Causes of International Production Fragmentation: Some Evidence

Russell H. Hillberry
University of Melbourne

Introduction

What forces have driven international fragmentation of production in recent decades? Perhaps technological innovations in information technology have allowed the coordination of integrated production processes that are separated by vast distances. Perhaps reductions in transportation costs, tariffs and other trade barriers facilitated multi-stage production, allowing components to cross several international borders and/or long distances with relatively low accumulated transit costs. Perhaps changes in the political economy of new market economies (first in Eastern Europe and then in East Asia) have opened up new possibilities for specialization in different segments of the supply chain. Each of these explanations undoubtedly plays a role, of course, and the interaction of these effects is also important. This document attempts to identify evidence that points towards one or more of these theories as a leading cause.

The definition of international product fragmentation used here follows Athukarola (2006): 'the cross-border dispersion of component production/assembly within vertically integrated production processes.'[1] The nature of the phenomena of interest might be illustrated by an example. A major manufacturing export of St Kitt's and Nevis, a small island nation in the Caribbean, is *electrical switches*. The major import commodities in St Kitt's and Nevis include *telephonic and telegraphic switching apparatus* and *electrical resistors*, both presumably inputs into the production of switches bound for export. One can imagine that the switches exported from St Kitt's and Nevis, upon reaching their destination, may well be incorporated into electrical components that are themselves exported for further processing. It is phenomena such as the specialization of St Kitt's and Nevis within an international vertical production chain that is the topic of interest to this paper.

The data available for an empirical assessment of these phenomena are imperfect, so we use different data series to evaluate different propositions. First, we use the OECD's consistent country-level input-output tables to investigate changes within national economies. These data allow an assessment of the characteristics of industries that have seen growth in the degree to which they participate in global markets. Of specific interest is the question of whether manufacturing industries that have been exposed to greater innovations in key service sector activities are those that have seen greater international sourcing of parts. Our regression framework allows us to evaluate whether there is evidence of systematic changes across industries and countries that links structural changes

[1] There are a number of related phenomena including outsourcing (i.e. changes in the boundary of the firm), foreign direct investment, and increasing trade in producer services with which we will not formally engage.

in industry purchases of key services to increased use of imported intermediate inputs such as components, parts and accessories ('parts').

The second exercise uses international trade data from across the world to evaluate changes in the share of parts trade across countries and over time. The international trade data give global coverage, and allow an investigation of specific hypotheses about the types of countries that have become more active in global parts trade.

The final exercise exploits U.S. import data. These data include details such as transportation mode choice, freight charges, and duties paid. This information is not available in the global trade data, and allows us to investigate specific hypotheses about the role of changing trade costs and shipment modes in parts trade. Importers' observed reliance on air vs. sea modes provide evidence on the role of speed in parts trade.

The picture that emerges puts significant weight on political economy reforms in countries that once had centrally planned economies. Such economies appear to export a disproportionate volume of parts, after controlling for per capita income and size. The integration of these countries into global parts trade seems to have occurred rather rapidly, with significant evidence of such integration by 1996. There is also evidence from U.S. data that parts trade has become relatively more dependent on air shipments than has trade in similar products. Evidence on the role of key amalgamating and coordinating services is lacking here, although the available data are not especially well suited to the task.

The paper is organized as follows. The following section explains several hypotheses that have been put forward as potential causes of the growth in product fragmentation. Section 3 uses country level input-output tables to look for cross-industry, cross-country changes in the nature of intermediate trade growth. Section 4 exploits global international trade data to identify the characteristics of countries that have seen a growing role in trade in international parts. Section 5 exploits the US trade data to investigate specific hypotheses about the role of trade costs and shipments modes. Section 6 concludes.

Explanations

As noted above, the purpose of this document is to evaluate hypotheses about the global fragmentation of production, which is defined as 'the cross-border dispersion of component production/assembly within vertically integrated production processes.' There are a number of explanations for growth in such activities. The purpose of this section is to explain them, offering suggestions, where possible, about how such explanations might be taken to the data. Initially, we outline two related frameworks within which specific hypotheses can be explored: production fragmentation, as it is presented in Jones and Kierzkowski (1990), and vertical specialization, as presented by Hummels et al. (2001). We then turn to specific hypotheses about potential explanations for recent changes in the two types of activity.

Frameworks

Intermediary services and production fragmentation

A useful overarching framework for this analysis is put forward by Jones and Kierzkowski (1990). These authors propose a (somewhat informal) model in which various 'production blocks' are linked by service sectors (especially in transport,

communications and information technology).[2] The key point is that the relevant service sectors are necessary for the coordination or amalgamation of production activities that take place in disparate locations. In this framework, fragmentation of production implies that the cost of coordinating multiple activities in their respective low-cost locations is lower than the cost of integrated production in a single location.

An intriguing feature of this framework is that the coordination/amalgamation activities are taken to have increasing returns to scale.[3] In this context, the presence of increasing returns to scale suggests large investments in these sectors can produce significant and enduring reductions in the marginal costs of coordination/ amalgamation. Costly investments in telecommunications and/or transportation networks are obvious sources of increasing returns that are relevant to this discussion. Both the laying of internet cables in telecommunications, and investments in facilities that allow containerization in transport are plausible large, up-front investments that have dramatically reduced the marginal costs of coordinating and amalgamating production activities over diverse locations. A belief that such investments are important naturally leads one to the Jones and Kierzkowski (1990) framework.

Underneath the umbrella of the Jones and Kierzkowski (1990) framework, there is substantial room for alternative explanations for growing international fragmentation. The headline story, of course, is that reduced costs of services that facilitate coordination or amalgamation of globally dispersed activities can lead to increasing fragmentation. Potential causes for reduced costs of these activities might be technical innovation, costly investments with increasing returns to scale, or both. In the presence of increasing returns to scale, a growing international economy is itself a reason for increased production fragmentation, as a larger market allows fuller exploitation of increasing-returns-to-scale investments in the service sectors that facilitate coordination and amalgamation of disparate manufacturing activities. A larger world economy might simply have arisen through the regular process of economic growth, but it might also have been sped up by the inclusion of formerly non-market economies such as China. The addition of these economies might also have expanded the set of choices over relative factor bundles amongst market economies, opening up further possibilities for specialization. The Jones and Kierzkowski (1990) framework can also accommodate stories about reduced trade frictions (i.e. tariffs), though such explanations are only tangentially related to the central line of argumentation.

Vertical specialization

A complementary framework that is useful for understanding international production fragmentation is the concept of vertical specialization put forward by Hummels et al. (2001).[4] This framework emphasizes the role of sequential production staging within international production networks. In Hummels et al. (2001) the specialized

[2] A formal theory that is largely consistent with the Jones and Kierzkowski (1990) framework is Grossman and Rossi-Hansberg (2008). Theirs is a formal model of 'trade in tasks.'

[3] Increasing returns to scale are not strictly necessary for some of the hypotheses that will be considered. A permanent reduction in fuel costs, for example, might reduce transportation costs and increase fragmentation without requiring any significant increasing returns to scale. However increasing returns to scale are a plausibly important feature of services like transport and communications, and should be part of the discussion.

