Global Production Sharing: Patterns and Determinants

Abstract:

This paper the analyses the impact of macroeconomic variables like technology, institutions and macroeconomic stability on network trade - these variables have so far been ignored in the literature on this subject. This paper finds that institutions, technology and macroeconomic stability play a prominent role in augmenting network trade in both developed and developing countries. These results are confirmed through a range of panel data estimation techniques including correlated random effects, Hausman-Taylor and random effect estimation.

Determinants of network trade and its implications are going to be particularly important for regions such as Europe, North America and South-East Asia, as these regions already have a large network trade presence. In addition, there is evidence that network based trade has grown at a much faster rate than total world manufacturing trade over the past four decades (Yeats, 1998, Yi, 2003). As such, determinants of network trade are likely to have important policy and development implications, especially for the integration of various economies into regional and/or global production chains.

1. Introduction

Global production sharing can be defined as splitting of the production process into discrete activities which are then allocated across countries in order to gain cost advantage[1]. The process of global production sharing involves slicing up of the production process production process across countries to gain cost advantage. Under this process, each production block takes a narrow range of production activities as the production process gets sliced up to provide cost advantage.

There is evidence that trade based on global production sharing (that is trade in parts and components and final assembly within global production networks, henceforth referred to as 'network trade' or global production sharing) has grown at a much faster rate than total world manufacturing trade over the past four decades owing to three mutually reinforcing development over the past few decades (Yeats, 1998, Yi, 2003). First, rapid advancements in production technology have enabled the industry to slice up the value chain into finer, 'portable', components. Second, technological innovations in communication and transportation have shrunk the distance that once separated the world's nations, and improved speed, efficiency and economy of coordinating geographically dispersed production process. This has facilitated establishment of 'services links' to combine various fragments of the production process in a timely and cost efficient manner. Third, liberalisation policy reforms in both home and host countries have considerably removed barriers to trade and investment. There is an important two-way link between improvement in communication technology and the expansion of fragmentation-based specialisation within global industries. The latter results in lowering cost of production and rapid market penetration of the final products through enhanced price competitiveness. Scale economies resulting in market expansion in turn encourage new technological efforts, enabling further product fragmentation. This two-way link has set the

[1] Global production sharing is also known as network trade, parts and components trade, production fragmentation, vertical specialization, production sharing, intra-product specialization and slicing up the value chain. All of these terms are interchangeably used.

stage for ‘fragmentation trade’ to increase more rapidly compared to conventional commodity-based trade.

Trade in parts and components behave differently to trade in final goods. For instance, variables that may play an important role in classical trade analysis such as home country’s gross domestic product (GDP) and exchange rate may not be relevant in explaining global production sharing. Furthermore, ‘service links’ play a vital role in global production sharing(Jones and Kierzkowski, 1990) . Jones and Kierzkowski define service link activities - and their associated costs – to involve communication, transportation, information gathering and costs of coordinating production activities across countries (Jones and Kierzkowski, 1990, Plümper and Troeger, 2007). Given this, modelling aggregate international trade flows without explicitly modelling network trade can be misleading. This will be particularly true for countries that have a high proportion of parts and components trade in their total share of trade.

In this paper, the determinants of global production sharing are studied using the Jones and Kierzkowski (1990) framework. In particular, I look at variables that have helped proliferate global production sharing. As global production sharing becomes more prominent its impact on international trade, economic growth and integration in the world economy is likely to have important national and global policy implications. Moreover, as trade in parts and components is dominated by intra-firm transections, global production sharing is likely to also have firm level implications.

On the empirical side, this paper makes several contributions to the literature as well. Firstly, an extensive data set of 44 countries engaged in global production sharing and covering 16 years is constructed to look at in-depth analysis of global production sharing. All countries which account for 0.01% of total parts and component exports are included in the country list. Secondly, this paper examines important macroeconomic important variables which have so far been ignored previously in the literature such as regulatory institutions, macroeconomic stability, technology and stages of development are examined. Thirdly, we improve on specification of economic mass variables (Baldwin and Taglioni, 2011) to make them tailor made to global production sharing in gravity model framework. Lastly, I incorporate Mundalk transformation/random correlated effect (RCE), in addition to using Hausman Taylor (HT) estimation and random effects (RE) in our regression to extensively test for robustness of the results. The focus in the empirical section is on trade in parts and components in global production sharing. Final assembly and other head quarter functions such R&D and management of the business are also process in global production sharing. However, due to data limitations it is hard to measure them accurately. As such, this paper focuses on parts and components trade only.

This paper finds that average level of institutional quality and technology level in a country play important roles in global production sharing. In addition we find that macroeconomic stability is also an important determinant for global production sharing, this may reflect the fact that most of trade in parts and components is dominated by multinationals which may be sensitive to macroeconomic stability of the country. Lastly, this paper finds that global production sharing has a quadratic relationship with stages of development. This partly reflects that as economies develop they transition out of manufacturing and into services thereby reducing parts and components manufactured in their economies.

The rest of the paper is organized as following: Section 2 gives overview of global production sharing, while section 3 extends existing theories on global production sharing, section 4 discusses estimation methodology for analysing determinants of global production sharing, section 5 discusses data, section 6 gives empirical results and section 7 concludes.

2. Literature review

The process of slicing up production into smaller blocks internationally is not a new phenomenon. Network trade has been an important process dating back to industrial revolution. Its importance in world trade has been highlighted since the early 1970's (Grunwald and Flamm, 1985, Helleiner, 1973). However, the modern process of global production sharing is different in that it intensively involves developing countries and the magnitude of global production sharing is significantly higher compared to historical standards (Yeats 2001).

Global production sharing has evolved from a simple process between two or so countries to a multi-stage and multi-country process. For instance, a firm's head quarter may be in the US and involved in head quarter functions like R&D, service linkages and coordination, while parts and components are assembled in countries like South Korea, Taiwan and Malaysia before being shipped off to China for final assembly. Following examples help to illustrate this process. Linden et al. (2009) analyse the production of iPod by the US based firm Apple. According to the industrial organization of Apple, the product design and software development are kept in the US(Linden et al., 2007, Linden et al., 2009). While other stages of production such as producing hard drive, display module, main board PCB and memory are produced in countries like Japan and Taiwan, while final assembly takes place in China.

Another example of global production sharing is that of the production of the Barbie doll (Tempest, 1996). Plastic and hair for the doll is acquired from Taiwan and Japan, while China provides cotton cloth for the dresses. Molds and paints come from the US and assembly gets done in Indonesia, Malaysia and China. This illustrates the multistage and multi country process that global production sharing has evolved into.

Given this, conventional approach of treating international trade as 'cloth for wine' (that is, the assumption that countries trade in goods produced from beginning to the end in a give country) needs to be altered to take account of global production sharing, especially as the share of trade in parts and components rises.

Factors like, proliferation of globalization, reduction in transport and communication costs, trade liberalization and advancements in technology, have boosted global production sharing and its importance in international trade. For instance, trade in parts and components have grown at a faster rate than trade in final goods(Yeats, 1998). Furthermore, between 1970 and 1990, increase in exports associated with global production sharing accounted for one third of world economic growth (Yi, 2003). This process has also expanded to include various products including automobiles, televisions, smart phones, sports and footwear items, sewing machines, cameras, office equipment, watches, etc Athukorala (2011). The impact of global production sharing on different industries has varied. Generally, industries that trade in high value to weight goods and ones where technologically it was feasible to slice up the production process have been better able to take advantage of global production sharing.

