integrated, firms fragment production across borders thereby expanding trade in intermediate inputs (Johnson and Noguera, 2012; Koopman, Wang and Wei, 2014) and creating vertical linkages in trade flows (Hummels, Ishi, and Yi, 2001). Economic reform in emerging economies, the proliferation of regional trade agreements, and improved global logistics have helped propel this expansion in offshoring (Subramanian and Kessler, 2013; Baldwin and Okubo, 2014). The growing complexity of trade patterns has captured attention among policy makers and scholars, alike.[1] Fragmentation changes relative factor demands and rewards, which affects income inequality worldwide (Feenstra and Hanson, 1999; Hummels, Jorgenson, Munch, and Xiang, 2014) and contributes to public unease about offshoring.[2] At the same time, production sharing can magnify the overall gains from trade (Caliendo and Parro, 2015).

In theory, offshoring entails dividing industry production stages across countries. In one class of models (Feenstra and Hanson, 1997; Grossman and Rossi-Hansberg, 2008), production of a final good requires a continuum of inputs or tasks, which vary in their factor intensity or in their ease of being performed abroad. Changes in total factor productivity or in the cost of offshoring affect the range of inputs or tasks that firms in the skill-abundant North choose to locate in the labor-abundant South. A related class of models assumes that within industries production occurs sequentially (Yi, 2003; Antras and Chor, 2013; Costinot, Vogel and Wang, 2013; Fally and Hillberry, 2014). The firm occupying the first link in the chain produces inputs which it ships to the firm occupying the second link which contributes its value added before shipping inputs on to firm number three and so forth until production of the final good is completed. Variation in country capabilities in coordinating manufacturing or in handling more complex production — where by assumption coordination costs and production complexity increase as one moves along the manufacturing chain — determines how the sequence of production stages is organized internationally.

While the precise theoretical mechanisms at work differ across models of offshoring, the frameworks share a prediction that when trade barriers are low enough individual countries will specialize in different stages of industry production. To apply these models empirically, one needs to know which industry tasks each country performs and the vertical position in industry production that

[1]Interest in offshoring arose relatively recently. Google Ngram shows scant mention of the term 'offshoring' before 2000, with its usage rising rapidly thereafter. Increasing references to 'offshoring' as a term of art may reflect its having partially supplanted 'outsourcing', which is currently used to refer to moving production outside of firm boundaries, without regard to whether international borders are crossed.

[2]See "Special Report: Outsourcing and Offshoring." *The Economist*, Jan. 19, 2013.

each country occupies. In practice, detailed data on input production, task specialization, or vertical orderings are often unobserved.[3] Standard practice in the literature is to infer the magnitude of global production sharing from indirect measures. Commonly used metrics include (i) the share of imported intermediate inputs in industry total material purchases (e.g., Feenstra and Hanson, 1999), (ii) the share of imports of inputs for further processing in firm total sales (e.g., Hanson, Mataloni, and Slaughter, 2005), (iii) the share of intra-firm trade in total industry trade (e.g., Antras and Chor, 2013), (iv) the share of foreign value added in industry gross exports (e.g., Johnson and Noguera, 2012), and (v) the "downstreamness" of production by a country in an industry (e.g., Fally and Hillberry, 2013; Chor, Manova, and Yu, 2014).

How reliable are these offshoring indicators? In truth, we do not know. Each measure imposes strong and difficult to verify assumptions about underlying input-output relationships. When an import arrives in a country its intended use as an intermediate input or as a final consumption good is typically not indicated. To measure offshoring using standard import data, one must assume that the proportional division of goods into inputs versus final consumables is the same for imports as it is for domestic production. Occasionally, trade data do identify which imports are to be used as intermediates (e.g., Hanson, Mataloni, and Slaughter, 2005; Antras, Forte, and Tintlenot, 2014; Hummels, Jorgenson, Munch, and Xiang, 2014). Yet, even in such cases we do not know whether the inputs that firms import replace intermediates that they previously produced domestically, as theory would require. The literature takes heart in the fact that indirect measures of offshoring are correlated with labor-market and other outcomes in the manner predicted by theory (Crino, 2009). Still, the precise dimensions of offshoring remain something of a mystery.

In this paper, I ask three question about global production sharing. First, in which industries does production sharing occur? Given the inadequacy of the data, I focus on one task whose offshoring can be readily observed: the assembly of inputs into final outputs for export. A growing literature uses export assembly to study offshoring (e.g., Feenstra, Hanson, and Swenson, 2000; Feenstra and Hanson, 2005; Swenson, 2005; Bergin, Feenstra, and Hanson, 2009; Koopman, Wang and Wei, 2012; Manova and Yu, 2012; Brandt and Morrow, 2013).[4] A limitation of these data is that they are only available for a few countries. Fortunately, these countries — China, Mexico and the United States, among them — are major players in global production networks. Further, there is strong overlap across countries in the industries that are most engaged in this form of global production sharing. Second, what are the characteristics of the industries that are intensive in the use of export assembly?

[3] Data on German multinational firms are an exception. See Becker and Muendler (2015).

[4] Fort (2014) studies the subcontracting of manufacturing services by U.S. plants. Her data indicate whether firms outsource specific tasks (and whether tasks are outsourced abroad) but do not identify the nature of these tasks.

Using industry data for the United States prior to its expansion of trade with low-wage countries, I examine the factor intensity and routine-task intensity of offshoring industries and compare these correlations with the predictions of theory. Third, which countries specialize in offshoring-intensive sectors? Following Hanson, Muendler, and Lind (2015), I use Balassa's (1965) measure of revealed comparative advantage to examine how country capabilities in offshoring industries evolve over time.

To begin with a note of caution about the data, export assembly is far from a complete measure of global production sharing. It excludes many types of trade in intermediate inputs. If one crudely organizes manufacturing into raw materials processing, parts and components production, and final assembly of parts and components, export assembly primarily captures trade in the third and final stage. Consider, for instance, the import of raw materials to produce intermediate inputs that will ultimately be used to manufacture an automobile, which will entail the conversion of imported iron ore into rolled steel, petroleum into plastic, or raw cotton into thread. The use of imported raw materials in production affects the measurement of trade flows, introducing double counting in goods that are later exported and creating discrepancies between gross trade and value added trade (Johnson and Noguera, 2012). But such trade probably isn't all that relevant for how the factory floor is organized, which is the concern of trade theory. When Dow Chemical shifts from purchasing oil from Texas to purchasing oil from Mexico, its plastics factories are unlikely to feel much change, nor are the auto factories that use Dow plastics. Export assembly also misses the subsequent stages of production in which rolled steel is stamped into auto bodies, plastic pellets are molded into the panels for a car dashboard, and cotton thread is woven into fabric for auto upholstery. The offshoring of production of parts and components likely does matter for what happens on the auto factory floor. I will capture global production sharing in parts and components only to the extent that firms offshore the assembly of these inputs. A countervailing advantage of using data on export assembly is that it occurs at the end of the production chain. The countries that specialize in export assembly will thus be the ones that dominate gross exports in a sector, making revealed comparative advantage a meaningful indicator of which countries specialize in assembly operations.

To preview the findings, in all three countries export assembly is concentrated in a handful of sectors, including apparel, electronics, footwear, furniture, toys, and transportation equipment. The presence of these industries on the list is hardly a surprise. Familiar examples of offshoring include Nike, which designs shoes in Oregon and subcontracts production to factories in Vietnam; Intel, which designs chips in the United States, produces integrated circuits in Taiwan, and assembles and tests its chips in the Philippines; and Samsung, which designs flat screen TVs in Korea, contracts parts production to local suppliers, and has the TVs assembled in China. What is perhaps more surprising is that little export assembly seems to happen outside these industries.

The Nike, Intel, and Samsung examples share three important features that are indicative of the industry characteristics that make production amenable to offshoring. First, factor intensity varies across production stages (Feenstra and Hanson, 1997; Costinot and Vogel, 2010). R&D is skill intensive, the production of parts and components is often capital intensive, and the processing and assembly of components into final products is labor intensive. Second, the technology of the distinct production stages permits their physical separation (Grossman and Rossi-Hansberg, 2008). Designing Nike shoes, Intel chips, or Samsung TVs can occur far from the production of leather shoe pieces, silicon wafers, or LCD displays, which in turn can be physically separate from the assembly of these components into final goods. Third, communication and transport costs are sufficiently low that firms are not deterred from locating design, parts production, and assembly in countries far from each other or from the location of final consumers.[5]

When we search for evidence of these characteristics in offshoring industries, it is variation in skill and capital intensity that shows up the most strongly. Offshoring sectors tend to be ones that pay low-wage workers relatively low wages, consistent with high average intensity in the usage of low-skilled labor, and that exhibit relatively high variation in wages across workers within the sector, consistent with high variation in skill intensity across production stages. I find no evidence that more routine-task-intensive sectors are more prone engage in the offshoring of final assembly.[6]

The importance of skill intensity for export assembly is also apparent in the evolution of revealed comparative advantage in offshoring sectors. Labor-abundant countries cycle through offshoring industries as they develop, frequently starting out in apparel, footwear, and toys. They later tend to move into electronics and electrical machinery. Specialization in transportation equipment tends to be more idiosyncratic, with relatively few countries making the transition to this sector. These patterns of industry dynamics — from apparel and footwear to electronics and machinery — are strongest in labor-abundant East Asia. They are not present in resource-abundant countries that specialize in exporting primary commodities.

What do these results imply for where research on offshoring should be headed? First, offshoring, at least in the form of moving assembly operations abroad, appears to be an unattractive strategy

[5]Note that in these examples offshoring doesn't define the boundary of the firm. Nike offshores production to arms-length suppliers, whereas Intel has historically kept chip production in facilities that it owns. Offshoring, then, is more about geography than about ownership (Antras, Forte, and Tintlenot, 2014).

[6]Using data on German multinationals, Becker, Ekholm and Muendler (2013) find a positive correlation between offshoring by MNEs (measured as the share of worldwide employment in a German multinational that occurs outside Germany) and employment in German MNEs in occupations that are intensive in non-routine and interactive tasks. In related work, Costinot, Oldenski, and Rauch (2011) examine the association between industry task intensity and the share of intra-firm trade in total firm trade.

in a large portion of manufacturing. One possibility is that in many industries technology constrains physically separating many production tasks. There would be value in knowing more about the technological conditions that make offshoring feasible. Whereas Blinder (2009) suggests that a large fraction of U.S. production is offshorable, the evolution of export assembly does not seem to support such widespread vulnerability. Second, factor intensity is a primary motivation for why firms offshore. Although recent literature on offshoring tends to see problems in contracting or coordinating production as driving offshoring, Heckscher-Ohlin motivations for fragmenting production appear to be among its first-order determinants. To help sort out the relative contributions of factor intensity and contracting/coordination problems for offshoring, there would be value in an analysis of the determinants of country capabilities in offshoring along the lines of Chor (2010). Third, there is substantial dynamism in country specialization in offshoring sectors. This dynamism appears to be associated with changes in factor supplies — for instance, high levels of human and physical capital accumulation in East Asia. It may also be related to improvements in industry productivity, perhaps associated with foreign direct investment. There would be benefit to understanding how changes in relative factor abundance, as in Schott (2003) or Romalis (2004), affect comparative advantage across industry production stages.

In section 2, I present data on global production sharing for China, Mexico and the United States. After identifying the industries in which offshoring is most common, in section 3 I use U.S. production and trade data to identify the characteristics that distinguish these industries from other sectors. In section 4, I examine how country comparative advantage in offshoring industries has evolved over time and evaluate the correlation between specialization in offshoring industries and changes in capital abundance. In section 5, I conclude.

2 Empirical Landscape

2.1 How do we measure offshoring?

Offshoring is inherently difficult to measure. To characterize the phenomenon, we need data on which production stages occur in which countries and how the tasks associated with these stages are traded across borders. Few public data sources provide detailed information on the organization of production. In typical data on manufacturing plants, we observe total sales of goods and services and total purchases of intermediate inputs, each reported for no more than a few industry codes and none broken out according to the precise identity of the transacting parties. Consider, again, the automobile production chain, which involves: designing autos; stamping and painting auto bodies;

manufacturing the chassis, engine, fuel tank, exhaust system, dashboard, seats, and other parts; and assembling the components into a finished car. In the United States, auto plants are classified in just three four-digit industries — producing motor vehicles (e.g., NAICS 3361), motor vehicle bodies (e.g., NAICS 3362), and motor vehicle parts (e.g., NAICS 3363) — which gives only a partial indication of where in the production chain an individual plant is located and no indication of which plants transact with which other plants, either within a country or across national borders.[7]

To measure offshoring, many studies follow Feenstra and Hanson (1999), who use the share of imported intermediate inputs in total material purchases for an industry (see, e.g., the survey in Crino, 2009). As actual imported intermediates are often unobserved, the imported input share is imputed using the share of imports in industry absorption times input purchases from that industry.[8] Imputed imported material purchases are indicative of offshoring and a powerful empirical signal of how trade changes the structure of industry factor employments. Yet, it does not constitute a direct measure of the specific types of activities that firms locate abroad. Rather, it indicates whether firms tend to buy inputs that on average have high import content.

Other approaches to measuring offshoring use data on intra-firm trade by multinational enterprises, such as BEA data on U.S. MNEs (e.g., Hanson, Mataloni and Slaughter, 2005; Harrison and McMillan, 2011; Oldenski, 2012; Antras and Chor, 2013). These data record one facet of offshoring: the shipment of goods for further processing from U.S. parent firms to their foreign affiliates located abroad. The transactions do capture the shipment of components that are produced in U.S. establishments and transformed into final products in downstream foreign subsidiaries for shipment back to the U.S. or to other markets. However, there are limitations to the BEA data for studying offshoring. First, these data don't record specific inputs, just the broad sector to which the goods belong. The data thus provide only a coarse sense of the division of production stages between parents and affiliates. Second, the data capture inputs for further processing in one direction only — from parent to affiliate — and not in the reverse direction — from affiliate to parent. While the BEA data do record shipments from affiliates to parents, they do not record the nature of the shipments (i.e., whether these goods contain any inputs that were originally produced in the United States and sent abroad for processing). Third, and perhaps most importantly, the BEA data do not record transactions between U.S. parents and arms-length foreign suppliers to which they may

[7]Antras, Forte, and Tintlenot (2014) circumvent such industry aggregation constraints by matching commodity flows data to U.S. manufacturing plants, which provides a high degree of product detail about the goods that an establishment imports from abroad.