[4] Hummels et al. (2001) attribute the concept to Balassa (1967) and Findlay (1978).

tasks undertaken in various countries are thought to be vertically linked, so that one country takes some inputs, adds value, and then send those inputs onto another country for further processing.[5]

Hummels et al. (2001) demonstrate the growth of this phenomenon through an assessment of national input-output tables. Using input-output analysis, they show that the embodied imported content of exports grew almost 30 percent between 1970 and 1990, on average, across 14 countries. Such calculations are fully consistent with the idea that production fragmentation is occurring through specialization in particular stages of multi-stage production chains. Given the highly aggregated nature of international trade data in input-output tables (the industries themselves are highly aggregated, and the input-output tables lack information on the origins of imports and the destination of exports), the calculations are unable to place countries at particular stages of the production chains. The focus of Hummels et al. (2001) is measuring both the levels of, and the changes in, the implied values of imported content in exports.

In the context of the work in this document, vertical specialization does not offer new hypotheses about possible sources of growth in production fragmentation. Rather, vertical specialization acts as a magnifier of particular forces driving fragmentation. The key hypothesis put forward in the vertical specialization literature is that the effect of trade cost reductions on cross-border trade volumes is substantially magnified by the presence of vertical specialization. Since spreading multiple production stages across many countries means that the output of early production stages crosses multiple borders and considerable distances, high trade costs can seriously impinge on such activities.[6]

Hypotheses

The goal of this project is to identify hypotheses about the growth of production fragmentation, and, to the extent possible, evaluate these formally. In this section we describe the phenomena of interest, and describe shortly how such changes are evaluated later in the document.

Many of the proposed hypotheses might have facilitated growth in international trade, even in the absence of production fragmentation. So, for example, the entry of China and other low-wage manufacturers into the global economy are thought to have increased manufacturing trade. They might have done this without inducing production fragmentation.[7] Thus a key difficulty in this exercise is to separate the effects that might have produced a more general increase in international trade in manufacturing from the particular factors that had a specific impact on the production fragmentation.

Hypothesis one: A central idea in Jones and Kierzkowski (1990) is that a critical input in fragmented production processes are key intermediary services that facilitate the coordination and amalgamation of dispersed production activities. A number of candidate service industries might be named. The focus here is on three service sectors of interest:

[5] These ideas are not inconsistent with the Jones and Kierzkowski (1990) framework, which can accommodate vertical specialization, though that framework does not formalize the sequential nature of production staging.

[6] See Yi (2003) for a formal statement of the claim, and a quantitative estimate of the role of vertical specialization in world trade growth.

[7] In a standard trade model with only final goods, the entry of such countries into the world economy would generate a shift of entire final goods industries, rather than intermediate stages within industries.

transportation, telecommunications, and information technology. Each of these sectors have seen important technical innovations in recent decades. They have also seen large investments that are consistent with the main idea in Jones and Kierzkowski (1990) that such sectors experience increasing returns to scale. The development of global standards for containers, along with the spread of container-ready ports, required substantial investments aimed at reducing marginal costs of shipping. Investments in broad-band technology have reduced costs of telecommunications, with flow on benefits for the information technology sectors. Information technology and improved telecommunications technology have, in turn, improved logistics. For example, the use of global positioning systems, along with efficient telecommunications and information technology, allows firms to better track and schedule their shipments of goods.

These ideas are difficult to evaluate formally in a simple empirical test. Put at its simplest, it seems that the Jones and Kierzkowski (1990) framework suggests that intermediary service sectors are complements in production to the use of imported intermediate inputs. We will formally examine this idea using input-output tables from the OECD. Our test will look for commonalities across countries and manufacturing industries in the joint use of these service sectors and imported inputs. Because there is substantial variance across manufacturing industries and countries in the degree to which these sectors and imported intermediate inputs are employed, the focus of the hypothesis is on joint changes in the use of the nominated service sectors and imported inputs. If changes in these service sectors have driven product fragmentation, then country-sector pairs in manufacturing that increased their use of these sectors should have seen a relative increase in the share of intermediate inputs that are imported.

Hypothesis two: Just-in-time production processes rely on the reliable flow of parts from one stage of production to another. One mechanism for assuring prompt and reliable delivery of products is the use of high speed transportation, especially air shipments. Hummels (2007) notes that an important relative price change that has occurred in recent decades is the fall in the relative price of shipping via air freight. These price reductions might explain growth in global production chains. We shall explore the role of increasing reliance on air transport in product fragmentation using the OECD's input-output tables. We shall also look for evidence on this point in the U.S. import statistics, which report information on the mode of shipment.

Hypothesis three: The entry of new economies into the global marketplace in the late 1980s and early 1990s created new opportunities for international organization of production. China is one obvious entrant into global marketplace during this period. The entry of formerly communist countries in Eastern Europe has also been a pluasible reason for increased processing trade.[89] Using the Jones and Kierzkowski (1990) framework, the entrance of new economies into the market system generates the potential for new production blocks to emerge, allowing for greater potential for fragmentation. The key

[8] One might have also taken trade and other market liberalization measures in countries like India to be important for offshoring. Indeed, this is quite plausibly important. In order to maintain a sharp hypothesis for empirical testing, this paper shall focus on countries that saw substantial changes in their political economy in the form of a movement away from a centrally planned economy administered by a communist party.

[9] Countries that have made significant moves to embrace the market, even if they have retained a formally communist party leadership (i.e. China or Vietnam) will be treated as 'formerly communist' in what follows. The emphasis here is the changing nature of production decisions, rather than the retention of formal political power by the party.

question in these cases is not whether such changes had an impact on growth in manufacturing trade, but rather whether there was a *differential* impact of such changes on trade in intermediate inputs, relative to other complex goods. We shall explore this hypothesis using international trade data. The idea is to investigate whether or not these countries have been especially important in the trade in parts.

Hypothesis four: One argument about the growth of global production fragmentation (as well as vertical specialization) is that they have been driven by reductions in trade costs. Formal evidence on trade costs lies in many places, but this information is only linked directly to trade flows in a few countries' data sets. The United States is a large country that trades with most other countries in the world. As such, U.S. import data provides information on tariff and freight cost margins across a wide variety of source countries. We shall investigate the wedge between import prices at foreign ports and their destination ports in the United States. The key question is whether there has been a differential effect of these trade cost reductions on trade in parts, and if so, whether that has produced relatively larger growth in imports in those commodities.

Changing input-output relationships

In this section we employ the OECD's cross-country data on input-output relationships to evaluate hypotheses about the role of specific services in the growth of international outsourcing. The OECD data are useful because they provide a common format for representing national production structures across a wide variety of countries.[10] This common format allows an opportunity to identify common changes in production structure across a large set of manufacturing sectors in a large number of industries.

The input-output tables produced by the OECD are fairly aggregated; they report information for only 48 sectors. 22 of these constitute manufacturing sectors producing tradeable goods.[11] For each of the 48 sectors, the tables report the value of intermediate inputs used (both those that are imported and those that are purchased from domestic sources). The tables also supply information on the use of particular services in each industry.

The sectors that are most relevant to the Jones and Kierzkowski (1990) framework are sectors 33 (Land Transport), 34 (Water Transport), 35 (Air Transport), 37 (Post and Telecommunications) and 41 (Computer and related activities). These sectors are plausible candidates as key service sectors involved in the coordination and amalgamation of manufacturing activities from around the globe. These are also sectors that have seen both sizable innovations, as well as major investments that might plausibly align with the Jones and Kierzkowski (1990) theory. Innovations include the growth and spread of the internet in computing and telecommunications, and major developments in logistics such as containerization and the adoption of computing- and communication-intensive 'just-in-time' manufacturing. These innovations required substantial new investments in recent

[10] The countries included in the OECD database are the developed country members of the OECD, as well as several large low- and middle-income economies. The sample employed in the estimation is limited to those countries with a table in 1995 as well as a table in either 2004 or 2005.