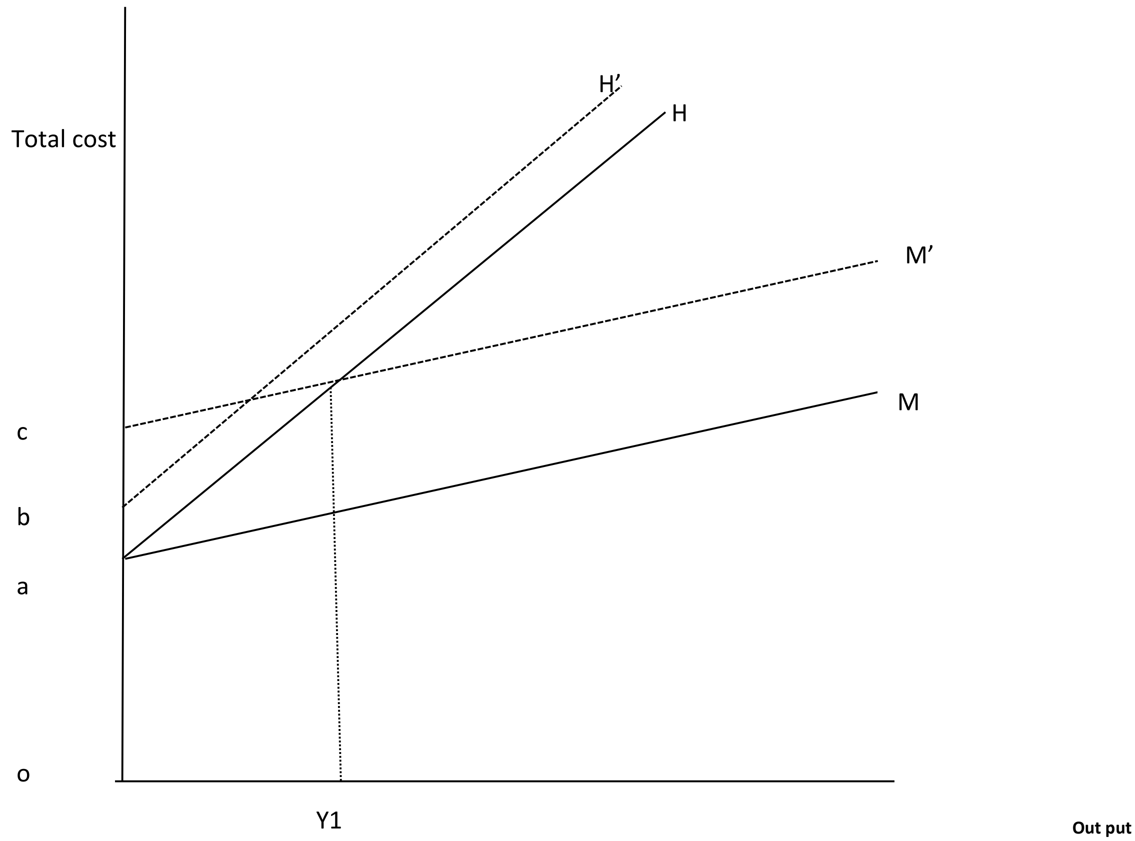
The role of service linkage costs for linking the various production units located across countries plays an important part in global production sharing (Jones and Kierzkowski, 1990). As these service linkage costs decline, due to reduction in transport and communications costs, technological breakthroughs and trade liberalization, production fragmentation would further endorse global production sharing. In the Jones and Kierszkowski's model scale economy is achieved by increasing production, why the service link costs remain fixed.

In addition, global production networks have established themselves around the globe. US, Canada and Mexican firms a have strong connections in parts in component trade across the border. It is estimated that around $250 dollar worth of parts components trade between US and Mexico border (Hanson et al., 2005). In addition, East Asia regions share in total network exports increased from 22.0 % in 1992/93 to 45.7% in 2005/06 (Athukorala, 2011). Moreover, there are increased linkages in production networks amongst European countries. In contrast to this, regions like South Asia and Africa have not seen a strong presence of global production sharing. Given this, it is important to note that global production sharing's impact has varied between industries and regions. With industries with high value to weight and technology to slice up production chains and regions like East Asia, North America and Europe taking a higher advantage from this process.

Jones and Kirezkowski (1990), Arndt (1997), Venables (1999), Jones and Kirezkowski (2001a), Grossman and Rossi-Hansberg (2006) and Baldwin and Robert-Nicoud (2007), have developed frameworks and extended standard trade theory to global production sharing. Arndt (1997) look at the impact of global production sharing on employment and wages. They use the neoclassical trade theory to decipher the impact of vertical specialization on wages and employment. A problem with the above framework is that it does not explicitly include the costs of linking the various stages of production like transportation, communication, trade and transaction costs. Feenstra and Hanson (1995) and (1997), build a model with a continuum of inputs over unit interval to analyze global production sharing. However, their model also does not deal with fixed costs and sunks costs that would be pertinent for setting up multiple production plants across several countries (Jones and Kierzkowski, 1990, Jones and Kierzkowski, 2001).

Jones and Kierzkowski (1990) focus on different production blocks and services link costs in determining global production sharing. Their paper describes how increasing output levels, increasing returns to scale and the advantages of specialization of factors within a firm can lead to a fragmented production process. They further postulate that trade liberalization and declines in the cost of transportation and communication has enhanced production fragmentation by reducing service link cost. Jones and Kierzkowski (1990) use the following diagram to explain their main ideas.

Figure 2.1



Line H in the above diagram gives the total cost of producing the whole product in one production block in a given country, this includes fixed costs and marginal costs. If a firm is to slice the production chain and locate over two or more different locations, then it will incur service link costs. As mentioned before service link activities - and their associated costs – involve communication, transportation, information gathering and costs of coordinating production activities. Line H' shows the added costs of service links for when the production blocks are in the same country.

Line M shows lower marginal costs by undertaking global production sharing and cost saving by having two production blocks and moving one of the production blocks to a foreign country. This lower marginal cost comes from the assumption that the foreign country has lower production costs for the second production block. Line M' shows increased services costs by producing in a foreign country. This can include planning, coordination and transport costs among others. Service costs are assumed to be higher when a firm has production blocks located internationally, this may reflect higher coordination, legal and transportation costs.

Service link costs can be shown to be increasing with output by showing steeper H' and M' lines. Furthermore, increased setup costs for global production sharing process can be shown by increasing the intercept of line M to a higher point than 'a'. Given this, total costs under global production sharing are given by line M'. While line H shows total costs in the absence of global production sharing. By looking at this diagram it is clear that if output was higher than Y1, then even with higher service link costs, it would be profitable for the firm to fragment their production process, leading to increased parts and components trade. It is important to note that global production sharing's impact has varied between industries and regions. With industries with high value to weight and technology to slice up production chains and regions like East Asia, North America and Europe taking a higher advantage from this process.

3. Extension of Theory

In this section, I will further extend Jones and Kierzkowski (1990) model to analyse global production sharing. Furthermore, using these determinants, I will explicitly incorporate variables which determine service link cost in Jones and Kirezkowski methodology and other important variables that determine network trade. These variables include:

1) Technological change that allows for finer slicing of production sharing ;
2) Institutions;
3) Infrastructure and tariff regimes;
4) Stages of development; and
5) Macroeconomic stability of the economy.

3.1 Determinants of global production sharing

Efficient global production process can be created if each slice of the production process is located to match the factor intensity of components to the factor abundance of countries. To analyse this phenomena and its determinants we begin by looking at the production process of a firm.

To analyse, we look at a case of 1*2*2. Where we have one final good called F1, that is composed of two subcomponents called G1 and G2, we have two factors of production Capital, K, and Labour ,L, and we have 2 countries – home country and foreign country. Home country is labour intensive and foreign country is labour intensive. The two subcomponents have different factor intensities. G1 is capital intensive and G2 is labour intensive. To produce F1, the firms need to produce G1 and G2and combine them using final assembly. Final assembly is assumed to be labour intensive. It is also assumed that G1 and G2 are used in a fixed ratio to produce F1, hence the production function is assumed to exhibit a Leontief production process.