[8]Feenstra and Jensen (2012) compare offshoring measures based on imputed versus actual imported inputs. Using data for three-digit input-output industries for 1997, they find that there is a correlation of 0.68 between the imported-input shares made with and without the proportionality assumption (and a higher correlation of 0.87 when the import shares are value weighted).

subcontract production. As a consequence, although Intel's offshoring (e.g., its use of in-house plants in the Philippines to assemble and test chip sets) would be included in BEA data, Nike's offshoring (e.g., its subcontracting of shoe production to independent Vietnamese factories) would not.

Similar approaches to measuring offshoring are followed when using data on MNEs in other countries (e.g., Alfaro and Charlton, 2009). These data allow us to see that parent firms and their foreign subsidiaries produce goods in similar industries and that changes in activities in the two entities are correlated (e.g., expansions in employment in foreign subsidiaries are associated with contractions in employment for less-skilled workers in the parent firm). But they don't let us see changes in the scope of production that occur on factory floors in the United States or abroad.

Some data on multinational plants permit matching employers to their employees, which provides information on task specialization. Becker, Ekholm, and Muendler (2013) match data on German MNEs with the employees in these firms who reside in Germany, which allows them to construct a measure of the types of tasks performed in the German parent firms (owing to the fact that employee data record the occupation of the worker and survey data identify tasks performed in each occupation). They find that when German MNEs expand abroad (via increased employment in their foreign affiliates) relative employment in the German parents shifts toward non-routine and more-interactive tasks and toward more-educated workers. This result is consistent with MNEs using offshoring to move routine tasks abroad. The data do not, however, provide information on the precise tasks performed by the German foreign subsidiaries. Taking a similar approach, Hummels, Jorgensen, Munch and Xiang (2014) use data on Denmark to examine how increased imports of intermediate inputs affect plant employment by skill level. Greater imports of intermediates appear to displace less-skilled workers and increase employment of more-skilled workers, suggesting that firms in high-wage countries offshore low-skill tasks via trade in intermediate inputs.

In related work on U.S. trade patterns, Bernard, Jensen, Redding and Schott (2010) combine data on U.S. manufacturing plants with transaction-level customs data on U.S. imports and exports to determine the fraction of trade that is between "related parties," defined as entities that are under common ownership. Plants engaged in related-party trade are responsible for the overwhelming share of U.S. trade. In 2000, firms that both import goods from and export goods to related parties accounted for nearly 80 percent of U.S. exports. The data record the industry code for the goods traded by the related parties but not how these goods fit into the production process of the observed U.S. manufacturing plants. Thus, the data let us see which types of firms engage in related-party trade but not whether or how U.S. firms offshore production – i.e., we can't tell which tasks U.S. firms have moved abroad. Much related-party trade in transactions-level customs data is for distribution and does not constitute offshoring per se (in the sense of being the result of a firm having relocated a portion of the production process to another country).

Recent work applies data on input-output relationships to identify the vertical location of industries in different countries (Antras and Chor, 2013; Chor, Manova, and Yu, 2014; Fally and Hillberry, 2014). This approach creatively combines input usage and trade flows to infer who must be trading what with whom. A limitation of this approach is that industry input-output relationships hold only on average and therefore may vary across firms within an industry according to firm export status, foreign ownership, size, factor intensity, or other attributes that matter for the transmission of trade shocks to the organization of the factory floor. Further, to obtain input-output tables that are country specific one must work at a relatively high level of aggregation.

Does it matter that we measure offshoring incompletely? There are several reasons why it may. First, we don't know how integrated parent firms and their foreign affiliates in fact are. What components or services do foreign affiliates or independent contractors purchase from U.S. parents? Is it just intellectual property or does it include actual goods and services? Ramondo, Rapoport, and Ruhl (2014) find that there is little vertical integration or horizontal commerce between most U.S. parent firms and their subsidiaries abroad. While most foreign affiliates tend to occupy the same horizontal layer as their parent, the majority do not trade with each other. This suggests that the global business units of multinationals are linked more by common usage of managerial strategy, brand name, patent portfolios or other intellectual property than by flows of physical goods. Second, we still don't know how the skill composition of tasks is divided among countries. How fine is the international division of labor? How sensitive is the offshoring margin to changes in transport costs or relative factor prices? Burstein, Kurz, and Tesar (2008) and Bergin, Feenstra, and Hanson (2009) find that more offshoring between two countries is associated with stronger business cycle comovement, which suggests that global production sharing may enhance the international transmission of country-specific shocks. Global production chains appear to have contributed to the dramatic impacts of the 2008-2010 global financial crisis on the volume of international trade (Levchenko, Lewis, and Tesar, 2010).

2.2 Which types of goods are offshored?

An alternative source of data on offshoring comes from global production sharing. Firms commonly produce inputs at home and send these inputs abroad for further processing, before re-importing the finished product for distribution to consumers. This type of offshoring, at least in terms of how it is recorded in trade data, is typically limited to the labor-intensive task of final assembly. Hence, it only captures one type of offshoring and misses that which may occur further up the production chain. The advantage of using data on export assembly is that we can observe the offshoring of a well-defined production task with a relatively high degree of precision.

Data on global production sharing are the byproduct of the administration of trade barriers. Countries measure trade associated with export assembly not because they care about the practice intrinsically but because its measurement is required for the proper application of restrictions on trade and the collection of tariff revenues. Consequently, reductions in trade barriers tend to reduce the availability of data on offshoring. To gauge the importance of offshoring by sector, I use data from three countries whose customs trade statistics capture export assembly in some form.

2.2.1 China

China is a major participant in global production sharing. In 2013, the country accounted for 18.6% of world manufacturing exports, up from 1.9% in 1990. Growth in export processing, a form of global production sharing, accounts for around half of China's overall manufacturing export growth.

The country's customs bureau classifies imports and exports according to 19 distinct trade regimes, each of which is subject to its own trade restrictions (Yu and Tian, 2012). The largest categories are for ordinary trade, processing with assembly, and processing using imported inputs. Export processing plants in China (similar to Mexico's maquiladoras, discussed below) import inputs via an in-bond arrangement (in which a bond is posted for the value of foregone import taxes), assemble or process the inputs into final outputs, and then export the goods abroad (at which point the bond is returned). Under the less common practice of processing with assembly, the foreign client in the transaction retains ownership of the imported materials; under the more common practice of processing with imported materials, the Chinese firm assumes ownership of these inputs.[9] In 2010, processing trade accounted for 47% of China's manufacturing exports and 30% of its manufacturing imports, whereas ordinary trade accounted for 46% of manufacturing exports and 55% of manufacturing imports.[10] Until 1992, export processing plants were confined to export processing zones (EPZs) concentrated on the country's east coast. During the 1990s and 2000s, the relaxation of trade and investment restrictions allowed the number and geographic expanse of EPZs to grow substantially. Whereas the largest EPZs are still located in eastern coastal provinces, export processing now occurs throughout the country.

[9] Yu and Tian (2012) report that in 2010 processing with imported materials accounted for 85% of processing exports.

[10] Other significant categories of exports including warehousing trade (2.2% of manufacturing exports in 2010) and entrepot trade in bonded areas (2.3% of manufacturing exports in 2010).

Figure 1: Share of processing exports in total industry exports in China

Industry Key: 13 (food processing), 14 (food manufacturing), 15 (beverages), 16 (tobacco), 17 (textiles), 18 (apparel), 19 (leather), 20 (wood products), 21 (furniture), 22 (paper products), 23 (recording media), 24 (sports equipment and toys), 25 (petroleum refining), 26 (raw chemicals), 28 (chemical fibers), 29 (rubber products), 31 (non-metallic minerals), 32 (ferrous metals), 33 (non-ferrous metals), 34 (metal products), 35 (general purpose machinery), 36 (special purpose machinery), 37 (transport equipment), 39 (electrical equipment), 40 (computers and electronics), 42 (artwork).

Figure 1 shows the share of export processing in total exports by industry in China over the period 1997 to 2012. There is substantial heterogeneity across sectors in the importance of export processing. In rubber products (which includes some footwear), electrical machinery, and computers and electronic equipment, processing is the dominant export mode, accounting on average for over 80 percent of exports. In six other industries – apparel, leather products (which also includes footwear), furniture, paper products, recording media, toys and sports equipment, and chemical fibers – processing trade is also a substantial activity, accounting for an average of 45% to 65% of exports. In 11 other industries – food processing, food manufacturing, beverages, tobacco, wood products, petroleum refining, raw chemicals, non-metallic minerals, ferrous metals, non-ferrous metals, and works of art – processing trade is much less consequential, accounting on average under one third of industry exports. Relative industry intensity in export assembly operations will turn out to be similar in the United States and Mexico.

What do Chinese industries that are relatively specialized in processing trade have in common? Brandt and Morrow (2013) find that Chinese industries that have higher shares of processing exports in total exports are ones that in the United States are more intensive in the use of less-skilled labor (measured as the ratio of production workers to non-production workers) and less intensive in the use of capital (measured as the ratio of capital equipment to employment).[11] The industries with the largest shift away from processing trade over the 2000s also tend to be those that are more intensive in less-skilled labor and that have lower capital-labor ratios.

As China liberalizes its trade, firms may become less inclined to classify their goods under the export processing regime. Export processing brings the benefit of avoiding tariffs on imported intermediate inputs (under the in-bond arrangement) but carries the cost of firms having to export all output. Firms that produce for both domestic and foreign markets have to organize production in separate plants if they wish to import inputs duty free for their export production. Where scale economies are strong, such separation may be inefficient. Reductions in import barriers may reduce the attractiveness of in-bond assembly. Brandt and Morrow (2013) find that in China reductions in tariffs on intermediate inputs, in particular after the country joined the WTO in 2001, have shifted the composition of trade inside industries away from processing exports and toward ordinary exports. Their finding does not necessarily mean that since joining the WTO China is engaging in less offshoring. It may mean, instead, that more plants are mixing production for domestic and foreign markets. Export assembly may still be occurring at the same frequency but now in plants that assemble goods for domestic consumption, too. Falling trade barriers thus may make it more difficult to observe China's participation in global production sharing.

2.2.2 United States

In China, we observe plants to which foreign firms contract assembly operations. In the United States, we observe the counterpart of this activity: the re-import of goods that have been sent abroad for assembly. Data for the two countries thus complement each other.[12]

The U.S. Offshore Assembly Program (OAP) provides direct observations on offshoring (Feenstra,

[11] Brandt and Marrow (2013) take their measures of factor intensity from the NBER productivity database.

[12] Much export processing in China is at the behest of Hong Kong or Taiwanese multinational firms and not of U.S. multinational firms.

Hanson and Swenson, 2000). Under the 9802 provision of the Harmonized System code, U.S. firms may export component parts, have these assembled abroad, re-import the finished goods to the United States, and pay import duties solely on the share attributable to foreign value-added. The program accounts for a relatively small fraction of total U.S. imports (less than 10 percent of U.S. manufacturing imports in the typical year). It would not apply to many common types of offshoring. Nike, for instance, has its leather shoe uppers and rubber shoe soles produced abroad, in countries such as Korea and Taiwan, and shipped to Indonesia, Vietnam, and other locations for assembly. The import of Nike shoes into the United States would record little or no U.S. content, as the physical component parts are largely foreign in origin. Of course, a substantial portion of the value of a Nike shoe is in its design, brand image, and trademark swoosh. Yet, the value of this intellectual property is not exempted from duty when Nike shoes manufactured abroad are imported into the United States. Nike's offshoring, and similar practices by other firms, is thus largely uncounted in 9802 trade flows.

For offshored goods that do embody U.S. produced parts and components (e.g., Intel's semiconductors), the OAP program is an illuminating source of data. Because duties at a U.S. port of entry are paid only on the portion of the good that constitutes foreign value-added, the administration of the program requires a separate accounting of the value of imports tied to foreign assembly. Trade data record dutiable OAP imports as the value added associated with foreign assembly services and non-dutiable OAP imports as the value embodied in U.S.-made goods that were previously exported from the United States for further processing abroad. This accounting makes it possible to estimate the value of U.S. production that is shipped abroad for assembly for later re-import into the United States as a finished product.

As a consequence of trade liberalization, the usefulness of the OAP to measure U.S. offshoring has diminished over time. Prior to NAFTA, for instance, virtually all maquiladora (i.e., export assembly) plants in Mexico were engaged in assembly of parts under the 9802 program (Feenstra and Hanson, 1997). These plants import parts and components, primarily from the United States and Asia, and assemble them into final goods for export, primarily back to the United States. Since the full implementation of NAFTA, goods entering the United States from Mexico that are deemed North American in origin are no longer subject to duties. U.S. offshoring to Mexico is thus no longer directly measurable in U.S. trade data, as the entire value of the good enters the United States duty free. Additionally, the Information Technology Agreement in 1996 exempted imports of many technology products from duty in the United States, limiting the usefulness of the OAP program for measuring offshoring in electronics.[13] Swenson (2005) reports that the U.S. content of OAP imports peaked in 1997. In light of these data constraints, I focus on OAP imports up to 1994, one year prior to NAFTA and two years prior to the ITA.

I measure U.S. offshoring as the share of non-dutiable OAP imports in U.S. exports. This share represents the fraction of U.S. exports that have returned to the United States (after being assembled abroad) as imported goods. As mentioned, this measure undercounts U.S. offshoring because it misses (i) trade no longer classified under the 9802 category because of trade liberalization, (ii) exports of U.S. goods that will be processed by foreign suppliers for delivery to foreign markets, rather than to the U.S. market, (iii) goods that contain U.S. intellectual property but no U.S.-made physical components (e.g., Nike shoes or Apple iPhones), and (iv) goods for which foreign processing embodies activities other than assembly.