[11] The supply of utilities such as electricity, gas and water are excluded from the analysis, even though these sectors, especially electricity generation, might be considered manufacturing under some definitions. The tradability of the output of such sectors is limited, and highly dependent on the specific geography of each country.

decades, including the laying of transoceanic fibre-optic cables and the retrofitting of ports to allow container traffic.

If the nominated sectors are complementary to international production fragmentation, then one might expect to see that manufacturing industries that increase their use of these sectors as inputs relatively more would have relatively larger increases in their use of imported intermediate inputs. In particular, we might expect to see industries with relative growth in the use of these sectors expand their use of imported inputs relatively more.

One of the key limitations of input-output tables for this purpose is that they report information solely in value terms. Large reductions in the prices paid for particular services may be masked in these tables, if industries increase the quantity purchased of the service as prices decline. The hypotheses are thus framed in relative terms. Given a change in the price of one of these services, the assumption is that industries that have relatively larger shifts toward the use of these services are purchasing larger relative quantities of those services. If such services are complementary with imported inputs, these sectors will shift more towards the use of imported intermediate inputs.

The empirical exercise conducted here evaluates changes in the production structure between 1995 and 2005. All countries in the database that have a 1995 table and a 2004 or 2005 table are included in the exercise.[12] The country coverage includes most of the OECD membership, as well as a selection of large developing countries and Israel.[13]

The empirical specification is as follows:

$$m_{ckt} = f_c + f_k + \beta_s s_{ckt} + \beta_T Time + u_{ckt} \qquad (1)$$

where m_{ckt} is the share of imports in intermediate purchases by manufacturing industry k in country c at time t, f_c and f_k are country and industry fixed effects, s_{ckt} is the cost share of a particular service activity, $Time$ is a dummy variable that takes the value of zero for 1995 and one for 2005, and u_{ckt} is a normally distributed error term. The coefficient β_T captures the average conditional change in import shares (across countries and industries). The coefficient β_s links changes in the input cost share of each respective service activity to the increasing reliance of manufacturing industry k on imported intermediates.[14]

We run the regression specified in (1), using each of four candidate variables as the independent variable of interest. Computers and related activities, post and telecommunications, and transportation are all service sectors that are potentially involved in the coordination/amalgamation of activities. We include the cost share of each service

[12] Belgium and Israel are the only two countries in the sample with 2004, rather than 2005, data.

[13] The countries with data that are included in the exercise are Austria, Belgium, Brazil, Canada, China, Denmark, Finland, France, Great Britain, Germany, Greece, Indonesia, Israel, Spain, Italy, Japan, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Sweden, and the United States.

[14] According to the theory of Jones and Kierzkowski (1990), industries are able to decrease costs by sourcing lower cost inputs from abroad, but must purchase more services in order to take advantage of those opportunities. Thus increased purchases of the service activity are taken to be necessary for increases in international sourcing.

activity in gross output (GO) as the independent variable in (1). We also employ the share of industry transportation expenditures that go to air transport as an independent variable. This evaluates the hypothesis that air transportation is a critical input in production fragmentation.

Before turning to the results, we report the conditional means of each variable of interest in Table 1. All of the service sectors of interest increase their share of output, on average, over time. In the case of transport, the increase is within rounding error. The mean of the air share of transport falls in this sample, perhaps in part because of significantly higher fuel prices in the later years.

Table 1: Conditional mean values of variables across countries and industries

Variable	1995	2004/5
Imported share of inputs	0.303	0.361
Computer and related activity share of GO	0.004	0.006
Post and Telecommunication share of GO	0.006	0.007
Transportation share of GO	0.021	0.021
Air share of transportation	0.147	0.132

Data taken from OECD input output tables.
'GO' indicates gross output.

The results of the estimation based on the econometric specification in equation (1) appear in Table 2. There is little evidence here to support the idea that key service sectors have driven the growth in intermediate input trade. Positive and statistically significant coefficients on the Time dummy indicate growth in the intermediate input share that is orthogonal to the changes observed in the use of sectors of interest. Only one of the variables (the share of post and telecommunications in output) has a statistically significant coefficient attached to it, and that coefficient is negative. This means that industries that saw relatively slower growth in their use of the post and telecommunications sector saw larger growth in the intermediate share of inputs. The remaining variables also had negative signs, counter to expectations, though these were not statistically different from zero.

Subsequent analysis will focus on 'complex goods' as a particularly interesting subset of manufacturing in which to evaluate fragmentation. As a robustness check, the sample was limited to OECD industries 14-24 and 10, which excludes heavy industry from the manufacturing sample. Results were similar to those that appear in Table 2. There is no evidence to suggest that industries that increased their intermediate input shares were those with relative increases in their use of nominated service sectors.

Table 2: Imported input shares and services use 1995-2005

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Time = 2005	0.06***	0.07***	0.06***	0.04***	0.04***	0.05***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
Computer share of GO		-1.18				-0.82
		(0.970)				(1.023)
Telecom share of GO			-2.96***			-2.74**
			(0.807)			(1.116)
Transport share of GO				-0.14		-0.26
				(0.389)		(0.406)
Air share of transport					-0.07	-0.04
					(0.045)	(0.045)
Constant	0.39***	0.40***	0.41***	0.41***	0.41***	0.43***
	(0.013)	(0.013)	(0.013)	(0.017)	(0.015)	(0.019)
Observations	881	786	880	719	719	695
R-squared	0.693	0.696	0.702	0.729	0.731	0.745

Dependent variable is imported share of intermediates purchased by manufacturing industry, country, year triplets.
Estimates include industry and country fixed effects.
Standard errors in parentheses
*** p<0.01, **p< 0.05, * p<0.1

Discussion

It is difficult to formally evaluate the hypotheses put forward by Jones and Kierzkowski (1990). They rely on complementarity between imported inputs and the amalgamating/coordinating sector. Were we to observe relative input prices and firm level behavior, we might be able to identify such changes closely. Even then, we would likely have to rely on input prices (for services especially) that vary with quality, and are difficult to measure.

The method identified above suggests a plausible test of substitution possibilities. Since developments in the service sectors of interest had global impact, the large amount of cross-country variation available in the multi-country input-output tables offered a chance to observe common changes across countries. The relatively aggregated nature of the industry flows, however, make clear assessments difficult. Substitution possibilities occur at the firm level, and what is observed here are highly aggregated industries. Automotive equipment, for example, is a single sector in these tables, including many complex staging possibilities and component parts. Sector-level analysis treats all firms within this industry as if they responded to relative price changes in equivalent ways.

Evidence from international trade flows

International production fragmentation involves two types of changes that are difficult to observe jointly in the data: national production structures change, as do trade flows. One of the difficulties associated with assessments of changing production

structures is that production data that are compatible across countries are typically quite aggregated. International trade data, on the other hand, offer considerably more detail.[15] The key question pursued here is how trade in parts differs from trade in other complex goods.

The trade data employed here are bilateral trade data collected by the United Nations Conference on Trade and Development (UNCTAD), and maintained by the World Bank using the World Integrated Trade Solution (WITS) software. The data considered here are from the years 1996, 2002, and 2008.[16] 1996 is the first year that the data is available through WITS.[17] The data contain product detail at the HS6 level of aggregation.