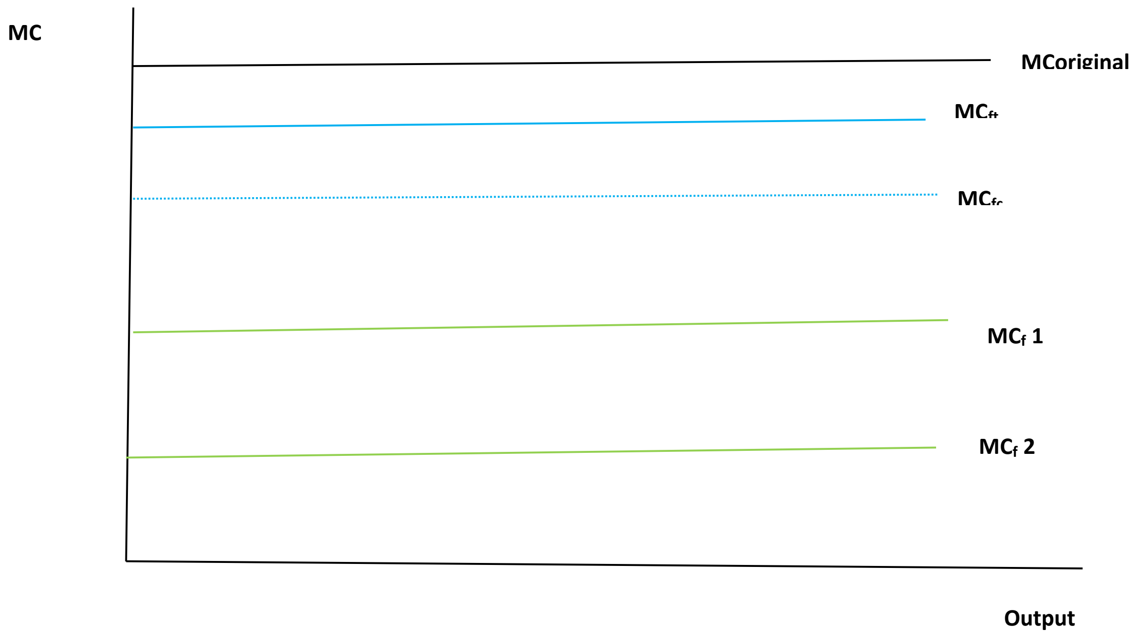
Moreover, it is assumed that marginal costs of producing G1, G2 and final assembly are constant – i.e constant returns to scale. However, service links are assumed to exhibit increasing returns to scale. This should not affect the results, but makes the analysis more straightforward.

Initially, suppose that both G1 and G2 were produced in home country A. In figure 3.1.1, total marginal cost for producing F1 at home country is given by black line (MC original). Assume now, that firm relocates the labour intensive component to foreign country B, and keeps the production of capital intensive component in home country (call home country A). Furthermore, assume that relocating the production of components yields costs savings. In the new production process the capital intensive good is produced in capital abundant country (where capital is cheaper) while labour intensive good is produced in labour intensive country (where labour is cheaper). Cost savings in the production assembly line may due to Hechsher-Ohilin theorem.

The marginal costs of each good are given by green lines $MC_{f\,1}$ and $MC_{f\,2.}$Marginal cost of producing both components is given by the dotted blue line, MC_{fc}, which is the vertical summation of the two green lines. The final marginal cost of the good, under fragmentation, is given by the solid blue line, MC_{fc} .The fact that MC_{fc}<MC_{ft} reflects service linkage costs including transportation, coordination and communication costs. It can also reflect assembly cost, but for simplicity at this time that assembly costs are negligible compared to other costs. Even if we incorporate tangible assembly costs, then lower costs of producing subcomponents may still lead to global production sharing being feasible.

$MC_{fc}<MC_{ft}$ (3.1.1)

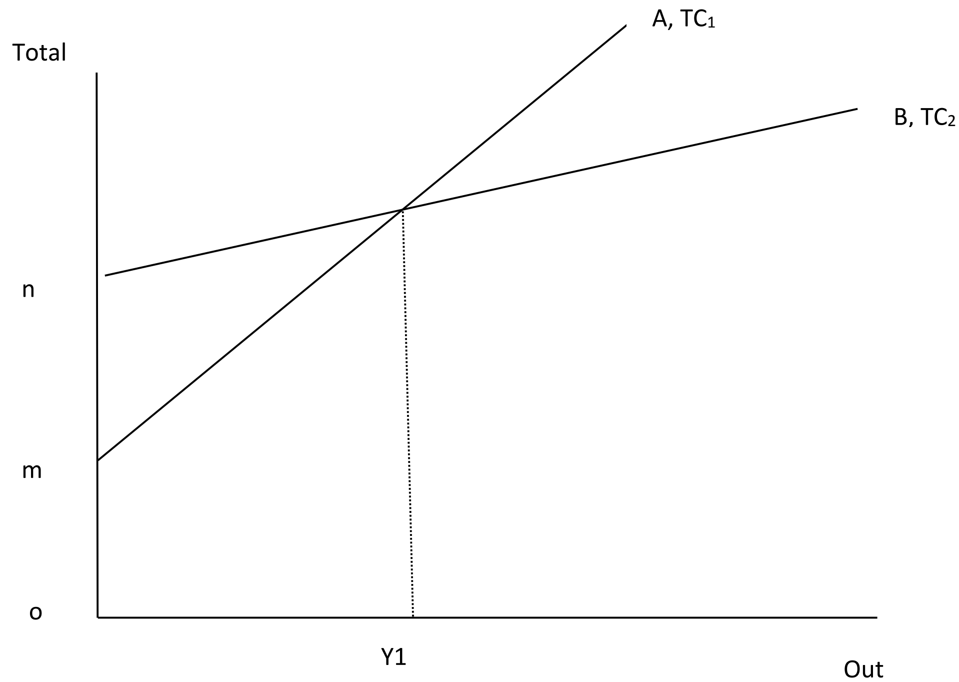
Figure 3.1



However, it should be noted that equation 3.1.2 shows a necessary but not sufficient condition for the firm to embark on global production sharing. To look at the sufficiency condition we need to look at total costs and the equivalent of Jones and Kierzkowski (1990)methodology.

$MC_{ft}<MC_{\text{original}}$ (3.1.2)

Figure 3.2



The figure above extends Jones and Kierzkowski (1990) diagram and is similar to figure 2.2.1. Line A, TC_1 in figure 3.2 is the same as H in Figure 2.1 and line B, TC_2 in figure 3.2 is the same as M' in figure 3.2. So that in the figure above, it is assumed that line B includes service linkage costs. In figure 3.2, output level beyond y1 makes it feasible for the firm to relocate its production process to get cost savings, equation 3.1.3 (where Y* denotes the actual production level of the firm). To summarize, along with the necessary condition of equation 3.1.2, we need the sufficiency condition of equation 3.1.3 to make global production sharing feasible.

$$Y1 < Y^* \qquad (3.1.3)$$

Further explanation of the diagram above is as follows. Line A represents totals costs when all production takes place in one production block. It depicts how total cost expands when output increases, the slope of the line shows marginal cost. Line B, on the other hand, shows how total cost varies when production blocks are located in different countries. Higher intercept for line B reflects the fact that having more production block incurs higher fixed costs as more production plants need to be built and higher service link costs. A flatter slope of line B, compared to line A, is based on lower marginal costs due to allocating good G_2 to a country where it is cheaper to produce it. The capital intensive component G_1 is still produced in country A, where capital is cheaper.

It would be helpful to draw similarities between Figure 3.2 and figure 3.1. Marginal cost when production is located in home country is given by MC original in figure 3.1.1 and is equivalent to the slope of line A in figure 3.1.2. Similarly total marginal cost under global production sharing is given by MC_{ft} in figure 3.1.1 which is equivalent to the slope of line B in Figure 3.1.2.

Mathematically, line A and B can be written down respectively as:

$TC_1 = a + by$ (3.1.4)

$TC_2 = c + dy$ (3.1.5)

Where a and c are fixed set up costs for production in one block and fragmented production process respectively. Variable b is the marginal cost of producing with one production block, while d is the marginal cost of production with fragmentation in two countries. These results could be generalized to more than one country.

To look at the determinants of global production sharing we equate 3.1.4 and 3.1.5 and solve for y.

$a + by = c + dy$

$y = \frac{a-c}{d-b}$ (3.1.6)

So any variable that affects a, c , b and d, would affect the process of production fragmentation and the level of output at which global production sharing becomes feasible. More precisely equation (8) says that the output level at which global production sharing becomes feasible depends on the ratio of relative fixed cost over relative marginal costs.