Figure 2 shows offshoring measured as the share of non-dutiable U.S. imports in U.S. exports for two-digit SIC industries.[14] This is the share of U.S. exports composed of U.S. produced inputs that have been reimported to the country for delivery to consumers. Similar to patterns observed for China, this form of offshoring is prevalent in just five of the twenty two-digit SIC industries: apparel (23), furniture (25), footwear and leather products (31), electronics and electrical machinery (36), and transportation equipment (37). There is virtually no offshoring in 11 other industries: food products (20), tobacco (21), lumber and wood products (24), printing and publishing (27), chemicals (28), petroleum (29), rubber (30), non-metallic minerals (32), fabricated metal products (34), industrial machinery (35), or instruments (38). These low offshoring industries are presumably ones in which using foreign plants for assembly is infeasible technologically or too costly in terms of the required transportation relative to the saving in production costs. Offshoring is small, but not zero, in four other industries: textiles (22), paper products (26), primary metals (33), and miscellaneous manufactures (39), which includes toys and games.

Comparing Figures 1 and 2 reveals that U.S. offshoring-intensive industries are a proper subset of Chinese export processing-intensive industries. The industries in which global production sharing is common in both countries include apparel, furniture, footwear, electronics, electrical machinery, and transport equipment. The industries that appear as major export processing sectors in China but not as major export assembly sectors in the United States include paper products, chemical fibers (part of textiles), and toys and games. Toys and games may not appear as a significant OAP sector in part because of the Nike problem — the products contain substantial U.S. intellectual

[13] The ITA began in 1996 with an initial group of 29 WTO signatories and now includes 73 WTO members.

[14] The dutiable share of U.S. imports includes all forms of foreign value added, be it assembly services or materials and other inputs.

property but have little in the way of physical components that were manufactured in the United States. Take Mattel, for instance. Its Barbie dolls are assembled in China and Indonesia using plastic molded from pellets imported from other countries. Although the Barbie design and trademark are quintessentially American, the physical components of the dolls long ago ceased being made in U.S. factories. The absence of U.S. parts would mean that OAP imports would record no non-dutiable content when the dolls are unloaded at U.S. ports.

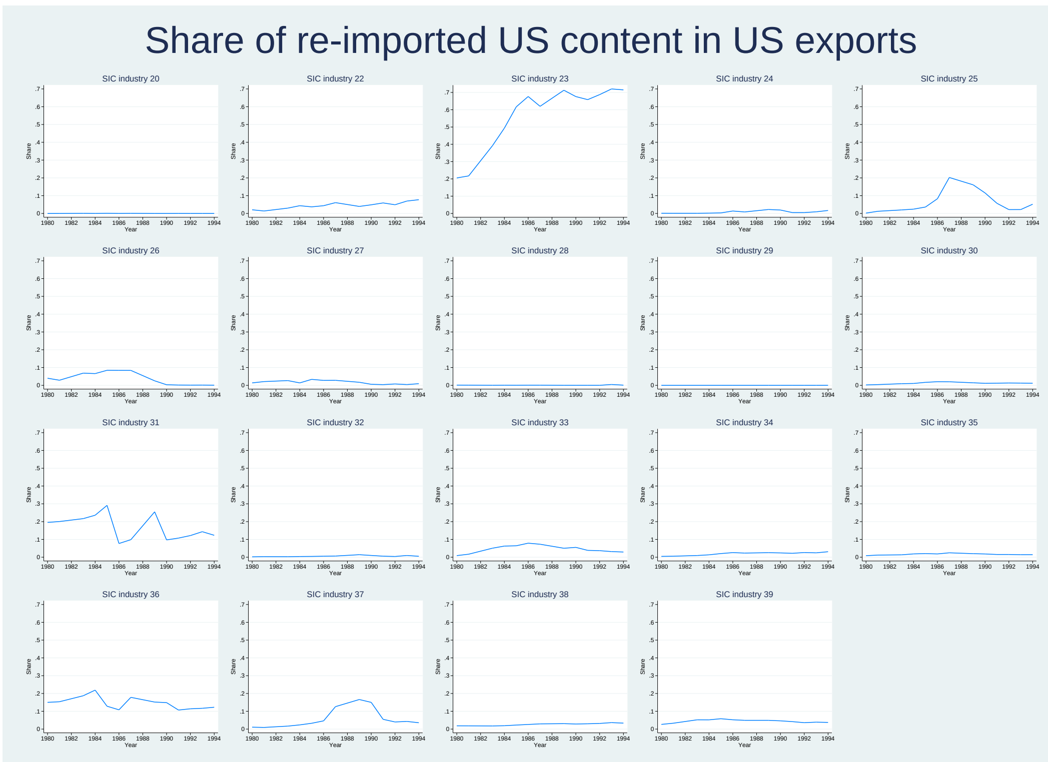


Figure 2: Offshoring content of U.S. manufacturing exports

Industry key: food products (20), textiles (22), apparel (23), lumber and wood products (24), furniture (25), paper products (26), printing and publishing (27), chemicals (28), petroleum (29), rubber (30), footwear and leather products (31), non-metallic minerals (32), primary metals (33), fabricated metal products (34), industrial machinery (35), electronics and electrical machinery (36), and transportation equipment (37), instruments (38), and miscellaneous manufactures (39).

2.2.3 Mexico

Mexico's participation in offshoring is measurable through the country's maquiladora industry, which is the downstream complement of the U.S. offshore assembly program. Mexico's maquiladora initiative was established in 1965 (Hanson, 2007), when the country first began to allow firms to import free of duty the inputs, machinery, and parts needed for export assembly. Under the program, a firm was allowed to import parts and components duty free as long as the inputs were used in the production of goods for export. At import, firms post a bond equivalent to the value of the foreign inputs, which is returned to the firms at time of export.[15] The U.S. 9802 program initially gave maquiladoras an advantage over Mexican producers using non-U.S. inputs in exporting to the U.S. market. That advantage was erased by NAFTA. In 2006, the Mexican government ceased publishing production and employment data on the maquiladora sector.

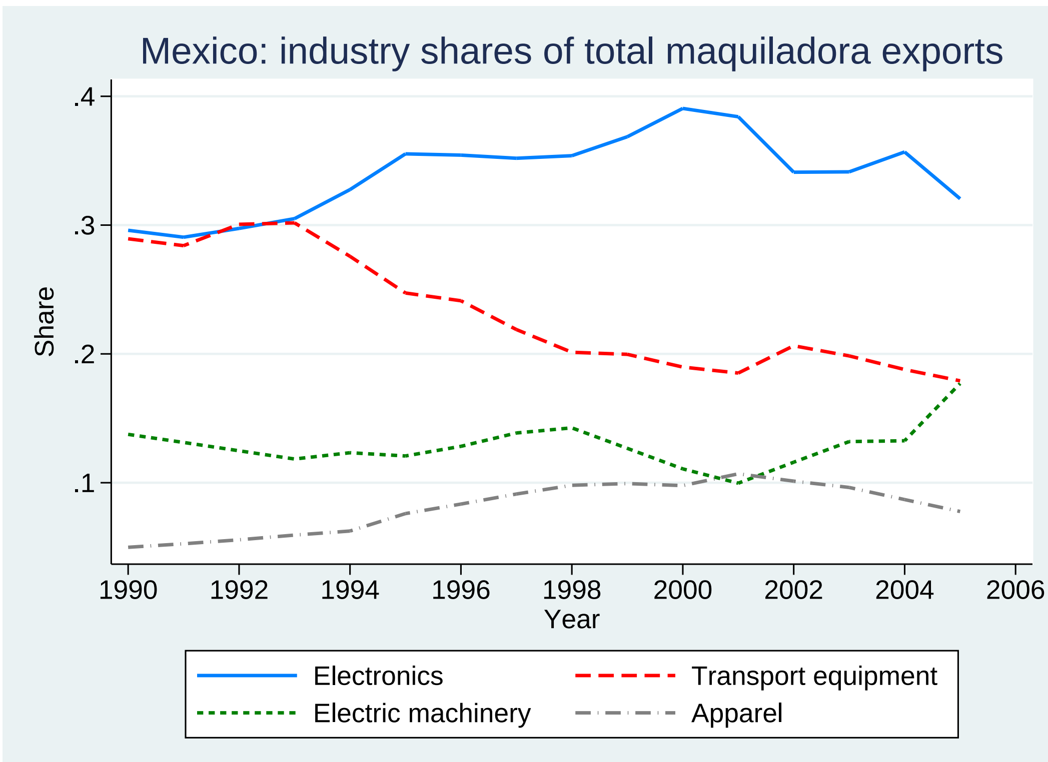


Figure 3: Industry shares of total maquiladora exports in Mexico

In Figure 3, we see that just four industries – electronics (34%), transport equipment (23%), electrical machinery (13%), and apparel (9%) – account for 78% of Mexico's maquiladora exports over the 1990 to 2005 period. By way of comparison, these sectors accounted for just 55% of Mexican manufacturing exports, when combining maquiladora and non-maquiladora exports together (for the

[15]Initially, maquiladoras were required to locate within 20 miles of an international border or coastline in Mexico. In 1972, the Mexican government relaxed these rules and allowed maquiladoras to locate throughout the country. Nevertheless, the plants continued to concentrate near the U.S. border.

period 2009 to 2012). Given Mexico's importance as a U.S. trading partner, it is not surprising that the dominant maquiladora industries in Figure 3 mirror the industries that are dominant in the U.S. offshore assembly program in Figure 2.

Summary Offshoring measures for China, Mexico, and the United States are not fully comparable. U.S. data capture inputs returned to the United States after foreign assembly but miss inputs exported for assembly and shipment to third countries. Mexican and Chinese trade data capture exports by assembly plants to all destination markets. However, they may miss cases where firms produce both for domestic and foreign markets and therefore do not classify their goods under an export assembly or export processing regime. Nevertheless, the data for these three countries tell a similar story. Offshoring in the form of export assembly is concentrated in a handful of sectors, including apparel, footwear, electronics, electrical appliances, transportation equipment, and toys and games. Offshoring by multinational enterprises is present in similar industries. Hanson, Mataloni, and Slaughter (2005) find that in 1994 the share of imported inputs for further processing in the sales of U.S. multinationals to their foreign affiliates is highest in electronics, electrical machinery, and transportation equipment and lowest in chemicals and steel and metal products.[16]

3 What do offshoring industries have in common?

3.1 The Determinants of Offshoring

Theory predicts that offshoring is the consequence of firms locating individual stages of production in the countries in which they can be performed at least cost. What does the literature say about the empirical determinants of offshoring? Whereas empirical research on the consequences of offshoring is large (see, e.g., surveys in Crino, 2009; and Harrison, McLaren, and McMillan, 2011), corresponding work on the causes of offshoring is less abundant. In referencing the literature, I exclude work on the boundaries of the multinational firm (see, e.g., Antras and Yeaple, 2012; Antras and Chor, 2013; Bernard, Jensen, Redding and Schott, 2014) and on inter-industry trade in intermediate inputs (e.g., Johnson and Noguera, 2012; Koopman, Wang and Wei, 2012; Fally and Hillberry, 2014), neither of which takes as its explicit focus how production tasks within an industry are divided across borders.

From the theoretical literature (e.g., Grossman and Rossi-Hansberg, 2008), a natural starting point for analysis of the determinants of offshoring is variation in relative factor prices across countries. Using data on the U.S. OAP program for 1980 to 2000, Swenson (2005) finds that the share

[16] Apparel and footwear do not appear as industries in which U.S. multinationals use foreign subsidiaries to process U.S.-manufactured inputs as these are goods in which assembly is primarily contracted to arms-length suppliers.

of OAP imports that the United States sources from a particular country is decreasing in that country's production costs and increasing in the production costs of competitor countries, where she measures production costs as a function of the Penn World Table country aggregate price level, industry freight rates for the country, and U.S. import tariffs in the industry. If we take variation in the aggregate price level as a measure of labor productivity in non-traded goods, Swenson's results suggest that the United States tends to source export assembly to countries with relatively low transport-cost-adjusted output per worker (which may indicate low wages for less-skilled labor).

In related work, Hanson, Mataloni and Slaughter (2005) consider the fraction of sales by foreign affiliates of U.S. multinational enterprises that is accounted for by imports of inputs for further processing from the U.S. parent firm. Using data for 1994, they find that this share, which captures affiliate demand for U.S.-made intermediate inputs, is decreasing in the ratio of low-skilled wages to high-skilled wages in the host country of the affiliate and decreasing also in industry trade costs from the United States to the host country. Demand for U.S.-made inputs is thus lower in countries in which low-skilled labor is cheap relative to high-skilled labor.

Turning to the role of production tasks in global sourcing decisions, Oldenski (2012) uses BEA data on U.S. multinational enterprises in 2004 to examine the share of sales by U.S. parent firms that is accounted for by imports from their foreign affiliates.[17] These imports include inputs and tasks offshored from the parent to the affiliate, as well as goods that may never have been produced in the United States to begin with. Oldenski finds that U.S. parent demand for imports from their foreign affiliates is higher in industries that are more intensive in occupations performing routine tasks and that are less intensive in occupations requiring extensive communication. Routine tasks include activities such as handling objects and operating machines (other than vehicles).

A second view on task intensity comes from Fort's (2014) analysis of the U.S. Census of Manufacturers in 2007, which reports the purchase of contract manufacturing services both from domestic and from foreign sources. These services are designated as being for customized inputs, rather than for standardized parts and components available on organized exchanges. Fort finds that plants that use electronic networks to manage their shipments are more likely to contract manufacturing services to foreign rather than to domestic entities. These results suggest that firms that adopt more sophisticated communication technology — which presumably lowers communication costs — also tend to engage in greater offshoring. In related work, Antras, Forte, and Tintlenot (2014) combine Forte's (2014) data with the Commodity Flows Survey, which provides highly disaggregated product-level data on the countries from which U.S. plants import specific goods. They use these

[17] See Costinot, Oldenski, and Rauch (2011) for an analysis of routine-task intensity and the share of industry trade that is intra-firm.

data to estimate the determinants of the fixed costs of sourcing inputs to particular countries.