In order to identify trade in parts, we employ a classification developed alongside the BACI data (Gaulier and Zignago (2009)). The classification is based on the United Nations' Broad Economic Categories. Each HS6 category is assigned to one of 5 groups: Parts and accessories, Consumption goods, Capital goods, Primary goods, and Processed goods. The focus of attention in this paper is the parts and accessories category.[18] This category of goods is compared against a broader grouping, labeled *complex goods*. For the purposes of the exercises in this section of the paper, complex goods will include all those in the three BACI categories: Consumption goods, Capital goods, and Parts and accessories. These goods are grouped together because they are relatively late stage in production, include multiple inputs, and are relatively footloose in terms of their natural resource requirements. In the absence of production fragmentation, parts and accessories would be expected to be produced in the same location as final goods in the capital and consumption goods categories.

We begin with an illustration of the cross-country distribution of parts trade. This information is displayed in Figure 1. The share of parts in complex goods exports is displayed along the vertical axis. The horizontal axis measures exporter size, using the (log of) total export value as the indicator of interest. Larger exporters tend to export more parts as a share of their complex goods exports. The outlier 'KNA' at the top of the figure is St Kitt's and Nevis. The high degree of parts trade in East Asia is also evident in the upper right hand of the figure. Many of these countries would also export a significant amount of capital and/or consumption goods, so the relatively large parts share displayed in the figure is notable.[19]

The purpose of this section is to attempt to explain variation in parts trade across countries and over time. In order to identify specific forces driving parts trade, the method must control for other explanations for variation in trade flows. One method of control is to also track changes in a broader set of complex goods.

---

[15] The primary difficulty with international trade data for an exercise like this one is that the end use of imported goods must be inferred, whereas input-output tables can distinguish between purchases by firms and purchases by consumers. External assessments of the likely end use of each commodity are used as inputs into what follows.

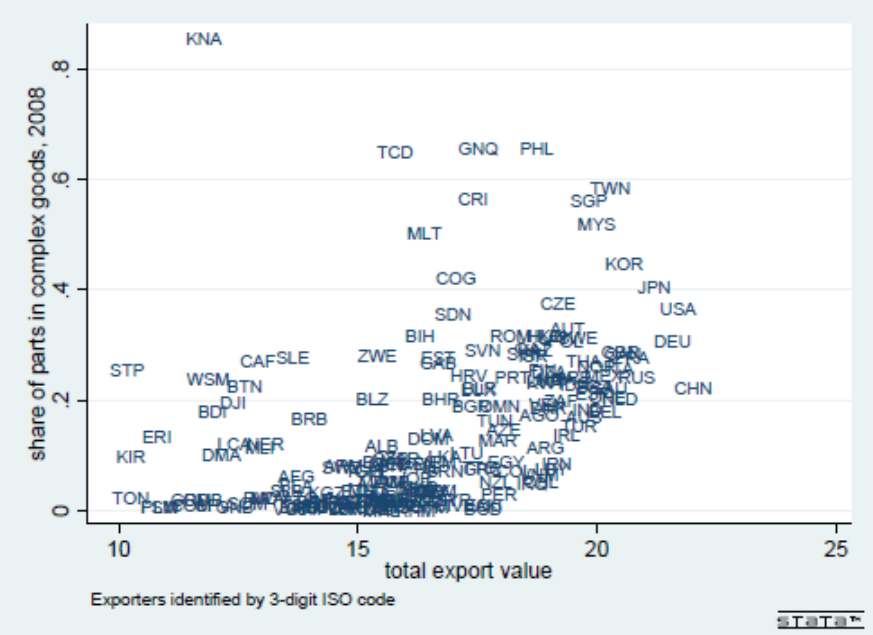
[16] Bilateral flows at the product level implies very large quantities of data. We limit the size of the problem by using data from selected years.

[17] Longer time series are available in the data collected by Feenstra et al. (2005), but these data end in the year 2000, and report product information in a more aggregated format.

[18] Parts and accessories are referred to as 'parts' throughout, including references to classifications.

[19] For a detailed discussion of parts trade in East Asia, see Athukarola (2006).

Figure 1: Share of parts in complex exports against exporter size, 2008



The primary analytical tool used here is a decomposition of trade flows, which will be applied to exports and imports in turn.[20] The decomposition for exports is as follows:

$$XP_{it} = \frac{XP_{it}}{XC_{it}} \frac{XC_{it}}{X_{it}} X_{it} \quad (2)$$

where country i's exports of parts at time t is denoted XP_{it}. Variation across time or across exporters can be decomposed, in turn, into movements in the three terms on the right hand side of (2). The first term on the right, $\frac{XP_{it}}{XC_{it}}$, measures the share of parts in total complex goods exports from i at time t, XC_{it}. The second term, $\frac{XC_{it}}{X_{it}}$, measures the share of complex goods exports in total exports from i at time t, X_{it}. The third term captures movements in total exports. It is the first term in this decomposition that is of interest. Changes in this ratio indicate differential changes in parts trade, distinct from broader changes in the trade of complex goods.

The method for what follows is to regress (the natural log) of the left hand side of (2) on independent variables of interest, and then regress the natural log of each of the components of the right hand side on those same variables. The coefficient from the left hand side regression explains how total parts trade relates to the independent variables.

[20] The decomposition originated in Hummels and Klenow (2005). Hillberry and Hummels (2008) and Bernard et al. (2007) applied it to spatial variation in trade flows. Hillberry and McDaniel (2002) applied the technique to bilateral changes over time in trade flows.

The coefficients from the right hand side regressions explain whether such movements are particular to parts trade, or common across a broader set of goods.

The initial exercise involves a series of single-period cross-section regressions using data from 1996, the first year of the sample. Three independent variables of interest are included: log per capita GDP, log population, and a dummy variable indicating if the country is a formerly communist country.[21] Per capita GDP offers a crude indicator of the relative availability of capital and skilled labor.[22] As relatively complex goods, one might expect that parts would be produced in relatively rich countries. The population variable measures country size, after controlling for per capita income. If either internal or external scale economies are important in parts production, one might expect to see large countries exporting parts.[23] The inclusion of a dummy variable indicating formerly communist countries reflects the idea that new entrants into the global marketplace may have brought new factor bundles that facilitate trade in tasks.[24] The results of these regressions appear in Table 3. Note that our decomposition structure ensures the coefficients from columns 2-4 sum to the coefficient in column 1, within rounding error.[25]

The results in the first column of Table 3 indicate that exports of parts are increasing in per capita income and country size. Formerly communist countries export significantly more parts than other countries, after controlling for per capita income and country size. The results in column 4 offer a useful comparison, as these coefficients define the effects of the same variables on total exports. Total exports are less responsive to per capita income and size than are exports of parts. Formerly communist countries export less in total than other countries, after controlling for size and per capita income.

---

[21] The countries included in this group are Afghanistan, Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Cambodia, China, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Laos, Latvia, Lithuania, Macedonia, Moldova, Montenegro, Poland, Romania, Russia, Serbia, Slovak Republic, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan and Vietnam.

[22] We employ per capita GDP from 1995 as a regressor for 1996 trade flows. GDP is endogenous to exports, so we use data from the year prior as our exogenous measure of per capita GDP.

[23] One might normally expect to see GDP enter alone as an indicator of market size, offering no distinction between large low-income countries and small high-income countries. Here we are we using the ratio of GDP/population as an income measure, and population as the country size measure.

[24] The inclusion of China in East Asian parts markets, as well as the shifting of parts production activities from Western to East Central Europe, are anecdotally important changes in parts and accessories trade. The exhaustive list of formerly communist countries is meant to assess whether such anecdotes consistent with a broader story about the entry of new markets into the world trading system. The entry of such countries into global markets allows new 'production blocks' in the language of Jones and Kierzkowski (1990), and this offers a test to see if those new entrants are especially important for parts trade.