The lower the marginal cost that firm can achieve by relocating production of some goods overseas and the lower the fixed costs of setting of production plants in foreign country, the more profitable it is to engage in global production sharing.

In section4 we look at variables that affect a,c,b and d. These include 1) infrastructure, transportation costs and tax regimes, 2) technology, 3) institutions, 4) macroeconomic stability and 5) competition among countries to capture part(s) of the value chain. In the next subsection, we develop the theory of production process more closely.

3.2 Macroeconomic variables affecting global production sharing

There are several macroeconomic variables that can affect global production sharing. These include technology, infrastructure, transportation costs, tax regimes, macroeconomic stability and institutions. These variables have been largely ignored in the literature for global production sharing. The remaining of the section briefly shows how these variables can affect global production sharing.

Technological advancements that allow for finer slicing of the production chain can help amplify global production sharing. To analyse this for instance assume that the capital intensive good G_1, due to technological advancement, can be further broken into two sub-goods. Where one is relatively capital intensive (call it $G_{1,1}$) and the other is labour intensive (call it $G_{1,2}$). Then the firm will allow for further fragmentation of the production process if it finds it cheaper do so. In the following diagram, it is clear that it is cost saving to have labour intensive $G_{1,2}$ component made in country B where it labour costs are cheaper, while producing capital intensive $G_{1,1}$ in home country where it is cheaper to produce capital intensive goods.

Another venue through which advancements in technology is likely to augment global production sharing is by reducing transport and other service link costs, which will further augment global production sharing. Given this, any model designed to capture global production sharing must include a variable on technology.

Figure 3.3

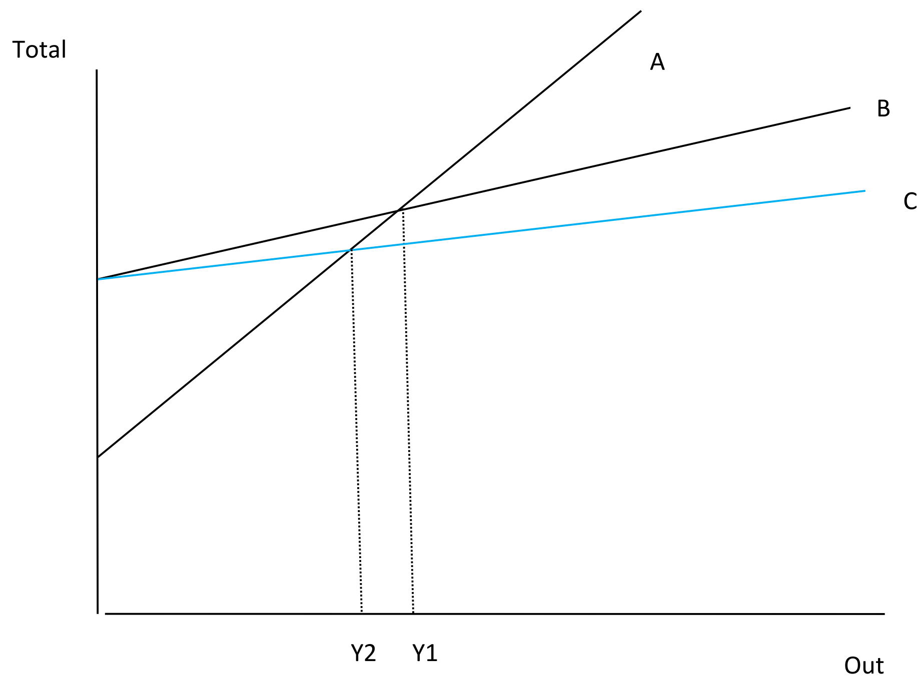


Figure 3.3 is the counter part of Figure 3.2. In this figure, line A and B are the same as they were in figure 3.1.2. However, line C represents cost reductions due to further fragmentation of the production of G_1 and lower transport and service link costs. Flatter slope of line C represents lower marginal costs of producing good F, which have come about due to further fragmentation of the production of G_1 and having$G_{1,2}$ produced in country produced in country B.

$Y2 < Y1$ (3.2.2)

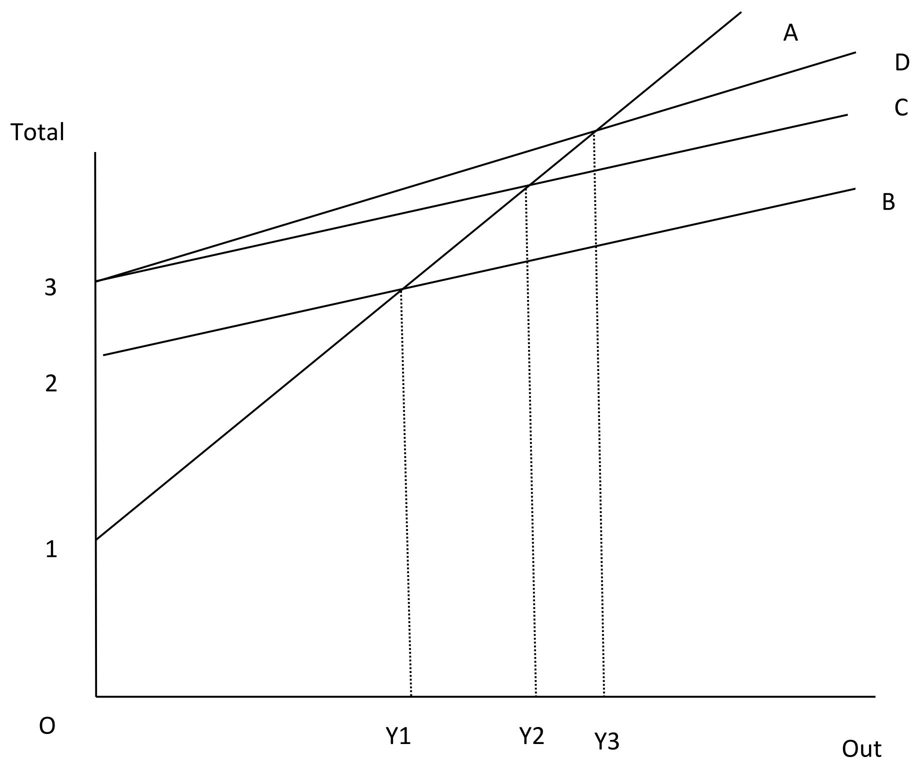
Interesting thing to note is that the intersection of line A and C is at a much lower output level then intersection of line A and B. Therefore, it becomes feasible to fragment at a lower production level due to the technological advancement that allows the firm to break up G_1 into further sub components.

This diagram analysis shows that there can be increased trade between two or more nations due to technological innovations, even if GDP of each nation does not change. This divorce between home country's and destination country's GDP means that we will need to augment the standard gravity model with a relevant variable for technology.

Moreover, better infrastructure can lower transportation costs which are a crucial factor for global production sharing. Furthermore, technological advances in services link sectors (like transportation and communication) and friendly tax regimes can also lower the costs of production. All of these factors can curtail marginal costs associated with global production sharing. Diagrammatically, this will mean that as the marginal cost declines, slope of line B in figure 3.3 will become flatter. Line C, which is flatter than line B, in figure 3.3 represents the new marginal cost of the firm. The new marginal cost is lower because of better infrastructure, lower service linkages costs and more business friendly tax regime. We can see that under this regime, global production sharing becomes feasible at a lower level of output Y2 compared to Y1. Based on this, countries that have better infrastructure, cheaper service linkage costs and more friendly tax regimes are likely to capture a higher share of global production sharing.

Moreover, macroeconomic stability can also induce extra costs limiting the ability of various countries to take part in global production sharing. This would be particularly true if volatility incurs extra cost for the firm, say in terms of menu costs, higher transaction and adjustment costs or costs in terms keeping extra capital to compensate for uncertainty then the excepted costs under global production sharing will be higher. This can be modelled by showing that marginal costs for global production sharing will increase if there is macroeconomic instability. This in turn, would limit the feasibility of global production sharing.