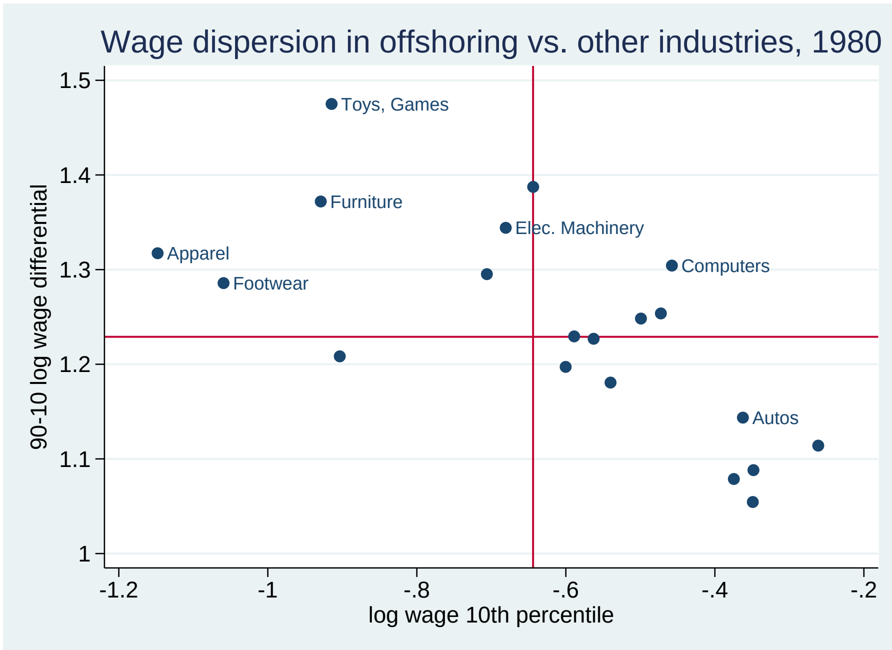
Additional evidence on trade costs and production sharing comes from Johnson and Noguera (2012b). Using data for 1970 to 2009, they find that the domestic content of gross bilateral exports — whose share declines steadily for most bilateral trade partners over the sample period — falls by more for country pairs that are nearer to each other and that enter into a regional trade agreement. They characterize the share of domestic value added in gross exports as being inversely related to production sharing, leading to their conclusion that geographic proximity and falling trade barriers tend to promote offshoring.

The literature thus identifies a role for relative factor costs, production task intensity, and communication and trade costs in determining the extent of industry offshoring. I next examine the characteristics of offshoring-intensive industries in further detail.

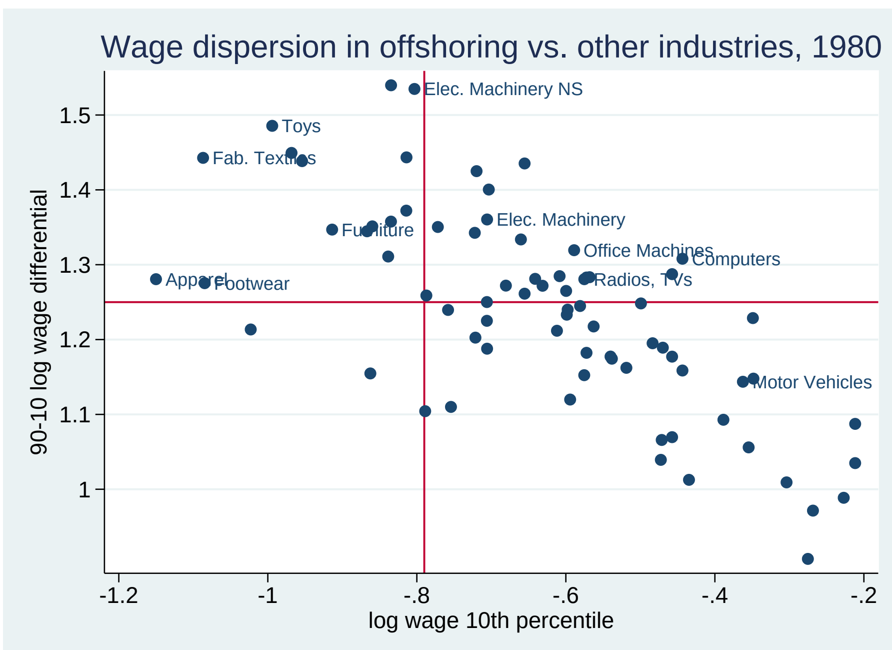
3.2 Offshoring and Skill Intensity

I first consider the skill intensity of production. To measure skill intensity, I use employment and earnings data from the U.S. population census. Obviously, equilibrium skill intensity may itself be determined by the extent of offshoring. As offshoring expands, average skill intensity among the tasks that remain in the United States may rise (Feenstra and Hanson, 1997). To account for the endogeneity of skill intensity to offshoring, I use data from 1980. This year is well before the increase in U.S. trade with low-wage countries. It predates Mexico's unilateral trade liberalization in 1986, China's turn toward export-led development in the early 1990s, and the demise of central planning worldwide after the fall of the Berlin Wall.

To measure the variation in skill intensity within industries, I estimate the within-industry log difference in wages for high-skill workers and low-skill workers. To the extent that wages capture labor productivity, the high skill-low skill wage gap will capture the variation in worker productivity inside industries. Also likely to matter is the absolute level of labor intensity. It is the most labor-intensive production tasks that firms may most desire to locate outside of a high-wage country such as the United States (Swenson, 2005). To capture the skill intensity of the least skilled production tasks inside an industry, I use the level of wages for low-skill workers in an industry. To measure skill, I use age-adjusted average weekly earnings (annual wage and salary income/weeks worked last year), weighted by total hours worked per full-time equivalent worker (Census population weight$\times$weeks worked last year$\times$usual hours worked per week/2000). I define high-skill workers to be those at the 90th percentile of weekly earnings and low-skill workers to be those at the 10th percentile of weekly earnings. Using the 75th percentile for high-skill workers and the 25th percentile for low-skill workers yields similar results.



(a) Two Digit Industries



(b) Three Digit Industries

Figure 4: Skill intensity in U.S. manufacturing industries, 1980

For two-digit U.S. manufacturing industries in 1980, Figure 4a plots the difference in log wages at the 90th and 10th percentiles against the log of wages at the 10th percentile. I use two-digit industries in order to match Census industry codes (for which earnings data are available) with SIC industry codes (for which trade data are available). Results are similar when using three digit Census industry codes, shown in Figure 4b, which may introduce more error in matching industries between Census and SIC codes. The figure shows a vertical line at the median value across industries for the 10th percentile of earnings and a horizontal line at the median value across industries for the 90-10 earnings difference.

Offshoring industries predominate in the upper left quadrant of Figure 4, which indicates above median 90-10 earning differences and below median 10th percentile earnings levels. Five of the six sectors in the quadrant are intensive in offshoring. Four of the seven high offshoring industries (apparel, footwear, furniture, toys and games) are also the four industries with the lowest wage for low-skill workers (weighted by hours worked to avoid the confounding effects of part-time work). Six of the ten industries with an above median 90-10 earnings differential are high offshoring sectors (apparel, electrical machinery, computers and electronics, footwear, furniture, and toys and games). The non-offshoring industries in this group include scientific instruments, plastics, and tires and rubber products. While these industries are not intensive in offshoring in the United States, they are in China. Offshoring industries thus tend to be ones with large differences in wages paid to high-skill and low-skill workers — indicating wide variation in within industry skill intensity — and with low wages for low-skill workers — indicating intensity in the use of very low-skilled labor.

One offshoring industry, automobiles, does not fit this pattern. It is located in the lower right quadrant, indicating above mean earnings for low-skill labor and a below median 90-10 earnings differential. Autos is a clear outlier among offshoring industries. One possibility is that rent-sharing resulting from heavy unionization in automobile production may cause wages to be a poor measure of skill intensity in the sector (Borjas and Ramey, 1995).

3.3 Offshoring and Routine-Task Intensity

A second industry characteristic that the literature associates with offshoring is the routine-task intensity of production (Oldenski, 2012). For U.S. multinational enterprises, Costinot, Oldenski, and Rauch (2011) find that intra-firm trade is higher in industries that are less intensive in routine occupations. As mentioned, in German multinationals Becker, Ekholm, and Muendler (2013) find that as offshoring increases German parents become more specialized in less routine, more interactive occupations, perhaps suggesting that routine tasks may be more likely to be offshored.

What does routine-task intensity imply about industry production activities? Autor and Dorn (2013) associate routine task intensity with the ease of automating production. Hence, they see industries that are intensive in routine tasks as those most likely to replace workers with computerized machines. Costinot, Oldenski, and Rauch (2011), in contrast, associate routineness with the need for "adaptation," meaning the likelihood that a firm and its suppliers will have to address problems whose resolution was not contractually specified ex ante. More routine industries are thus those more likely to benefit from vertical integration, which helps mitigate holdup problems arising from contractual frictions. In a yet third interpretation of routineness, Becker, Ekholm, and Muendler (2013) see more routine jobs as those that can be more easily relocated away from a firm's headquarters and therefore more easily offshored.

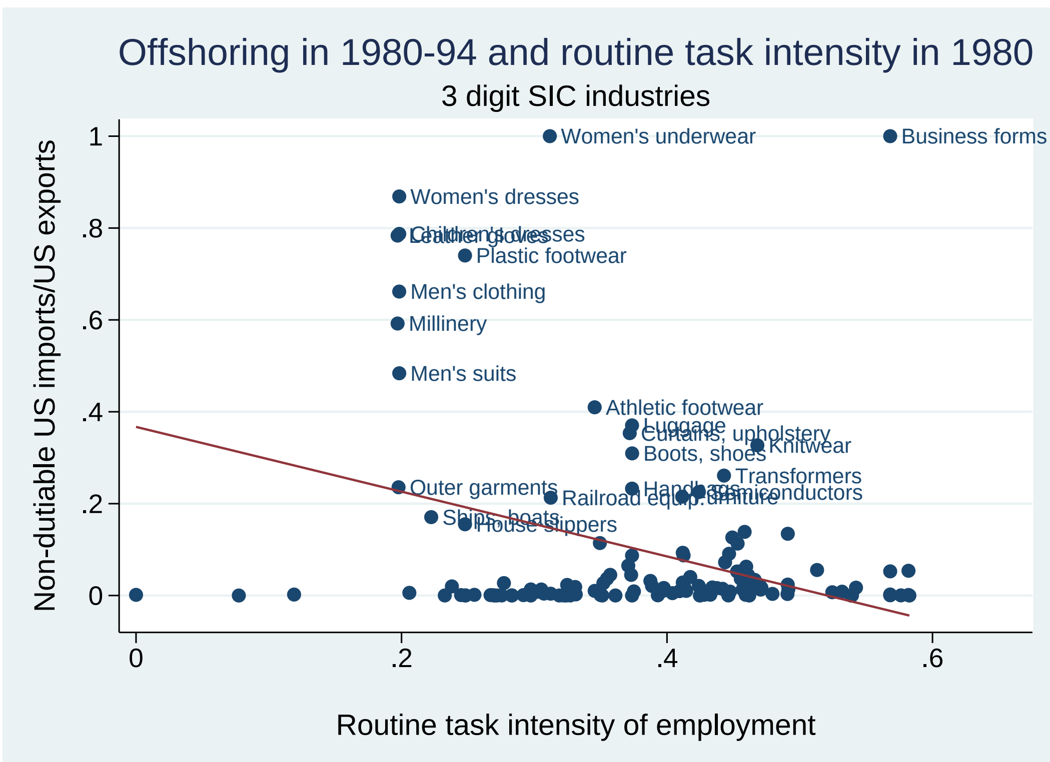


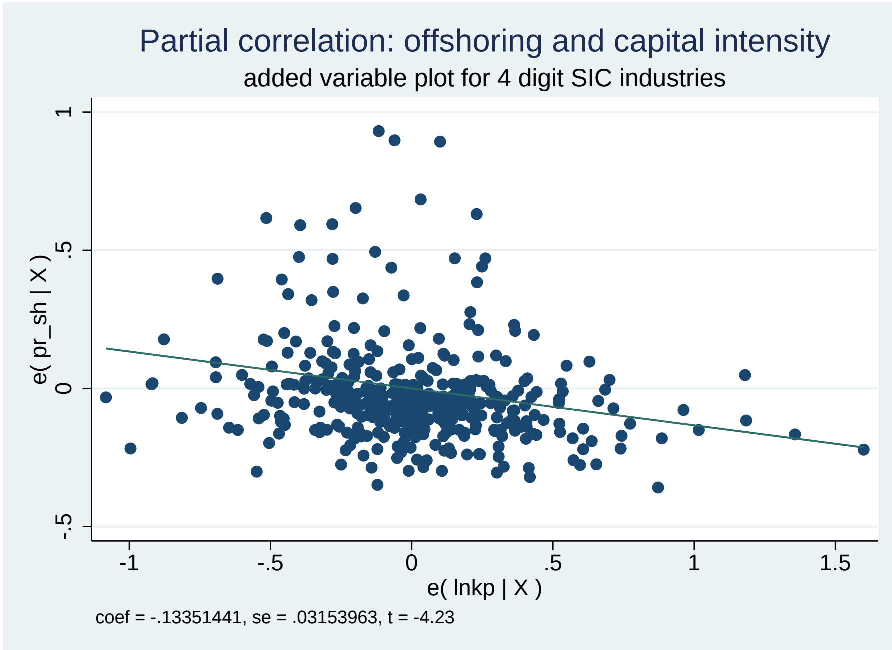
Figure 5: Offshoring and task intensity in U.S. industries, 1980s

When we examine an explicit measure of offshoring — the use of foreign plants to assemble goods for export back to the United States — is there a systematic relationship between routineness and offshoring? Figure 5 plots non-dutiable U.S. imports as a share of U.S. exports, averaged over 1980 to 1994, against routine task intensity in 1980 from Autor and Dorn (2013). These imports capture parts and components U.S. firms exported abroad to be assembled into goods for later shipment back to the United States. The plot and the regression line are weighted by industry total employment in 1980. There is a negative and statistically significant relationship between offshoring and routineness (slope coefficient -0.71, standard error 0.16). Industries that are more intensive in routine-task occupations are thus less likely to offshore product assembly.