[25] This structure facilitates a convenient decomposition of the effects summarized by the coefficients in column 1. Consider the coefficients on log per capita GDP in columns 1 and 2 as an example. $\frac{0.63}{2.47} = 0.27$ implies that 27 percent of the response of total parts trade to per-capita GDP is due to the fact that the share of parts and accessories in complex goods rises with per capita GDP. Such thought exercises can be done with any of the coefficients in columns 2-4.

Table 3: Decomposition of exports, across countries, 1996

	(1)	(2)	(3)	(4)
Variables	$\ln(XP)$	$\ln\left(\frac{XP}{XC}\right)$	$\ln\left(\frac{XC}{X}\right)$	$\ln(X)$
Per capita GDP, 1995	2.37***	0.63***	0.32***	1.41***
	(0.121)	(0.086)	(0.078)	(0.099)
Population, 1995	1.15***	0.26***	-0.06	0.94***
	(0.062)	(0.055)	(0.037)	(0.034)
Formerly communist	0.76***	0.65***	0.38*	-0.27*
	(0.243)	(0.167)	(0.196)	(0.152)
Constant	-19.37***	-10.54***	-3.52***	-5.31***
	(1.246)	(0.941)	(0.716)	(1.006)
Observations	179	179	179	179
R-squared	0.834	0.337	0.112	0.861

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Columns 2 and 3 of Table 3 illustrate how total exports and parts exports differ across these three independent variables. The share of complex goods in total exports is rising in a country's per capita income. There is relatively little evidence that complex goods exports differ from total trade with respect to country size and the formerly communist dummy. The most notable differences between parts trade and total trade are illustrated in column 2, where each of the variables of interest has a large positive and statistically significant coefficient. Each of these independent variables predicts relatively more parts exports than exports of other complex goods.

The statistical and economic significance of the coefficient on the formerly communist dummy in column 2 is notable. These data are for 1996, just 7 years after the fall of the Berlin Wall, and only 5 years after the collapse of the Soviet Union. Chinese market reforms took place over a longer period, but were only firmly in place by the early 1990s.[26] Yet already in the 1996 data, formerly communist countries were unusually large exporters of parts. Furthermore, it seems that there is something unusual about parts, since they are relatively more important in exports from these countries than were exports of other complex goods.[27]

[26] Deng Xiaoping's 'southern tour' is a notable landmark in Chinese economic reforms. That event took place in 1992.

[27] Note that while China undoubtedly has a large economic role in parts and accessories trade, the regression procedure here allows relatively little influence of China in a statistical sense. It is just one of 33 countries for which the dummy variable takes the value of one. As such, its influence on the regression is rather small.

Table 4: Decomposition of imports, across countries, 1996

	(1)	(2)	(3)	(4)
Variables	$\ln(MP)$	$\ln\left(\frac{MP}{MC}\right)$	$\ln\left(\frac{MC}{M}\right)$	$\ln(M)$
Per capita, GDP995	1.65***	0.12***	0.07***	1.46***
	(0.067)	(0.030)	(0.015)	(0.048)
Population, 1995	0.92***	0.13***	-0.03***	0.82***
	(0.038)	(0.017)	(0.011)	(0.024)
Formerly communist	-0.29*	-0.08	-0.20***	-0.01
	(0.160)	(0.092)	(0.056)	(0.093)
Constant	-9.01***	-3.79***	-0.89***	-4.33***
	(0.599)	(0.289)	(0.135)	(0.480)
Observations	113	113	113	113
R-squared	0.920	0.407	0.347	0.953

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results for an equivalent exercise on imports is reported in Table 4.[28] In these regressions variation in overall trade is linked more closely to trade in parts. The coefficient estimates in columns 1-4 are quite similar. Nonetheless, there remains some interesting variation revealed in columns 2 and 3. The share of complex goods in total imports is rising in per capita income, and falling in population size, though these effects are not large. Formerly communist countries are less likely to import complex goods than other countries. The share of parts in complex goods in parts is also rising in per capita income and population size.

The evidence from Table 3 indicates that in the period following significant changes in political economy in formerly communist countries, parts became an important part of these countries' exports by 1996. The next set of exercises looks at subsequent changes in the pattern of trade. One might imagine production fragmentation involving new market participants as a one-time shift that had been completed by around 1996. If these countries are as important for production fragmentation as the previous regressions indicate, then a key question is whether production fragmentation continued after 1996, or if the transition into significant parts trade had already been completed by then.

Once again the decomposition in (2) is the central empirical tool, along with its counterpart for imports. This time the sample includes data from two later years, 2002 and 2008.[29] The regression specification includes time dummy variables, as well as fixed effects

[28] The data used here are those that importers reported to UNCTAD. (Data reported by importers are often better than data reported by exporters because import tracking is linked to traditional mechanisms for collecting tariff revenue.) The use of importer reported data means that there are fewer importers observed in these data than there are exporters. Countries which are not reporters to UNCTAD are observed as exporters in these data, but not as importers. Such countries are typically quite small participants in global trade.

[29] In order to control for US dollar inflation, the figures here are deflated by the US import price

that control for country-specific averages over time. The regressions employed here indicate whether, across the sample, countries observed significant changes in the composition of their exports, on average.

Table 5: Decomposition of exports, 1996-2008

	(1)	(2)	(3)	(4)
Variables	$\ln(XP)$	$\ln\left(\frac{XP}{XC}\right)$	$\ln\left(\frac{XC}{X}\right)$	$\ln(X)$
Year = 2002	0.57***	0.14*	0.06	0.37***
	(0.082)	(0.076)	(0.046)	(0.058)
Year = 2008	1.45***	0.29***	-0.22***	1.37***
	(0.087)	(0.082)	(0.057)	(0.068)
Constant	9.53***	-2.88***	-1.20***	13.61***
	(0.065)	(0.059)	(0.038)	(0.048)
Observations	687	687	687	687
R-squared	0.968	0.816	0.895	0.973

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Country level fixed effects included in all regressions.

Results for exports are reported in Table 5. Both parts trade (column 1) and overall trade (column 4) grew substantially during the period. Coefficients on the *year=2008* dummy indicate that complex goods fell as a share of exports in the average country, but parts as a share of complex goods exports rose. This is consistent with a story of ongoing product fragmentation. These effects are not large however. Variation in parts trade barely exceeded growth in overall trade. The overall conclusion is that, in the typical country, parts exports did not substantially outpace overall export growth in the years 1996-2008.

Table 6 reports the results of similar regressions using country level imports. In this case, the cross country average imports of parts grew slightly more slowly than overall trade. There is very little evidence to suggest that the trade in parts or complex goods had notably different time paths.

index for manufactured goods, excluding petroleum, which is available from the US Bureau of Labor Statistics.

Table 6: Decomposition of imports, 1996-2008

	(1)	(2)	(3)	(4)
Variables	$\ln(MP)$	$\ln\left(\frac{MP}{MC}\right)$	$\ln\left(\frac{MC}{M}\right)$	$\ln(M)$
Year = 2002	0.25***	-0.03	0.02	0.26***
	(0.051)	(0.026)	(0.017)	(0.034)
Year = 2008	1.06***	-0.05*	-0.08***	1.19***
	(0.058)	(0.027)	(0.019)	(0.039)
Constant	13.02***	-1.63***	-0.63***	15.28***
	(0.042)	(0.021)	(0.014)	(0.027)
Observations	412	412	412	412
R-squared	0.988	0.925	0.816	0.992

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Country-level fixed effects included in all regressions.