Institutions can also make a significant impact on production fragmentation outcomes. For instance, corruption can increase fixed and marginal costs of production. Let's assume that business friendly regulatory framework decreases fixed costs (easier to start businesses and the business does not have to pay bribes to officials to buy land, get company registered etc). In figure 3.4, line A and B are the same as in figure 3.2. Business friend regulatory framework can reduce setup costs, as mentioned before. This can be shown by a decrease in the intercept from o3 to o2. As a result, line C and A intersects at a higher output level, y2. This means that firms producing between Y1 and Y2 will not be able to take advantage of lower labour costs in country B and will not fragment their production process.



If in addition lack of appropriate institutions also increases marginal costs, then slope of the total cost line will also increase to a line like D. In this case, there will be even fewer firms undertaking global production sharing in country B. This is evident from the fact that firms whose output level is between Y1 and Y3 will not want to setup supply chains in country B. In this case, if the firm has not already sunk costs in country B, then it may choose to locate in a different, more feasible country. We will return to this topic when we talk about competition among countries to capture value added of global production sharing.

Another channel for institutions to work is that weak institutions and bad governance can make investments more risky. Hence making the respective country less likely to get vertical FDI, which drives global production sharing. This can be modelled by building in extra costs in the total cost function. The costs can come in the form of extra costs for security, or lost output due to closed days or lost property due to unrest.

4. Econometric approach

4.1 Econometric model

Based on the theory developed in the previous section, this section develops the model for examining the determinants of global production. The focus here is on trade in parts and components in global production sharing. Final assembly and other head quarter functions such R&D and management of the business are also process in global production sharing. However, due to data limitations it is hard to measure them accurately. As such, this paper focuses on parts and components trade only. The basis of this paper's model starts with the standard gravity equation, and builds on previous studies which have used this framework to examine determinants of global production sharing based trade (Athukorala and Menon, 2010, Athukorala and Yamashita, 2009, Athukorala and Yamashita, 2006, Baldwin and Taglioni, 2011, Hanson et al., 2005). We augment the standard gravity model using the following econometric model. The variables in the equation 4.1.1 are explained in table in 4.1 and section 4.2 explains the specification of the variables.

$$\ln Exp_{ijt} = \alpha + \beta_1 \ln SBV_{it} + \beta_2 \ln DBV_{jt} + \beta_3 \ln RER_{ijt} + \beta_4 \ln GDPPC + \beta_5 \ln GDPPC^2 + \beta_7 CI + \beta_8 SDinfrate_{it} + \beta_9 l7Distw_{ijt} + \beta_{10} \ln s_{it} + \beta_{11} \ln Tech_t + \beta_{12} \ln LPI_{ijt} + \phi' Loc_{ij} + \eta_c + \eta_t + \epsilon_{ijt}$$

(4.1.1)

The subscript i indexes home country, while subscript j indexes partner country and the subscript t indexes years. Furthermore, the letter "ln" in equation 4.1.1 represents natural log of the relevant variable. Natural log is taken to give an elasticity type interpretation to coefficients, and they are also used to linearize variable like trade and real GDPs.

Table 4.1

LnExp	**Exports (Ex) between country i and j at time t**
SBV_i	Country i supply base variable
DBV_j	Country j demand base variable
RER	Real exchange rate
SDinfrate	Standard deviation of home country's inflation rate
Distw	Population weighted distance
GDPPC	GDP per capita
$GDPPC^2$	GDP per capita squared
CI	Communication infrastructure
Ins	Institutional quality
Tech	Technology captured by patent application
LPI	Logistic performance index
LOC	Vector of geography and culture based variables
η_c	Country fixed effect
η_t	Time fixed effect
ϵ	Error term
β_k(K=1 to 8)	Relevant coefficients of the explanatory variables.
Φ	Vector of coefficients for geography and culture based variables.
A	Constant term

Equation 4.1.1 is run separately both for manufacturing and parts and components exports to gauge the difference between final goods and network trade in manufacturing. This paper argues that in the presence of global production sharing, an econometric models for

network trade and manufacturing final goods trade should be estimated separately. Otherwise, if network trade and manufacturing final goods trade is aggregated then the models will be miss-specified.

4.2 Specification of variables

This section explains the specification of equation 4.1.1 and sets out the various versions of equation 4.1.1 that will be important for our analysis. Setting out the various versions of equation 4.1.1 will help explain the estimation techniques in section 4.3.

In standard gravity models (Chaney, 2013, Feenstra et al., 2001, Head and Mayer, 2013, Anderson and Van Wincoop, 2001, Feenstra, 2003), demand base of partner country and supply base of home country are captured by real GDP. The standard economic reasoning is that as income of partner country –as measured by real GDP – increases then it will consume more of all normal goods including imported goods, while the home country's real GDP is a good measure of what the home country can produce.

Baldwin and Taglioni (2011) argue that with global production sharing often demand for parts and components is being generated by the third country where final good will be consumed. As such, they argue that GDP's of home and partner country will have diminished explanation power in the presence of global production sharing. They suggest that home country manufacturing production and import from other countries of parts and components should be used to augment the gravity model. In the presence of global production sharing, they show that home country's manufacturing value added along with imported parts and components is a more appropriate measure of supply base for the home country, while partner country's GDP plus import of network trade from other countries is an appropriate measure of demand base.

This paper uses home country manufacturing value added and partner country manufacturing value added to captures the supply and demand base variables for global production sharing respectively. This measure is conceptually more appropriate because Baldwin and Taglioni measure sums value added figure of manufacturing with gross sales value of imported parts and components. In addition, as this paper uses annual data, incorporating Baldwin and Talgnoi specification will induce simultaneity bias in our results if not properly accounted for. This happens because imports of parts and components are likely to be processed within a year and exported to other countries. Moreover, as our preferred estimation technique is correlated random effect, whose results are exactly the same as fixed effects, Baldwin and Talgnoi critique is not relevant to our specification (Baldwin and Taglioni, 2011). Lastly, Baldwin and Talgnoi specification is highly correlated (above .95) with its manufacturing valued added counter parts, see table 4.3. As such manufacturing value added can serve as a close and appropriate substitute for the Baldwin and Talgnoi specification. Given these reason, we prefer using manufacturing value added as the economic mass variables for our regression analysis. For completeness, this paper uses the Baldwin and Taglioni specication along with the standard home country and partner country real GDPs to check for robustness in our regression.

$$lnExp_{ijt} = \alpha + \beta_1 lnMVA_{it} + \beta_2 lnMVA_{jt} + \beta_3 lnRER_{ijt} + \beta_4 lnGDPPC + \beta_5 lnGDPPC^2 + \beta_7 CI + \beta_8 SDinfrate_{it} + \beta_9 l7Distw_{ijt} + \beta_{10} Ins_{it} + \beta_{11} lnTech_t + \beta_{12} lnLPI_{ijt} + \phi' Loc_{ij} + \eta_c + \eta_t + \epsilon_{ijt}$$

(4.2.3)

MVA_i	**Country i'smanufacturing value added in real terms.**
MVA_j	Country j's manufacturing value addedin real terms.
	Remaining variables same as equation 4.1.1

Table 4.3, correlation matrix.

	h_supply_bt	h_man_real	p_demand_bt	p_man__real
h_supply_bt	1	0.994497	-	-

h_man_real	0.994497	1	-	-
p_demand_bt	-	-	1	0.955594
p_man__real	-	-	0.955594	1

Man_real stands for manufacturing value added in real terms and supply_bt and demand_bt stand Baldwin and Talgoni specification of supply and demand variables.

Population weighted distance is used as a proxy for transport cost and other associated time lags. As network trade involves multiple border crossings, we can hypothesize that global production sharing exports are likely to be sensitive to transport costs.

Infrastructure, both for physical goods and communications, are important variables in our regression. In section 3.2.2 we saw that infrastructure improvement can augment global production sharing by reducing transport cots. Moreover, in recent years, this variable has received increased importance in trade regressions (Athukorala, 2011, Athukorala and Menon, 2010, Athukorala and Yamashita, 2009, Mundlak, 1978). Given this, this paper includes Logistic performance indicator (LPI) as an explanatory variable. LPI (Athukorala, 2011, Athukorala and Menon, 2010, Athukorala and Nasir, 2012, Arvis, 2010)is an index that measures physical goods trade related infrastructure of the relevant country. In addition to this, infrastructure related to communications and service link costs is essential to global production sharing, so we use communications infrastructure to capture this variable. To proxy for communications infrastructure this paper uses trade is services as a percentage of GDP.