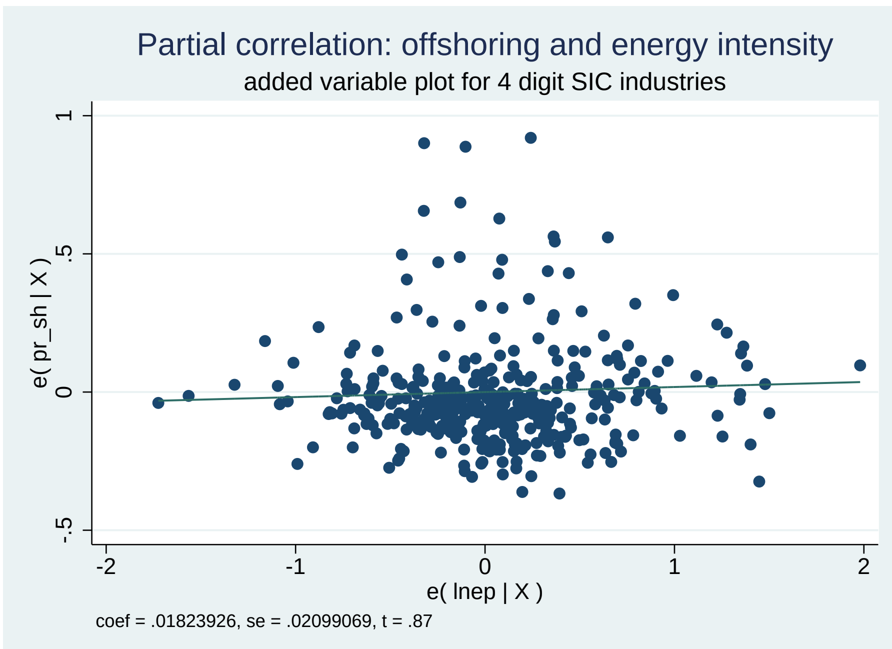
It is evident in Figure 5 that the three-digit industries that are most prone to use foreign firms for assembly services are in the apparel and footwear industries. These are industries, in turn, that tend to have low routine task intensity. These industries abound in repetitive tasks — sewing fabric pieces together to make a blouse or sewing shoe uppers to shoe soles — but not ones that are easily automatable. Automation is notoriously difficult in apparel and footwear, due in part to formless nature of the materials used (e.g., cloth, leather). Consequently, these industries remain highly labor intensive globally. Such inescapable labor intensity may be precisely what makes offshoring an attractive strategy for these and similar industries. Routineness creates opportunities for automation, allowing firms to replace labor with capital. The absence of routineness negates the automation option, making offshoring more attractive.

3.4 Offshoring and Capital and Energy Intensity

Finally, I consider the correlation between offshoring and industry factor intensity, taking multiple factors into account. I again measure offshoring using non-dutiable U.S. imports as a share of U.S. exports, averaged over 1980 to 1994. As measures of factor intensity, I use log capital stock per production worker (capital intensity), log energy costs per production worker (energy intensity), the log ratio of non-production workers to production workers (skill intensity), and log average earnings of production workers (average skill level). Data are from the NBER Productivity Database. I use factor intensity averaged over 1974-1978 in order to target factor usage in the period before offshoring became a common practice in U.S. industries. I choose 1974 and 1978 as cutoff years to avoid the distorting effects of oil price spikes in 1973 and 1979. I regress average offshoring for 1980-1994 on these four measures of factor intensity for 1974-1978 and report the resulting partial correlations between offshoring and each measure separately.

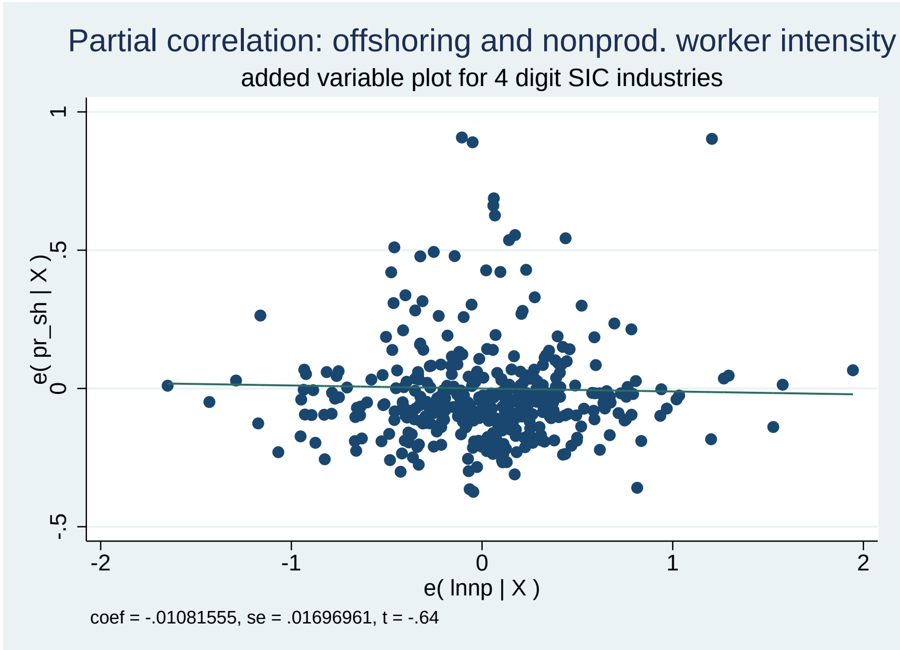


(a) Capital Intensity

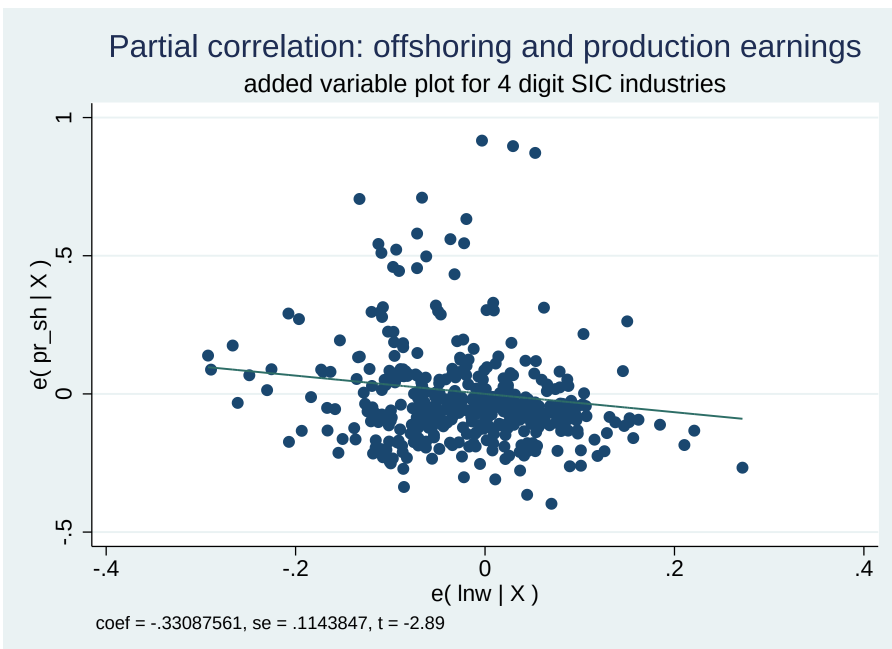


(b) Energy Intensity

Figure 6: Partial Correlation between Offshoring and Alternative Measures of Factor Intensity



(c) Nonproduction Worker Intensity



(d) Average Wages for Production Workers

Figure 6: Partial Correlation between Offshoring and Alternative Measures of Factor Intensity

Figures 6a-6d show the partial correlations between offshoring and each of the four measures of factor intensity. There is a strong negative partial correlation between U.S. offshoring in the 1980s and 1990s and initial capital intensity (Figure 6a), indicating that offshoring is more common less capital intensity sectors. Consistent with Figure 4, there is also a negative partial correlation between offshoring and average production worker earnings (Figure 6d). Offshoring is more common in industries in which average wages—indicating average skill levels— are lower. There is, however, zero partial correlation between offshoring and initial energy intensity (Figure 6b) or between offshoring and initial nonproduction worker intensity (Figure 6c). Whereas we know that increase in offshoring are associated with increasing intensity of nonproduction workers (Feenstra and Hanson, 1999), there is no indication that industries that ultimately engage in offshoring are more or less intensive in nonproduction workers to begin with.

Summary The theoretical literature suggests that the industries in which firms are most likely to offshore production from high-wage to low-wage countries are ones with wide variation in factor intensity across tasks, substantial demand for tasks requiring low-skilled labor, production processes that facilitate geographically separating production tasks, and ease of communication and transportation across borders. Empirical research shows strong support for industry factor intensity and communication and trade costs as being important drivers of offshoring. Results on ease of separating production stages are less conclusive. The empirical literature tends to use routine-task intensity as an indicator of the desirability of moving production offshore. It is the case that as German multinational firms expand abroad employment at home contracts in routine-task-intensive jobs. Yet, we also see that the industries most engaged in export assembly — at least in China, Mexico, and the United States — are ones in which routinization is least pronounced. A lack of a connection between routinization and export assembly makes economic sense. Where production is highly routinized, firms in high-wage countries may have the option of automating assembly on the factory floor. However, where assembly is not mechanizable, offshoring may be the only available means to reduce the labor intensity of production in high-wage labor markets.

4 Comparative Advantage in Offshoring Industries

The relative labor intensity of offshoring industries raises the prospect that industry specialization in these sectors is driven by larger aggregate processes of factor accumulation and economic growth (Schott, 2003). As countries acquire human and physical capital and thereby raise their labor productivity, they may cycle through offshoring industries, moving from the less skill intensive (apparel, footwear, toys and games) to the more skill intensive (electronics, machinery, transport equipment). This cycle is likely to apply only to countries, such as China or Korea, that begin with a comparative advantage in labor-intensive manufacturing. Countries, such as Argentina or South Africa, that begin instead with a comparative advantage in primary commodities may see no such evolution, as their resource abundance may channel investment into activities outside of manufacturing (Costa, Garred, and Pessoa, 2014).

I examine whether country specialization in offshoring industries follow a well-defined development path. I begin by plotting a measure of industry comparative advantage against log per aggregate capital per worker in nine key offshoring sectors. To measure comparative advantage, I use the ad hoc formulation of revealed comparative from Balassa (1965), defined in log values as:

$$\ln\left(\frac{X_{ist}/\sum_{s'} X_{is't}}{\sum_{i'} X_{i'st}/\sum_{i'}\sum_{s'} X_{i's't}}\right)$$

for exports X_{ist} in industry i by source country s in year t, where the numerator is the share of country s in world exports of industry i and the denominator is the share of country s in world exports of all goods (which I will define to be all merchandise trade, including both manufacturing and non-manufacturing sectors but excluding services). A positive log RCA index indicates an export advantage in a sector (country share of world industry exports $>$ country share of world aggregate exports), whereas a negative log RCA index indicates an export disadvantage.

Although the Balassa RCA measure is ad hoc, it resembles a theoretically valid measure of comparative advantage derived from a multi-sector Eaton and Kortum (2002) model (Costinot, Donaldson, and Komunjer, 2013). It is straightforward to show that the deviation of the Balassa RCA index from its theoretical counterpart is due to the distorting effects of geography, which affect realized export values. As a practical matter, the Balassa RCA index tends to track its theoretical cousin rather closely. Hanson, Lind, and Muendler (2015) document that the Balassa RCA index is strongly positively correlated (0.65) with a theoretically consistent measure of comparative advantage based on exporter-sector-year fixed effects estimated using the gravity model of trade.

The presence of imported intermediate inputs used to produce exports complicates using the RCA index to measure comparative advantage. Wang, Wei, and Zhu (2013) calculate revealed comparative advantage using value added exports, defined to be gross exports less the estimated value of imported intermediate inputs used in export production. RCA indexes for gross and value added exports appear to be strongly positively correlated, at least for the manufacturing sectors they examine. The correlation is weaker for business services.

When focusing on sectors heavily engaged in export assembly, the problems introduced by using gross rather than value added exports may be less severe. Because assembly occurs at the end of the production chain, the country performing assembly will get credit for gross exports of the final good. Of course, upstream trade in intermediate inputs means that, if assembly's share of value added is small, both the last and next to last countries in the production chain will record nearly the same value for their exports. Two features of production, when present, help ameliorate this problem. One is production having a network or "spider" structure — with many countries producing inputs that in an ultimate stage are assembled into a final output — rather than a sequential or "snake" structure — in which countries process inputs in strict order (Baldwin and Okubo, 2014). Uniqlo's garments, for instance, are produced in a network structure. The components of a pair of chino slacks — cotton fabric, zippers, buttons, thread — are produced simultaneously in a first stage and then assembled by workers using sewing machines into khaki pants in a second stage. Other goods produced in a network structure include automobiles, cell phones, laptops, shoes, travel goods, and some toys and games. Intel's chips, in contrast, are produced sequentially, with stages involving fabricating pure silicon ingots, slicing wafers from these ingots, depositing materials onto wafers, lithographically forming integrated circuits from these materials, and assembling and testing integrated circuits into finished chips. The network structure tends to involve less back-and-forth trade than the sequential structure, which should result in less double counting in gross exports.