Discussion

One of the implications of the Jones and Kierzkowski (1990) framework is that the emergence of new trading possibilities makes possible increased production fragmentation. Economic reform in centrally-planned economies in in Eastern Europe and in Asia generated these new possibilities. In most cases, these new market-based economies were geographically close to developed country markets, so that developed countries could offshore parts activities at relatively low cost. Evidence from multinational trade data suggests that these new market economies export relatively more parts, as a share of complex goods, than other countries that are of similar sizes and levels of development. This appears to have been true as early as 1996, which is the initial year of the data employed here.

One of the questions of interest to policymakers will be whether the episode of product fragmentation that was observed in recent decades was a single large event, or is a process that is likely to continue unabated. Evidence from the international trade data suggests that trade in parts did not exceed general trade growth following 1996. This would be consistent with the view that the opportunities for product fragmentation that arose due to political economy reforms in former communist countries were seized quickly.

As indicated above, recent decades have also seen economic reforms in countries other than those identified here as formerly communist. For example, India has embarked on significant economic reforms, as have large parts of Latin America. It is likely that such reforms also increased the size of the global marketplace. It is difficult to evaluate such reforms, or to identify as easily the countries participating in them.[30] The role of other, non-communist reforming countries in global parts trade is left to future work.

[30] Trade reforms may be visible as tariff cuts, but one might also wish to identify significant changes in ownership, investment and competition policies, for example, that allowed deeper integration into global marketplaces.

Evidence from U.S. trade data

This section reports the results of an exploration of U.S. trade data over the period 1989-2008.[31] The questions investigated benefit from a number of details available in U.S. data that are not available in cross-country data sets, nor in many other single-country data sets. The U.S. data include information on shipment mode, which allows us to look for growing differences across goods and over time in the use of air transportation. Information on freight charges and tariffs allows an evaluation of changes in relative trade costs over the period. The U.S. data also report a finer level of product classification than is available in cross country data. An end-use classification in U.S. data allows us to separate parts from other trade at this more detailed level.

The identification strategy is similar to that followed in the previous section. The primary analytical tool is a decomposition that distinguishes between parts and other complex goods.[32] This isolates movements in aggregate parts trade from trade in other goods of similar complexity. Within the U.S. sample, most of the exercises will focus on within-country changes over time in the pattern of exports to the United States.

Changes in trade costs facing U.S. imports, 1989-2008

One of the key advantages of the U.S data is that includes good measures of trade costs. Information about duty collections is reported alongside the value of shipments. The U.S. data also includes direct measures of customs, insurance and freight (cif) charges. We begin the analysis of the U.S. data by calculating *ad valorem* tariff and cif rates for every country-commodity pair.[33] In order to see how relative trade costs have changed, we report the median value of these in 1989, for parts, and for all complex goods. The results appear in Table 7.

Table 7: Median charges: commodity-country pairs in U.S. imports

Trade Cost	Year	Parts	Complex
Customs, insurance and freight	1989	0.031	0.044
Customs, insurance and freight	2008	0.028	0.042
Duties	1989	0.036	0.046
Duties	2008	0.000	0.017

Trade costs measured on an ad valorem basis.
Complex goods in SITC 5-8.

Trade cost reductions appear in both cif charges, and in *ad valorem* tariffs. Both parts and complex goods saw notable reductions in duties, while the cif charges fell by much less. Measured in levels, *ad valorem* duties fell more amongst parts than amongst complex goods more generally. In the case of parts, the median *ad valorem* duty falls all the way to zero for parts trade, while in complex goods some duties remain.[34] It may be that moving

[31] The data are annual figures from *U.S. Imports for Consumption* published by the U.S. Census Bureau.

[32] Complex goods in these exercises are defined as commodities in SITC categories 5-8. Parts are defined by the U.S. end use classification. End use categories 2 and 3 are included, with exceptions for those subcategories that identify final capital or consumer goods.

[33] Commodities defined at the HS 8 level of disaggregation.

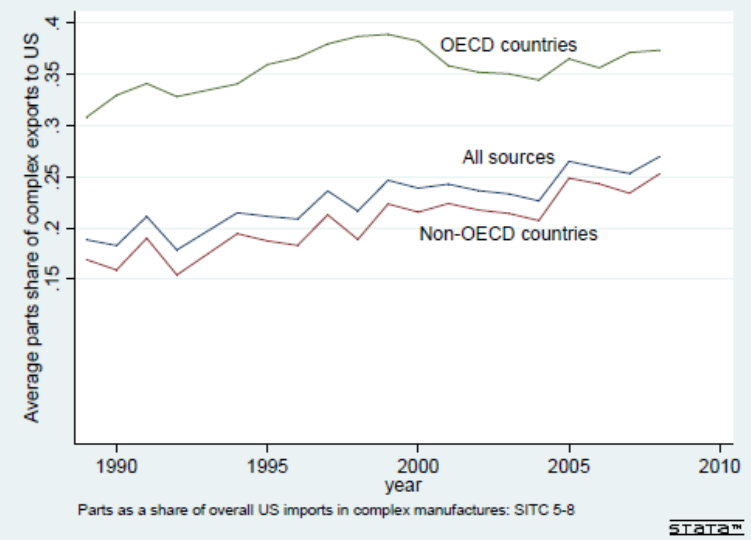
[34] The median duty for parts reached zero in the year 2000.

towards a zero tariff across a large group of parts was important for increasing trade flows.

Sources of U.S. parts imports

This subsection provides some short historical background on the evolution of U.S. parts imports over the period of interest. The purpose is to demonstrate movements over time in parts imports, as compared with imports of other complex goods. Each country's share of parts in complex exports to the U.S. is calculated, and this share regressed on a vector of country-specific fixed effects and annual year dummies. This exercise is also conducted for OECD countries and for non-OECD countries. The fitted values are plotted in Figure 2.

Figure 2: Fitted values of regression of share of exports in each country on annual dummy variables.



The central line in the figure captures movements over time in the average share of parts in countries' exports of complex goods to the U.S. This share is rising over much of the sample, from 0.19 in 1989 to 0.26 in 2008. The top line in the figure reveals that the high income countries in the OECD tend to have much larger shares of parts in their complex goods exports than does the average country. This is consistent with the earlier regression analyses linking per capita income to rising parts shares in multi-country data. Much of the growth in OECD parts shares in exports to the U.S. seems to have occurred in the 1990s. The lower line captures movements in the average share of parts for non-OECD countries, which moves in tandem with that of the typical country, but sits somewhat below the average.[35]

[35] In each case, the difference between the parts share at the end of the sample and at the beginning is highly statistically significant. A similar exercise for U.S. imports from formerly communist countries also demonstrated growth in the parts share post-1991, but the series is volatile, and has relatively large standard errors, so it is not shown here.

Within-commodity movements

The next exercise uses U.S. imports in complex goods as a benchmark against which to evaluate changes in the volume and nature of U.S. parts imports over time. Rather than aggregate across commodities into countries, as we did for the figure, in this set of exercises we aggregate across countries to the commodity level. We hope to capture average, within-commodity changes, in U.S. imports, and evaluate them in a useful decomposition. The decomposition appears as follows:

$$V_{it} = N_{it}\overline{PQ}_{it} = N_{it}\overline{Q}_{it}P_{it} \qquad (3)$$

where N_{it} represents the number of countries exporting commodity i to the U.S. at time t, $\overline{PQ}_{it} = \frac{V_{it}}{N_{it}}$ represents the average value of country exports, $\overline{Q}_{it}$ is the average quantity per country that is exported, $\frac{Q_{it}}{N_{it}}$, and P_{it} is the average unit price, $\frac{V_{it}}{Q_{it}}$, inclusive of duties and cif charges.