GDP per capita is a standard variable used in gravity models to capture levels of development in an economy. GDP per capita is likely to have a quadratic relationship in this equation. This is based on the fact that growth in economies leads to a transition away from manufacturing into services and the fact that rising wages will decrease competitiveness of manufacturing industries. GDP per capita squared is used to capture this quadratic functional form.

To look at the sensitivity of trade to macroeconomic stability we include standard deviation of home country inflation rate. Section 3.2.4 explained how a macroeconomic instability is likely to reduce the feasibility of global production sharing. Given this, we can hypothesize that trade in part and components will be more sensitive to a high standard deviation in inflation rate.

Real exchange rate (RER) is incorporated to capture the impact of competitiveness of tradable goods production on trade flows. The way RER is constructed in this paper implies that an appreciation of RER is likely to increase manufacturing exports. We expect RER to have a more pronounced impact on final goods as trade in global production sharing is mostly intra-firm and is unlikely to be impacted by fluctuating nominal exchange rate.

In addition, we look at the impact of institutions on global production sharing. We expect institutions to play a significant role in global production sharing by providing a more conducive environment to doing business. This is primarily because most of trade in global production sharing is dominated by MNEs, who would prefer to invest in a more stable environment.

Furthermore, weak regulatory institutions will lead to higher corruption and higher setup and running costs for business. This is likely to directly increase the cost of doing business. Section 3.2.4 showed how setup costs, running costs, corruption and other associated costs can discourage global production sharing in particular and business in general. Improvement in institutions is also likely to make the whole production process more efficient. Based on this, we would expect that improvement in institutions is likely to support increased exports in both network and final goods trade in manufacturing.

In section 3.2.1 we saw that advancement in technology can both enable the production process to be sliced into smaller sections and reduce transport costs. Both of these processes will augment global production sharing. This is especially true for developing countries. However, for developed countries improvements in technology exerts two opposing forces. Improvement in technology reduces transport costs so it allows more trade, but improvement in technology also allows manufacturing industries to be offshored from developed countries. As such, for complete sample it is unclear whether the technology variable will have a positive or a negative sign. To capture this effect, we include a technology variable in our regression, where patent application is used as a proxy for innovation.

We also include standard geographic and cultural variables in our gravity model to capture how geographic and cultural characteristics of a country affects its trade patterns in both final goods and global production sharing.

4.3 Estimation

This paper employs correlated random effect (CRE), Hausman-Taylor (HT) and random effect approach to estimate the equation (Dascal et al., 2002, Wooldridge, 2005, Athukorala and Nasir, 2012, Anderson and Van Wincoop, 2001, Wooldridge, 2012). Hausmen test favours CRE between the 3 estimation techniques.

There is a growing literature on using time invariant variables in panel data approach (Krishnakumar, 2006, Mundlak, 1978, Oaxaca and Geisler, 2003, Wooldridge, 2012). Given this, the CRE approach is employed to capture time invariant variables.[2] The coefficients of the CRE are the same as fixed effects (FE), with the added advantage that time invariant variables are not cancelled out. Moreover, CRE allows us to control for marginal improvements as well as the average levels of the variables we are interested in. The other main advantages of using the CRE approach is that it allows us to test the assumptions used in HT and RE estimation using the Hausman Test. However, one of the problems with CRE is that because of multicollinearity, its estimates are a lot less precise. As such, it would be useful to supplement CRE results with HT and RE estimates.

HT approach is widely used in estimating the gravity model (Chaney, 2013, Feenstra et al., 2001). HT[3] approach can control of endogeniety in RE and Pooled OLS methodology. In RE and pooled OLS there can be time-invariant country specific effects not accounted for in our regression that are correlated with the independent variables. HT approach controls for endogeniety by using internal instrument approach (see appendix 1B for further discussion)

This paper follows the standard practice of allowing for economic mass variables and RTA to be endogenous in our HT approach (Feenstra et al., 2001) . In addition, it can be argued that

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[2] CRE approach is explained in appendex 1B

[3] There is reverse causality from exports to economic mass variables which has largely been ignored in the literature. Often a pretext used to ignore the reverse causality is that individual bilateral trade is a very small part of GDP, as such the reverse causality is not very big. This paper checks for robustness of results by explicitly taking into account this reverse causality. We follow the growth literature that estimates the flip side of trade and GDP relationship FEENSTRA, R. C., MARKUSEN, J. R. & ROSE, A. K. 2001. Using the gravity equation to differentiate among alternative theories of trade. *Canadian Journal of Economics/Revue canadienne d'économique,* 34**,** 430-447. In particular, we lag economic mass variables where our identification assumption is that current trade value cannot impact appropriately lagged past values GDP and manufacturing value added. These results are produced in the appendix 1c table 2 and show that our main results are still robust after accounting for reverse causality.

additional variables used such as GDP per capita , GDP per capita squared, technology and institutions can also be endogenous to time-invariant country specific effects. As such, we allow for these variables to be endogenous as well, and call this set of endogenous variables [economic mass variables, GDP per capita, GDP per capita squared, RTA, institutions and technology]. This paper also presents RE for comparison and robustness of the results.

Furthermore, using a panel data approach allows us to capture the relationship between relevant variables over a longer period of time, thus allowing us to identify the role of the overall business cycles over this period. Given that global financial crises (GFC) and the Asian financial crises (AFC) happened over the time frame of our data set, accounting for business cycles will be particularly important for regressions of this paper.

5. Data

The data set cover all countries which account for 0.01% of total world parts and component exports in 2000. The time coverage is from 1996 to 2012 (16 years) The data set contains 30854 observations. A list of the countries is given in the appendix.

This paper follows (Athukorala and Menon, 1994, Athukorala, 2011, Athukorala and Yamashita, 2006, Yeats, 1998) in using UN trade data base to delineate trade in parts and components from the final goods. Parts and components are delineated from the trade data using a list compiled by UN Broad Economic Classification (BEC). This list uses Harmonize System (HS) of trade classification at the six digit level of UN trade data. In addition, World Trade Organization (WTO) Information Technology data at firm level is used to augment the BEC data. While the prices data used to deflate the trade data is taken from Bureau of Labour Statistics (BLS).

Data on GDP, manufacturing value added, LPI, investment, patent application, inflation and exchange rate is take from World Development Indicator (WDI)[4]. To look at the impact of institutions on trade and global production sharing we use the variable from World Governance

[4]Data for manufacturing is missing for some of the countries for initial years.

Indicators (WGI) on corruption. The values for WGI are missing for 1997, 1999, 2001 and 2012. Given that institutions don't change rapidly, we have used previous year's values to fill these gaps.

We consider two samples for our regressions. One is the comprehensive sample that includes all countries and has 30854 observations. The second data set looks at developing countries only as home countries and has about 8101 observations. A list of countries classified as developing is given in the appendix.

6. Results and robustness tests

6.1 Resutls

This section summarizes the main results for both parts and components and final manufacturing goods trade. The estimated trade equations are reported in Table 6.2. Colum 1 and 2 in the Table present the results based on CRE. While column 3 to 6 looks at robustness tests. Specifically, column 3 and 4 give results based on HT estimation and column 5 and 6 give results based on RE estimation. The discussion in this section focuses on CRE estimates - this paper's preferred estimation technique.

Manufacturing value added for home country and partner country is statistically significant (at the one-percent level) with the expected sign in all of our regressions. Moreover, manufacturing value added both as a supply base variable and demand base variable lies in the range of previous studies (Athukorala, 2005, Athukorala, 2011, Athukorala and Menon, 2010, Athukorala and Yamashita, 2006, Baldwin and Taglioni, 2011) for both final goods manufacturing exports and parts and components exports.

More specifically, for parts and components, a one per cent increase in manufacturing value added of home country increases parts and components exports by 0.85 per cent. The elasticity of partner country manufacturing value added is also statistically significant at one per cent level and in the range of previous studies for parts and components. In particular, a one per cent increase in partner country manufacturing value added implies 0.93 per cent increase for parts and components exports.