A second condition that helps ensure credit for gross exports in the RCA index goes to the country performing final assembly is an input-output structure in which inputs are purchased primarily from outside the industry in question. Uniqlo's chino pants are in the apparel industry and use as direct inputs cotton fabric from the textile industry, steel zippers from the metal products industry, and buttons from the plastics industry. If the fabric, zippers and buttons are imported, exports of chino pants will lead to double counting in gross exports. But the apparel RCA index for, say, the Philippines will still indicate the country's comparative advantage in final apparel assembly. Many industries, however, purchase a substantial share of their inputs from themselves (Koopman, Wang, and Wei, 2014). Intel's chips are in the electronics industry and use as inputs silicon components also from that industry. The RCA index for electronics will thus give credit both to Taiwan, which fabricates silicon wafers, and to China, which assembles and tests integrated circuits, complicating inferring comparative advantage in final assembly from gross export data. To examine the robustness of my results to measurement error in revealed comparative advantage arising from double counting in exports, in a sub-section of the analysis I study RCA indexes in detail for apparel and footwear, two sectors that are network-based industries in terms of their production structure and that purchase inputs primarily from other sectors.

The export data I use are for two-digit SITC sectors for the period 1980 to 2008 from Feenstra et al. (2005) for 90 exporting countries that collectively account for an average of 98% of world trade. The SITC industry categories do not match exactly the industry definitions for China, Mexico, or the United States used in the plots shown in section 2. Consequently, I am more rather than less inclusive in selecting offshoring-intensive sectors, using a two-digit level of aggregation rather than a three or four-digit level. Aggregation may add measurement error to the analysis by including non-offshoring subsectors in the two-digit sectoral totals. The nine sectors are computers (75), telecommunications and sound recording and reproducing equipment (76), electrical machinery (77), road vehicles (78), furniture (82), travel goods (83), apparel (84), footwear (85), and miscellaneous industries (89), which includes toys and games (89).

4.1 Comparative advantage in offshoring industries and country economic growth

In Figures 7a and 7b, I plot the log RCA index on log aggregate capital per working age person. Data on country aggregate capital stocks are from the Penn Work Tables; data on the working age population are from the World Bank World Development Indicators. I detrend both the RCA index and capital per worker by regressing values for each variable, pooled across countries, on year dummies and using the residuals from these regressions in the analysis. To examine the connection between economic development and comparative advantage in offshoring-intensive industries, I split the sample into two groups of countries. I define manufacturing exporters to be the 44 countries that have an average share of manufacturing in total merchandise exports of at least 35% over the period 1980 to 1984, which are the first five years of the sample; I define commodity exporters to be the 46 countries whose average share of manufacturing in merchandise exports for 1980 to 1984 is less than 35%. Figure 7a plots RCA and capital per worker for manufacturing exporters; Figure 7b plots this relationship for commodity exporters.

Consider, first, manufacturing exporters in Figure 7a. There is a stark contrast in outcomes between the more skill-intensive industries in one-digit sector 7, which is machinery and equipment, and those in the more labor-intensive one-digit sector 8, which is household articles. In three of the four sector 7 industries — computers (75), electrical machinery (77), and road vehicles (78) — there is a positive correlation between capital per worker and the RCA index. More capital abundant manufacturing exporters tend to have a stronger comparative advantage in machinery and equipment. This relationship is particularly pronounced for computers. In all five of the sector 8 industries — furniture (82), travel goods (83), apparel (84), footwear (85), and miscellaneous goods (89) — there is a negative correlation between capital per worker and revealed comparative advantage. Less capital abundant manufacturing exporters tend to have greater strength in household articles.This relationship is most apparent in apparel, footwear, and travel goods.

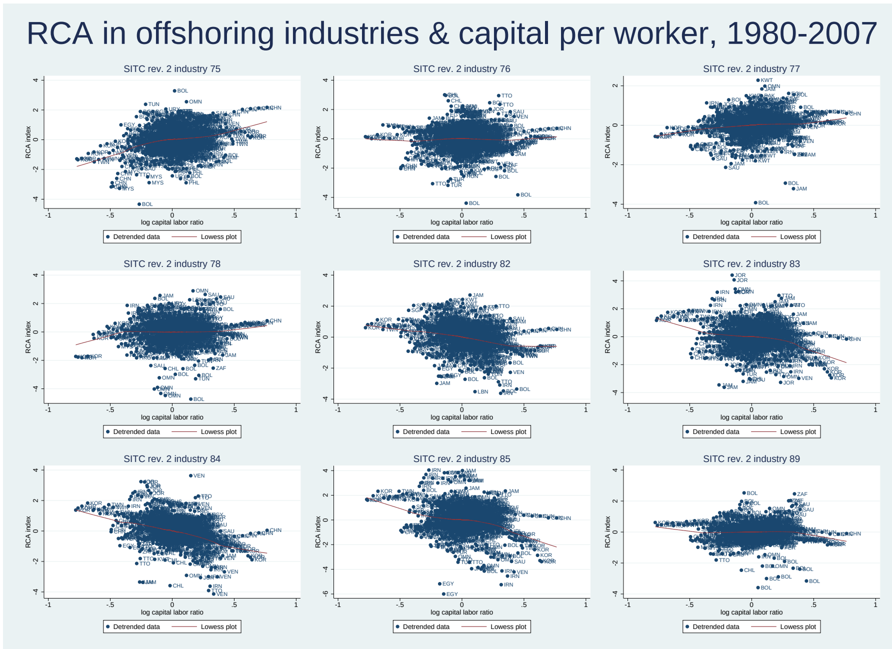


Figure 7a: RCA in offshoring industries and country capital per worker, manufacturing exporters

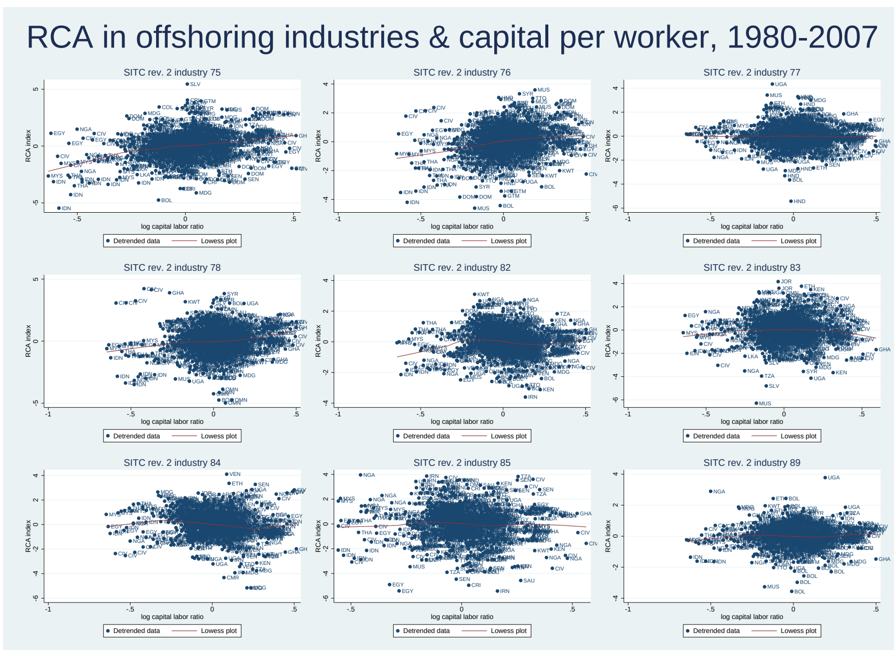


Figure 7b: RCA in offshoring industries and country capital per worker, commodity exporters

Industry key: computers and peripherals (75), telecommunications and sound equipment (76), electrical machinery and appliances (77), road vehicles (78) furniture (82), travel goods (83), apparel (84), footwear (85), miscellaneous industries (89).

A key distinction between the sector 7 and sector 8 industries is in their factor intensity. Returning to Figure 4, three of the sector 7 offshoring industries — autos, computers and electronics — are relatively skill intensive, as indicated by their relatively high values of weekly earnings for workers at the 10th percentile. All of the sector 8 industries — apparel (which in Figure 4 includes travel goods), footwear, furniture, and toys and games — are highly non-skill intensive, as seen in their very low values for 10th percentile earnings. It thus appears that manufacturing exporters in the later stages of development lose export advantage in offshoring industries intensive in less-skilled labor and acquire advantage in offshoring industries intensive in more-skilled workers.

Consider, next, outcomes for commodity exporters, shown in Figure 7b. We see quite different patterns from those in Figure 7a. For these countries, in the labor-intensive sector 8 industries there is zero correlation between the RCA index and capital per worker. Less capital abundant commodity exporters show no tendency to have stronger comparative advantage in apparel, footwear, furniture or the other non-skill-intensive offshoring sectors. There is a mild positive correlation between RCA and capital per worker in three of the four sector 7 industries, computers (75), telecommunications equipment (76), and transport equipment (78).

4.2 Case studies of comparative advantage in offshoring industries

Does comparative advantage in offshoring sectors change as countries' factor abundance and labor productivity evolve? Because Figures 7a and 7b mix cross-section and time-series evidence, we cannot infer whether the correlation between comparative advantage and capital per worker among manufacturing exporters is the result of differences between countries at different stages of development or of changes within countries over time. To isolate the within-country variation, I conduct two case studies. In this section, I examine apparel and footwear, two labor-intensive offshoring sectors for which gross exports are indicative of advantages in export assembly. In the next section, I consider time-series evidence on comparative development in offshoring industries for East Asia.

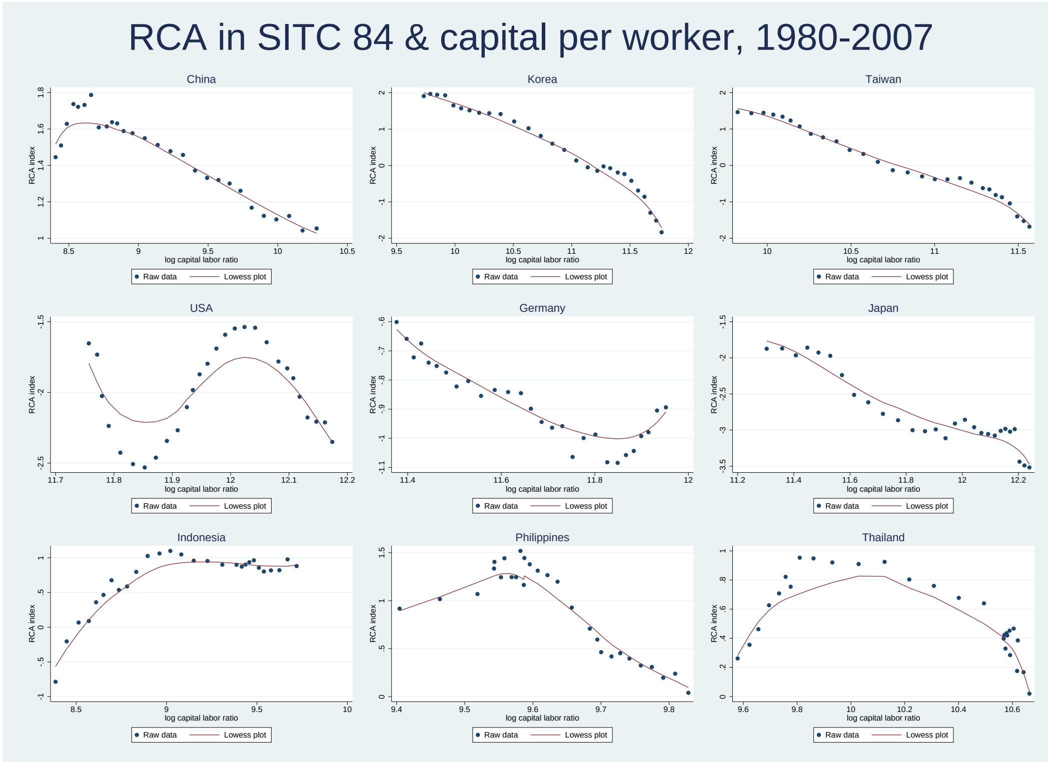


Figure 8a: Revealed comparative advantage in apparel for selected countries

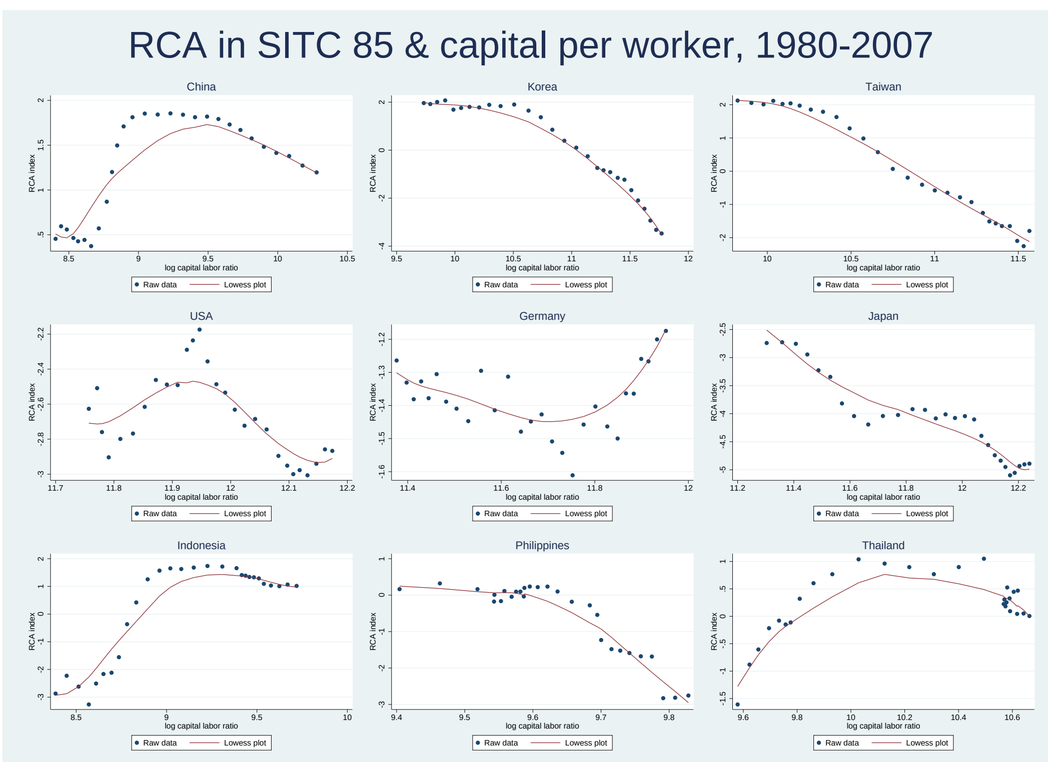


Figure 8b: Revealed comparative advantage in footwear for selected countries

Figures 8a and 8b show RCA indexes for 12 countries in apparel (SITC 84) and footwear (SITC 85). The first row has three countries that specialize in non-oil commodities. Argentina's strengths are in agriculture, Colombia's strengths are in agriculture and mining, and South Africa's strengths are in mining alone. I use these countries as illustrative examples; results for other countries specialized in primary commodities are broadly similar. For none of the three countries is there a stable relationship between capital per worker and comparative advantage, either in apparel or in footwear. The group has strong disadvantages in the two sectors, except for Colombia whose advantage in apparel is approximately neutral. These disadvantages do not change as the countries accumulate capital. The absence of a connection between RCA and capital per worker in Figures 8a and 8b supports the results in Figure 7b: in countries oriented toward commodity exports, changes in factor supplies do not foretell changes in comparative advantage in labor-intensive offshoring sectors.