The logged terms in (3) are each regressed on a dummy indicating whether the HS8 commodity has been designated as a part, year dummies throughout the sample, and an interaction of the part and year dummies. This allows us to see average within-commodity movements over time, in U.S. imports, and to contrast the movements of parts imports with those of complex goods as a whole.[36]

The results of these exercises are reported in Table 8. In column 1, we see that the value of U.S. complex goods imports in a given commodity has risen over the period, as is clear from the positive and statistically significant coefficients on the year dummy variables. Further down the column, the interactions of the part and year dummies are also significant and positive, which indicates that the value of U.S. parts imports has grown more quickly than the value of other complex imports.

Column 2 demonstrates that approximately one-third of the increase in the value of complex goods imports into the U.S. has occurred because the U.S. now imports each product from more countries. Parts trade is not notably different, although in the period 2005-2008, the average number of source countries rises among parts while falling amongst other complex goods, generating a small but significant difference. Column 3 illustrates that most of the growth in average import value occurred because of growth in the average value shipped by each country. The average value per country grew faster among commodities identified as parts than among other complex goods.

Columns 4 and 5 offer a further dissection of the changes in the movements of column 3. Among all complex goods, unit prices and average quantities rise together. This suggests an increase in demand for imported complex goods. Against that baseline, there appear to be no significant relative price movements for parts. Rather, the relative increase in the average value of parts trade appears to arise as the result of increasing average quantities. If the entry of cheap new sources of parts supply were a dominant feature of the data, one might have expected to see relative parts prices fall. If new technological improvements allow higher quality parts to be produced overseas, one might have expected unit prices to have risen. The lack of definitive within-commodity price

[36] All dollar values are deflated by the U.S. producer price index in manufacturing.

movements, relative to other complex goods, suggests that such effects might be offsetting.[37]

Table 8: Changes in US Imports of Complex Goods, 1989-2008

	(1)	(2)	(3)	(4)	(5)
Variables	$\ln(val_{it})$	$\ln(N_{it})$	$\ln(\overline{PQ}_{it})$	$\ln(\overline{Q}_{it})$	$\ln(P_{it})$
part = 1	3.70***	0.82***	2.89***	3.05***	-0.16***
	(0.047)	(0.015)	(0.042)	(0.053)	(0.032)
year = 1995	0.33***	0.10***	0.23***	0.11***	0.12***
	(0.017)	(0.006)	(0.016)	(0.020)	(0.012)
year = 2000	0.61***	0.24***	0.38***	0.36***	0.02*
	(0.017)	(0.006)	(0.016)	(0.020)	(0.012)
year = 2005	0.83***	0.30***	0.54***	0.49***	0.04***
	(0.017)	(0.006)	(0.016)	(0.020)	(0.012)
year = 2008	0.89***	0.27***	0.63***	0.37***	0.26***
	(0.018)	(0.006)	(0.016)	(0.020)	(0.12)
part = 1 & year = 1995	0.00	0.00	0.00	-0.05	0.05*
	(0.042)	(0.014)	(0.037)	(0.047)	(0.029)
part = 1 & year = 2000	0.16***	0.01	0.14***	0.11**	0.03
	(0.041)	(0.014)	(0.037)	(0.047)	(0.028)
part = 1 & year = 2005	0.12***	0.02	0.09**	0.10**	0.00
	(0.041)	(0.014)	(0.037)	(0.047)	(0.028)
part = 1 & year = 2008	0.26***	0.06***	0.19***	0.20***	0.00
	(0.042)	(0.014)	(0.038)	(0.048)	(0.029)
Constant	14.66***	2.21***	12.45***	9.74***	2.71***
	(0.014)	(0.005)	(0.013)	(0.016)	(0.010)
Observations	128778	128778	128778	128778	128778
R-squared	0.888	0.903	0.855	0.914	0.956

Estimates include commodity fixed effects at the HS8 digit level.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[37] Unit prices reported in column 5 are gross of duties and cif costs. Reductions in these costs over time, as reported in Table 7 imply that source country prices are rising somewhat faster than is observed in column 5. The relative difference in trade cost changes are not large enough, however, to imply substantial relative changes in parts price movements, as compared with movements of prices of other complex goods.

Parts imports and high speed shipments

Hummels (2007) surveys changes in transportation costs, and finds a key notable change in recent decades is the reduction in the costs of air shipments (in absolute terms, and relative to other transportation costs). If such changes are important to the growth of intermediate goods trade, one might expect to see that reflected in shippers' choice of transport mode. This section exploits the information on mode choice within the U.S. trade data to identify *relative* changes in the mode choices of parts trade. Once again, we employ the decomposition outlined above. In this case, we adopt a relative comparison that jointly evaluates the characteristics of shipments moving by air and by sea.[38]

The exercise is once again framed in relative terms. The question is whether parts trade has become more dependent on air shipments. Once again, these movements are judged against movements in other complex goods, so that the evidence of changes in parts trade is compared against a meaningful set of products acting as a control group. An initial calculation derives the relative value of shipments by air and sea at in commodity *i* at time *t*. This ratio can be regressed against part and year dummies, as well as interactions between the two, in order to investigate common movements in the ratio of air to sea shipments. Ratios of a decomposition allow further investigation into the nature of changes across the relative mode choices.

The decomposition follows that observed in (3), although it does so in relative terms. The form of the decomposition is as follows:

$$\frac{V_{it}^{air}}{V_{it}^{sea}} = \frac{N_{it}^{air}}{N_{it}^{sea}} \frac{\overline{Q}_{it}^{air}}{\overline{Q}_{it}^{sea}} \frac{P_{it}^{cif-air}}{P_{it}^{cif-sea}} \tag{4}$$

where $V, \overline{Q}$, and P are defined as above, with *air* and *sea* superscripts indicating mode of shipment. Prices are calculated gross-of-trade costs P_{it}^{cif} and net of trade costs P_{it}^{fob}, in order to evaluate relative movements in tariff and cif costs. A regression using relative prices measured at the origin ports, P_{it}^{fob} is included for comparison purposes. The results appear in Table 9.

Column 1 indicates that the relative value of air and sea shipments in complex manufactures fluctuated over the period, rising initially and then falling. These moves can be explained in part by movements in fuel costs, which were relatively stable over the period 1989-2000, and rising thereafter. Among the commodities in the parts category, the relative quantity of air shipments rose, offsetting the decline in the ratio for complex goods that occurred post-2000. This evidence suggests that parts trade shifted more heavily in to air shipment than did other complex goods.

[38] Overland shipments to the United States are dominated by shipments from Canada and Mexico. The time required for such shipments is ambiguous, as the U.S. trade data do not say how far the shipments are travelling (in the U.S. or inside the respective trading partner). For these exercises we discard shipments from Canada and Mexico, looking only at air and sea shipments from non-NAFTA partners.