For manufacturing final good trade, a one per cent increase in manufacturing value added for home country increases final goods manufacturing exports by 0.69 per cent and while a similar increase in partner country manufacturing value added increases final goods manufacturing exports by 0.92 per cent. Sensitivity analysis based on HT and RE estimation yield similar results for both final goods and parts and components manufacturing trade.

GDP per capita and GDP per capita squared have the expected signs and are significant at the one per cent level for both parts and components exports and manufacturing final goods exports. The coefficient on GDP per capita is positive, while the coefficient on GDP per capita is negative, showing that the relationship between exports and GDP per capita is quadratic. This is in line with the theory that as countries develop, services sector gains share of the GDP and crowds out the manufacturing sector. These results remain robust to HT and RE specifications.

Based on CRE results, the institution variable is insignificant at the conventional levels (1 per cent, 5 per cent and 10 per cent levels). However, the mean value of in the institution variable is significant at the 1 per cent level. Implying that it is improvement in the mean level of institutions and not the marginal improvements in institution that matter for export performance in global production sharing. Importance of institutions in global production sharing is consistent with the theory developed in section 3. Ceteris paribus, a one unit increase in the mean level of institution index increase parts and components exports of parts and components by approximately 91 per cent for all the countries. Given that the World Governance Indicators lies between -2.5 and 2.5, a one unit increase in this institution index signifies a substantial improvement in governance. To give an idea of the magnitude, a one unit increase in institutions in 2005 for Philippines will make its institutions the same quality as that of Japan based on this index. Therefore, as theorized before, institutions play a significant role in determining network trade. However, the institution variables are insignificant for final manufacturing exports. The coefficient on institution is significant at the 1 per cent level, based on RE estimation but is insignificant based on the HT approach for parts and components exports. This partly reflects the fact that the HT and RE approaches do not have a way of dealing with the mean levels of institutions as opposed to the CRE approach. In addition, there is a lot of correlation between GDP per capita and institutions, which may be one of the reasons why the institutions variable is insignificant. [5]

Similar to institutions, based on CRE estimates, it is the average level of technology that matters for global production sharing. A one per cent increase in the mean level of patent applications increases exports by 0.11 per cent for parts and components. This coefficient is statistically significant at the 10 per cent level. In contrast the coefficient on the technology variable itself is insignificant at the conventional levels. Part of the reason of why the technology variable may be insignificant while the mean leave of technology may be significant is because of mulitcollinearity between variables, which becomes more pronounced in CRE estimation. Moreover, estimates based on HT and RE yield statistically significant estimates for the technology variable at the 1 per cent level. These estimates are in line with this paper's theory that advocates that technological growth will lead to finer slices of production process causing an increase in global production sharing. Another reason why technology plays a more significant role in network trade is that improvement in technology will reduce transport and communication costs which are central to service link costs (Jones and Kierzkowski, 1990).

For manufacturing final goods exports a one per cent increase in the mean level of patent applications increases exports by 0.11 per cent. However, the coefficient on patent application itself is only significant at the conventional levels based on the RE estimation. This may indicate that technology variable may not be as important for final goods exports as it is for global production sharing. It should also be mentioned that the technology variable is highly correlated with GDP per capita and part of the technology impacts on part and components exports and final goods exports may be captured by GDP per capita.

The coefficient on standard deviation of domestic inflation rate has the expected sign and is significant at one per cent level for parts and components. Ceteris paribus, a one unit increase in

[5] Once GDP per capita is dropped from these regressions, the institution variable becomes significant.

standard deviation of inflation decreases parts and components exports by approximately 3 per cent. In addition, results of HT and RE approach also consistently show a negative relationship between standard deviation of domestic inflation and exports of parts and components. This confirms our hypotheses that macroeconomic stability is important for global production sharing. In particular, as parts and components trade is dominated by multinationals, a stable and conducive macroeconomic environment provides a safe investment atmosphere for multinationals that helps augment parts and components trade.

The coefficient of LPI is positive and highly significant for parts and components. A one per cent increase in the LPI increases exports by 0.81 per cent. This result remains robust to HT and RE estimation techniques. This shows that physical infrastructure is an important determinant for global production sharing. However, the coefficient on LPI in the final goods regression is insignificant[6]. In addition, the coefficient of services export as a percentage of GDP has the expected sign and is significant at the 1 per cent level. A one unit increase in this variable increases global production sharing exports by 1 per cent. As this variable is a proxy for communication infrastructure, it shows that services link costs are an important determinant for global production sharing.

The coefficient on distance is highly significant and negative in all of our regressions. This shows that transport costs play an important role in trade flow for both manufacturing final good and parts and components exports.

RER is statistically insignificant at the conventional levels but the mean of RER is statistically significant at the one per cent level. A one per cent depreciation in the mean of RER increases parts and components and final manufacturing goods exports by 0.15 per cent and 0.07 per cent respectively.

Results for RTA and geographic variable are consistent with previous studies on global production sharing. The coefficient of RTA is insignificant for both parts and components and manufacturing final goods exports. This is consistent with previous studies (Athukorala, 2011,

[6] This may partly be because there is multicollinearity between GDP per capita and LPI.

Athukorala and Yamashita, 2009, Athukorala and Yamashita, 2006) that show that RTAs do not play an important role for global production sharing. Moreover, similar to previous studies, our results for other geographic variable are comparable to previous studies on manufacturing and parts and components trade (Athukorala, 2005, Mundlak, 1978).

Table 6.1

lhmva	**Log of home country manufacturing value added**
lpmva	Log of partner country manufacturing value added
lhmvaim	Log of home country based on Balwind and Talgoni measure
lpmvaim	Log of home country based on Balwind and Talgoni measure
h_ins_corr	Institutions variable based on corruption
totalpa	Technology captured by patent application
LPI	Logistic performance index
LOC	Vector of geography and culture based variables
l	Letter 'l' before a variable signifies natural log
p and h	Letter p before a variable signifies partner country and letter h signifies home country.

Table 6.2

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	PC* RCE	MNF* RCE	PC HT	MNF HT	PC RE	MNF RE
Lpmva	0.93***	0.92***	1.19***	1.11***	0.89***	0.84***

	(9.35)	(13.39)	(16.12)	(24.92)	(34.73)	(44.55)
Lhmva	0.85***	0.69***	0.83***	0.80***	1.01***	0.94***
	(4.91)	(6.19)	(11.01)	(16.60)	(24.99)	(34.24)
Sdinfrate	-0.03***	-0.01	-0.06***	-0.03***	-0.07***	-0.03***
	(-4.84)	(-0.99)	(-4.56)	(-3.32)	(-8.40)	(-5.42)
h_tradeinservicesofgdp	0.01***	0.00	0.02***	0.01***	0.04***	0.02***
	(3.25)	(1.13)	(7.26)	(3.99)	(15.42)	(11.48)
Lgdppc	5.63***	2.55***	5.11***	1.71***	4.72***	0.80***
	(5.12)	(3.72)	(8.46)	(4.63)	(13.20)	(3.21)
Lgdppcsq	-0.33***	-0.12***	-0.27***	-0.09***	-0.26***	-0.05***
	(-4.82)	(-2.99)	(-7.48)	(-3.99)	(-12.78)	(-3.36)
Ltotalpa	0.02	-0.01	0.10***	0.02	0.14***	0.06***
	(0.50)	(-0.47)	(3.55)	(1.14)	(5.97)	(4.12)
Lrer	-0.02	0.01	0.01	0.02***	0.03***	0.02***
	(-1.08)	(0.83)	(1.38)	(3.69)	(3.77)	(5.19)
l_h_lpi	0.81**	-0.15	0.90***	-0.01	1.55***	0.30**
	(2.51)	(-0.74)	(4.38)	(-0.05)	(7.49)	(2.38)
h_ins_reg_forward	-0.10	0.08	0.03	0.08*	0.20***	0.10**
	(-1.01)	(1.22)	(0.43)	(1.75)	(2.74)	(2.20)
Rta	0.06	-0.11	0.01	-0.27	0.12	-0.05
	(0.40)	(-1.18)	(0.04)	(-1.55)	(0.99)	(-0.58)
Colony	0.24	0.32**	-0.18	-0.17	0.26	0.21
	(1.34)	(2.03)	(-0.53)	(-0.68)	(1.19)	(1.27)
Ldistw	-1.21***	-1.07***	-1.21***	-1.27***	-1.19***	-1.12***
	(-17.14)	(-20.68)	(-8.91)	(-14.47)	(-19.87)	(-25.05)
Contig	0.01	0.20	-0.16	-0.15	-0.12	0.09
	(0.06)	(1.35)	(-0.48)	(-0.62)	(-0.58)	(0.55)
comlang_ethno	0.68***	0.73***	1.05***	1.10***	0.88***	0.90***
	(5.08)	(7.05)	(5.24)	(7.42)	(6.79)	(9.15)
Mlpmva	-0.10	-0.12*				
	(-1.00)	(-1.76)				
Mlhmva	0.09	0.12				
	(0.48)	(1.00)				
mh_tradeinservicesofgdp	0.01***	0.02***				
	(2.75)	(4.70)				
Mlgdppc	-0.43	-1.95***				
	(-0.39)	(-2.64)				
Mlgdppcsq	-0.00	0.07				
	(-0.03)	(1.56)				
Mltotalpa	0.11*	0.11**				
	(1.96)	(2.35)				
Mlrer	0.15***	0.07***				
	(7.37)	(5.42)				
ml_h_lpi	6.73***					
	(8.67)					
mh_ins_reg_forward	0.91***	-0.12				