The second through fourth rows of Figures 8a and 8b include a subset of low-income (second row), lower-middle-income (third row) and middle income (fourth row) countries whose export strengths at the beginning of sample period are decisively in manufacturing. The experiences of these countries are illustrative of broader trends among manufacturing exporters. For the nine countries, there is a well-defined relationship between RCA and capital per worker, but not one that is monotonic over the development process. For the low-income nations of Indonesia, Pakistan and Sri Lanka, there is a non-decreasing relationship between RCA and capital per worker. In Indonesia and Sri Lanka, RCA in both apparel and footwear is increasing in capital per worker at low levels of the capital stock. At higher levels of capital per worker, the relationship flattens out, suggesting that at some point further capital accumulation no longer enhances comparative advantage in apparel or footwear assembly. Over the sample period, Indonesia moves from disadvantage (negative log RCA) to advantage (positive log RCA) in both sectors; Sri Lanka sees its existing advantages strengthen. Pakistan's experience is distinct. In apparel, its RCA is increasing in capital per worker at all levels of the capital stock, whereas in footwear it exhibits a negative revealed comparative advantage that changes erratically over time.

Turning to the middle-income nations of the third and four rows of Figures 8a and 8b, there is further evidence of an inverted U-shaped relationship between revealed comparative advantage and capital per worker. In all six of the countries, revealed comparative advantage either increases or is flat in capital accumulation at low levels of capital per worker and is decreasing in additions to the capital stock at higher levels of capital per worker. Although the level of capital per worker at which the point of inflection occurs differs across countries, in all cases there appears to be a level of capital per worker above which further expansions of the capital stock are associated with declining comparative advantage in labor-intensive offshoring industries.

The patterns of industry evolution seen in Figures 8a and 8b align with Schott (2003), who estimates the impact of capital accumulation on country specialization patterns. Schott motivates his analysis using a version of the Heckscher-Ohlin model of trade in which an extreme global distribution of relative factor supplies (or industry productivities) induces countries to specialize in distinct product mixes.Within a given cone of diversification, capital accumulation tends to have a monotonic impact on country production levels, either positive or negative. A labor-abundant country would tend to begin in a cone of diversification that has specialization in labor-intensive products. As the country accumulates capital, it would expand output across all of the labor-intensive goods that it produces. Once the country accumulates sufficient capital to move into a new cone, the sign of the relationship between production and capital per worker may flip (or go from zero to positive). Further capital accumulation may yield contractions in output in more labor-intensive products and expansions in output in more capital-intensive ones.

The offshoring models in Feenstra and Hanson (1997) and Grossman and Rossi-Hansberg (2008) also have a Heckscher-Ohlin flavor. There is specialization according to factor abundance, with this specialization occurring across production stages rather than across industries. The empirical results is this section are suggestive of cones of diversification in production stages. At low levels of capital per worker, countries specialize in export assembly in apparel, footwear, and other labor-intensive industries. Factor accumulation causes export assembly operations to expand. Indonesia's growth in the 1980s and 1990s, for instance, allowed it to attract ever larger numbers of assembly plants in the garment and shoe industries, Nike prominent among them. Capital accumulation, however, will raise the relative wage of less-skilled labor, making a country less attractive as a destination for final assembly in very labor-intensive production. Ultimately, capital accumulation prices a country out of assembly in apparel and footwear, moving it into new activities

Cycles of offshoring industry growth and decline are partially evident in Figures 7 and 8. Complicating the analysis is the fact that most countries accumulate capital only so quickly. Hence, we are often only able to observe one part of the inverted U. In Figure 8a, we see the rise and then leveling out of the U in Indonesia and the leveling out and then decline in the U in Thailand. To see the full inverted U, one needs to observe manufacturing exporters that grow sufficiently rapidly to move through multiple stages of industry evolution over the same period. Fortunately, the nations of East Asia provide exactly such a case.

4.3 East Asia's offshoring industry growth paths

East Asia stands out for its exceptional performance in export manufacturing, due in part to the labor abundance of countries in the region. The Asian Tigers — Hong Kong, Singapore, South Korea and Taiwan — began their export careers in the 1960s and 1970s by assembling clothing, shoes, and toys. By the 1990s, they had progressed into manufacturing sophisticated electronics, and, in South Korea's case, transportation equipment. Today, China is following a similar pattern of advancement (Schott, 2008).

As a concluding exercise, I search for common development paths among East Asian countries. This analysis marries the cross-section perspective in Figure 7 with the time-series perspective in Figure 8. As the manufacturing nations of East Asia develop, do they follow a consistent progression through offshoring industries? Is the timing of this progression similar among countries? In Figure 9a, I plot log RCA indexes for China, Japan, South Korea, and Taiwan over the extended period of 1962 to 2007.[18] Pushing the initial year back to 1962 is helpful for uncovering export patterns in Japan, which began its export-led growth process much earlier than the other nations.

In Figure 9a, Japan appears as the leader in the region, being the first to acquire export advantage in offshoring industries. In the early 1960s, the country had a positive log RCA index in four of the five low-skill sector 8 industries — travel goods, apparel, footwear, and miscellaneous products (e.g., toys and games) — but in only one of the four higher-skill sector 7 industries — telecommunications and sound recording equipment. Its export advantages changed quickly in the 1960s and 1970s. By 1974, Japan had lost its comparative advantage in all of the low-skill sector 8 industries, with RCA values dropping sharply in travel goods, apparel, and footwear. By 1970, Japan had a positive log RCA index in all of the higher-skill sector 7 industries, which it maintained over the next two decades. In the 1990s, Japan's advantage slipped in two of these sectors, computers and telecommunications equipment, such that by the 2000s its advantage in the two industries had evaporated. The country has maintained export advantages in electrical machinery and road vehicles.

[18]Hong Kong's and Singapore's roles as entrepot economies make them less appealing candidates for analysis.

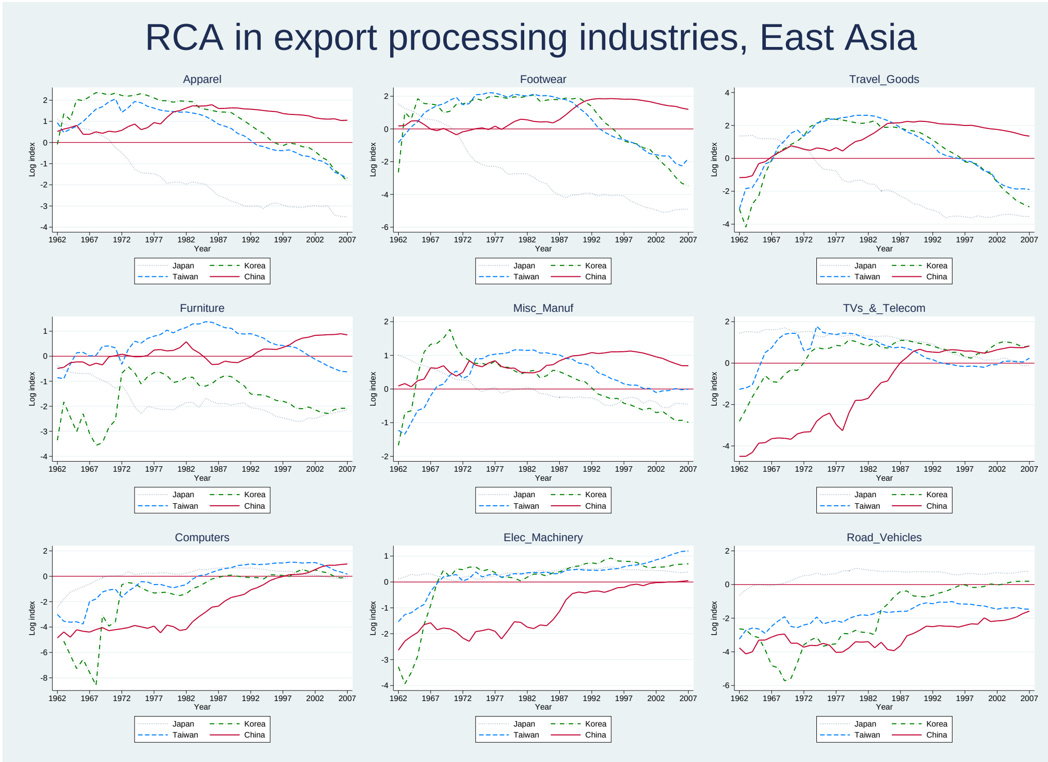


Figure 9a: Revealed comparative advantage in East Asia, 1962-2007

Industry key: computers and peripherals (75), telecommunications and sound equipment (76), electrical machinery and appliances (77), road vehicles (78) furniture (82), travel goods (83), apparel (84), footwear (85), miscellaneous industries (89).

South Korea and Taiwan follow a path similar to Japan, but advanced forward in time. During the 1960s, the two countries' RCA indexes rose sharply in four of the five low-skill sector 7 industries — travel goods, apparel, footwear, and miscellaneous industries. RCA values peak in these industries at approximately the same time in the two countries: in apparel around 1970, in travel goods around 1980, and in footwear around 1984. Their comparative advantages then decline steadily in low-skill offshoring industries, falling into disadvantage during the 1990s. Declining advantage in low-skill industries is matched by rising advantage in higher-skill industries. The log RCA indexes in South Korea and Taiwan become positive in telecommunications equipment by the late 1960s, in electrical machinery in the early 1970s, and in computers in the early to mid 1980s. Only in road vehicles do the two countries trajectories diverge. South Korea acquires an advantage in road vehicles by the early 2000s, whereas Taiwan maintains a strong disadvantage in the sector throughout the period.

Within East Asia, China is the third mover. Before 1978, its export patterns are difficult to evaluate, given the extreme economic distortions of the Maoist era (Naughton, 2007). Beginning in the early to mid 1980s, following the onset of its market-oriented reforms, China's RCA indexes rose sharply in three of the five low-skill sector 8 offshoring industries, peaking at a value of 1.8 in apparel in 1986, 2.3 in travel goods in 1990, and 1.9 in footwear in 1995 (a log RCA index of 2 indicates a country's share of world industry exports is 7.4 times its share of all merchandise exports). In the four higher-skill, sector 7 offshoring industries, China begins with a strong comparative disadvantage, with RCA indexes at -2 or below in the 1970s. During the 1980s, its fortunes in these sectors change rapidly. China's log RCA index becomes positive in telecommunications equipment in 1987, in computers in 1995, and in electrical machinery in 2004. In road vehicles, however, China retains a strong comparative disadvantage, even at the end of the sample period.

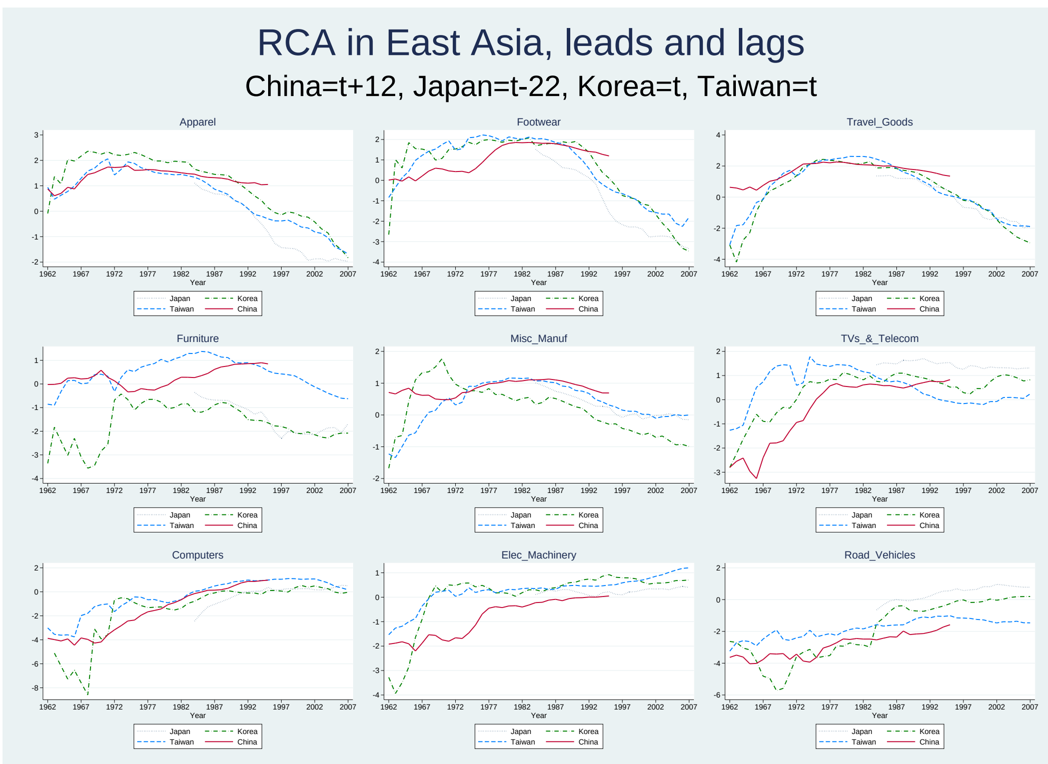


Figure 9b: Leads and lags in East Asian growth paths for comparative advantage

To compare growth cycles across offshoring industries in East Asia more formally, I search for temporal shifts in country RCA growth paths. Specifically, I estimate the leads and lags that yield maximum overlap in RCA indexes among the four countries, where I force leads and lags to be common across industries and further require South Korea and Taiwan to have the same lag structure relative to Japan and China. Figure 9b shows contemporaneous values for South Korea and Taiwan along with 22-year lags for Japan and 12-year leads for China, which is the structure that maximizes overlap in the four countries RCA trajectories. There is strong overlap in RCA values in all industries except furniture. Whereas the catch up of South Korea and Taiwan to Japan required more than two decades, China's catch up has required only slightly more than one decade.