Table 9: Relative changes, air versus sea shipments, US Imports, 1989-2008

	(1)	(2)	(3)	(4)	(5)
Variables	$\ln\left(\frac{V_{it}^{air}}{V_{it}^{sea}}\right)$	$\ln\left(\frac{N_{it}^{air}}{N_{it}^{sea}}\right)$	$\ln\left(\frac{\overline{Q}_{it}^{air}}{\overline{Q}_{it}^{sea}}\right)$	$\ln\left(\frac{P_{it}^{cif-air}}{N_{it}^{cif-sea}}\right)$	$\ln\left(\frac{P_{it}^{fob-air}}{N_{it}^{fob-sea}}\right)$
part = 1	0.20***	0.08***	0.04	0.08*	0.07
	(0.071)	(0.024)	(0.075)	(0.047)	(0.049)
year = 1995	0.18***	0.18***	-0.04	0.03*	0.03
	(0.028)	(0.010)	(0.032)	(0.020)	(0.020)
year = 2000	0.26***	0.20***	-0.05*	0.11***	0.13***
	(0.026)	(0.010)	(0.031)	(0.019)	(0.020)
year = 2005	-0.01	0.21***	-0.46***	0.25***	0.26***
	(0.027)	(0.020)	(0.031)	(0.019)	(0.020)
year = 2008	-0.11***	0.25***	-0.58***	0.22***	0.23***
	(0.028)	(0.010)	(0.033)	(0.020)	(0.021)
part = 1 & year = 1995	0.17***	-0.02	0.18**	0.02	0.02
	(0.058)	(0.021)	(0.063)	(0.039)	(0.040)
part = 1 & year = 2000	0.12**	-0.05**	0.17**	0.00	0.00
	(0.056)	(0.020)	(0.060)	(0.037)	(0.038)
part = 1 & year = 2005	0.17***	-0.02	0.26**	-0.07*	-0.07*
	(0.057)	(0.020)	(0.062)	(0.038)	(0.039)
part = 1 & year = 2008	0.14**	-0.08***	0.26**	-0.05	-0.05
	(0.059)	(0.020)	(0.026)	(0.016)	(0.017)
Constant	-2.05***	-0.18***	-3.10***	1.23***	1.14***
	(0.024)	(0.008)	(0.026)	(0.016)	(0.017)
Observations	113485	113485	113485	113485	113485
R-squared	0.821	0.798	0.702	0.542	0.537

Estimates include commodity fixed effects at the HS8 digit level.
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Column 2 indicates that ratio of source countries supplying by air (relative to sea) rose among all complex goods, with little substantive differences relative to parts.[39] Among complex goods, the quantity per country fell as fuel prices rose post-2000. This also occurred among parts, but to a lesser degree. Relative prices gross of trade costs (cif) rose over time for complex goods, with no substantive difference for parts. The same story holds up for relative net of trade cost (fob) prices. Overall it seems that there was a relatively larger shift towards air shipments in parts trade than in complex goods. As fuel prices rose at the end of the period, the shift towards air was more than reversed among complex goods, while parts remained reliant on air shipments as it had been when fuel prices were lower. This suggests that the availability of air shipment possibilities was an important reason for increased trade in parts.

[39] By the year 2008, the relative number of source countries had fallen slightly.

Discussion

Particular features of the U.S. import data allow us to investigate growth in parts trade, and to compare these to other complex goods. Reductions in trade costs were similar across the two categories of goods, although duties fell to zero for many commodity-country pairs in the parts categories. The relative increase in the value of parts imports operates through a relative increase in the quantities of imported parts. Relative price changes are not significantly different across these two categories of goods.

An assessment of relative air versus sea shipments reveals that mode choices moved as might have been expected given fuel cost changes. An initial increase in parts trade occurred in the years 1989-2000, when fuel prices remained fairly constant. As fuel prices rose following 2000, however, complex goods were increasingly shipped by sea, rather than air. This reversion was muted among commodities in the parts category, however. This points to evidence that parts became relatively more dependent on air shipments over this period, when compared with other complex goods.

Conclusion

The reliance of modern manufacturing on integrated international production processes is a phenomena that requires further study. This paper developed a series of hypotheses about the causes of international production fragmentation. Where possible, these hypotheses were taken to the data.

One important theory of production fragmentation puts the coordinating and amalgamating services - such as transport, communications, and information technology - at the center of the discussion. One implication of these theories is that increased reliance on such services is complementary with increased use of imported intermediate inputs. In this paper, the evidence for such complementarity was investigated, with growth in intermediate input use across sectors regressed against growth in those sectors dependence on key service sectors. There does not appear to be convincing empirical evidence in support of this hypothesis. The data, however, are quite aggregated, and not well suited for the task.

Another implication of the theory is that the introduction of new trading partners into the system should facilitate production fragmentation. The question of particular interest in this paper is whether political economic reforms in formerly communist countries might have been responsible for additional production fragmentation. The evidence suggests that those countries are notably dependent on parts in their exports. Even after controlling for size and income levels, it seems that such countries have relatively high shares of complex goods their exports. It also appears, however, that these outcomes were largely determined by 1996. Trade growth in parts since then has been more or less in line with trade growth in other commodities.

U.S. import data suggests modest growth in parts trade, relative to other complex goods. It appears that much of this relative growth has occurred in the form of increasing relative quantities of parts shipped, rather than changes in relative prices or the relative number of source countries. Evidence from shippers' mode choices suggests that parts trade has become relatively more dependent on air shipments than has trade in other complex goods. Rising fuel prices have led complex goods to become less dependent on air shipments, while parts trade was as dependent on air in 2008 as it was in 1989.

In the end, production fragmentation is a multi-faceted phenomenon with many interlocking parts. Data difficulties make it difficult to explain convincingly in unified terms. Evidence presented here suggests that more readily available air transport and the

introduction of new production blocks in Eastern Europe and East Asia may have been important sources of growth in international production fragmentation. While the evidence did not point convincingly to other explanations, the quality of data available for evaluation such stories remains weak.

References

Athukarola,Prema-Chandra (2006) 'Product fragmentation and trade patterns in East Asia.' Asian Economic Papers 4(3), 1–27

Balassa, Bela (1967) Trade liberalization among industrial countries (New York: McGraw Hill)

Bernard, Andrew B., J. Bradford Jensen, Stephen J. Redding, and Peter K. Schott (2007) 'Firms in international trade.' Journal of Economic Perspectives 21(3), 105–130

Feenstra, Robert C., Robert E. Lipsey, Haiyan Deng, Alyson C. Ma, and Hengyong Mo (2005) 'World trade flows: 1962-2000.' NBER Working Papers 11040, 1–63

Findlay, Ronald (1978) 'An Austrian model of international trade and interest rate equalization.' Journal of Political Economy 86, 989–1008

Gaulier, Guillaume, and Soledad Zignago (2009) 'BACI: International trade database at the product-level, the 1994-2007 version.' CEPII Document de Travail 2009-xx pp. 1–32

Grossman, Gene M., and Esteban Rossi-Hansberg (2008) 'Trading tasks: A simple theory of offshoring.' American Economic Review 98(5), 1978–97

Hillberry, Russell, and David Hummels (2008) 'Trade responses to geographic frictions: A decomposition using micro-data.' European Economic Review 52(3), 527–550

Hillberry, Russell H, and Christine A. McDaniel (2002) 'A decomposition of North American trade growth since NAFTA.' U.S. International Trade Commission Working Paper

Hummels, David (2007) 'Transportation costs and international trade in the second era of globalisation.' Journal of Economic Perspectives 21(3), 131–154

Hummels, David, and Peter Klenow (2005) 'The variety and quality of a nation's exports.' American Economic Review 95(3), 704–723

Hummels, David, Jun Ishii, and Kei-Mu Yi (2001) 'The nature and growth of vertical specialization in world trade.' Journal of International Economics 54(1), 75–96

Jones, Ronald W., and Henryk Kierzkowski (1990) 'The role of services in production and international trade.' In The Political Economy of International Trade: essays in Honor of Robert E Baldwin, ed. Ronald W Jones and Anne O Krueger (Basil Blackwell) pp. 31–48

Yi, Kei-Mu (2003) 'Can vertical specialization explain the growth of world trade?' Journal of Political Economy 111(1), 52–102