	(4.66)	(-0.80)				
Mrta	-0.14	0.14				
	(-0.61)	(0.97)				
Constant	-46.17***	-19.51***	-48.17***	-25.13***	-43.22***	-19.21***
	(-19.31)	(-10.99)	(-13.41)	(-11.53)	(-23.16)	(-14.64)
Observations	8,101	8,139	8,101	8,139	8,101	8,139
Number of pairid	1,707	1,710	1,707	1,710	1,707	1,710

Robust z-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
PC stand for parts and components, while MNF stands for final manufacturing.

7. Conclusion

Global production sharing has seen an increasing importance in international trade. This paper has added to the growing literature on this subject by exploring the implications of macroeconomic variables such technology, institutions, investment and macroeconomic stability on global production sharing. This paper uses a battery of estimation techniques including CRE, HT and RE to test the importance of these results and finds that the results of this paper remain robust to these estimation techniques.

This paper also found that institutions play a significant role in determining both manufacturing final goods and network trade. This fact shows that institutional reforms in countries can significantly augment a country’s export performance. Moreover, this paper found that macroeconomic stability also plays a significant role in global production sharing. This is an important result with policy implications for countries that want to capture part of this growing network trade. In particular these results suggest that providing business friendly and conducive environment is important for attracting investment from multinationals which dominate parts and components trade.

Based on the results of this paper, there is evidence that technological improvement plays a role in augmenting network trade. Given this, as technological innovation continues we would expect a further proliferation of global production sharing. This reflects the fact that technological advancements will further enable the production process to be sliced up into smaller sections and allocated across the world based on comparative advantage

This paper also confirmed previous results that transport costs and other service link costs played a significant role in determining bilateral trade flows. This paper found that transport costs were always highly significant and robust to different speciation. Given this, it can be argued that reducing trade related costs by reducing transport costs or signing trade agreements can augment bilateral trade flows between countries.

The results for this paper raise several policy implications, especially for countries which want to increase exports and capture part of the network trade. In particular, this paper suggests that to capture part of the network trade countries need to reduce service link costs by improving both physical and communications infrastructure. Moreover, as network trade is dominated by multinationals, then in order to be a part of global production sharing process countries need to improve institutions, provide for a stable macroeconomic environment and create a conducive investment environment to attract multinationals. Attracting multinationals will also help these countries gain access to global innovations, which may also foster global production sharing.

Appendix 1 A Data

Full data set. Country Names	
Argentina	Mexico
Australia	Netherlands
Bangladesh	Norway

Belgium	Pakistan
Brazil	Philippines
Canada	Poland
China	Portugal
China, Hong Kong SAR	Rep. of Korea
Costa Rica	Russian Federation
Czech Rep.	Singapore
Denmark	Slovakia
Finland	Slovenia
France	South Africa
Germany	Spain
Hungary	Sri Lanka
India	Sweden
Indonesia	Switzerland
Ireland	Thailand
Israel	Turkey
Italy	United Kingdom
Japan	USA
Malaysia	Viet Nam

Appendix 1 B.1 Correlated Random Effect (CRE).

This section briefly explains the CRE approach. For detailed description see Wooldridge (2012).

To explain the CRE, this section follows Wooldridge (2012). Assume, for simplicity, a case of one explanatory variable. Where a_i are unobserved country fixed effects.

$$Y_{ijt} = \alpha + X'_{i1t}\,\beta_1 + a_i + \epsilon_{ijt}$$

Average of the above equation is:

$$\bar{Y}_{ijt} = \alpha + \bar{X}'_{i1t}\,\beta_1 + a_i + \bar{\epsilon}_{ijt}$$

Since a_i is by definition constant over time, it is correlated with the average level of explanatory variable $\bar{X}$. Following (Wooldridge, 2012), assume a simple linear relationship.

$a_i = \delta + \bar{X}'_{i1t}\ \beta_1 + +r_i$

Then the original equation becomes:

$Y_{ijt} = \alpha + X'_{it}\ \beta_1 + \delta + \bar{X}'_{it}\ \beta_1 + r_i + \epsilon_{ijt}$ (CRE1)

WE assume that r_I is uncorrelated with X'_{it} and because $\bar{X}'_i$ is a linear function of X'_{it}, then:

$Cov(\bar{X}'_{it},\ r_i) = 0$

As $Cov(X_{it},\ a_i) = 0$ holds and as ϵ_{ijt} is assumed to be uncorrelated with X'_{it} and $\bar{X}'_I$, then we can estimate (CRE1) using random effects. So CRE1 is like RE estimation with the addition of $\bar{X}'_I$.

Appendix 1 B.2 Hausman Taylor (HT)

HT regression distinguishes between endogenous and exogenous variables. The individual effect model is written as follows:

$Y_{ijt} = \alpha + X'_{i1t}\ \beta_1 + X'_{i2t}\ \beta_2 + Z_{i1}'\beta_3 + Z_{i1}'\beta_3 + \eta_i + \epsilon_{ijt}$

Where X variables denote time variant variables and Z variables denote time invariant variables. Furthermore this approach assumes the following:

$E(Z_{i1},\ \eta i) = 0$ and $E(X'_{i1t},\ \eta i) = 0$ but Z_{i2} and $X'_{i2t}$are assumed to be correlated with η_i. HT is based on Random Effect type transformation as follows:

$Y_{ijt} = \alpha + \widetilde{X}'_{i1t}\beta_1 + \widetilde{X}'_{i2t}\beta_2 + \tilde{Z}_{i1}'\beta_3 + \tilde{Z}_{i2}'\beta_3 + \tilde{\eta}_i + \tilde{\epsilon}_{ijt}$

Where $\widetilde{X}_{i1t} = \widetilde{X}_{i1t} - \gamma\overline{X}_{i1}$. This transformation ensures that time invariant variables are not dropped. Now to deal with the correlation between $\tilde{X}_{i2t}$ and $\tilde{Z}_{i2}$ with $\tilde{\eta}_i$. To deal with this, HT approach uses IVs. For $\widetilde{X}_{i2t}$ instrument used is $\ddot{X}_{i2t} = X_{i2t} - \bar{X}_{2i}$, for $\tilde{Z}_2$ the instrument used is $\overline{X}_{i1}$. The variable uses $\ddot{X}_{i1t}$ as an instrument for $\widetilde{X}_{i1t}$ and Z_{i1} as an instrument for $\tilde{Z}_{i1}$ (Wooldridge, 2012, Krishnakumar, 2006, Oaxaca and Geisler, 2003).

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