What accounts for the common cycles of East Asian comparative advantage in offshoring industries? Possible explanations include the initial labor abundance of these economies, their rapid pace of accumulation of human and physical capital, and common industrial policies. The rapid catch up of China to South Korea and Taiwan in comparison to their own catch up to Japan is not explained by differential rates of growth in the capital stock among these countries. Whereas after 1980 capital per worker in China grew at 6.9% per year, it grew at comparable rates in South Korea and Taiwan for this period (7.5% and 6.6%, respectively) and at higher rates for the two countries over the entire 1962 to 2007 period (7.1% and 8.3%, respectively). The explanation for China's accelerated convergence must lie elsewhere.

5 Discussion

When it comes to offshoring, theory remains far ahead of measurement. The literature has a rich set of models that show how firms divide production tasks across borders, determine which stages to perform inside their boundaries, and alter their sourcing decisions in response to changes in trade costs or the ease of contracting. Existing data, however, provide only an imperfect glimpse into these facets of firm behavior. Confronted with troublesome data limitations, the empirical literature has constructed an impressive arsenal of indirect measures of global production sharing. But because of this indirectness, it is hard to say how well theories of offshoring fit the facts.

Trade in assembly services is the canonical form of offshoring. When one thinks of global production sharing, what comes immediately to mind are factories such as the Foxconn complex in Shenzhen, China, which assembles iPhones from parts imported from Germany, Japan, and South Korea. Less appreciated, perhaps, is that moving assembly abroad does not appear to be a viable strategy in many industries. In the United States, exporting components for foreign assembly is limited to less than a half dozen two-digit sectors. Whereas it is common in clothing, shoes and electronics, it is rare in food and beverages, wood products, chemicals, non-metallic and metallic minerals, and printing and publishing. Production, at least within industries, may not be as separable many think. Food products often need to be processed near farms, wine needs to be bottled near vineyards, the packaging of chemical solutions and pharmaceuticals was mechanized long ago, and the transformation of mineral ores into metals remains vertically integrated. Whereas there is clearly a great deal of trade in intermediate inputs — milled lumber, steel, glass, petroleum derivatives, and even cement — these goods have long been produced far from the factories that use them to make final goods. The fragmentation of production within industries appears to be idiosyncratic to a subset of manufacturing activities. It is these industries that have been most affected by the rise of global production sharing.

What offshorable industries have in common is intensity in the employment of low-wage labor. It is, after all, this labor intensity that motivates production sharing in the first place. And it is this labor intensity that may make country comparative advantage in offshoring industries episodic in nature. In the 1990s, China came to dominate global exports of garments and footwear almost overnight, only in the 2000s to shift into laptops and cellphones. The country's industrial transition may be due in part to its own rapid accumulation of capital and acquisition of foreign know-how and to Bangladesh, Indonesia, and Vietnam being in position to fill China's wake in its formerly dominant industries.

There is surely much more to offshoring that trade in assembly services. For this one commonly traded production task, a narrative with strong Heckscher-Ohlin plot lines seems to tell much of the story of changes in global production sharing. It may require much richer industry data to find other determinants at work.

References

Alfaro, Laura, and Andrew Charlton. 2009. "Intra-Industry Foreign Direct Investment." *American Economic Review,* 99(5): 2096–2119.

Antràs, Pol, and Davin Chor. 2013. "Organizing the Global Value Chain." *Econometrica*, 81(6): 2127-2204.

Antràs, Pol, Teresa Forte, and Felix Tintlenot. 2014. "The Margins of Global Sourcing: Theory and Evidence from U.S. Firms." NBER Working Paper No. 20772.

Antràs, Pol, and Elhanan Helpman, "Global Sourcing," Journal of Political Economy , CXII (2004), 552-580.

Antràs, Pol, and Stephen Yeaple. 2012. "Multinational Firms and the Structure of International Trade." NBER Working Paper No. 18775.

Autor, David H. and David Dorn. forthcoming. "The Growth of Low Skill Service Jobs and the Polarization of the U.S. Labor Market." *American Economic Review.*

Autor, David H., David Dorn, and Gordon H. Hanson. 2013a. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, 103: 2121-2168.

Autor, David, David Dorn, Gordon Hanson. 2013b. "The Geography of Trade and Technology Shocks in the United States." *American Economic Review Papers and Proceedings*, 103(3): 220-25

Balassa, Bela. 1965. "Trade Liberalization and Revealed Comparative Advantage." Manchester School of Economic and Social Studies, 33: 99–123.

Baldwin, Richard, and Toshihiro Okubo. 2014. "Networked FDI: Sales and Sourcing Patterns of Japanese Foreign Affiliates," *The World Economy*, 37(8):1051-1080.

Becker, Sasha, and Marc Muendler. 2010. "Margins of Multinational Substitution." *American Economic Review*, 100(5): 1999-2030.

Becker, Sasha, and Marc Muendler. 2015. "Trade in Tasks: An Exploration over Three Decades in Germany." NBER Working Paper No. 20739.

Becker, Sasha, Karolina Ekholm, and Marc Muendler. 2013. "Offshoring and the Onshore Composition of Tasks and Skills." *Journal of International Economics*, 90(1): 91-106.

Bergin, Paul, Robert C. Feenstra, and Gordon H. Hanson. 2009. "Offshoring and Volatility: Evidence from Mexico's Maquiladora Industry." *American Economic Review*, 99: 1664-1671.

Bernard, Andrew, J. Bradford Jensen, Stephen J. Redding, and Peter K. Schott. 2010. "Intra-Firm Trade and Product Contractibility." *American Economic Review Papers and Proceedings*, 100(2): 444-448.

Blinder, Alan. 2009. "How Many U.S. Jobs Might Be Offshorable?" *World Economics* 10 (2): 41–78.

Borjas, George J., and Valerie A. Ramey. 1995. "Foreign Competition, Market Power, and Wage Inequality." *Quarterly Journal of Economics,* 110 (4) : 1075–110.

Brandt, Loren, and Peter Morrow. 2013. "Tariffs and the Organization of Trade in China." University of Toronto.

Burstein, Ariel, Chris Kurz, and Linda Tesar. 2008. "Trade, Production Sharing and the International Transmission of Business Cycles." *Journal of Monetary Economics.*

Caliendo, Lorenzo, and Fernando Parro. 2015. "Estimates of the Trade and Welfare Effects of NAFTA." *Review of Economic Studies*, 82 (1): 1-44.

Chor, Davin. 2010. "Unpacking Sources of Comparative Advantage: A Quantitative Approach." *Journal of International Economics*, 82 (2): 152–67.

Chor, Davin, Kalina Manova, and Zhihong Yu. 2014. “The Global Production Line Position of Chinese Firms.” Stanford University.

Costa, Francisco, Jason Garred, and Joao Paulo Pessoa. 2014. “Winners and Losers from a Commodities-for-Manufactures Trade Boom.” LSE.

Costinot, Arnaud, Lindsay Oldenski, and James Rauch. 2011. “Adaptation and the Boundary of Multinational Firms.” *The Review of Economics and Statistics*, 93(1): 298–308

Costinot, Arnaud, and Jonathan Vogel. 2010. “Matching and Inequality in the World Economy.” *Journal of Political Economy*, 118(4): 747-786.

Costinot, Arnaud, Jonathan Vogel, and Su Wang. 2013. “An Elementary Theory of Global Supply Chains.” *Review of Economic Studies*, 80: 109-144.

Crino, Rosario. 2009. “Offshoring, Multinationals, and Labour Market.” *Journal of Economic Surveys*, 23(2): 197–249.

Ebenstein, Avraham, Ann Harrison, Margaret McMillan, and Shannon Phillips. 2014. “Estimating the Impact of Trade and Offshoring on American Workers Using the Current Population Surveys.” *Review of Economics and Statistics*, 96(4): 581-595.

Feenstra, Robert C., and Gordon H. Hanson. 1997. “Foreign Direct Investment and Relative Wages: Evidence from Mexico’s Maquiladoras.” *Journal of International Economics,* 42 (3), 371-393.

Feenstra, Robert C., and Gordon H. Hanson. 1999. “The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the U.S., 1979-1990.” *Quarterly Journal of Economics*, 114(3), 907-940.

Feenstra, Robert C., and Gordon H. Hanson. 2003. “Global Production Sharing and Rising Inequality : A Survey of Trade and Wages.” In James Harrigan, ed., *Handbook of International Trade*, Basil Blackwell, pp. 146-185.

Feenstra, Robert C., and Gordon H. Hanson. 2005. “Ownership and Control in Outsourcing to China: Estimating the Property Rights Theory of the Firm.” *Quarterly Journal of Economics*, 120(2), 729-762.

Feenstra, Robert C., Gordon H. Hanson, and Deborah Swenson. 2000. "Offshore Assembly from the United States: Production Characteristics of the 9802 Program," in Robert Feenstra, ed., *The Impact of International Trade on Wages* , University of Chicago Press and the NBER , 85 - 128.

Feenstra, Robert C., and Bradford Jensen. 2012. “Evaluating Estimates of Materials Offshoring from U.S. Manufacturing.” NBER Working Paper No. 17916.

Fort, Teresa. 2014. “Technology and Production Fragmentation: Domestic versus Foreign Sourcing.” Dartmouth College.

Grossman, Gene M., Esteban Rossi-Hansberg. 2008. "Trading Tasks: A Simple Theory of Offshoring." American Economic Review, 98(5): 1978-1997.

Hanson, Gordon H., Raymond J. Mataloni, and Matthew J. Slaughter. 2005. “Vertical Production Networks in Multinational Firms.” The Review of Economics and Statistics, 87(4): 664-678.

Hanson, Gordon, Marc Muendler, and Nels Lind. 2015. “The Dynamics of Comparative Advantage.” UC San Diego.

Harrison, Ann, John McLaren, and Margaret McMillan. 2011. “Recent Perspectives on Trade and Inequality.” *Annual Review of Economics*, 3: 261-289.

Harrison, Ann and Margaret McMillan. 2011. “Offshoring Jobs? Multinationals and U.S. Manufacturing Employment.” *Review of Economics and Statistics*, 93(3): 857-875.

Hummels, David, June Ishii, and Kei-Mu Yi. 2001. “The Nature and Growth of Vertical Specialization in World Trade.” Journal of International Economics, 54(1): 75-96.

Hummels, David, Rasmus Jorgenson, Jakob Munch, Chong Xiang. 2014. “The Wage Effects of Offshoring: Evidence from Matched Firm-Worker Data.” *American Economic Review*, 104(6):

1597-1629.

Johnson, Robert, and Guillermo Noguera. 2012. “Accounting for Intermediates: Production Sharing and Trade in Value Added.” *Journal of International Economics*, 86(2).

Johnson, Robert, and Guillermo Noguera. 2012b. “Fragmentation and Trade in Value Added over Four Decades.” NBER Working Paper No. 18186.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei. 2012. “Estimating Domestic Content in Exports when Processing Trade Is Pervasive.” *Journal of Development Economics*, 99(1): 178–189.

Koopman, Robert, Zhi Wang, and Shang-Jin Wei. 2014. “Tracing Value-Added and Double Counting in Exports.” *American Economic Review*, 104(2): 459-94.

Levchenko, Andrei, Logan T. Lewis, and Linda L Tesar, 2010. "The Collapse of International Trade during the 2008–09 Crisis: In Search of the Smoking Gun." *IMF Economic Review*, 58(2): 214-253.

Manova, Kalina, and Yu. 2012. “Firms and Credit Constraints along the Global Value Chain: Processing Trade in China.” NBER Working Paper No. 18561.

Oldenski, Lindsay. 2012. “The Task Composition of Offshoring by U.S. Multinationals.” *International Economics*, 131: 5-21.

Ramondo, Natalia, Veronica Rapoport, and Kim Ruhl. 2014. “Horizontal versus Vertical Foreign Direct Investment: Evidence from U.S. Multinationals." UC San Diego. .

Romalis, John. 2004. “Factor Proportions and the Structure of Commodity Trade.” *American Economic Review*, 94(1): 67–97.

Schott, Peter K. 2003. “One Size Fits All? Heckscher-Ohlin Specialization in Global Production.” *American Economic Review*, 93(3): 686–708.

Schott, Peter K. 2008. “The Relative Sophistication of Chinese Exports.” *Economic Policy*, 23(53): 6-49.

Subramanian, Arvind, and Martin Kessler. 2013. “The Hyperglobalization of Trade and Its Future.” Peterson Institute for International Economics Working Paper 13-6.

Wang, Zhi, Shang-Jin Wei, and Wu. 2013. “Quantifying International Production Sharing at the Bilateral and Sectoral Levels.” NBER Working Paper No. 19677.

Yi, Kei-Mu. 2003. “Can vertical specialization explain the growth of world trade?" *Journal of Political Economy*, 111(1): 52-102.

Yu, Miaojie, and Wei Tian. 2012. “China’s Firm-Level Processing Trade: Trends, Characteristics, and Productivity.” China Center for Economic Research Working Paper No. E2012002.